Application of lichenometry to slided materials in the Higher Himalayan landslide zone

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The lichen-based study involving the measurement of per cent cover of lichens on slided materials in the Pawari landslide zone located in the Higher Himalaya is described. This has been correlated with the indicators showing movement of deposits and activity of the slide. It is well documented that in a slided mass, boulders containing more lichen cover are stable in the present climatic scenario or have moved least compared to the ones showing lesser lichen cover. Slopes covered with more or less fresh rock boulders and pebbles in the slide zone indicate an active part within the slided mass. This study can be used as an indirect method to assess the differential movement of slope within the slide mass.

Keywords: Higher Himalaya, lichenometry, landslide, Pawari landslide zone.

LICHENOMETRY is the study of lichens and as a dating technique is based on the fact that fresh rock surface gets covered by lichens after a period of time. After a fresh rock surface is exposed, lichens will begin to colonize it. This does not usually happen instantaneously. It may vary from one year[1] to about ten years or more[2]. It is not possible to give a minimum period of time after which lichens will become visible on the rock surfaces in the Himalayan terrain. This is because the process of colonization is dependent on several factors, especially on local climate and rock type.

Lichenometry has long been recognized as useful in geomorphic studies, particularly to date moraines in glacial settings[3,4], where the diameter of a specific type of lichen is used as a proxy for estimation of the duration for which a rock has been exposed at the surface[4–7]. The lichen commonly employed is the rhizocarpon, which is crudely circular in shape, and whose diameter is thought to increase linearly with time. It is assumed that when the deposits are formed, they are free of any lichen cover. It has been proved that lichen populations growing on similar microhabitats having the same orientation (i.e. aspect)[1] and the same rock-type[2] influence the growth rate. The practice was to record the largest lichen thalii found on hundreds of boulders on the surface to be dated or to take the mean of the five largest lichens[8]. However, local calibration is necessary, as climate dictates the rate of lichen growth. Typically, calibration of the growth-rate curve comes from surfaces that have been exposed for a known period of time.

Lichenometry has also been adopted to investigate the spatial and temporal pattern of debris flow or other mass-wasting deposits[9] and major rockfalls in rugged landscapes[10]. Bull[11], and Bull and Brandson[12] applied this technique in California and New Zealand respectively, to resolve discrete pulses of rockfall material associated with seismic activity. In the present study, lichenometry has been applied to the Pawari landslide zone located in the Higher Himalaya, Kinnaur District, Himachal Pradesh. This study seeks to correlate the growth of lichens with landslide activity in a particular geomorphic and climatic setting. As the presence of lichens on the surface of rocks is always an indicator of time of exposure of the rock surface, this preliminary study intends to establish a relation between the presence or absence of lichens, their size and activity of the slide, from which a more general model may ultimately be constructed.

The study area is located around village Pawari (31°33′30″N and 78°16′E), on the right side of river Satluj, Kinnaur District, Himachal Pradesh (Figure 1). It is located to the north of the Vaikrita Thrust (VT) in the Higher Himalaya and is situated between altitude 2600 and 2000 m amsl. VT separates the Vaikrita Group gneisses from Lesser Himalayan metamorphics of the Karcham Group. The area consists mainly of the Vaikrita Group of rocks exposing highly jointed, sheared and fractured mica gneisses interbanded with quartz mica gneisses. The slopes are covered with thick veneer of sediments of glacial and periglacial origin. The terrain is highly rugged and the slopes are generally steep with an angle more than 50°. The average slope of the hill is 55 to 60°, with local variations.

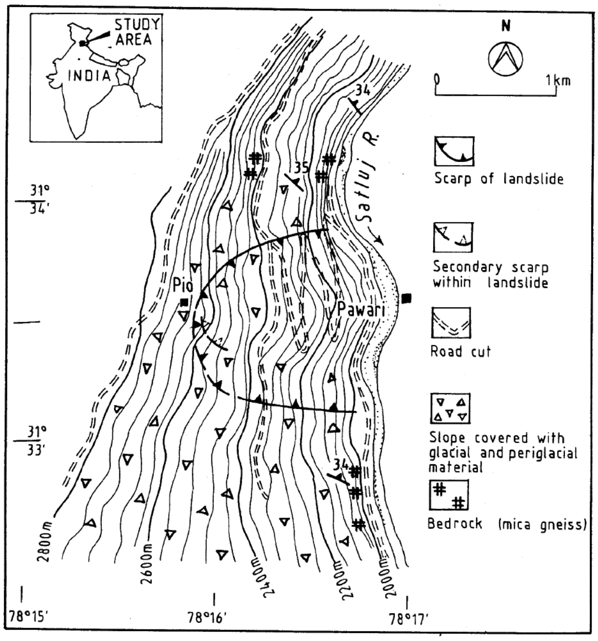

Figure 1. Location map of Pawari landslide zone situated on the right bank of river Satluj. Slopes in the slide zones are covered with thick veneer of sediments belonging to glacial and periglacial origin.

