NRs 40 DM 9
IRs 25 £ 4
Nu 30 U$ 5
U$ 4.75 in North America

Vol 7 No 3
May/Jun 1994

HIMAL

HIMALAYAN MAGAZINE

Marginalised

old world under the new world order

The Next Great Earthquake

The Next Gre

Great earthquakes are a permanent, if intermittent fixture of the Hin exists between Kathmandu and Dehradun. The most disastarous

by Rog

Five minutes is not a long time unless something really unpleasant is happening. Two million square miles of northern India and western Nepal shook violently for 5 minutes starting at 2:13 in the afternoon of 15 January 1934. The occasion was the Great Bihar Earthquake. It took a further 15 minutes for hanging lamps to stop swinging in Calcutta. It took many days for the dust to settle from landslides in the mountains of Nepal. It took many weeks for sand ejected from the ground to be removed from fields and villages in Bihar, and the roads and railways of Bihar to be brought into service. It took many years to reconstruct the tens of thousands of damaged buildings in hundreds of villages and cities. In the sixty years since this event, we have learned that such great earthquakes are necessary events in the building of the Himalaya. Some seismologists believe that the next great earthquake may be long overdue.

Great Earthquakes Are Inevitable

The processes responsible for the collision between the Indian and Asian tectonic plates are found deep below the Earth's surface and because of this we know of them only indirectly. A gravitational depression of the Earth's shape near Tibet suggests that an almost vertical current of viscous rocks plunges deep into the Earth's mantle, dragging India and southern Tibet towards each other and both of them northward. The result is that each year India approaches Tibet by 2cm, causing the intervening rocks to be squeezed horizontally and upward. The Himalaya is the result of this collision.

The Great Bihar Earthquake was the most recent of three great earthquakes that have occurred in the Himalaya in the past 100 years. The other two involved similar intensities and duration of shaking: the 4 April 1905 Kangra earthquake to the East and the 10 June 1897 Assam earthquake to the west. The 1934 earthquake destroyed buildings in hundreds of villages and dozens of cities, many of them in northern India, and hence became known as the "Bihar earthquake". But it equally well could have been called the Kathmandu Earthquake, or the Patna Earthquake, or named after any one of the many damaged cities. In fact, for several days after the Bihar earthquake it was thought that the epicentre was at Darjeeling.

The difference between a moderate earthquake such as the Uttar Kashi earthquake of 20 October 1991, and a great earthquake like the Bihar event, is that great earthquakes alone permit the Earth's tectonic plates to slip past each other. In the 1934 earthquake, the low mountains of eastern and southeastern Nepal sprung forward more than 5 metres over the plains of India. Great earthquakes are more effective in allowing slip than smaller events because the amount of displacement in an earthquake is proportional to the length of the zone over which rupture occurs. Although friction limits this slip, the slip is driven by the amount of convergence between India and Tibet since the time of the last earthquake.

If a great earthquake has not occurred on a specific segment in the Himalaya for 200 years, that segment will slip 4m because the convergence rate between India and Tibet is roughly 2cm each year. If it has not occurred for 500 years the segment would slip 10m, enough for an event that would measure M=8, or Magnitude Eight on the Richter Scale. The time interval between great earthquakes thus determines the amount of slip that will occur in the next one. Thus, if we know the time of the last earthquake, we can estimate the maximum size of the next one. For example, if the Assam, Kangra and Bihar earthquakes were to recur again today they would slip 2m, 1.8m, and 1.2m respectively, sufficient to drive only M=7 events. We are thus not too concerned about these regions because they have recently slipped. But what of regions in between? When did they last slip?

West Nepal Disaster Area

A large segment of the Himalaya between Kathmandu and Dehradun has a record of several earthquakes but only two large ones: an event in 1803 and another in 1833. If these were great earthquakes then there is now roughly 3m of slip ready to go. However, if they were magnitude 7 earthquakes, then there may be more than 20m of slip still available for a future great earthquake.

History is patchy concerning great earthquakes in western Nepal near the

at Earthquake

alaya. A major earthquake is due to occur in the "seismic gap" which vent in history will be a pale shadow of the next great earthquake.

r Bilham

seismic gap shown in the illustration. The earthquake history in even the past 200 years is incomplete. The 26 August 1833 earthquake was felt in Lhasa, Agra and Calcutta, but because fewer fatalities (414) were reported in Kathmandu compared to the Bihar event, it may have been not substantially larger than the Uttar Kashi event of 3 years ago.

We can certainly exclude the possibility of an earthquake having hit the entire region between Dehradun and Kathmandu. Its effects would have eclipsed the Bihar or Assam earthquakes and would surely have been entered into the records of the British administration. Repairs to buildings, wells, etc. indicative of a widespread destruction in 1833 are absent.

