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RESEARCH ARTICLE

LICHENOMETRIC DATING CURVE AS APPLIED TO GLACIER RETREAT STUDIES IN THE HIMALAYAS.

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Abstract

The study critically favours the importance of lichens in estimating palaeoclimatic events and its use in depicting the future discretion regarding glacier retreat. Besides the various lichenometric studies carried out in Indian Himalayan region, the world-wide classical work of different glaciologist and geologist on different applications of lichenometry is also well focused. The study also highlights the benefits, restrains, and drawbacks associated with the lichenometry. Being a globally accepted biological technique particular emphasis is given on the need of innovative approach in implementation of lichenometry in Indian Himalayan region.

Introduction:-

Lichens are slow growing organisms and take several years to get established in nature. Lichens are a unique group of plants, comprising of two micro-organisms, fungus (mycobiont), an organism capable of producing food via photosynthesis and alga (photobiont). These photobionts are predominantly members of the chlorophyta (green algae) or cynophyta (blue-green algae or cynobacteria). The peculiar nature of lichens enables them to colonize variety of substrate like rock, boulders, bark, soil, leaf and man-made buildings. In the alpine region of the Himalayas higher plants are not found but lower group of plants including micro and macro lichens are luxuriant grow because of peculiar physiological, morphological and anatomical characteristics features. Lichenometry has long been recognized as useful in geomorphic studies, particularly to date moraines in glaciers. The lichenometry is the study of lichens and as a dating techniques is based on the fact that fresh rock surface get covered by lichens after a period of time. The diameter of lichens of a specific type of lichens is used as proxy for estimation of the duration for which a rock has been exposed at the surface. The technique is globally applicable because of the wide environmental tolerance of lichens and Rhizocarpon sp. is commonly used in the study. Among the different genera the lichen genus Aspicilia calcarea (L.) Sommerf. radial growth rate is (0.24–2.3 mm Winchester, 1984), Dimelaena oreina (Ach.) Norm. (0.3 mm Awasthi et al., 2005; 0.57 mm Hale, 1959), Diploschistes scruposus (Schreb.) Norm. (0.44 mm Hale, 1959), Lecanora muralis (Schreb.) Rabenh. (1.30 mm Hakulinen, 1966; 2.14 mm Winchester, 1984), Lobothallia alphoplaca (Wahlenb. ex Ach.) Hafellner (0.95–1.40 mm Frey 1959), Rhizocarpon geographicum (L.) DC. (0.1– 0.21 mm Leonard and Rosentreter, 1994; 0.2 mm Hansen, 2008; 1.0 mm Chaujar, 2009b), Rhizoplaca chrysoleuca (Sm.) Zopf. (0.32–0.89 mm Kevin et al., 2004), Verrucaria muralis Ach. (0.38–1.0 mm Winchester, 1984) and Xanthoria elegans (Link.) Th. Fr. (0.5–0.9 mm McCarthy and Smith, 1995; 1.35 mm Hakulinen, 1966; 0.43–0.44 mm Vitt et al., 1988) used in lichenometric studies.

Glaciers are among the most sensitive indicator of climate change. Their recession and advancement depends on the prevailing climate conditions. Glaciers on recession leave heaps of moraines that on steady and continuous exposure provide habitat for some lichens that are peculiar in their ecological amplitudes and are restricted to alpine localities. Lichenometry takes advantage of the lichens growing in the vicinity of the glaciers and predict the minimum time of exposure of these moraines and there by anticipate the age of glacier retreat. Subsequent to Baschel (1950, 1957, 1961, 1973), other workers such as Griffey (1977), Porter (1981), Gordon & Sharp (1983), André (1986), Werner et al. (1987), Spence & Mahaney (1988), Werner (1990), Burrows et al. (1990), Rodbell (1992), Matthews (1994), Smith et al. (1995), Harrison & Winchester (2000), Smith & Desloges (2000), Sancho et al. (2001), Solomina & Calkin (2003) and Armstrong (2005) has applied the technique on glacier deposits in different countries. Forman et al. (2007) used lichenometry to estimate the age of recent exposed morines close to Inland Ice. Hansen (2008) outlined and discussed the different applications and field methods which may result in lichen growth curves and lichenometric dating curves.