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Figure 2. Panoramic view of Pawari landslide. Six road cuts were made on a single slope to connect the National Highway-22 passing through the bottom of the slope with the village Pio situated at an altitude of 2700 m amsl (crown of the slide).

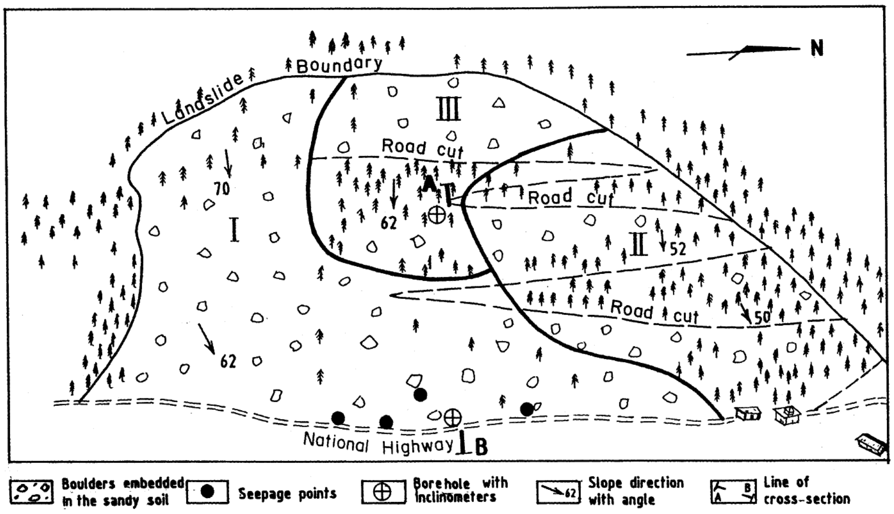

Figure 3. Sketch map of Pawari landslide depicting three zones; zone I exposing fresh rocks with no lichen coverage; zone II with dominant lichen coverage of about 70% and zone III, lichen coverage of about 40%.

The climate of the area is characterized by cool, wet winters and hot, dry summers with mean annual rainfall between 400 and 800 mm. Precipitation is highly seasonal, with 70 to 80% falling between August and September as also December and January. The minimum temperature varies from –5 to –3°C during January, whereas the maximum temperature ranges from 28 to 30°C in May and June.

Five criteria that make the Pawari slide zone ideal for a study of this type are:

1. The spatial limit of this landslide is clearly defined and access is easy to all parts of the slide, unlike many landslides in the Himalayan terrain.
2. Climate is more or less uniform throughout the slide zone.
3. The aspect of the landslide is uniformly consistent throughout the slide zone, i.e. easterly facing.
4. The slide has developed on glacial and periglacial material consisting of boulders, pebbles and sandy material of only one kind of lithology, i.e. mica gneisses.
5. The slide is old, definitely more than 50 years, as it is clearly marked on the Survey of India 1 : 50,000-scale toposheet published in 1962 and was possibly surveyed earlier.

The Pawari landslide measures about 1200 m in length and 700 m in width, affecting about 1600 m of National Highway-22 (NH-22) passing through the toe portion of the slide (Figure 2). Six boreholes through the slide mass dug by the Central Road Research Institute (CRRI)[13] New Delhi, confirmed that the maximum depth of this slide is about 25 m (Figures 3 and 4). It is one of the largest landslides located in the Satluj valley. It is a typical example of a complex slide, which represents a combination of debris slide in the upper part, subsidence in the middle slope and debris slide at the toe. Six hairpin bend road cuts were made on a single slope to connect the NH-22 passing through the toe region of the slope with the village Pio, district headquarters of Kinnaur, located at an altitude of 2700 m amsl, in the middle portion of slope. Activity in the slide zone has increased due to road-cutting in 1975. The slide has been studied for its causative factors by many workers (V. Gupta, unpublished)[13,14]. It has also been monitored by CRRI[13] for 489 days during 1992–94. Two inclinometers were installed at two different locations, one at the bottom of the slide near NH-22 and other in the middle of the slope (Figure 4). The average rate of movement for uphill and downhill slopes recorded during 1992–94 was 0.23 and 0.56 m/yr, respectively. Each year several cubic metres of materials find their way into the river, thus creating a nickpoint in the river Satluj[15] which flows at the base of the hill.

