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LICHENOMETRY DATING IN THE ALPS: IMPLICATIONS ON HANNIBAL'S ROUTE

Abstract - Hunt P., 2015 - Lichenometry Dating in the Alps: implications on Hannibal's route.

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This paper examines the feasibility of lichenometry as a relative dating mechanism for alpine archaeological features from Iron Age to Medieval contexts. The primary lichen genus examples with known growth rates represented here are *Rhizocarpon* and *Xanthoria*, with *Rhizocarpon* potentially better for older contexts and *Xanthoria* potentially better for younger contexts, although both can also work together for calibration when possible. A possible Hannibal route through the Cottian Alps (Col du Clapier-Savine Coche) is most likely strengthened by lichenometry in this alpine region, especially at the summit Lac du Savine as a viable campground.

Key words - Lichenometry, Relative dating methods, Rhizocarpon, Xanthoria.

Riassunto - Hunt P., 2015 - Datazione lichenometrica nelle Alpi, con implicazioni sulla strada di Annibale.

Questo articolo esamina la possibilità di utilizzo della lichenometria come metodo di datazione relativa per strati antropici in siti archeologici alpini nei contesti dall'età del ferro a quella medievale. I principali esempi di geni di licheni con tassi di crescita noti qui rappresentati sono *Rhizocarpon* e *Xanthoria*, con *Rhizocarpon* potenzialmente migliore nei contesti più antichi e *Xanthoria* potenzialmente migliore nei contesti più recenti, sebbene entrambi possano essere utilizzati insieme, ove possibile, per la calibrazione. Un possibile percorso di Annibale attraverso le Alpi Cozie (Col du Clapier-Savine Coche) è avvalorato dalla lichenometria in questa regione alpina, specialmente al Lac du Savine, considerato come possibile campo base.

Parole chiave - Lichenometria, Metodi di datazione relativa, Rhizocarpon, Xanthoria.

Introduction and rationale

Since Beschel's initial mid-20th century Alps lichenometry research (1), observing certain species lichen growth on stone monuments or human modified stone in the Alps leads to the tentative conclusion that the smallest lichen thallus bodies on relatively recent (medieval in this paper) contexts are the youngest and the largest lichen thallus bodies on Iron Age (Celtic and Roman in this paper) contexts are the oldest, all else being roughly equal. Elsewhere selected lichenometry has been hypothesized as being useful for chronometry at Bronze Age and even Neolithic contexts (2) and the current research project has also applied lichenometry from medieval to Neolithic contexts in the Alps.

The primary lichen genus chosen for Alpine lichenometry for this study is *Rhizocarpon*, especially *R. geographicum*, a global montane or alpine climate lichen of green hue and the one most used in glaciological dating where thallus size growth is correlated to time. A second useful lichen for Alpine lichenometry is the mostly orange hued genus *Xanthoria*, especially *X. elegans*, another global montane or alpine climate lichen of orange hue and also used in dating glaciological contexts (3). Identification testing for these lichens is generally done with 5% solution of "C" (calcium or sodium hypochlorite) and/or "K" (potassium hydroxide) – elaborated shortly in this paper – as well as UV light and the geological rock type is also tested by hydrochloric or citric acid and other tests.

If it is possible to extrapolate a relative datation of lichenometry to archaeological contexts in the Alps, it may be possible elsewhere to apply archaeological lichenometry to other global contexts. The premise of this paper is that it may be feasible to demonstrate the qualified use of lichenometry for selected lichens (*Rhizocarpon* and *Xanthoria*) in certain Alpine contexts in the Cottian Alps, potentially useful for reconstructing some of the ancient environment around the time Hannibal might have crossed the Alps in 218 BCE if this is a plausible summit route.

Some of this prior ongoing research has aimed at reconstructing the paleoclimates of alpine regions in postglacial but nonetheless montane environments where marginal periglacial conditions have influenced the generation of geosols from ancient glacial moraine. Above tree lines in the Alps – generally around 2000 meters elevation – and especially above 2500

(1) Beschel 1961, esp. 1044.

(2) Lev-Yadun, Mizrachi & Kochavi, 1996.

(3) *Xanthoria* can also be found across global montane contexts, including in the igneous geology of the Andes but very fast-growing thee due to its tropical climate.

