# PANDIT GOVIND BALLABH PANT MEMORIAL LECTURE: VIII

## Mitigating Disasters in the Himalaya: A Basic Agenda for Development

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## About Prof. Vinod K. Gaur

Prof. Vinod K. Gaur
Distinguished Professor at Indian Institute of Astrophysics, Bangalore
(Born: 11th July, 1936 at Azamgarh, U.P.)

Fellowships
Fellow, Indian national Science Academy
Fellow, Indian Academy of Sciences
Fellow, National Academy of Sciences
Fellow, Andhra Pradesh Science Academy
Fellow, Indian Geophysical Union
Written/ edited six books and over 90 research papers

### Education

High School (1949). Wesley High School, Azamgarh; Intermediate (1951), Agra College, Agra: B.Sc (1953) Lucknow University; M.Sc. (1966), Banaras Hindu University: D.I.C. (1959), London University: Post-Doctoral Fellow (1959-60) Sornonne University, Paris

Scientific Services to the nation:

(i) Design of Academic programmes in Geosciences (under the aegis of UGC)
(ii) Restructuring research directions and approaches at the Nat. Geophys. Research Institute, by initiation digital data acquistion in Seismology, magneto-telluries and Gwomagnetism, and new research fields, notably: seismic Tomography, Isotope Geochemistry and Mineral Physics.
(iii) Design of contemporary Information Systems aimed at operational Ocean forecast service:
    Marine Satellite Information Service (1991)
    Coastal Ocean Monitoring and Prediction Systems (1989)
    National Ocean Information Service (1990)
(iv) Founding of a science to people programme in Hyderabad, as Andhra Pradesh Vigyan Parishath (1984), since grown into a state wide vibrat organization (1989) as Andhra Pradesh Vigyan Vedika with over 50 centres across the state

### *Current Services*

*(i)* Research programme to quantitatively define the strain field in the Indian territory, especially in and across the constantly deforming Hmalaya (funded by the Dept. of Science and Technology and the National Science Foundation, USAO using millimeter accurace Global Positioning System receivers.
*(ii)* Setting up a 2 meter diameter Optical and Infra-red telescope at the world's highest sites (15,200 feet) in Ladakh Himalaya as Chairman of the committee.

*(iii)* Formulation of a National multidisciplinary science programme for implementation at the telescope site in Hanle in Ladakh to take advantage of its unique location in the globe, these will include: Cosmic-ray research, Geomagnetism. Aeronomy, Bondary-layer meteorology, Glaciology, Broad band seismology, GPS Geodesy, Gamma-ray astronomy, and Ionospheric research

*(iv)* Design of a moderncurriculum for Integrated School Science (As Chairman of the committee constituted by Indian Nat. Sc. Academy in consultation with NCERT).

## Research Contributions

(i) Discovery of host-rock effect, an unsuspected phenomenon which completely modifies the electromagnetic response of conducting bodies hurried in the earth, if surrounded by a partially conducting medium (1959).

(ii) Confirmation of the hypothesis that the Indian plate underthrusts the Asian plate along the Main Boundary Fault (1973).

(iii) Discovery of a thick high velocity (400km) high velocity root of the Indian lithosphere under the Deccan Volcanic Province, using seismic tomography experiments, initiated for the first time in India.

(iv) Quantitative measurement of the velocity of the Indian plate with respect to the Eurasian plate (between Bangalore and Siberia) using Global Positioning System, for the first time in India, as well as delineating the strain field in the southern Indian Peninsula (1994).

(v) Shear wave velocity picture under the Deccan (Hyderabad) using broad band seismogram analysis, the first in India (1996).