The exact date of the initiation of this slide is not known. However, the slide gets activated every year immediately during or after the rains or snow melt. The inclination of the failure plane of the slide varies between 60 and 70° due east (Figure 4).

The rock types surrounding the Pawari landslide zone are mica gneisses and quartz mica gneisses belonging to the Vaikrita Group of Higher Himalaya. These rocks dip 34° due NE. The entire slide zone is covered with boulders and pebbles of mica gneisses and quartz mica gneisses. These are embedded in the sandy soil. The average size of the boulders varies from 1 to 3 m. Three prominent sets of joints and fractures dipping in the slope direction were present. An unlined irrigation canal is present along the upper part of slope. The percolation of water, six road cuts on a single slope and continuous toe erosion by river Satluj are the main causative factors of this landslide (V. Gupta, unpublished)[13,14]. The presence of NE–SW-oriented transverse cracks on the flanks of the landslide, convex slope in the toe portion, tilted trees in the central portion, sinking of roads, and distress seen in the retaining wall are indicative of the active nature of this landslide.

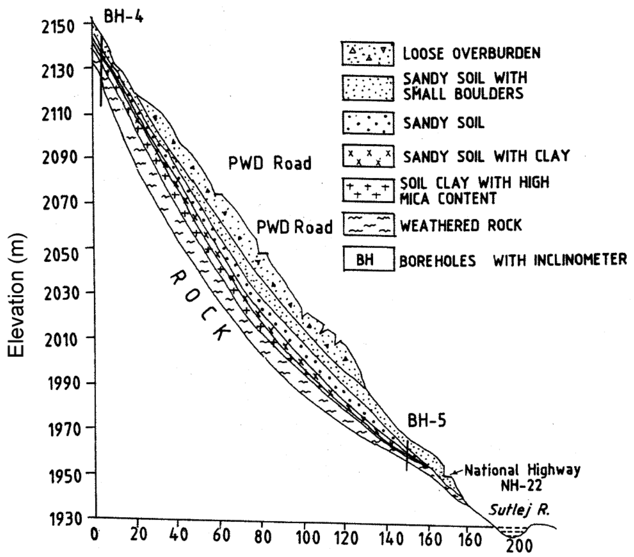

Figure 4. Cross-section across the Pawari landslide based on field observations and borehole details (adapted from O. P. Yadav[13]).

It is well documented by previous studies[1–6] that presence or absence of lichens is an interplay of many factors like climate, smoothness of the substrate, local mean annual temperature, precipitation and length of growing season, whereas the size of any particular species is a function of time of exposure. Various species of lichens thrive on the surface of mica gneisses in the Satluj valley, and therefore, this technique has been applied in the present case.

In the present area of study, the slide has been mapped by the presence or absence of lichens, irrespective of the type of species. Further, the per cent lichen coverage on the easterly facing surface of boulders embedded in the landslide zone was noted. Based on these observations, the Pawari landslide has been divided into three zones (Figure 3). The characteristics features of each zone are as follows:

Zone I is devoid of any lichen coverage (Figure 5). It is located on the southernmost side and at the lower reach of central part of the slide zone (Figure 3). In the southernmost part of the slide, it runs from the crown to the tip. The slopes in this zone are covered with boulders and pebbles of mica gneiss. This is the most active part of the slide as documented by the presence of numerous cracks, distress in the retaining wall (Figure 6), lack of trees and bushy vegetation, blockade of the National Highway in this part every year as confirmed by the villagers and documented unpublished reports. One inclinometer installed at the toe portion of this slide falls in this zone (Figure 3) and recorded a movement of 0.56 m/yr during 1992–94.