Map: Col du Clapier, border between Italy and France. Context 1 is Roman Road just along border on Italian side corresponding to Figs. 1-2; Context 2 is at northwest corner of Lac du Savine corresponding to Figs. 3-4; Context 3 is at top of map along Vallon de Savine corresponding to Fig. 5; Context 4 is just off map along same Vallon de Savine. Scale: Lac du Savine is about 1.75 km in length. North at top of map.

meters, lichens are the dominant vegetation on rocks. Where these rocks have been modified, shaped, moved and placed in structures like road terraces, shepherd huts, refuges, monastic buildings and shrines, forts and castles, and even prehistoric megaliths, we have observed lichen growth is roughly visually commensurate with expected dates even given the variations in microclimate, elevation, geological rock type, solar exposure and other variables. We begin the lichenometry testing by thinking about the model, where we hypothesize that lichen age is the explanatory (independent) variable and lichen size is the response (dependent). Then we reverse the roles when attempting to predict an unknown age value, based on a given lichen thallus size, averaging the three parameters of horizontal, vertical and diagonal diameters.

Fig. 1 - Late Roman road terrace (ambona) section on Col du Clapier-Savine Coche just over border in Italy (Context 1) cliff view to north.

Examining this question of deriving a relative datation chronometry for at least this alpine region of portions thereof, includes archaeological contexts where a decade of current research has been conducted in the Western Alps between Italy and France, including the Cottian Alps, Pennine Alps, Mont Blanc Massif, Otztal Alps and Upper Adige Valley, Upper Rhine Valley between St. Gallen and Graubunden Cantons of Switzerland, Upper Rhone Valley between Vaud and Valais Cantons of Switzerland, Dora Riparia watershed and Dora Balthea of watershed of Piemonte and Valle d'Aosta of Italy respectively. Over several dozen archaeological contexts with lichenization have been viewed and measured with zero destructive testing of archaeological material. In these contexts over 120 different lichen thalli have been measured with micrometers and calipers. Regression analysis and calculation of standard deviations and *p* values have been conducted by our team and statisticians (including Dr. Nancy Pfenning, University of Pittsburgh) ([4]). Our tentative conclusions are that these lichenometry contexts show linear growth rate rather than logarithmic growth rates, highlighting the correlation between lichen thallus size and age. To date, although a relatively small sample size, nonetheless representative of all the lichens measured, the most promising contexts are those in the Italian-French summit border region of the Cottian Alps at the Col du Clapier-Savine Coche at fairly high altitude (2100-2450 meters) that best promote *Rhizocarpon* and *Xanthoria* lichenization.

Because most of the prior lichenometry studies elsewhere but especially in the Alps have concentrated on geological (glacial and epiglacial) processes rather than archaeological research, examining post-glacial lichenization and long-term chronologies and erosional rates of talus and rockfall, none of which are expected to have human modification, this new proposed research is pioneering lichenometry for longer time periods as expected of archaeological contexts. Because of the longevity range of lichen, unknown but not unreasonable to be sustained for long time spans, the feasibility of lichenometry as a relative dating mechanism for alpine features from Iron Age contexts is being examined. Some of the literature suggests a very feasible archaeological applicability for relative datation ([5]) and other literature suggests from global fieldwork that it takes about 5-10 years for a lichen to start growing on fresh rock surface. The lichen growth rate curve is not linear but asymptotic as it starts out very slowly then growing much faster and then ultimately slows down considerably over time before reaching an

([4]) Regressed size on age produced an inverse linear slope (y=185.22x), resulting in the equation: average *Rhizocarpon* lichen thallus Size = 2.35168+0.0033788Age [t=-4.81, p=0.000) for prior lichen growth rates; statistical analyses 2012-14 by Nancy Pfenning, University of Pittsburgh and Henry Liao, Stanford University. These prior analyses are based on multiple Alps contexts (at least 25), not just the Col du Clapier-Savine Coche elaborated in this aper, and are also not limited to the two lichens and the Savoie-Piemonte contexts specified here in some detail.

([5]) Broadbent & Bergqvist, 1986; Lev-Yadun, Mizrachi & Kochavi, 1996, p. 197.

Fig. 2 - Lichen thallus on top of Late Roman road Savine Coche side of Col du Clapier (Context 1).

equilibrium growth rate (6). How applicable these prior studies are to the extended study in this paper remains to be verified. In latitudes around 60° north, *Rhizocarpon* lichen growth, for example, simulates high altitude Alpine lichen growth contexts since the climatic contexts are often very similar (the latitude-altitude correlation) with many months of snow and cold temperatures but also with a lower tree line at 60° latitude north than at 45° latitude north (7).