## Awards

Khosla Research Award (1971)
Shanti Swarup Bhatnagar Prise (1979)
Krishnan Medal of the Indian Geophysical Union
*Honoris Causa* Doctoral degrees from Jawaharlal Nehru Technical University and Andhra University
Award of Excellence of the Ministry of Mines (1996)

## Professional Career

Scientific Officer at National Physical Laboratory, U.K. (1960-61); Reader at University of Roorkee (1962-66), Professor (1966-83) and Dean of Research at University of Roorkee (1978-83); Director, National Geophysical Research Institute, Hyderabad (1983-89); Secretary to Government of India, Dept. Ocean Development (1989-92); CSIR distinguished Scientist at Centre for Mathematical Modeling, National Aerospace Laboratory, Bangalore (1992-96); Distinguished Professor, Indian Institute of Astrophysics, Bangalore (1996-to date).

# Pandit Govind Ballabh Pant Memorial Lecture

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Tragedy perennially stalks many a valley slope in the Himalaya. Year after year, catastrophic landslips detrude and wash away large tracts of productive soil cover which would take thousands of years to regenerate. Massive rockfalls from sheared or jointed cliffs frequently dam flowing streams, stockpiling debris that eventually burst forth and surge down, wiping out entire villages. Only a few months ago, mass movements of this kind demolished tens of villages in Guptakshi and entombed the village of Malpa in Pithoragarh, taking a toll of more than 600 lives.

Most of these episodes are basically related to the slow inexorable earth processes that have raised and keep aloft these mighty ranges against the equally inexorable wearing down processes of erosion. For, down slope gravity sliding is a universal planetary phenomenon constantly at work to moderate topographical relief and eventually level them wherever the tectonic construction processes have ceased to exist. In the active Himalayan region, however, mountain slopes are at once subject to both the tectonic construction processes powered by the earth's internal heat and the mass wasting processes induced by weather and gravity. They, thus, constitute an open dynamic system constantly supplied with potential energy by the slow driving tectonic forces, which is then dissipated in catastrophic bursts whenever the system crosses the threshold of stability. One consequence of the existence of this threshold is the wide separation between the time scales of the two countervailing processes of building –up and relaxation, which, in turn, cause landforms to evolve into a poised critical state, perpetually out of balance, where minor incremental changes may lead to disproportionately large changes or catastrophic. it is this ubiquitous tendency[1] of large open dynamic systems, such as landforms in tectonically active regions, to self organize themselves in a critical state, that is responsible for the high hazard background in the Himalaya where deformation rates are much larger than the global average.

Anthropogenic stresses, unmindful of these intrinsic sensitivities of natural systems, have thus triggered large scale disasters throughout the Himalaya. For example, fifty percent[2] of landslide occurrences in the region have been found to be associated with road construction activity each kilometer of which entails the uprooting and displacement of about 60,000 cubic meters of debris, besides truncating slopes that may have attained a fair degree of stability. Much of the attendant recurring losses could have been greatly reduced by adopting sound construction practices such as controlled blasting and a more careful selection of routes based on a scientific analysis of the geological environment, particularly the disposition of potential planes of slippage and the integrity of substratum rock formations, as well as of slope stability. Likewise, undirected spread of subsistence agriculture (per capita only about 0.06 ha in Kumaun) to support a growing (2.18% annually) undernourished population and the corresponding increase of grazing pressures that outstrip the carrying capacity of forests by 300 to 400 percent, continue to abridge supportive ecosystems by defoliation and denudation. Not only has this led to increased soil erosion[3,] about 300 tons annually from every square kilometer of barren, deforested and agricultural areas as compared with about 60 from undisturbed lands, but also driven the unwary in search of new lands, to occupy steeper high risk slopes. But, humans are also unique in their ability for critical thinking. They are capable of intuitive perceptions and with some stimulation, analytical understanding of the chain relationship between cause and effect, to visualize the wider and longer-term implications of certain actions. This intrinsic human sensibility, I believe, is our most viable resource from which alone can emerge the design of creative and harmonious solutions that would soften the impact of natural hazards that may not be avoided, and thereby prevent disasters that can be.

