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The Application of the Lichenometry Method to Estimate Petroglyph Ages in Cholpon-Ata, Kyrgyzstan*

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Abstract

Dating methods for rock art have traditionally been divided into two categories: traditional and scientific, both with challenges regarding accuracy. The universal appeal of rock art drives scholars to decode its imagery and underlying narratives, requiring an understanding of its origins, context, and influences. This research aims to evaluate the precision of lichenometry as a technique for dating rock art. Fieldwork conducted in 2023-2024 across several sites in the Örnök region of Kyrgyzstan spanning villages between Balykchy and Cholpon-Ata marks the first use of this method for rock art in the country. The study seeks to provide new insights and potentially challenge established dating methodologies. By applying lichenometry in this context, the research intends to refine current tools used in archaeological and historical studies, improving our understanding of the age of rock art. The results of the fieldwork are presented in the findings and conclusion sections.

Keywords

Rock art, lichenometry, dating rock art, ancient artwork, Kyrgyzstan.

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Kırgızistan Çolpan Ata Petrogliflerinin Yaşının Belirlenmesinde Likenometri Metodunun Kullanımı*

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Öz

Kaya sanatını tarihlendirme yöntemleri, geleneksel ve bilimsel olmak üzere iki ana kategoriye ayrılmıştır ve her ikisi de doğruluk açısından zorluklar taşır. Kaya sanatının evrensel çekiciliği, akademisyenleri bu sanatın görüntülerini ve alttaki anlatıları çözmeye yönlendirir; bunun için de kökenleri, bağlamı ve etkileri anlamak gerekir. Bu araştırma, kaya sanatını tarihlendirme tekniği olarak likenometrinin doğruluğunu değerlendirmeyi amaçlamaktadır. 2023-2024 yıllarında Kırgızistan'ın Örnök bölgesindeki çeşitli alanlarda yapılan saha çalışması, bu yöntemin ülkede ilk kez kaya sanatı için uygulanmasını sağlamıştır. Araştırma, yeni bulgular sunmayı ve mevcut tarihlendirme yöntemlerine meydan okumayı hedeflemektedir. Likenometrinin bu bağlamda uygulanmasıyla, arkeolojik ve tarihsel çalışmalarda kullanılan mevcut araçları geliştirerek kaya sanatının yaşına dair anlayışımızı derinleştirmeyi amaçlamaktadır. Saha çalışmasının sonuçları bulgular ve sonuç bölümlerinde sunulmaktadır.

Anahtar Kelimeler

Kaya sanatı, likenometri, kaya sanatının tarihlendirilmesi, antik sanat eseri, Kırgızistan.

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Introduction

Archaeologists have long been intrigued by rock art, considering them not only as artistic expressions but also as insights into past cultures. Dating these artworks has involved various techniques, from traditional approaches like iconographic analysis to empirical methods like scientific measurements. These include iconographic identification, stylistic comparisons, correlation with archaeological finds, geographical proximity, weathering and patination studies, and motif superimposition analysis (Bednarik, "Only time will tell" 3-6). Despite the array of methods, debates persist regarding the most effective and accurate means of dating rock art. The introduction of newer techniques such as lichenometry offers promise in refining age assessments in this complex and contentious field.

The traditional methodologies for dating rock art, such as grouping similar motifs and thematic analysis, might appear straightforward. However, practical issues arise, such as the superimposition of different artworks, which complicates the determination of their respective ages. Moreover, these issues are compounded by deeper, epistemological challenges regarding how one can definitively link the physical age of an artwork with its historical and cultural significance (Bednarik, "Characterization of Petroglyphs" 1-2). The inherent difficulty in fully understanding this relationship highlights the need for a clear distinction between direct dating methods, which measure age based on physical or chemical changes, and indirect methods, which infer age from contextual or stylistic clues.

The interpretation of rock art is significantly influenced by the observer's beliefs and cultural background, introducing subjectivity. The worldviews of ancient artists likely differed greatly from those of modern scholars, making interpretations speculative and resistant to empirical verification (Bednarik, "The dating of rock art: a critique" 1213-1214). This subjectivity also affects dating methods. While identifying depicted objects can be precise, it does not scientifically date the artworks. These identifications provide insights into the cultural and environmental contexts, which, though valuable, require complementary scientifically falsifiable dating techniques.

This study aims to explore the effectiveness of lichenometry in the context of rock art in Kyrgyzstan, a region renowned for its rich heritage of rock art across various sites. Traditional methods have often been employed in attempts to date these artworks, with varying degrees of success and scientific acceptance (Tashbayeva 1; Amanbaeva 43-44; Chan et al. 11-13). By introducing lichenometry to this field, this research seeks to provide a more robust and testable method for dating rock art, potentially offering a new perspective on the chronology of these ancient artworks. Because lichenometry is used particularly in cases where other dating techniques cannot be applied. The presence of lichens on rock surfaces provides a suitable environment for this method. Moreover, in areas where lichen growth rates have been well-calculated, it can offer reliable results for long-term structures such as rock art. This method is a cost-effective and practical option for dating natural rock formations or archaeological sites.