It is the tremendous size of the region that apparently remains still to fail that concerns most seismologists. Theoretical calculations indicate that a 500km long segment could fail in a single event with a maximum slip of 50m. This maximum estimate would require that a great earthquake has not occurred in the region for 2500 years and would certainly explain why no historical event has been recorded. But by breaking the region up into smaller segments less extreme estimates can be obtained. A 300km long segment would slip 10m to 30m, allowing for some permanent deformation of the Himalaya, and would release about 1000 years of Indian movement.

Unfortunately it does not seem possible to replace a great earthquake with dozens of less damaging M=7 earthquakes. Suppose a M=7 event has a rupture area of 50km by 30km, it would require roughly 30 such events to completely rupture a 300km by 150km seismic gap. However, because an M=7 event allows slip of only 2m, these 30 events must occur each century to keep pace with the 2cm/year convergence rate of India and Tibet. Thus we should expect earthquakes every 3 years. The actual rate in the region is more like one every 25 years. Great earthquakes are thus essential to catch up with the rate of convergence.

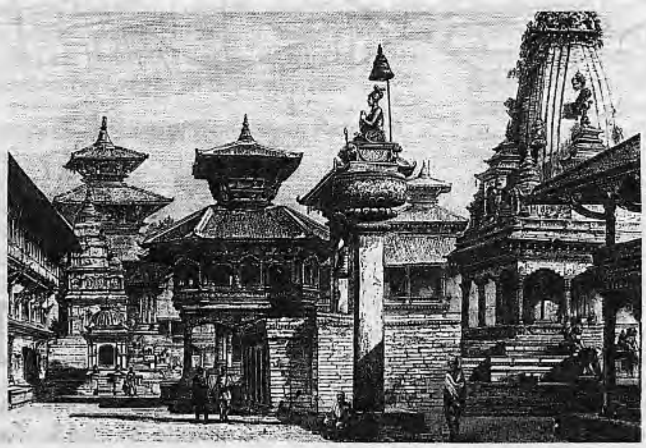
Creep without Earthquakes

There is one tectonic process that could eliminate the possibility of a future great earthquake. Some plate boundaries slip by a process known as "creep". An unique blend of material properties and physical conditions exists on the rupture plane of these areas that prevents the fault surface sticking. Instead the fault slides slowly without earthquakes. The process is known as a seismic creep. Could the west Nepal seismic gap be creeping?

The region near Kathmandu appears to indeed undergo limited creep. The creep

The Great Bihar Earthquake devastated all 3 towns of Kathmandu. Picture at left shows the destruction at the Bhaktapur Durbar Square. 19th Century lithograph (below) shows the templescape as it was before the quake.

COURTESY: NILS GUTSCHOW



causes buckling of the rocks in the Siwalik and the High Himalaya, causing them to rise a few millimetres each year. This evidence comes from very careful measurement of the height of roadside markers in the past 15 years along the road that passes through Nepal from the Indian border to the Tibetan border.

Calculations show, however, that no more than 30 percent of the convergence signal can be released in this way or the rate of rise would be much higher. If 70 percent of the 2cm per year convergence signal remains stored in the rocks as elastic strain then it would merely delay a future great earthquake. It would not prevent it. Because the existence or not of creep is crucial to seismic risks, we would like to know more about its contribution. Fortunately, an additional test of the effects of creep is possible.

An accurate survey to map India was conducted between 1800 and 1870. Each great earthquake subsequent to the completion of the survey has left an imprint on the Indian plate, and so has any creep that may have been released. That is, the Survey of India recorded the shape of northern India prior to these earthquakes and by re-measuring the positions of these original points we can ascertain whether, in addition to the deformation caused by the earthquakes there has been deformation from significant creep in western Nepal.

Although many of the original survey points have been lost, and some are now shrines and are thus unusable, sufficient points remain to search for patterns that can tell us whether creep in West Nepal is significant. This search is urgent from a seismic hazards viewpoint, but the Survey of India who were responsible for the original work have no interest in re-measurements related to seismicity. Such re-measurements would need to be initiated by the seismological community. If no evidence for creep is apparent we would conclude that a great earthquake has yet to occur in the region of western Nepal.

Confronting the Big One

Seismic engineers in Nepal and northern India are reluctant to admit the worst case possibility of an inevitable bigger than M=8 event. The size of historical earthquakes and the delaying effects of creep can be questioned. However, there is no doubt that great earthquakes are a permanent, if intermittent, fixture of the Himalaya. Thus, the hazardous nature of the northern plains of India is beyond dispute and it is certain that an M=8.5 earthquake, were it to occur in the next few decades, would constitute one of the worst disasters in history.