The mountains of the western and central Himalayas and Karakoram comprise the greatest concentration of glaciers outside of the Polar Regions (Owen et al. 1996). The high terrain of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and few states of Eastern Himalaya constitute the major proglacier regions of Indian Himalaya. This makes the Indian Himalayas particularly important in understanding environmental change with reference to the nature and timing of glacier fluctuations. Studies on Indian glaciers recently gain prolific attention due to increase load of earth worming.

Database along with satellite pictures and old maps hold valuable information pertaining to the recession of glaciers. However in the absence of historical data, absolute dating of moraines exposed after the recession of glaciers provide valuable information regarding the period and rate of glacier retreat. Lichenometry is well implemented world-wide technique in estimating the age of glacier retreat. In India, lichenometry was first undertaken in the Gangotri glacier area of Uttarakhand (Srivastava et al., 2001). Science then only few studies on proglacier valleys has been accomplished. Awasthi (2005) carried out studies on Gangotri glacier valley using lichenometry (with Dimelaena oreina) and Schmidt hammer techniques simultaneously. Based on the known age of two moraines, the relative ages of the other two unknown moraines have been calculated. According to him both the techniques are negatively correlated to each other since the size of the lichen thallus (lichen growth) increases with time, whereas the Schmidt Hammer R-values decreases with time because the intensity of rock weathering increase with time.

The study accomplished by Chaujar (2009) deals mainly with Chorabari glacier of Garhwal Himalayas in Uttarakhand. In this study climate change and its impact on the Himalayas glaciers based on the dating of lichens, developed on loops of marines formed due to various stages of advancement and recession of the Chorabari glacier. According to Chaujar (2009) the Chorbari glacier started receding 258 years ago from the point of its maximum advancement. He has interesting envisaged the age of glacier retreat and correlated and justified his result with the help of old Kedarnath temple situated nearer to the snout of glacier.

The lichenometric techniques are applied on the lichens inhabiting on fixed long standing material (glacier moraines, rocks, stones and boulders). The application of lichenometry on moraines near glacier vicinity is essential to understand the date and frequency of glacier retreat.
Instead of the importance of the techniques in the relevant field not much significant work based on this biometric technique in India has been conducted.

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Instead of the importance of the techniques in the relevant field not much significant work based on this biometric technique in India has been conducted.

Material and Methods:-

1. **Identification of lichens:-**

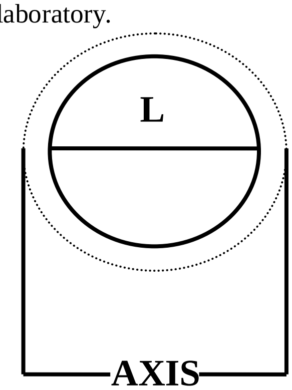
Accurate identification of lichen taxa is necessary for successful study. To the acsul observer some lichens of different taxa may appear to be similar and may thence be misidentified as belonging to the same taxon. The misidentification may lead to incorrect dating as the growth rate of two species differs even in same climatic conditions. The reference specimens can be collected and identified in the laboratory. The identification will be based on the methodology followed by Orange et al (2001) and literature published by Awasthi (1991, 2007).

2. Field methods:-

Lichenometric studies which are necessarily conducted in the field, involve measurement of lichen size. Under ideal conditions measuring lichen size should be relatively simple because of their circular habit and their host surfaces are simple in morphology and aspect. In reality, however, lichen thalli are typically irregular and rarely circular in form and surface are rarely uniform. The use of consistent approaches to measurement is therefore required.

