Prediction of earthquakes – Frustrating research

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Earthquakes are associated with large fractures or faults in the Earth's crust or upper mantle and according to a simple model, when two crustal blocks are forced to slide past each other, friction along this plane (called fault plane) causes some portions to stick to each other, resulting in a build up of deformation strain. When finally the frictional lock is overcome at some point along the line, an earthquake slip occurs. This point of slip is the focus of the earthquake and the site on the surface of the earth above this focus is the epicentre. While elastic strain builds up along the line of fault over several years, the release of the stored-up energy takes only a few minutes.

Among the various natural hazards, earthquakes in populated areas pose the greatest threat to life and property and they have, therefore, prompted serious studies from the scientific community for over 100 years. Needless to point out, major handicaps to directly monitor the forces that trigger these natural catastrophies are the inaccessibility of the zones experiencing build-up of friction and also want of appropriate instrumentation. Further, the building up of strain occurs very gradually, typically over decades. Nonetheless, thanks to systematic advances in the physics of the interior, particularly in seismology, we have been able to recognize potentially hazardous areas and assess the likely impact on structures and buildings to enable development of proper designs to withstand the shocks and to construct 'intelligent' buildings that have masses that shift to counter the tilt movement of the ground during an earthquake. However, in spite of the voluminous data gathered from innumerable earthquakes, short-term prediction of an imminent earthquake has been eluding the scientists.

During the 1970s and 80s, a few systematic approaches to earthquake prediction were undertaken by researchers on some of the monitorable changes preceding the events. One of them correlated the regularity of earthquake events (e.g. six earthquakes struck every 22 years since 1857, along the San Andreas fault in California) with time taken for the stress to build up between two successive events and based on such data, forecast for the next rupture was made after allowing for natural variables; but the predictions failed[1]. Another research approach in the seventies was based on the rock dilatancy effect[2], which had initially a few successful predictions but failed subsequently. This method relied on the inelastic volumetric increase observed in the rocks due to the formation and propagation of cracks within the zone prior to an earthquake. In yet another approach to this problem, Chinese scientists achieved a few successful predictions by extrapolating ongoing seismic activity in the earthquake-prone Jiashi County in China. They could forecast accurately the time and magnitude of three successive quake events in 1961; this made it possible for the authorities to evacuate residents hours before quakes of 6–6.4 magnitude destroyed over 2000 homes. However, as the Chinese and US seismologists later admitted, such forecasts in areas experiencing swarm type events, as in the Jiashi county, are easier but predictions for isolated regions is more challenging and complex[3].

Today, the conventional notion that an earthquake occurs when the accumulated stresses along a fault section exceed a threshold is much doubted. Two geophysicists, Didier Sornete and Leon Knopff of the University of California (L.A.), feel that this view has to be revised as we now know through seismology that faults are not isolated systems but are controlled by complex forces acting on inhomogeneous rocks having variable strength and other mechanical properties. In fact, the two geophysicists have even doubted the assumption that longer the time since the last earthquake event, the sooner will be the next one. Their mathematical calculations on this aspect have actually led to an opposite conclusion; they say that the chances of a major earthquake event in an area diminishes as time goes by, a conclusion they were led to, when they evaluated statistically the 'probability density of time intervals between quakes'[4]. Where small earthquakes strike periodically, they conform to a simple mathematical probability density; in other regions, where events are irregular or infrequent, this probability density follows a Poisson distribution. The chances, say the authors, of another earthquake striking the area remain constant with passage of time and it is unrelated to the elapsed time since the last event.

Researchers are now increasingly turning to computer modelling, thanks to the ability of the computer to simulate in a few hours stress build-up of decades; the results of such studies have indicated that predicting earthquakes accurately is complex and difficult[1]. Apart from these few approaches to earthquake prediction, several signals preceding quakes have been suggested as precursors such as crustal movements, spate of micro shocks, changes in hydrological, geochemical and biological spheres in the neighbourhood of the zones, anomalous animal behaviour, variations or spurt in electromagnetic radiation, and many more measurable or perceptible phenomena including astrological forebodings; but none of these precursors was found to be viable when evaluated against the norms for acceptability (developed, for example, by International Association for Seismology and Physics of the Interior). Earthquake predictions, to be meaningful, should give the warning of the forthcoming event in a reasonably short time, accurate with respect to location and magnitude and should have high reliability and universal applicability.

In a recent report, Robert Geller of the University of Tokyo and his colleagues at the Universities of California (L.A.) and Bologna[5], have pointed out that many of the suggested precursors have been reported only after the earthquakes had taken place and some of them have been recommended without even an assessment of their suitability by conducting rigorous statistical correlation. In fact, these authors say that each new claim publicized stipulates a new set of conditions, making 'hypothesis setting, which is what separates speculation from science, nearly impossible'[5]. Presently, the global endeavour for deriving foolproof set of viable clues for earthquake prediction has been so frustrating that some of the countries like Japan, who were in the forefront in this field, are having second thoughts on continuing the projects.

In a meeting on 'Assessment of Schemes

for Earthquake Prediction', held in London last November, a number of scientists discussed the various precursory phenomena put forward so far and concluded (i) that the complexities in the build up of Earth's continents and ramifications of several forces in operation leading to an earthquake, make predictions extremely difficult, a reason why none of the recommended precursors could be successful[5-7]; (ii) also, the earthquake-prone areas can be visualized as existing in a state of self-organized criticality or at the edge of chaos, a situation comparable to a pile of sand grains, where addition of a few grains can precipitate avalanches ranging in size from a few grains to entire slopes. Likewise, a minor event in these critical areas within Earth's crust experiencing interplay of assorted physical and chemical forces, can trigger disrupting earthquakes of varying magnitudes; actually, seismologists have noted that a rupture in one fault can transfer stresses to neighbouring ones and initiate a cascading response from them[8-10]; (iii) rupture initiation in a fault zone (nucleation zone) for small magnitude earthquakes is quite different from that of larger ones[11,12], and, further, this rupture can be due to factors other than those that build up friction; (iv) knowledge of several of the interlinked forces in operation is a pre-requisite for prediction and this is impossible to achieve, given the complexities of the problem involving systematic observation of 'subtle phenomena, formulating hypothesis and testing them thoroughly against future earthquakes spread over decades, with no guarantee of success'[5].

The geoscientists who gathered in London last November to assess the prediction schemes have rightly felt that the hiatus in the development of reliable prediction methods should at least spur investigative agencies to concentrate more on hazard mitigation by intensive study of the mechanism of earthquakes, their seismic propagation and likely impact on potential sites so that better guidelines can emerge in reducing damage to life and property.

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