There is tremendous reluctance among those in office to believe that nightmare earthquakes are inevitable.

The reason for concern is that the population of the northern plains of India and Nepal is now at least ten times greater than it was during the last great earthquakes in the region. Aggravating the problem is that construction methods in the cities (where much of this increased population now reside) is inadequate to resist the highest accelerations anticipated from an earthquake.

In the Assam earthquake and in the Bihar earthquake there were reports of stones and buildings thrown into the air indicating vertical accelerations greater than 1g (the acceleration due to gravity, 1g equals 10 meters per second squared, and is used as a measure of acceleration). Typical design accelerations applied in the Himalaya are less than 0.5g and even for ongoing engineering projects (e.g. Tehri Dam), lower accelerations (0.3g) are considered acceptable. The recent M=6.4 earthquake in Los Angeles confirms that accelerations can exceed 1g. The application of such low design codes in a region where a bigger than M=8 earth-quake is anticipated must be considered irresponsible.

As an example of the ambivalent acceptance of possible future seismicity, consider Kathmandu, the rapidly growing Nepali valley currently with a population exceeding one million. Seismic resistant building codes are applied to limit the height of construction in Kathmandu to about 15m, yet reinforcing rods protrude skyward above newly constructed roofs, clearly in expectation that height restrictions will be lifted.

Construction methods are weakly supervised by engineers and most of the construction is undertaken by contractors anxious to increase profit margins by using inexpensive materials: low quality bricks, weak cement and brittle steel. Lower stories of multi-storey buildings are constructed to maximise window space for commerce, resulting in a soft lower level that is the first to fail during seismic shaking. Electrification in the old parts of the town where narrow streets and wooden houses remain, now constitute a major fire hazard that did not exist during the Bihar event. The absence of an adequate piped water system means that fires may not be extinguished for days following an earthquake.

Finally, although liquefaction (when soil attains a 'liquid' state due to high pressure) of solid layers was not widespread in the Kathmandu valley in the 1934 earthquake, perhaps due to the absence of extensive sand layers in the lake sediments on which the city is built, it did occur along the banks of the rivers, and it is likely that bridges in the city will fail, in addition to extensive damage to approach roads and even the airport runway. Relief to the city will be hampered by the inevitable closure of all roads by

Readings on Earthquakes

The Indian Earthquake, C.F.Andrews, George Allen and Unwin, 1935

The Bihar-Nepal Earthquake of 1934, Mem. Geol.Soc. of India, 73, 1939

Seismology in India, H.K.Gupta, *Current Science*, 62, 1992

Himalayan Seismicity, G.D.Gupta, ed. Geol. Soc. of India, *Memoir* 23, 1992

The Kangra Earthquake of 4 April 1905, C.S.Middlemiss, Mem. Geol. Soc. of India, 29, 1910

Structure and Tectonics of the Himalaya: Constraints and Implications of Geophysical Data, P.Molnar, Ann. Rev. of Earth and Planetary Sciences, 12, 1984

Report on the Great Earthquake of 12 June 1897, R.D.Oldham, Mem. Geol. Soc. of India, 29, 1899

Seismicity and Continental Collision in the Himalayan Arc, in Zagros, Hindu-Kush, Himalaya, L.Seeber, Armbruster and Quittemeyer, Geodynamic Evolution, Amer. Geophys.Un., Washington DC 1981

rockslides and avalanches. A consequence of the restricted access and water supplies following the earthquake is that it will probably be difficult to control epidemic diseases in the subsequent months.

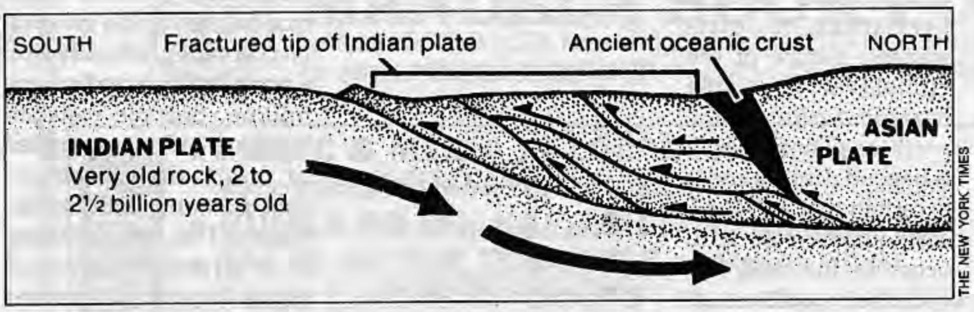
What Should be Done?