## Confronting Natural Hazards for Disaster Reduction

The severity of disasters precipitated by natural hazards is, in fact, determined by our ability or otherwise to confront them with knowledge, understanding and commitment. Considerable understanding now exists regarding the characteristic features and temporal evolution of various types of natural hazards: cyclones, floods and drought, earthquakes, volcanic eruptions and landslides. Carefully recorded account of past events wherever chronicled, have also led to the recognition of their space-time patterns, while analyses of these patterns have created insights in predicting the probabilities of their occurrences in future.

Powerful analytical frameworks and computer simulation models have also developed apace with progress in computational techniques, which enable one to translate these prognostications into quantitative descriptions of probabilistic hazards. These figures when incorporated in the design of land-use patterns, hazard-resistant structures and preparedness strategies, can greatly minimize the impact of nature's fury. Thus, by intelligent management of land slopes backed by scientific mapping and monitoring of vulnerable areas, Japan was able to considerably reduce[4] the scourge of recurrent landslides from 130,000 dwellings destroyed in 1938 to just 2000 in 1976 (Table1).

Table 1:

Recognition of these potential capabilities that now lie within our grasp, in enhancing our resilience to face the rigours of natural hazards, led the UN General Assembly to declare the decade of nineties as the International Decade for Natural Disaster Reduction (IDNER). India too has taken a number of measures to mitigate the severity of natural hazards. The projects initiated by the G.B. Pant Institute of Himalayan Environment & Development at Almora under the Mountain Risk Engineering Programme in designing and implementing low cost, locally supportable, slope stabilization and protection systems are indeed most gratifying and would, one fondly hopes, be emulated by executive agencies for wider application. Other organizations too have demonstrated viable approaches to slope stability analysis and landform classification to provide the basic perspective for hazard-resilient land-use planning. But these scientific tools have yet to be adopted as a regular basis for advance planning and rehabilitation, and integrated into the administrative protocols of enforcement and regulatory controls. In its absence, most of our endeavours in disaster mitigation have remained reactive, largely limited to rescue and relief operations. A serious programme to reduce their impacts to the level now possible through a systematic and focused application of available knowledge and technology, therefore, still remains in being as we approach the closing year of IDNDR.

## Basic Strategy for disaster Mitigation

An effective strategy for mitigating disasters caused by natural hazards consists in the design and implementation of four related activities: advance action for long-term protection: preparedness for efficient response to a hazardous event that has happened or is about to happen; recovery and rehabilitation; and research for improving prediction reliability, as well as the design of appropriate engineering and social structures that would effectively embed in the local culture.

## Advance Planning

This is the most important activity aimed at providing basis directions for creating an environment for long-term protection and enhancing the resilience of a community in braving natural hazards. The basic grounds prepared in this process also come in handy for implementing rehabilitation measures that would instill confidence in their future viability. This activity involves the following tasks:

* Identification hazard-prone regions on the basis of historical and current knowledge as well as conceptual anticipations.

* Evaluation of the probability of exceedance of hazard intensities over various intervals in the future, corresponding to the life spans of different types of structures, utilities and systems; and preparation of hazard intensity maps.

* Creation multi-hazard Geographical Information Systems and design of land use managements schemes.

* Design of engineering specifications for various kinds of structures and systems.

* Assessment of risks faced by existing structures and systems and designs for retrofitting and relocation them wherever necessary.

## Disaster Preparedness

These measures, necessitating horrendous outlays, can obviously be targeted only to specific areas that have already been identified as being vulnerable. They are most effective when well designed protocols for rescue and relief are already in place and can be directed by computer-simulated visualizations of the progress of a suspected of imminent catastrophe. Its basic elements are as follows:

* Design and operational readiness of protocols for effective rescue and relief measures, prevention of cascade disasters such as epidemics, and emergency operation of critical service in the event of their failure.

* Operational prediction models energized by real-time data for forecasting the progressive evolution of natural hazard, its estimated space-time characteristics and intensity.