Assumptions and Methodology

As always for rock lichenization, several important assumptions are applicable. One is that lichens usually begin to grow within five years of lichen diaspores reaching a fresh rock surface, in this case on archaeological or human-modified contexts. Another assumption is that lichen growth rates are highly variable between lichen groups or genus: some are fairly

(6) Bull & Brandon, 1998.
(7) Beschel, 1961.

Fig. 3 - Lac du Savine northern lake edge, northeast side, with weathered schist and lichen (Context 2) view to west.

fast-growing like *Xanthoria* and others are slow-growing like *Rhizocarpon*. Another important consideration is that the literature on lichen growth rates is variable at best and not conclusive, in fact at times contentious. If possible, it is vital to know lichen growth rates where understood but also to assume their growth rates likely slow down over time even though lichens like *Rhizocarpon* are stable and can live for extremely long times, easily hundreds and even thousands of years. *Xanthoria* appear to live less long and their cores also fairly easily deteriorate or exfoliate whereas *Rhizocarpon* do not exfoliate but continue to grow outwards from the older center. Also important is that some lichens colonize with multiple thalli that may join together; both *Rhizocarpon* and *Xanthoria* grow in highly circular individual thalli (with radial increase), making them fairly easy to measure with calipers and micrometers ([8]).

Pursuant to this lichenometric research, several dozen contexts have been mapped and tested with measuring and quantitative assessment. Since 2008 preliminary lichen surveys of archaeological contexts have established criteria for assessment: A) many share roughly the same climate a the same altitude; B) many share roughly the same date range in the Iron Age based on geological weathering and known dates; C) they all share the same silicate rock as geological medium of construction, generally schist; D) they share roughly the solar orientations. Thus it is likely to be able to control as many variables (specie, climate, elevation, orientation, geological medium) as possible, with time suggested as being the primary factor that this research aims to isolate for lichen growth. There is also a subsidiary hypothesis that higher alpine elevations with different climates result in inhibited rates of lichen growth, partly due more to deep snow cover for several months of the year than to hypoxic conditions. Lower temperatures and diminished light for about six months per year could be a factor for some inhibited lichen growth, although some orange and red Alps lichen thalli (generally *Xanthoria)* are seemingly more specific to certain elevations (2000-2500 meter optimum range) and grow at a faster rate relative to *Rhizocarpon* (especially *Rhizocarpon geographicum*) ([9]). It is reasonable to apply the suggestion ([10]) that the largest sample thalli should be measured wherever possible – using LL ("largest lichen" method or 5LL, "five largest lichen" thalli) if many are present and that elliptical or asymmetrical thalli sizes can be normalized by representing thallus volume along three measurements; the methodology used here measures horizontal, vertical and diagonal directions on both circular and non-circular lichen thalli, using calipers with both analog and digital features for measuring.

Growth rates for certain lichen species are fairly established – although not always sufficiently regular for global contexts, other lichen growth rates are being estimated and developed ([11]). The growth rate for some *Rhizocar-*

([8]) Hooker & Brown, 1977, esp. 65 ff.

([9]) For genus and species, the *Rhizocarpon* species identified to date are *R. geographicum*, *R. effiguratum*, *R. superficiale;* of the *Xanthoria* genus, the *Xanthoria* species identified to date are *X. parietina*, *X. elegans.*

([10]) Innes, 1985.

([11]) Pech, Jomelli, Baumgat-Kotarba, Bravard, Chardon, Jacob, Kedzia, Kotarba, Raczkowska & Tsao, 2003.

pon lichens such as *R. geographicum* has often been posited as .033 mm per annum at lower elevations (many under 1700 meters altitude in Scandinavian contexts) and more recent contexts of glaciation (within 500 years). But in new field alpine research in 2013-14 based on dated archaeological contexts around 2400 meters elevation exhibiting lichenization, however, it appears reasonable given a slowing down of growth and inhibited climatic response that *Rhizocarpon* lichen may instead grow at a slower rate of .02 mm per annum after around a millennium ([12]), although is not yet confirmed elsewhere other than in fieldwork by our teams 2012-14 ([13]). The growth rate of some very fast-growing *Xanthoria* lichen has been posited as about 0.095 mm per annum, others like *Xanthoria elegans* initially grow up to 0.5 mm per annum for a decade or so, although this rate may soon slow down to around 0.3-0.1 mm per annum. One of the known variables for lichenometry is the rock type, as some lichens like *Rhizocarpon* do not grow well on calcareous rock whereas others like *Xanthoria* also thrive on calcareous rock. After an initial period of *ecesis* – a few decades or more of becoming established – lichen growth rates appear to slow down after at least a century depending on multiple factors ([14]).