There has been much worldwide research on the possibility of predicting future earthquakes. The results of these investigations are disappointing in that no clear physical process has been found to precede seismicity. Although the work has thus far provided little hope for accurately predicting the time, location and magnitude of a future earthquake, the subject is still in its infancy and progress may yet occur.

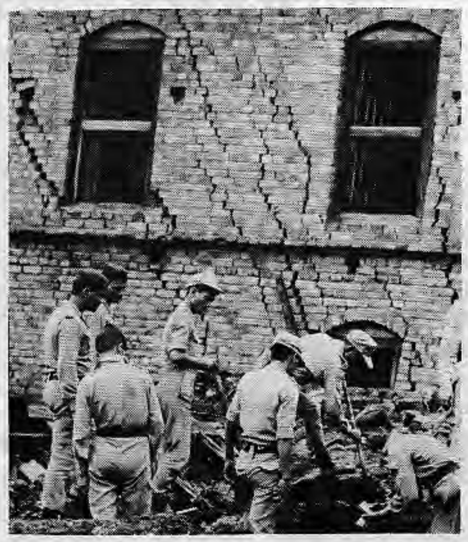
Probabilistic forecasts of future seismicity are, however, improving in quality and would be of immense use in the Himalaya. The data on which to base these forecasts could be much improved with investigations of historic earthquakes. The written record in India exists for centuries and may contain entries of value to assessing the dates of previous earthquakes in the Himalaya. The colonial record must surely contain more complete records of 18th and 19th century events than those currently interpreted. There is much that can be done to extend the historic record backward by excavating the liquefaction features of historic earthquakes. An army of historians, language experts and geologists should be mobilised to attack these problems.

One important application of seismic research that is readily available is the use of instantaneous shut-down procedures in northern India. An array of seismometers in the Himalaya would constantly monitor seismic tremors and in the event of a large common signal a computer would radio a shut-down message to nearby critical facilities. Given that many of India's large urban populations live 100km to 200km from the Himalayan foothills, it would thereby be possible to obtain up to 30 seconds of warning before the arrival of seismic waves from the focus of the earthquake. In 30 seconds, nuclear plants could be shifted to non-critical status, hospitals could be switched to emergency power, underground pipelines could be isolated. Seismic warning systems have been implemented in Japan and Mexico and are being discussed in California.

One of the most vexing aspects of research on disastrous earthquakes in the Himalaya, however, is that the Government of India restricts the activities of its scientists in acquiring data in the region. The reason given is that it is not in the interests of India's national security that raw data be obtained on the disposition and deformation of the Himalaya or regions within 100km of any national border. This is, of course, a bizarre manifestation of military thinking. Surely it is more important to reduce seismic risks to perhaps 200 million people in northern India, than to pretend that an invading army is hovering at India's borders and cannot proceed without the precise re-measurement of a 19th century survey?



The Asian and continental plates collided about 45 million years ago. The Indian plate has been attempting to dive violently beneath the Eurasian plate ever since, producing multiple fractures around the area of collision.



The 1988 Udaipur earthquake (M=6.3) destroyed villages and towns in East Nepal such as Dharan, shown here.

India's worst enemies are her natural disasters, and the sooner that politicians admit this, the sooner they will be working in the interests of her people. Realistic building codes should be implemented throughout northern India on all new construction. Critical structures (dams and nuclear power plants) must be retrofit or abandoned if they cannot be designed to survive levels of shaking associated with historic great earthquakes in the Himalaya. Scientists should be encouraged to intensify their studies of the region, to test or refute the approach of a great earthquake in West Nepal.

There is no shortage of expertise in India and Nepal to investigate the real risks from earthquakes, to investigate the historic record with thoroughness, to excavate the geologic effects of pre-historic earthquakes, to monitor ongoing seismicity and deformation in real time, and to apply earthquake design to existing and future structures. There is a tremendous reluctance among those in public office, however, to believe that the continued recurrence of nightmare earthquakes is inevitable, or that due to changed building methods and increased populations, the most disastrous historic event will be a pale shadow of the next great earthquake. To admit that this is a possibility and to do nothing is surely a criminal act.

Mahatma Gandhi said of the Bihar earthquake, "Such calamities are not a mere caprice of the Deity, or Nature. They obey fixed laws as surely as the planets do. Only we do not know the laws governing them." He goes on to ask what sin can warrant such a calamity. It is becoming increasingly clear that the only sin on which a future disaster can be blamed is the sin of indifference. △

R. Bilham is with the Department of Geological Sciences of the University of Colorado, Boulder.