* Regular dissemination of information through bulletins carefully designed to evoke a constructive response and avoid panic.

* Rapid response action planning and implementation.

## Rehabilitation

The only way to reduce the continuing impact of natural disasters on affected communities is to provide rapid relief ad rehabilitation while at the same time freeing them from the specter of similar catastrophes in the future. In implementing this activity, therefore, ad hoc measures should be consciously eschewed and strict adherence enforced to follow the recommended land use pattern and codes for engineering design and control.

## Research and Development

While all-out efforts should be immediately launched to use globally available knowledge and technologies in estimating and mapping hazard intensities in threatened areas, and in the development of operational prediction systems, continual improvement of these capabilities will require and equally focused effort to close the critical gaps in our understanding, through further research. Nature usually offers considerable revealing information in the wake of highly energetic catastrophes; notably earthquake aftershocks. An important research strategy should therefore aim at meticulous scientific preparedness to glean this information contained in the post-disaster behaviors of earth systems.

But, let me digress a while to sketch the specific hazard environment of the Himalaya rooted in its dynamic setting which renders disaster mitigation tasks at once most urgent and exacting, and thereby provides a focus for meaningful research efforts.

## Dynamic Setting of the Himalaya

The Himalaya stretching from Kashmir to Assam have been extruded against gravity, meter by meter, through fractures induced in the leading edge of the Indian Continent ever since it first arrived face to face with the Tibetan front of South Asia about 55 million years ago. Pervasive geotectonic movements[5] in the region affirm that the entire 2400km long Himalayan mountain are continues to be built up by an unceasing succession of catastrophic over-thrusting, creating once every few hundred years a series of great earthquakes (M>8.5) from one end to the other. The steady source of stress required to sustain this process in provided by the persistent northward drive of the strong Indian plate against the thickened and now fortified buttress of the Tibetan plateau. As a result, the whole Indian continent is at any given time, under high stress particularly its northern limb, which penetrates unabatedly into the rest of Asia.

When mounting internal stresses in some large coherent part of this leading limb reach a breaking point, it is sliced and pushed up and southward on to its own beheaded front (Figure 1) in a giant leap of about 6 to 10 or perhaps even 20 meters. Equivalently, the corresponding segments of the Indian plate under thrusts the pile of its own severed extremities by an equal amount.

Figure 1: The continued underthrusting of the Indian plate beneath the blocks severed from its leading edge due to unabated compression and recurrent cycles of strain accumulation and its catastrophic release due to continuing compression

The great Himalayan slips manifested by the four great earthquakes that have each ruptured about 200 to 300 km long segment of the plate boundary over the past 100 years, are known to have occurred on extensive fracture planes about 80 to 100 km wide that gently dip northward beneath the Himalaya. Such slips relieve most of the strain accumulated in the region some tens of hundreds of kilometers southward of the rupture and thereafter suffer a fresh build-up of strain characterized by several hundred years of low and moderate seismicity, preparatory to the next cycle of catastrophic slop and great earthquake.

Slivers of the Indian continental crust have thus been stacked ever higher over the past 55 million years to form the spectacular Himalaya. Majestically sustained against the rapidly wasting processes of erosion and constantly rejuvenated on a grand scale, they bear eloquent testimony to the extraordinary persistence and mechanical strength of the Indian continental lithosphere, which respectively provide a constant source of stress and a large reservoir of strain. As the recently measured[6] rate of ongoing inter-plate convergence between India and Asia by 5-5 cm a year clearly indicates, this process still continues. There is no longer any doubt, therefore, that the Indian continental plate coherently under thrusts the great Himalayan pile of its own erstwhile leading edge, and would continue to do so for a few million years yet, periodically ripping the entire 2400 km long stiff collision boundary in a series of 8 to 10 great earthquakes of comparable magnitudes.