Field identification of the lichen *Rhizocarpon geographicum* used in this study include visual field examination of lichen thalli for color and physical features and aided by chemical field tests known as K-C-P (Potassium hydroxide – Chlorox – [Para]phenylenadiamine PPD) in low concentration alcohol or water solutions ([15]). Additionally, ultraviolet light (UV) responses are also useful for identification. Other resources include publications and illustrated lichen field guides and natural history for the above alpine regions built up over decades of archaeological, geoarchaeological and geomorphological research, including detailed topographic and geological maps, many at 1:25,000 scale.

Algorithmic tools to more quantitatively assess data for possible environmental trends and biological connections for lichen growth rates are also being constructed; their aim is to explain the differences by adjusting

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([12]) As elaborated in this paper, part of this new data is based on known and dated Alpine Roman road contexts; arguing from such contexts is tenuous until confirmed by further fieldwork. On the other hand, medieval contexts in the same Savoie region and valley – also elaborated in this paper – agree with this suggested growth rate.

([13]) Although tentative, some of this adjusted, slower growth rate for *Rhizocarpon* is suggested by logical constraints suggested here – higher elevation, being under longer snowpack, lower temperature and less solar exposure – but also calibrated by known dates of archaeological contexts to attempt to form a statistical baseline.

([14]) McCarthy & Smith, 1995.

([15]) Orange, James & White, 2010.

Fig. 4 - Lichen thallus on northern lake edge, northwest side of Lac du Savine (Context 2).

coefficients numerically for the variables (lichen specie, rock type, solar exposure, altitude, climate, etc.) other than time, all else being roughly equal. For lichen identification of species, color scales and UV light are also used to gauge and record lichen hue and spectra as well as UV reflectance since these also help determine lichen species. The UV response of the *Rhizocarpon* lichens tested here is a bright yellowish-green glow; that of *Xanthoria*

Fig. 5 - Medieval ruin in Vallon du Savine (Context 3), view to south.

lichens tested here is a bright orange-red glow. Not all lichens fluoresce but these two genus examples have strong identifying UV responses to go along with the K-C-P chemical testing of various parts of the lichen thalli.

Field results for alpine lichenometry in selected contexts

Three primary contexts in the Cottian Alps between Italy and France appear to be most useful to date. The Col du Clapier-Savine Coche context in France between the Val Cenis (Savoie) above Bramans from the Savine Grange (about 2200 meters elevation) Lac du Savine a few kilometers within the French border (2400 meters elevation) to extant putative Roman road sections just over the Italian border in the Commune of Giaglione (Piemonte), both of the latter and less than 2 kilometers apart. The total distance between all three contexts is less than 5 kilometers near or at the Italian-French border ([16]).

([16]) Permits were obtained from the Soprintendente of Piemonte in Torino in 2008 for work in Italy with added permission from Marco Rey, Mayor (at the time) of the

Context 1: An extant late Roman road section of several hundred meters in length with raised *ambonae* terraces on the border of the Col du Clapier-Savine Coche just into Italy. This Roman road followed a likely Medulli Celtic pathway and connects between the Arc River valley between Bramans and the Roman town of Segusio in Italy, now Susa. Most of the road vestiges have been destroyed by talus and rock fall but this section is mostly intact with clear humanly-constructed archaeological terracing. Various numismatic finds have corroborated the posited date of this road section as being around the 3rd century CE ([17]). Selected *Rhizocarpon* lichenometry of this schist-rock road section shows the largest average thallus dimensions on the top of the road – a known archaeological context – as 70.32 mm (80.23 mm horizontal, 57.6 mm vertical, 73.13 mm diagonal). Assuming a radius of 35 mm x .02 mm per year or 1 mm per 50 years at this altitude and date, this *Rhizocarpon* thallus appears to be around 1750 years old, thus in relative agreement with the assessed age by numismatic and other evidence. If applicable, this context can be used as a datable baseline. Other segments of the same road vestige yield similar lichen thallus size.