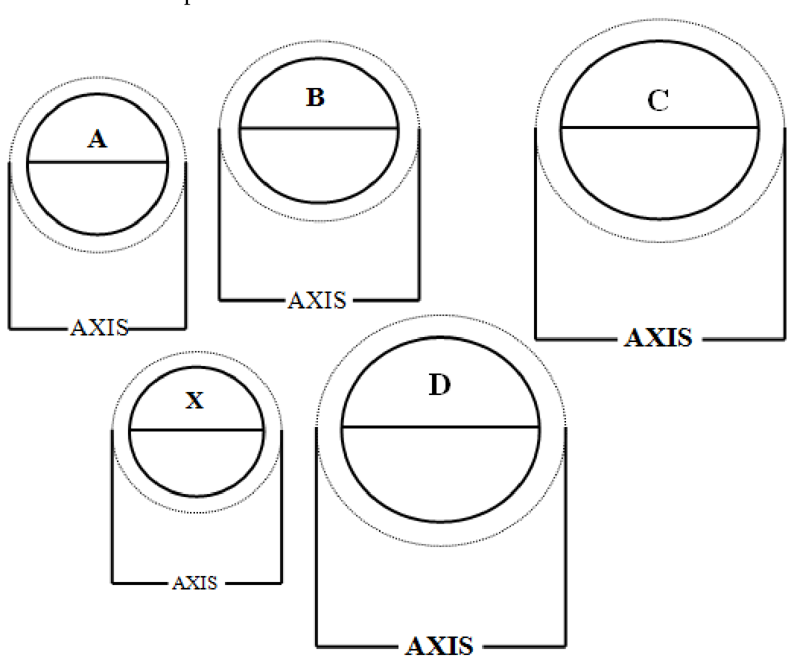
a) Longest axis measurement of largest lichens:-

The longest axis is measured from edge to edge along the greatest diameter of the largest lichen thallus on the exposed surface. But this may allows the possibility of measuring overlapping thalli. So the role of hypothallus is significant in delimiting the single thallus from the neighboring ones. In most of the recent studies (Bull et al., 1995: McCarroll, 1994) this methodology is applied. Typically only five or ten largest thalli measurements are deemed necessary to estimate the age of the study surface (Innes, 1985a). The measurement is simple and most often made with a flexible rule or tape. The measurement can be made directly on the samples in field or using transparency to trace the outline of the samples and measure it in the laboratory.



b) Mean of largest lichens in single substratum:-

The mean of the largest lichens diameter in one substratum (rocks, boulders, pebbles, stones) will be assumed as the largest orbicular growth of the lichen. Recent studies (Bull et al., 1994) have utilized the mean of the largest individual thalli at a large number of sites (defined as individual boulders), assuring that a sample of the largest lichens best characterize the lichen population. As with the use of the single largest thallus, use of the mean of largest thalli emphasizes rapid colonization and optimal microenvironments.