A remarkable feature of Himalayan tectonics, which is of great significance to earthquake hazard assessment along the chain, is the manifest uniformity of deformational behavior and style of over thrusting along the entire Himalayan arc from Nangarparabat in the west to Namcha Barwa in the east. Evidence that this is indeed the case, is eloquently preserved in its strikingly arcurate shape that has, as a result, survived thousands of cycles of strain build-up and relaxation. This, in turn, implies that the rate of strain accumulation and release are on average uniform from one end to the other. Analytical results drawn from the study of the four great earthquakes that are the only ones known to have occurred in recorded history thus provide reliable guides to quantifying earthquake hazard in the region straddling the intervening segments which are seismic gaps in the sense that whilst being subject to the same stress that continually compresses the entire chain they are not known to have ruptured for at least 300 years of longer.

This uniform north-south convergence of the two continents astride the Himalayan arc requires that the recurrence time in years, between great earthquakes of comparable magnitudes that rupture its different segments be, on average, the same. However, fault heterogeneity along the arc would in reality be expected to prevent the entire chain from rupturing synchronously. In particular, different segment of the arc, which may be transversally decoupled by tear faults, would tend to respond to the self-same uniform stressing by individually adjusting the exact timing of their rupture. Therefore, great earthquakes along different segments of a plate boundary whilst having the same recurrence interval on average, would tend to stagger in time, as is indeed the case in the Himalaya.

Estimated rupture lengths of the four great earthquakes and the existence of tear faults ripped by strong continental grains of the under thrusting Indian plate, suggest that the Himalayan arc is, thus, segmented into seven parts: Kashmir, Himachal, Uttar Pradesh, Nepal and West, Middle and Eastern Assam. Four of these, (Figure 2), each measuring about 200 to 300 km in length were ruptured by great earthquakes in 1905, 1934, 1897 and 1950, respectively relieving about 5.5, 6.5, 8 and 9 metres of accumulated strain as estimated form their magnitudes.

Figure 2: Transverse incisor grains of the Indian continental fabric and segments of the overthrusting Himalayan mountain are by the faults that act as transform faults in facilitating strain relaxation of individual segments through slips staggered in time over a whole recurrence period.

Those not known to have been ruptured in recorded history, at least for the past 300 years of longer are the westernmost Kashmir segment about 250 km long, the shorter middle Assam segment, and the Central Himalayan seismic gap which is over 700 km long. However, we do not have adequate seismic data to decide whether this central segment is effectively decoupled into two or three blocks that could rupture independently, in tandem of synchronously, or behaves as a single coherent unit. The western boundary of this segment that decouples it from the eastern extremitly of the rupture zone of 1905 Kangra earthquake is well marked by the prominent Delhi-Hardwar ridge transverse to the Himalayan strike and by its subsurface seismic signatures further north as a right lateral strike slip (Figure 3) shear right upto Sayanachatti between the valleys of Yamuna and Bhagirathi where the main Central Thrust swerves southwards in a sharp bend before straightening out again on its eastward course.

Fig: 3: Seismicity belt delineated from regional and teleseismic data for the period 1684-1991. Focal mechanism and location of Uttarkashi earthquake are also shown. Note that fault plane solution of earthquakes along the north Yamuna valley shown right, show right lateral strike slip motion.

The only definite clues as to where the eastern extremity of this central segment may lie is provided by the western-most limit of the 1934 rupture, geologically marked by the Patna fault or the Manghyr-Saharsa ridge. But, there is some indication yet to the tested, that a similar tear along the Morabdabad-Dharchuala transversal marked by unusual seismicity, might be dividing this long unruptured segment into a west central part of U.P. Himalaya and another one or two the east in Nepal Himalaya. There are therefore no clear leads at present to exclude the horrific possibility that the entire 700 km or so long Central Himalaya from Dehradun to Patna/ Monghyr which would be most likely close to rupture at any time between now and 2150 AD (assuming an average recurrence interval of 400 years) may relieve the accumulated strain in the region by a giant southward slop of upto 20 metres, like the great Alaskan earthquake, also of a compression zone, caused by a reverse slop of 21 metres on a 700 km long thrust plane.