Context 2: A weathered section of schist base rock along the Lac du Savine's western edge also has a considerably larger *Rhizocarpon* lichen thallus, measured as averaging 104.95 mm (95.98 vertical, 116.96 mm horizontal, 101.91 mm diagonal). Assuming a radius of 52.5 mm x .02 mm per year or 1 mm per 50 years, this *Rhizocarpon* thallus appears to be around 2625 years BP. The importance of this context will be elaborated in succeeding paragraphs on Hannibal implications.

Context 3: A group of Medieval stone ruins at 2200 meters altitude on the Savine Grange – most likely from around 1350 based on local esti-

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Commune of Giaglione, Val di Susa, Italy as well as from Yvon Claraz and Marcel Favre, successive Mayors of the Commune of Bramans, Val Cenis, France annually since 2007. The project has also consulted with the Italian Meteorological Society of Italy in the Val di Susa (Piemonte) and international academic colleagues including in Italy and France, all of which studies and permits were completed in good standing with applications to be renewed as needed.

([17]) In the 4th c. CE Ammianus Marcellinus, *Roman History* 15.10.2,7) mentions Segusio (modern Susa), best approached via the Clapier-Savine Coche pass route; W.W. Hyde. "The Alps in History". *Proceedings of the American Philosophical Society* 75.6 (1935) 437. The Romans did not know of the Mont Cenis route, which appears to be later and medieval with its earliest reference in CE 731; Jean Prieur, *La province romaine des Alpes Cottiennes*, University of Lyons, 1968. On the other hand, the Clapier-Savine Coche route was not only a Celtic pathway but also Romanized in the 3rd century, see Geoffroy de Galbert, *Hannibal et César dans les Alpes*. Grenoble: Editions Belledonne, 2008, pp. 61-72.

mates – on the Col du Clapier-Savine Coche pass route have shared groupings of both *Rhizocarpon* and *Xanthoria* lichens. The average lichen thallus of *Rhizocarpon* on the ruined schist walls is 42.98 mm (45.86 horizontal, 38.59 vertical, 44.48 diagonal). Assuming a radius of 21.50 x .03 mm per annum (therefore younger and lower altitude) or 1 mm per 30 years = 645 years. Additionally, the *Xanthoria* lichen on these ruins, with a considerably faster growth rate (around 0.095 mm per annum) has a very round lichen thallus that averages 130 mm (126.6 horizontal, 132.79 vertical, 132.99 diagonal). Assuming a radius of 65 x 0.095 mm per annum or 0.95 mm per 10 years = lichen age is around 617 years. This could be interpreted to mean that not only are the *Rhizocarpon* and *Xanthoria* lichenometry relative dates in some agreement with each other – within ±28 years but also to the assumed medieval date of the ruins themselves.

Context 4: The old schist Italian-French border stone with an inscription dated to 1861 at 2163 meters elevation has a *Xanthoria* lichen thallus on its top rounded surface averaging 34.7 mm (33.05 horizontal, 35.04 vertical, 36.02 diagonal). It is estimated that *Xanthoria*'s optimum growth rate here is at around a range of 2200-2400 meters. Assuming a radius of 17.35 x 0.095 mm per annum or 0.95 mm per 10 years = 164 years, in which case the *Xanthoria* lichen relatively dates to 1850, also in basic agreement with the border stone date, in relative agreement within ±11 years. Based on this stone monument with an inscribed date of 1861 and its largest lichen thallus as almost 35 mm in diameter, it seems reasonable that the growth rate for this *Xanthoria* is very close to 0.1 mm per annum over the first few centuries, a very important baseline datum point.

Hannibal implications

One of the most important extrapolations of the new lichenometry conducted and presented here is relevant because this particular Alpine route and region ([18]) is often associated with Hannibal's passage over the

([18]) Perrin M., *Marche d'Annibal des Pyrenees au Po*. Paris, 1887; Paul Azan. *Hannibal dans les Alpes*. Paris, 1902), J. Colin. *Annibal en Gaule*. Paris: Librairie Militaire R. Chapelot et cie, 1904 (Nabu Press, 2010 repr.) 1904, and Spencer Wilkinson. *Hannibal's March Through the Alps*. Oxford: Clarendon Press, 1911, esp. 32-6. Since the mid-20th century, credible studies advocating the Clapier-Savine Coche route include M. A. de

Alps between Allobroges territory along the Rhone River and the Taurini tribe associated with Torino. If according to Polybius *History* III.52-55 with its description of Hannibal's summit encampment ([19]), this Col du Clapier region might be where Hannibal's army summited with associated animals, then a campground ought to be reasonable here for several days as Polybius records.