Zone II is located on the northern end of the landslide zone and also runs from the crown to the tip of the landslide. The boulders and pebbles lying in this zone are covered

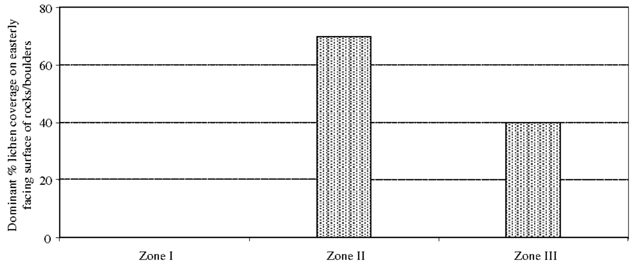

Figure 5. Graph showing dominant per cent of lichen coverage on easterly facing surface of rocks and boulders in various zones within the Pawari landslide.

with lichens. The dominant lichen coverage on the easterly facing rocks and boulders is about 70% (Figure 5). On most of the surfaces of the boulders, lichens coalesce to a diameter as much as 50 cm (Figure 7). This is the most stable part of the slide in the present climatic regime. No distress and slumping or subsidence of roads in this zone has been noticed. Also from the documented unpublished reports and eyewitness accounts, this zone appears to be stabilized and no activity has been reported here during the last 10 years.

Zone III is located in the upper reaches of the central part of the landslide zone. In this zone, the dominant size of lichens on the easterly facing boulders is about 40% (Figure 5; c.f. coverage of boulders in zone I). There appears to be movement in this part of the slide as evident from creeping of loose materials and also by the tilting of trees and subsidence of the road passing through this zone. One inclinometer installed in this zone[13] recorded a movement of 0.23 m/yr during 1992–94, which is smaller compared to the movement in zone I.

Figure 6. An offset of about 3 m in the retaining wall in zone I. Widespread damage to the wall and subsidence in the road indicate movement in zone I of the Pawari landslide.

Figure 7. A boulder lying loose on slopes in zone II of the Pawari landslide containing lichen coverage of about 70%. These slopes are stable in the present-day climatic scenario, as no movement indicator has been noticed.

The growth of lichens on the surface of rocks under appropriate climatic conditions is a natural process. For the application of lichenometry, two factors are assumed. The greater the coverage of lichens on the boulders facing one particular direction, greater is the exposure time, and the growth rate of the lichen species is constant. Thus by measuring the percentage cover of thalli of lichen species on several sites (several boulders in the slide zone in the present case), which may give maximum relative age of exposure, comparison can be made with other deposits. Also, indirectly one can conclude that boulders having no lichen coverage have not been exposed for sufficient time. This points to a shift in environmental conditions or exposure history. The change in environmental condition for such a small area is ruled out, but the presence of indicators of slope movement makes it possible to ascribe the deposits within the Pawari landslide zone to different exposure periods due to movement of boulders in the body of the slide zone. This has been well documented by inclinometer data.

At present the only technology available for the differential movement of slope or the microzonation is full scale geotechnical site investigation or continuous monitoring of slope with instruments like Global Positioning System and Total Station, which is expensive in the rugged Himalayan terrain. This site-specific geotechnical study is of practical use to construct engineering structures. However, there is a need for first order microzoning technique that is least expensive and less time-consuming. The present lichenometry technique is qualitative and subjective.

The microzonation approach used in this study for a particular landslide is partly acceptable. As in all techniques, there are limitations and uncertainties. Here one must obviously have an appropriate climate in which well-behaved lichens thrive. There will always be some lag between deposition of a rock on a surface and its colonization by lichens. In addition, lichens apparently grow rapidly at first (the great-growth phase), before entering their linear growth phase. In the present case, the specific species of lichen is not taken into account, however, the correlation of size and presence or absence of lichens on boulders in different zones are well documented with the rate of movement. Further testing of the population techniques for lichenometry is warranted. This approach holds promise for developing rather detailed chronologies on geomorphic surfaces in active landslide areas.

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ACKNOWLEDGEMENT. I thank Prof. B. R. Arora, Director, Wadia Institute of Himalayan Geology, Dehra Dun for providing facilities and encouragement to carry out this work.

Received 27 January 2005; revised accepted 30 May 2005

MEETINGS/SYMPOSIA/SEMINARS

The Second Conference of the Western Ghats Forum

Date: 1–2 December 2005
Place: Coimbatore

The conference has been structured to include 7 symposia: Pollination services, Invertebrates and conservation management, Water and forests, Policy imperatives for the Western Ghats, Species recovery and restoration, Conservation and livelihoods, Conservation and education and Forest management.

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National Conference on Aquatic Resources, Aquaculture and Aquashow

Date: 15–17 February 2006.
Place: Palayamkottai

Topics include: Fish germplasm, Management and conservation, Integrated coastal zone management, Quality and safety of sea food, Socio economics, etc.

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