## Earthquake Hazard Assessment

It should thus be clear that earthquake hazard all along the Himalaya, which marks the world's most active locus of continental convergence earthquakes, is generally quite high. Since most of the accumulated energy is released in great earthquakes, the potential severity during a given epoch will vary along the different segments depending upon their accumulated strain budget at the time and their closeness to the rupture limit. In particular, the hazard would be expected to be extremely high in the region adjoining the unruptured segments of Central Himalaya, Kashmir and Middle Assam around Tezpur. However, in order to quantify eathquake hazard in and the Himalayan region one must first define the great rupture planes the produce major earthquakes and constrain the rate of underthrusting or strain accumulation and recurrence relation of earthquakes, and also produce experimental determination of crucial quantities that express the local and regional behaviour, notably attenuation laws, free surface amplification and terrain effects. In particular, research efforts need to be addressed to answer the following questions:

* What is the geometrical and geographical disposition of the great rupture planes along various segment of the Himalayan arc?

* How are coherent rupture planes in the Himalayan segmented from west to east? What is the rate at which they accumulate strain and what is the pattern of their historical and paleoseismicity?

* What recurrence relation do earthquakes of different magnitude ranges follow along the various segments? And what would be the likely magnitude a their respective characteristic (?) earthquakes, if any?

* What would be the peak ground acceleration tat would to be exceeded over a given period in the future at different levels of confidence to enable judicious social choices to be made in order to balance risk and cost effectiveness for various range of engineered structures?

In addition to the hazard posed by the relatively infrequent great earthquakes (M>8), the highly shared and variously segmented Himalaya continue to release energy at more frequent intervals through smaller earthquake that locally relieve stress on its myriad faults, some of these like the 1991 Uttarkashi also prove to be quite disastrous. Besides, steady deformation in the region adjoining both the longitudinal and transverse faults, constantly modifies landforms inexorably driving them towards instability. Earthquake hazards assessment in respect of such non-great earthquake rupture planes is therefore equally important, both for estimation probabilistic ground acceleration to the expected as well as for identifying stressed landform, which may need to be targeted for continual monitoring. However, since fault expressions in the Himalaya are legion, adequate field investigations complemented by analysis of small scale landform features now possible through multispectral satellite imageries must be carried out first, to identify and classify high risk areas for a quantitative assessment of hazard. Even whilst experimental determinations are still in being, one can on the basis of indirectly inferred figures, attempt to estimate earthquake hazard using i) a deterministic model to compute accelerations at different distances from the rupture plane [7] of ii) a statistical approach which makes use of global information on instrumentally determined values of ground accelaration[8].

## Return to Landform Stabilization

Landforms are the most basic and precious resource of mountain communities and their continued stability is of vital interest to them. This stability is determined by the balance of forces between the downward pull on a mass of detachable material and its shear strength along surfaces of possible slippage (Figure 4). Failure occurs when this balance is lost in favour of the gravitational pull along one of these surfaces. Understandably, this happens when the downslope component of the weight of the material increases, simultaneously with a decrease in its cohesive strength – a situation that can be brought about by the progressive steepening of slope by tectonic processes or saturation with water caused by extended periods of rainfall or intense cloudbursts.

Cohesive or shear strength may also be precipitously reduced by the strong ground shaking caused by earthquakes, particularly its horizontal component, resulting in catastrophic slips, if the slope shape and aspect is unfavorable an other contributory factors such as long rainy spells also intervene. Moderate and great earthquakes destabilize landslopes by altering the distribution of stresses and pore pressure fluctuations.