Most important here for this paper is the Lac du Savine on the Clapier summit plain, a valley stretching west-east from France into Italy. For some time it has been suggested the lake has only been here since the medieval period with rock fall at the time closing off the summit valley and minimizing the water outflow. The new evidence suggests instead the lake has been there for at least 2,625 years, hundreds of years minimum before Hannibal if he crossed here. Since the *Rhizocarpon* lichen of *Context #1* on the Ro-

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Lavis-Trafford. *Le Col Alpin Franchi par Hannibal*. St. Jean-de-Maurienne, 1956; McDonald A.H., "Hannibal's Passage of the Alps", *Alpine Journal*, 61, pp. 93-101; Hoyte J., *Trunk Road for Hannibal*. London: Geoffroy Bles, 1960 (Fabrizio, 1975), p. 81 & ff.; Richard A., Jolly. "Hannibal's Pass: Results of an Empirical Test", *Alpine Journal*, 1962, pp. 243-249; Meyer E., "Hannibals Alpenübergang" in K. Christ, ed. *Hannibal*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1974 (1958 & 1964 repr.), pp. 195-221, esp. 218-21; Proctor D., *Hannibal's March in History*. Oxford: Clarendon Press, 1971, pp. 212-216; Lazenby J., *Hannibal's War*, 1978, pp. 45-47; Lancel S., *Hannibal*. A. Neville, tr. Blackwell, 1998, pp. 78-80; Annequin C. & Barruol G.,"Les grandes traversées des Alpes: l'itinéraire d'Hannibal", in C. Annequin & M. Le Berre, *Atlas Culturel des Alpes Occidentales: de la Préhistoire à la fin du Moyen Age*, Paris: Picard, 2004, 100-101; de Galbert G., *Hannibal en Gaul*. Grenoble: Éditions de Belledonne, 2006; Hunt P., *Alpine Archaeology*. New York: Ariel Books, 2007, "Hannibal's Passage in the Alps," ch. 8, pp. 97-108; Kuhle M. & Kuhle S., "Hannibal gone astray? A critical comment on Mahaney W.C. *et al.*, (2010), "the Traversette (Italia) rockfall: geomorphological indicator of the Hannibalic invasion route", *Archaeometry* 54, (2012), pp. 591-601; Kluhe M. & Kluhe S., "Lost in translation or can we still understand what Polybius says about Hannibal's crossing of the Alps? – A Reply to Mahaney (2013)", Forthcoming in *Archaeometry*, 2014, 1-19. In addition, F. W. Walbank also makes a partial case for Col du Clapier based on philological grounds as opposed to Col de la Traversette espoused by Gavin de Beer for the same reason if approached via Drome River to the Durance River route. Again, see Walbank F.W., "Some reflections on Hannibal's Pass", *Journal of Roman Studies*, 46 (1956), pp. 37-45; Hunt P., "Rhône" in Wiley-Blackwell *Encyclopedia of Ancient History*. 2012, pp. 5843-5844.

([19]) Polybius III.53.9 , «*After an ascent of nine days Hannibal reached the summit, and encamping there remained for two days to rest the survivors of his army and wait for stragglers*». Paton W.R., tr. Harvard-Loeb Classical Library, vol. 137, 2001 repr., pp. 128-129. Polybius notes elsewhere Hannibal had started his ascent of the Alps with up to 40,000 soldiers and up to 37 elephants with at least 5,000 pack animals, finishing with about half that number of soldiers but still retaining 6,000 Numidian cavalry – having started out with 90,000 infantry and 12,000 cavalry from Spain (Polybius III.35.1) but significant loss en route – for his next series of battles in Italy.

