In this issue

High seismic hazard along the central Himalaya (Dehra Dun to Muzaffarpur), and risk to Tehri dam

The first step in estimating earthquake hazard in an area, from which engineering specifications could be derived for the design of earthquake-resistant structures, is to define the possible earthquake threat(s) to the region. This, in turn, requires (a) delineation of the most likely fracture plane(s) (geological faults) that could be the site where long-accumulated strain will be suddenly released and (b) rates of strain accumulation and the current strain budget(s) of these faults or fault systems, the last of these being difficult to determine directly except through stress measurements and/or the historical records of past earthquakes associated with the fault(s). Assuming a failure strain of 10^{-4}, one can then estimate the probabilities of exceedance of strain release or slip on these faults over a given period of time in the future, and further, as shown by Khattri (page 161) the expected ground motion time histories and the probabilities of exceedance of ground motion parameters (displacement, velocity, acceleration and duration of strong shaking) at a specified distance from them. The latter constitute the basic quantities needed for a seismic design.

Earthquake hazard in the Himalaya and in the adjoining densely populated plains to the south is dominated by the great plate boundary earthquakes which accompany a sudden slip of the persistently northward driving Indian plate, beneath the overriding Himalaya. Once every few hundred years, therefore, when the steadily accumulating strains exceed the bearing capacity of the intervening fault systems, various segments of the Himalaya lurch forward over the foothill plains in a giant leap of 6–10 m along a gently northward dipping fracture plane, which is typically 300 km long and 100 km wide.

However, the entire 2400 km long Himalayan belt from Nangaparbat in the west to Namcha Barwa in the east, although compressed at approximately the same rate, does not slip as a single continuous rupture. For, there are a number of transverse fractures incised by the strong pre-existing grains of the underthrusting Indian plate, that segment the Himalayan arc mechanically, thereby providing an additional degree of freedom which allows its various segments to slip independently, adjusting the times of their slippage (earthquakes) according to the nature and strength of their respective fault asperities. Thus, the giant slips of the various Himalayan segments whilst having approximately equal renewal intervals (recurrence periods of great earthquakes) tend to stagger in time.

Four great earthquakes have been known to rupture about half of the Himalayan plate boundary over the past 100 years, and although a direct determination of the strain rate across this boundary still remains to be made, various constraints indirectly indicate a figure of 15 mm/yr (strain rate $\approx 1.5 \times 10^{-7}$/yr). This, in turn, suggests that the recurrence interval for a great Himalayan earthquake would be about 600 years. Unfortunately, our historical record of seismicity in India is rather poor, which makes it impossible to estimate the current strain budget along a fault that has no known record of an associated earthquake in the past, even if the rate of strain accumulation is known.

It will thus be apparent that whilst it would be safe to assume that those parts of the Himalaya which have ruptured in the past 100 years are unlikely to accumulate enough strain for a great earthquake at least for the next 400–500 years, others that have not been ruptured for 500–600 years by a great earthquake have most likely accumulated more than 8 m of slip (strain $= 10^{-4}$) and are, therefore, ripe for a great earthquake which could have a magnitude greater than 8.5.

One such long segment in the Himalaya where no great earthquake has occurred since the 13th century and where potential seismicity is, therefore, extremely high is the Central Himalayan seismic gap extending from Dehra Dun to Muzaffarpur. Since a number of large dams are being constructed in this area, an evaluation of its seismic potential over the next 300–400 years, covering the life and residual after-effects of the dam, has been a matter of great public concern and regrettably of an unresolved public debate between seismologists and engineers, particularly in respect of low estimates of earthquake hazard and high percentile of risk adopted in the engineering design of the dam structure.

Two well researched papers in this issue (Bilham, **page 101**) and (Khattri, **page 161**) address the two main arguments underlying the adoption of low hazard figures: (a) the assumption that the 1833 Nepal earthquake did considerably diminish the accumulated strain in this part of the Himalaya and (b) that the rock attenuation figures in the area being high, ground accelerations would decrease rapidly away from the fault. The two papers contained in this issue provide enough evidence to refute both these possibilities, and call for attention to the dangerous consequences of inadequate safety figures incorporated in the design of this large critical structure.

