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Letter to the Editor

Lichenometric dating: Science or pseudo-science?—Comment to the paper published by Osborn, McCarthy, LaBrie, and Burke, Quaternary Research 83 (2015), 1–12

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The 2015 article by Osborn and others entitled 'Lichenometric Dating: Science or Pseudo-Science?' delivers an unprecedented, in-depth critique of the cumulative problems associated with the development and application of lichenometric dating techniques over the past 65 years. Their stated goal is to appraise the validity of numerical ages derived from lichen measurements, but in doing so, they present a broader, systematic deconstruction of current lichenometric dating practices by emphasizing the unreliable, incomparable, and irreproducible results published by many studies. Osborn et al. revisit a few examples where some scientific rigor has been applied to the methodology, but overall, they cast doubt on the usefulness of any lichenometric analysis by revealing a global failure to avoid poor techniques and outcomes, heedless of the caveats stated in past literature.

Despite their warnings of the severe limitations on lichenometry, a current literature search indicates that geoscientists persist, without pause, in relying upon lichenometric dating techniques, without any indications of seeking to improve the common methodologies. This persistence is likely because lichenometric dating provides the only method of estimating landform ages in many field settings. For lichenometry – and studies that use it – to be held to a higher degree of scientific merit, the many variations of current practice need to be unified and standardized by: 1) establishing a community-wide agreement with regards to the statistical logic of sampling, and 2) applying modern standards of digital documentation and data dissemination. Although this effort requires significant contributions from the scientific community as a whole, in this brief response to Osborn et al., I offer a few observations and suggestions towards the establishment of a standard set of best practices.

Improving the age-dates inferred by lichenometry can only occur when the community can agree to couch our expectations in the limitations of the technique. When presented with age-dates, a geoscience audience often assumes the sturdy finality expected of radiogenic and isotopic dating. It is important to remind ourselves that lichenometry must operate within the domain of biometry (see the text by Sokal and Rohlf (1995)). Issues inherent to how biological populations work both naturally and in response to different forcings (e.g., Farrar, 1974) will inevitably yield sampling statistics fraught with noise. It is worth pointing out that the summary of lichenometric dating by Noller and Locke (2000) was published as 'Chemical and Biological Methods', and not in a venue that would have elevated the results to providing the numerical-age accuracy expected from radiogenic and isotopic techniques.

Issues of accuracy, confidence, and error simply boil down to various limitations of inherent in biological sampling. Atomic-clock techniques are able to minimize error by using enormous sample size (an entire population of atoms sampled by atomic-scale measurements). In contrast, lichenometric dating requires sampling on a visible scale, measuring individual biological colonies that have grown so appreciably as to be recognizable as lichen on a landscape. That growth itself is concomitantly affected by surface characteristics of the rock substrate, the very object of the dating technique. Physical properties of the rock, combined with changing physical and environmental characteristics of the setting over time, all affect surface exposure, both of the rock itself, and of the rock as a substrate for lichen colonization. Thus, lichenometry runs into another hitch – lichen population and growth-rate data obtained at one landform may not be valid for an adjacent landform. Additionally, as with any biological system, lichen growth rates may change over time, due to environmental factors such as tree- or snow-cover, or due to the age of the lichen colony (i.e., assuming older lichen grow more slowly). Altogether, the many forces affecting lichen growth cannot be accounted for completely by a reasonable lichenometric study, and yet they necessarily affect the accuracy of lichenometric age-dates themselves.

The single unifying theme of all lichenometric dating is that *some measure* of the size-frequency distribution of a lichen population on a landform will represent a *minimum* age of deposition if the growth rate can be determined. Albeit time consuming, the measurement of large sample populations, and repeated measurement of a subsample of the same lichens over several years, address two key concerns. First, measurements of direct growth rates (i.e., measuring the same lichens over time) ensures a more reliable estimate of age from size, eliminating the temptation to use a statistic of lichen populations growing on surfaces of known age to develop a dating curve. The latter approach has been popular among time-constrained researchers, but has only served to ensure unreliable outcomes and propagated the ill-conceived need for complicated error functions. Second, when a statistic is used to infer a surface

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age, large sample populations improve the likelihood of reproducibility. Not all researchers have access to the resources, skilled personnel, and time required by such studies as the Lowell et al. (2005) herculean effort to measure tens-of-thousands of lichens on a terrain. However, for most studies, making an obvious effort to sample as many lichens as possible, with some repeated measurements at the same site over time, will yield minimum age-estimates that benefit from lower error and higher confidence.

To measure lichens in the field, current studies continue to rely on the decades-old standard equipment of rulers and calipers. However, as technology continually increases in accessibility and decreases in cost, it is time for lichenometry to move towards digital record-keeping. Researchers can easily transition their individual measurements to an all-digital archive by capturing high-resolution images of lichens using digital cameras. Over 40 years ago, Miller (1973) described a method of assessing lichen size via photogrammetry. Readily available image and photogrammetry software (e.g., McCarthy and Henry, 2012) would permit easy and reproducible measurement of individual thalli. Importantly, these photographic data can be made available for any subsequent need to re-evaluate observed direct-growth rates, or the geometric measurements of a sampled lichen population. With numerous avenues for data dissemination to the public without cost, a digital lichen archive would add an important and heretofore unseen level of transparency to the process. .

The suggestions above provide a starting point towards the development of a set of best practices so that lichenometric dating remains a valid and valued approach to providing minimum exposure ages. More remains to be done; for example, as a community, we must move towards an agreement of the most appropriate geometric measurement to assess lichen growth. In the meantime, I encourage fellow lichenometrists to vigorously pursue the creation of an openly available digital lichen archive, to share a goal of measuring as many lichens within a population as possible, and to continue to communicate a clear understanding of lichenometry's strengths and inherent biological and geological limitations. All together these steps will serve to enhance the technique's scientific rigor and reputation. Until these best practices become automatic for our community, I join Osborn et al. in encouraging consumers of the scientific literature to apply the numerical ages derived from lichenometric dating with caution.

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