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Forum Article

Lichenometric dating: Science or pseudo-science?

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ABSTRACT

The popular technique of estimating ages of deposits from sizes of lichens continues despite valid criticism, and without agreement on range of utility, treatment of error, and methods of measurement, sampling, and data handling. A major source of error is the assumption that the largest lichen(s) colonized soon after deposition and will survive indefinitely. Recent studies on lichen mortality suggest that this assumption is untenable. Meanwhile, the use of "growth curves" constructed from independently dated substrates is problematic for many reasons, but this has not prevented the publication of baseless claims of accuracy and ages that are extrapolated well beyond data. Experiments indicate that numeric lichenometric ages are not reliable, and in general do not advance the cause of Quaternary science. There are a few studies suggesting reliability, and indeed there may be cases where lichens and growth curves actually provide realistic numerical ages. But it cannot be foretold which lichen assemblages will provide good ages and which bad ages. The logical conclusion is that no assumption of good ages can be made, and that it is folly to assign numerical ages to a deposit on the basis of lichen sizes.
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There must be some way out of here,
Said the joker to the thief;
There's too much confusion,
I can't get no relief……
[Bob Dylan]

Introduction

Since its conception by Beschel (1950) the measurement and interpretation of lichen sizes have become a very common technique with which to determine ages of deposits, most commonly moraines and bodies of colluvium. This technique is properly called lichenometric dating, as lichenometry is a broader term that may encompass measurements of lichens for other purposes. But almost all of the geoscience and biological literature uses lichenometry as a short form for lichenometric dating, as do we in this paper.

Overviews of the technique include those of Webber and Andrews (1973), Locke et al. (1979), Worsley (1981), Innes (1985), Osborn (1988), Noller and Locke (2000), McCarthy (2002, 2007, 2013), and Benedict (2009). According to Noller and Locke (2000) references to lichenometry in the total geosciences literature increased from an average of 5 per 100,000 papers in 1960 to 25 per 100,000 in 1995. O'Neal (2009, p. 316) states that "a survey of current literature illustrates the dominance of lichenometry in the reconstruction of late Holocene glacier chronologies worldwide". A Google search of "lichenometry" in 2012 returned 30,600 results.

Although the technique is popular, it has not escaped criticism. The most critical outlook is that of Jochimsen (1973), who concluded that highly variable lichen growth rates, resulting from dependence on substrate lithology and various microclimatic conditions, are not (and generally cannot) be accounted for in age studies. She also perceived problems with variable lichen ecesis intervals, ambiguous thallus morphology, and potential inheritance of the largest lichen(s). Worsley (1981) listed the same problems in different forms, and concluded that "the lichenometric dating method in its present form is conceptually unsatisfactory both with respect to its basic assumptions and to its method of field application". Elsewhere in the literature, Innes (1981) is critical of many of the lichenometric techniques recommended by Locke et al. (1979) in their Manual of Lichenometry, and Innes (1985) notes that "…the technique has been much abused…". McCarthy (2007) concluded that there is doubt as to how closely some lichenometric ages match the true ages of surfaces, and noted (McCarthy, 2013) that neither authors/editors nor readers ask or seek answers to basic questions arising from the method. Armstrong (2011) raised biological issues pertaining to development and growth of *Rhizocarpon* which impact lichenometry.

Despite the many published doubts, use of lichenometry continues, apparently oblivious to criticism. Its popularity stems no doubt from

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apparent ease of application and general lack of expense. The result is a plethora of ages of glacial advances and landslides that may not have any basis in reality. In this paper we offer a strongly pessimistic perspective of the method as currently practiced, based on three claims: (1) A startling lack of agreement, and in fact debate, on range of utility, methods of measurement, data handling, and treatment of error suggests that lichenometric ages in general cannot be regarded as reliable; (2) There are theoretical reasons and observational data to show that crucial assumptions employed in lichenometry are not valid; (3) Experiments on reproducibility, and on lichenometric ages of independently dated deposits, generally come out negative.

The objective of this paper is not to review the whole subject, which has been done before, but to appraise the validity of numerical ages derived from lichen measurements. We do not assess other avenues of research that may depend on such measurements. It should be noted that some of the authors of this study have in earlier lives engaged in some of the practices criticized here, and favorably reviewed some of the papers criticized below.

Lack of agreement on practice

Range of utility

There are great differences of opinion as to what range of time may be addressed by the technique. Miller and Andrews (1972) suggest that *Rhizocarpon geographicum* may be a useful time indicator for deposits up to 7000 or 8000 yr old. Noller and Locke (2000) suggest that the range may extend beyond 9000 yr. Benedict (2009) suggests that the "theoretical dating range of maximum-diameter lichenometry may approach 10,000 years", but concludes that the practical limit of the method is closer to 4000–5000 yr. On the low end, Matthews and Trenbirth (2011) state that in Norway lichenometry has been most successful on surfaces dating from the last 500 yr, and Innes (1985) proposed 500 yr as the general useful limit. Because of lichen weathering at their site in Iceland, Gordon and Sharp (1983, p. 197), noted that "there may be limitations in extending the technique to dating surfaces more than about 100 to 150 yr old…". According to Matthews (1994), there is uncertainty over temporal range because of uncertainties regarding growth rates and the longevity of very old lichens.