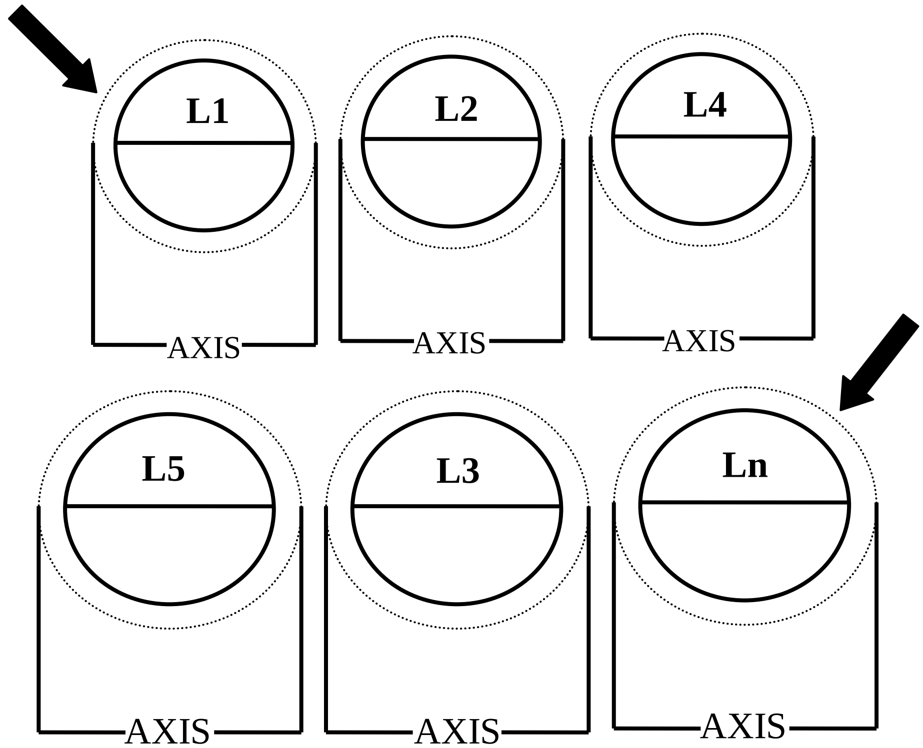


$$\frac{A+C+D}{3} = X$$

X = Diameter of largest lichen growth

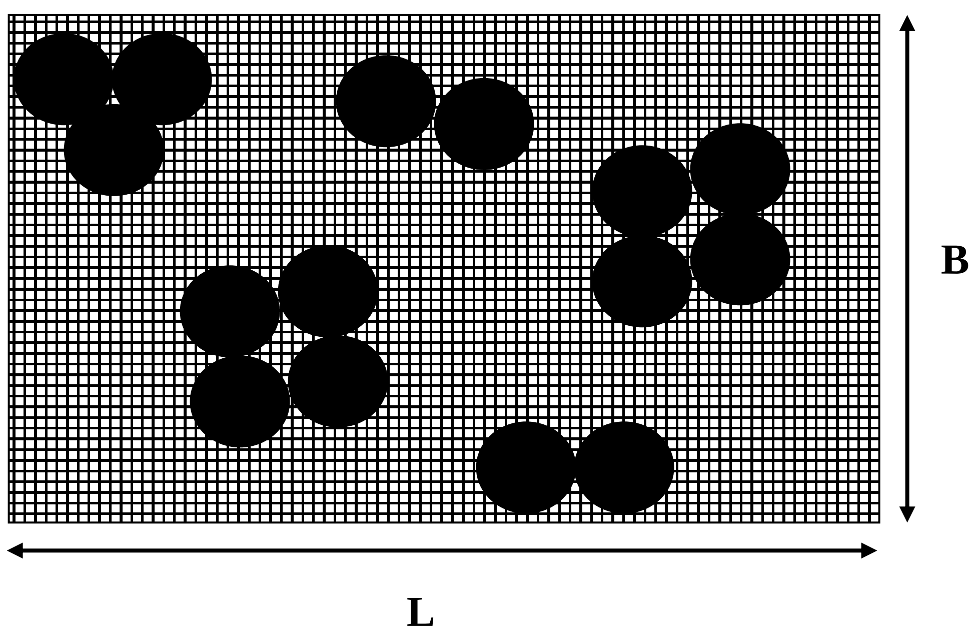
c) Size-Frequency measurement:-

The size-frequency approach involves the measurement of several hundred to several thousand lichen thalli; these data are used to estimate the largest thalli or ages of subpopulations of lichens in the data set. This approach has been successful in number of studies (e.g. Benedict, 1967; Smirnova & Nikonov, 1990; Winchester & Harrison, 1994).



d) Percentage cover:-

Percentage cover is the ratio of the area of lichen covered surface to the total exposed surface area. This technique allows for the inclusion of coalesced thalli in the data set that would otherwise be ignored by other techniques. However, percent cover can only be estimated (not measured) in most studies.



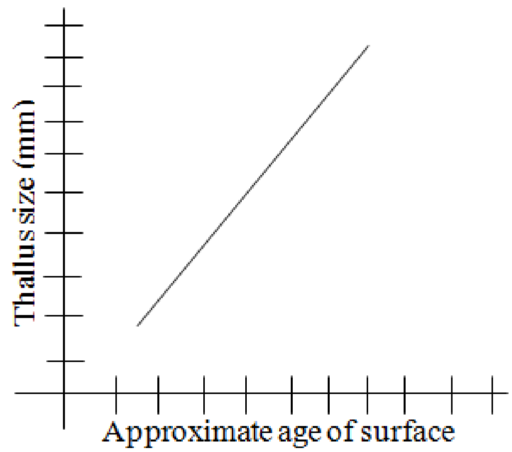
$$\frac{\textbf{Area of circular } [\pi\,(r_1^2 + r_1^2 + r_1^2 \ldots\ldots\ldots + r_1^2)] \times 100}{\textbf{Area of rectangle } (L \times B)} = \textbf{\% lichen cover}$$