The first paper by Bilham shows convincingly that the only major earthquake to occur in this region after the well-documented disastrous earthquake of 1255 was the 1833

Nepal earthquake, which more or less coincided with the western extremity of the 1934 Bihar earthquake rupture and, in any case, was too moderate to cause any significant reduction of the strain budget in the Central Himalayan seismic gap. The message, therefore, is that this sector of the Himalaya has not experienced a great earthquake for about 750 years and unless accumulating strains are relieved by aseismic creep, which appears unlikely on the basis of the evidence of recent levelling data in Nepal, the accumulated slip in the region may be as high as 10 m, capable of generating a great earthquake of magnitude 8.5–9.0 in the near future.

The second paper by Khattri, using the actual ground acceleration records of the 1991 Uttarkashi earthquake as a basis for simulating the ground acceleration record at Tehri, which lies in the Central Himalayan seismic gap, shows that peak ground acceleration expected to occur at Tehri in the wake of $M = 8.5$ earthquake would be as high as $1.0\,g$, and would continue to shake the ground intensely a period longer than 20 s.

These two papers thus make a valuable and timely contribution towards alerting all those concerned with the construction of large critical facilities in the Central Himalaya to study carefully the scientific results and computer-simulated visualizations that argue against the unrealistically low figure of earthquake hazard adopted in the design of the 260 m high Tehri dam and to revise its design so as to ensure long-term protection to large unwary communities downstream.

V. K. G.

Molecular processes: Faster and faster

Chemical kinetics is the study of the rates of chemical reactions and their interpretation in terms of molecular mechanisms. Classically, the determination of rates was restricted to processes occurring in time scales of several seconds or longer due to limitations of measurement. Over the last forty years or so there has been a steady improvement in the shutter speed of chemists' cameras. While measurements in the millisecond regime were at the forefront in the 1950s, even picosecond time scales will be passé in the late 1990s. Technical barriers have been regularly breached and experimental studies of femtosecond (10^{-15} s) processes are now possible.

Part of the motivation for studying ultrafast molecular processes stems from the increasing inroads that have been made in understanding critical biological events in ultimate chemical detail. Electron transfer processes in photosynthesis and the critical isomerization of the visual pigment retinal in the rhodopsins following photoexcitation are among the best studied. It is after all enormously exciting to be able to follow events immediately after photon capture which eventually lead to the wonderful phenomenon of vision. Biology affords the physical scientist an extraordinary range of immensely complex problems, which may be addressed using techniques that have been tried and tested on the more tractable problems of physical chemistry.

Ions and molecules in solution are solvated and there is an unceasing dance of chemical species in solution, modulated by myriad interactions. Excitation of chromophores most often leads to changes in charge distribution, necessitating solvent rearrangements to achieve an equilibrium excited state. Measurements of solvent reorganization times, sometimes of the order of 200 fs to 1 ps, have become possible recently using ultrashort laser pulses, providing remarkable temporal resolution of molecular processes. The detection of ultrafast events in liquids like water, methanol and acetonitrile, of course, raises the question of their origin. This is happy hunting ground for theoreticians and provides many insights into the dynamic behaviour of liquids.

For the connoisseur of ultrafast events, electron transfer is undoubtedly one of the most delectable items on the menu of chemical processes. The celebrated Marcus theory is the cornerstone in the understanding of electron transfer. Can solvents or the medium affect the very rapid electron transfer reaction? Recent studies suggest that there are specific situations where medium effects are indeed observable. What appears to be a rather esoteric area of physical chemistry may acquire broad importance in the light of the determination of the detailed molecular structures of proteins involved in biological electron transfer, where electrons hop between metal ion centres through a dense thicket of protein atoms, with the aqueous solvent being almost completely excluded. The interplay of experiment and theory has been particularly fruitful in the area of ultrafast chemistry as highlighted in the review by Bagchi (**page 129**).

P. B.