man road vestiges agrees in relative dating with the prior date estimation as Late Roman or 3rd century CE, it should be reasonable to assume the lichens on the stones for *Context #2* along the western lake edge of Lac du Savine are also datable in their natural context. First, examining the stone at lake edge yields a geological age, evidenced by the very weathered state of these same lacustrine rocks. The geological ages of the valley floor schists at lakeside are deducible by weathering. Fresh schist fractures in sharp edges, sometimes in rhomboidal sections. Iron oxides leaching from micas also usually stain fresh schist with a brownish tinge and on a fresh break, the micas shine out. Some fresh schist breaks can indeed be seen along the summit Savine Valley above the lake, with accompanying fresh schist rock fall along the valley. But here at the west end of the lake, the rock fall blockage that resulted in the lake formation are much older than a medieval date. These schist rocks are extremely weathered to a light gray hue; also having extremely waned parabola – not sharp – edges, with no remaining iron oxide surface traces plus the rock micas are so weathered to have lost their reflective shine. The rock weathering of these lacustrine edge Savine schists is of least 3,000 years beyond deposition. Furthermore, the schist's geological age is corroborated by lichenometry of the *Rhizocarpon* lichens. The lichen suggests these stones at lake edge have formed a natural barrier for the lake level much earlier than a presumed medieval date, having been here for at least 2600 years, predating a possible Hannibal passage. So both geology and lichenometry are useful together.

The importance of this new lake dating is critical for a possible Hannibal campground. Some details about the lake are relevant. The lake, about 700 meters long in high summer, had its depth tested by a recent high-altitude diving team as part of this ongoing project in 2013. The depth of the alpine lake at the middle is 5 meters with an additional several meters of alluvium below this; the source of water for the lake on both sides (north and south) are the surrounding high altitude ridges with considerable high glacier ice-pack above 3300 meters from the Dents d'Ambin and other peaks.

The importance of why the Lac du Savine being present for at least 2600 years follows. If Hannibal's army rested here for two days at the summit in a mile long valley floor that is a quarter mile wide, it is a summit valley that could certainly accommodate at least 20,000 foot soldiers, 6,000 cavalry horses ([20]), several thousand pack animals and likely several dozen elephants

([20]) Polybius III.56.3-4: «[...] *He had spent fifteen days in crossing the Alps* [...] *when he had thus boldly descended into the plain of the Po* [...] *his surviving forces numbered 12,000 African and 8,000 Iberian and not more than 6,000 horse in all as he himself states in the inscription on the column at actinium relating to the number of his forces*».

in early winter when snow drifts began to accumulate around the valley's natural grassy floor, now beyond autumnal but still possible for fodder.

Polybius informs us that Hannibal carefully considered his Alps passage with much practical inquiry about the landscape and had guides who knew the terrain ([21]). This summit lake would have been a much-needed source for watering Hannibal's army because less water would be trickling down from higher frozen sources; given the high water consumption of men and animals its natural resource is a requisite for a campground lasting several days and the previous medieval date estimate for the age of the lake partially based on dating only the fresh epiglacial ([22]) talus on the steep slope – a continuous process for millennia – rather than on the valley floor is no longer valid.

Naturally, one important caveat is that the lichenometry rates of growth offered here for *Rhizocarpon geographicum* and *Xanthoria elegans* and their alpine variants are tentative. Because it may be a circular argument to postulate an adjusted rate of growth from already-dated or estimated date contexts, this must be tested on many other contexts to be considered fully representative. On the other hand, if the lichenometry offered is both accurate and representative, this could be a valuable relative dating method for alpine archaeology.

Conclusion

While the lichenometry conducted to date in the Cottian Alps on both archaeological and natural contexts is tentative for selected *Rhizocarpon* and *Xanthoria* lichens following established precedents of measuring the largest lichen thalli, it is nonetheless reinforced by prior estimated historical dates for the Roman road vestiges, as well as the natural geological weathering processes and inscriptions on extant border stones.

As mentioned, Polybius makes a vital point that Hannibal carefully studied his pass route options; prior knowledge of a summit lake here could have helped cement his choice of alpine routes. Conversely, not having a lake here in the Savine summit valley since antiquity – synchronous with a possible Hannibal passage – would seriously challenge any army pres-

([21]) Polybius III.48.1-12. «*Regarding the Alps* [...] *Hannibal conducted his plans with sound practical sense* [...] *ascertained by careful inquiry* [...] *for the difficulties of the route he employed as guides and pioneers natives of the country*». (again, Paton tr.)

([22]) The last glaciation on the valley floor here is pre-Holocene, that is, greater than 10,000 years BP.

ence for several days beyond credibility, an alpine passage that was already extremely challenging. Thus, lichenometry in the Col du Clapier-Savine Coche may offer important Hannibal alpine pass route implications for the needed water to supply a large army of soldiers and animals.

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