3. **The age of surface can be estimated by applying the formula:-**

$$\frac{\mathbf{1 \times Thallus\ size\ (mm)}}{\mathbf{Growth\ rate\ (mm/yr)}}$$

4. **Development of dating curve:-**

In this way by establishing a relation between the presence or absence of these lichens and their size, the activity of the glaciers in different glacier valleys can be modeled. This model will help in depicting the minimum age of the exposure of the surface near the glacier vicinity that eventually envisage the age of the glacier retreat. A graph of lichen thallus size can be plotted against age of the surface on which it grows. There must be a distinct positive correlation of pattern of size of thallus with the approximate age of the exposed surface.



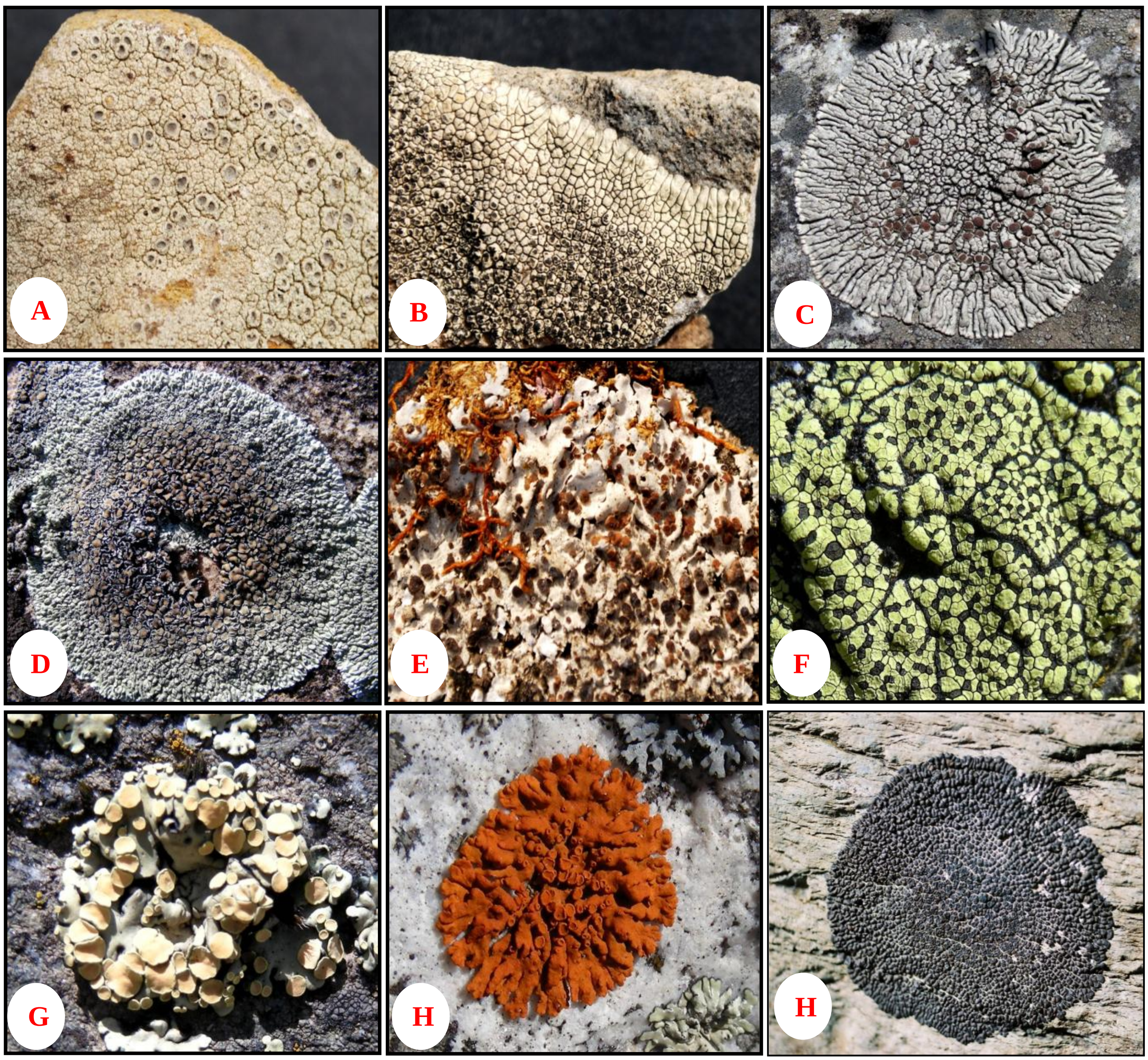
Result and Discussion:-

Lichens are well known for their endurable life styles and therefore have miscellaneous importance in calibrating environmental changes. Also lichens are selective in their environmental regimes and their existence signifies the stable conditions of the environment. One aspect of lichens i.e, lichenometry relates the lichens with different geochronological activities. However, the acceptance of lichenometry got deferred due to lack of any direct relation of lichens with age of surface. There is a great debate in the use of lichenometry in dating (absolute or relative) various geological events. The variations in environmental factors affect the growth size but the life period of lichen thallus suggest that the technique is best suited for relative dating or as a secondary method for absolute dating, only in the places where dates are secured or known as an alternative (Winchester and Harrison 1994). The technique has been chiefly employed in glaciology and geomorphology but has recently been applied to slope movements, fluvial processes and other landforms. It is well accepted by previous studies that presence or absence of lichens is an interaction of many micro and macroclimatic conditions and length of growing season, whereas the size of any particular species is a function of time of exposure. However, local calibration is necessary, as climate dictates the rate of lichen growth (Gupta 2005).

The dynamic environment of the Himalayas is the abode of eternal snows mostly in the form of glaciers. The vast snow-covered areas of more than 30 glaciers in Indian Himalayas play a crucial role in regulating climate forcing. Lichenometry provides an alternative means to evaluate the recession rates of glaciers. Inspite of that, not much work in India has been carried out using this technique. Similarly, role of lichenometry