The great variation in opinions suggests that (1) there is no definitively established range of lichenometry for any given species or any given environment, and (2) at a new site there is not much chance of knowing what the range will be for any given species, and whether or not the age of any given deposit is greater than that range.

Measurement

There is no general agreement on what to measure. Beschel (1961) suggested that any lichen with an oblong shape should be considered only in its shortest diameter. However, many have measured the longest axis of thalli that have roughly circular outlines (e.g., Calkin and Ellis, 1980; Denton and Karlén, 1973; Kirkbride and Dugmore, 2008), some have used the shortest axis (e.g., Dahms, 2001; Luckman, 1977; Osborn and Taylor, 1975) or the mean of the longest and shortest axes (Erikstad and Sollid, 1986) or the diameter of the largest circle that can fit inside the thallus (Gellatly, 1982; Locke et al., 1979). Some suggest that inclusion of coalesced thalli can be avoided by selecting only circular to nearly circular thalli (e.g., Lewis and Smith, 2004), but no parameters are given to define "nearly circular". Others measure the short axis "to avoid over estimating the size of less-than-circular lichens" (Dahms, 2001, p. 63). But, lateral expansion can be slowed by obstacles or microenvironment (Innes, 1985) so it can be argued (e.g., Locke et al., 1979) that longest axis best reflects growth under optimal conditions and the shortest axis underestimates growth potential. All users recognize that inclusion of coalesced thalli can potentially overestimate growth rate and underestimate age. However, as Bradwell (2010) notes, coalesced thalli can often go unrecognized. Overall, it seems that measurement of *any* size property is problematic, and every possibility has been criticized. Perhaps there is no good way to measure a lichen.

Sampling strategy

Number of lichens sampled

There are debates over whether the single largest lichen is the best indicator of substrate age (e.g., Calkin and Ellis, 1980; Webber and Andrews, 1973) or if an average of several thalli (usually 5 or 10) provides more accurate results by limiting the effects of anomalous thalli, (e.g., Innes, 1984; Matthews, 1974, 1975, 1977; Sikorski et al., 2009), or whether statistical treatment of data is best served by sampling hundreds or thousands of thalli.

Those who use the single largest lichen assume that the largest individual colonized the substrate first and is the best indicator of the age of the substrate. The argument against this method is that the single largest lichen on a deposit might somehow pre-date and survive the event to be dated and thus be older than the event. Use of the 5 largest lichens has also been suggested in light of the extreme variability seen in directly measured growth rates (Haworth et al., 1986).

Because mean long-term growth rates estimated from the five largest lichens will be slower and may not well correlate with that of the largest lichen, error is introduced when the two rates are used interchangeably. Calkin et al. (1998), for example, extended their growth curve for the Seward Peninsula by drawing it parallel to Denton and Karlén (1973) growth curve for the Swedish Lapland, based on a perceived similarity in macroclimates, although the Swedish Lapland curve was constructed using the single largest lichen while the Seward Peninsula curve uses the mean of the 5 largest lichens.

For other workers, 5 or 10 measurements on a deposit are not enough. McKinzey et al. (2004) conclude this approach is limited by the small data set that is not statistically robust. Many workers (e.g., Bradwell, 2004; Caseldine, 1991) employ a size-frequency approach which requires a large number of lichen measurements on a surface, often 200 or 500 or 1000, so that age estimations are based on a large data set. Some, (e.g., Bull, 2000; Matthews, 1975), average the largest individuals at a number of sites or stations. But there is little or no agreement on the appropriate statistical treatment of large data sets.

Opposed opinions are strong. Matthews (1974, p. 229) declares "Use of the [statistical] techniques outlined above provides a method which avoids the dubious practice of relying entirely upon the single largest lichen on each surface for dating purposes." The writer is thus in direct opposition to Webber and Andrews (1973), who state that "only the lichen thallus with the maximum diameter is an indicator of surface age, and that use of the single largest thallus is essential for effective use of lichenometry."

Kirkbride and Dugmore (2001) showed that variations in sampling strategy result in "poor repeatability" of lichenometric conclusions.

Search area

Where to search and how big an area to search are important considerations in lichenometry. Some workers keep search areas small to limit misinterpretations due to moraine morphology (e.g., Larocque and Smith, 2004), while others favor large search areas to increase the potential for finding the largest lichen(s) (e.g., Bradwell, 2009; Matthews, 1974; McCarthy, 2003). Innes (1985) recommends a search of the entire landform, while Locke et al. (1979) suggest that large fixed-area searches would allow for more comparable results between studies. This is another facet of lichenometry where disagreements in the methods applied create results that are not directly comparable between studies. If the effect of search area is as important as has been suggested (e.g., Innes, 1984), the results of a study where only the crests of moraines have been searched can hardly be compared to a study where an exhaustive search of the entire moraine has been

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