Figure 4: Diagram showing the forces acting on a rock particle on a hillslope. The force directed downslope, therefore depends on the weight of the object and angle of slope. In this example the particle will remain stable as long as the frictional cohesion of the surface material is greater than 0.5kg. if the downslope force is increased by adding weight, increasing the slope angle, or by decresing the cohesive strength, movement occurs.

Oldham[9] gives a graphic account of the extensive landslides generated the the great Assam earthquake of 1897:

"*Viewed form the deck of a steamer sailing upto sylhet, the southern face of these hills presented a striking scene. The high sandstone hills facing the plains of western Sylhet, usually forest clad from crest to foot, were stripped bare, and the white sandstone shone clear in the sun, in an apparently unbroken stretch of about 20 miles from east to west".*

Both deterministic and probabilistic approaches to quantitative slope analysis are now well developed for estimation the safety factor of a landslope in a given eoclimatic environment. Spatial maps of slope safety factors constitute a basic canvas to direct the design of hazard resilient land-use plants, the first step in disaster mitigation. Figure 5 shows an example of such analysis classifying landslide hazard[10] zones over a 66 km square area in the Srinagar-Rudraprayag area of Garhwal Himalaya, using Information theory concepts.

Figure 5: Landslide risk mapping by Information Theory

Slope analysis can be greatly refined by incorporating other important details not easily gleaned form field studies that implicate landslope stability. This is now possible through the use of satellite images in black and white or colour as well as spectral bands through red, green and near infrared wavelengths. Modern Geographic Information Systems which are digital systems of mapping the spatial distribution of various attributes of a landscape, are most amenable to incorporation of such multifaceted set of information and lend themselves conveniently to pattern recognition and model building that, in turn, help determine the best geotechnical approaches to mitigation.

## New Opportunities

Most catastrophies are apparently preceded by low intensity precursory phenomena such as foreshocks before a major earthquake on show creep preparatory to a disastrous landslide. For example, analysis of the instrumental records from the Vaiont dam reservoir slopes in Italy showed that the catastrophic slide of more than 240 million metre cube of rocks that splashed into the reservoir on Oct. 9, 1963, raising a wave of water over 100 metres high which swept over the dam destroying everything in its path for several kilometers downstream, was preceded by a slow creep over a three year period. About a month before the event, the rate of creep that had been found to be about 1 cm/day increased to 25 cm/day and to 40 cm/day on the day before the slide.

Such precursory phenomena can be captured through well-planned investigations and multi-sensor arrays to develop physical warning systems. This is already a reality at many a potentially hazardous site in Japan and the United States, which are instrumented with real-time monitoring systems. One such system deployed at active landslide sites in California, consist of 11 stations and 58 surface and subsurface instruments that constantly relay wide dynamic range ground deformation and vibration data from GPS receivers and geophones as well as rainfall and pore-water pressure information to central station for prediction and warning. The ongoing revolution in Information Technology and wide area connectivity combined with considerable expertise in sensor technologies available in the country, open up exciting workable opportunities for developing such systems even in a low technology environment such as the Himalaya. Figure 6 shows a conceptual sketch of a fibre optic based landslide monitoring system proposed by CSIO, Chandigarh

Figure 6 : Conceptual sketch of a fiber optic based landslides monitoring system proposed by CSIO, Chandigarh.

These are great opportunities of our age waiting to be grasped and harnessed, to realize a great dream of banishing the spectre of disasters from the Himalaya, and turning the mountain fastnesses into the dreamland that would continue to chasten and exalt out spirits. Himalaya today is in a highly degraded state. Its barren tree bare hills bristle with ominous instabilities. Unwitting human influences are largely responsible for this grave state. But humans can also transform the scene through intelligent action.

We need to dream about and visualize the beautiful possibilities that these enchanted regions hold, and endeavour in every possible way to turn these into an experience realizable by all others. Pandit Govind Ballabh Pant, one of the greatest men of this land, was moved by such a transcendental vision of 'beyond here and now' and pursued it under circumstances far less propitious. May his spirit enlighten ours.

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