in estimating magnitude of palaeolandslides hold valuable information regarding land stability in several context. The lichenometric studies in the country have been initiated and confined to date glacier deposits and landslide debris flow however, use of lichenometry in dating high altitude riverbeds is not evident. Indian glaciers feed many life-line rivers (Indus, Ganges, and Brahmaputra) and their tributaries that are under continuous trend of changing their directions and levels. In India most of the flood affected areas lie in the Ganga and Brahmaputra basins since these rivers and their tributaries bring down exceptionally large volumes of sediments which cause aggradation of river beds and changes in the river courses. Use of lichens in estimating the frequency and intensity of palaeofloods and changed water level will help in predicting the impact of climate on present river dynamics in India. Lichenometry may find some application in the study of Iron Age remains and rock art where conventional dating methods have so far found limited application (Joubert et al. 1983). Dating Indian monuments, graveyards and other historic building will also enhance the present day knowledge in the relevant field.

In India the lichenometry has been initiated in the initial years of the last decade. But lack of valuable information in the study sites in favor of palaeoclimatic conditions and surfaces to date, are the major problems in application of the technique in India. In the recent years, there has been a growing awareness on the factors triggering alteration in the environment and their consequences. Drastic change in climate makes it obligatory to collect and maintain the database for future climate monitoring processes. Being a developing country India is facing tremendous pressure due to climate change events. The influence of changing environmental conditions and ecological stress on socioeconomic system in the country accelerates the importance of the investigations and forethoughts in developing economic measures such as lichenometry, to assess the impact of prehistoric natural disasters for future discretion.

PLATE 1. SOME LICHEN TAXA USE IN LICHENOMETRIC STUDIES



A. Diploschistes rampoddensis (Nyl.) Zahlbr., **B.** Dimelaena oreina (Ach.) Norman, **C.** Lobothallia alphoplaca (Wahlenb. ex Ach.) Hafellner, **D.** Lecanora muralis (Schreb.) Rabenh, **E.** Physcia aipolia (Ehrh. ex Humb.) Fürnr., **F.** Rhizocarpon geographicum (L.) DC. **G.** Rhizoplaca chrysoleuca (Sm.) Zopf, **H.** Xanthoria elegans (Link) Th. Fr., **I.** Acarospora oxytona (Ach.) Massal.

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