Traditional dating methods attempt to establish a timeline based on the content and stylistic features of artworks, while scientific methods measure physical or chemical changes. Traditional methods can offer visual clues through the iconographic analysis and thematic similarities of artworks, but these approaches often rely on subjective interpretations. In contrast, scientific methods provide concrete data, allowing for more reliable results. Specifically, direct dating techniques are based on measuring physical or chemical changes in rock, and these methods can yield more precise outcomes compared to the contextual or stylistic clues offered by indirect methods (Benedict, "Recent Glacial History" 817). In this context, lichenometry provides more robust and testable data by measuring lichen growth on rocks.

Kyrgyzstan presents a particularly compelling case for this study due to its diverse and extensive rock art sites, some of which, like Saymalytash, have been recognized by UNESCO as part of the world heritage. The significance of these sites, both culturally and historically, makes them ideal candidates for applying new scientific dating methods. By focusing on lichenometry, this study not only tests a novel scientific method but also contributes to the broader field of archaeological science by potentially refining the tools available for dating ancient artworks.

The structure of this article will first provide a literature review of current dating methods with a particular focus on the application and reliability of lichenometry in rock art dating. This review will be followed by a detailed description of the fieldwork conducted in Kyrgyzstan, the methodologies employed, and the subsequent results. The discussion section will then interpret these findings, evaluating the methodology's effectiveness and situating it within the broader context of rock art research. Finally, the conclusion will reflect on the implications of these findings for future research and outline the limitations encountered during the study.

The Use of Lichenometry in Archaeology and Rock Art Studies

Determining the age of rock art is crucial in archaeological research, requiring various methods, each with its advantages and limitations. The iconographic method, a prevalent approach, involves analyzing the depicted content to infer age. This method identifies specific animals, artifacts, or activities linked to known archaeological or historical periods. For instance, animal depictions can be cross-referenced with paleozoological data to determine their historical presence in a region. Similarly, objects such as boats, plows, and weapons can be correlated with reliably dated archaeological finds, suggesting a tentative age for the art. Depictions of lifestyles, such as hunting or ceremonies, provide additional clues by linking to broader archaeological evidence of past societies (Bednarik, "The dating of rock art: a critique" 1213).

Excavation is another critical method used in the dating of rock art. This approach is particularly useful when artworks are covered by sediment layers that can be dated, providing a minimum age for the rock art. Such layers may contain materials like carbon or artifacts that can be radiocarbon dated or linked to specific cultural phases in archaeology. While this method provides valuable chronological data, it is often limited to instances where overlying or underlying deposits are present and can be associated with the art (Combier 595; Málaga 54-55; Bednarik, "The dating of rock art: a critique" 1214).

Radiocarbon analysis of mineral accretions is yet another sophisticated technique employed in rock art dating. This method involves analyzing the age of calcite deposits that form over or under the rock art, providing an estimate of the minimum or maximum age of the art based on the known rates of radiocarbon decay. However, this technique faces challenges such as radiocarbon rejuvenation, where carbonate speleothems may absorb carbon from recent sources, thus skewing the age results (Moore 2).

Microerosion analysis represents a different scientific approach, relying on the chemical weathering patterns of rock surfaces to estimate the age of the art. This method assumes that a newly exposed rock surface will show signs of weathering that progress over time. By examining these weathering patterns and comparing them to known rates of erosion under similar environmental conditions, researchers can estimate the age of the rock surfaces. This method, however, requires precise control of environmental and contextual variables, which can affect the rate of erosion and lead to significant variations in age estimates (Williamson and Rimstidt 5443–5454; Busenberg and Clemency 42; Bednarik, "The dating of rock art: a critique" 1219).

The Uranium-Thorium (U-Th) dating method has also contributed significantly to the field of rock art dating. This technique is based on the decay of uranium into thorium isotopes within calcite deposits associated with rock art. It has the advantage of providing age estimates that can extend far back into prehistory, particularly useful in dating older art that falls beyond the range of radiocarbon dating. Nevertheless, the challenge with U-Th dating lies in the heterogeneous nature of uranium distribution within calcite deposits, which can lead to inconsistent results. Additionally, the physical process of sampling for U-Th dating can be invasive, potentially damaging the rock art (Bednarik, "Die Bedeutung" 73; Bednarik, "The dating of rock art: a critique" 1217; Bednarik, "The dating of rock art and bone " 195-202).

Emerging in more recent times, luminescence dating techniques, including thermoluminescence, optically stimulated luminescence, and infrared stimulated luminescence, have begun to show promise in archaeological contexts. These methods estimate the last time quartz or feldspar grains were exposed to sunlight, providing an age estimate for sediment burial or last heating. Although these techniques have not been widely applied to rock art, ongoing research suggests they might offer new possibilities for dating such artifacts, particularly in cases where other methods are unfeasible or provide ambiguous results (Nanson et al. 72-78; Oyston 739; Roberts et al. 58-59).

The complex nature of rock art, coupled with the various contexts in which it is found, demands a multifaceted approach to dating. Each method brings its own strengths and weaknesses, and often, a combination of techniques is required to build a comprehensive understanding of the age and significance of rock art. For instance, while iconographic analysis might suggest a broad time frame based on stylistic elements or depicted motifs, corroborating this with radiocarbon dates from associated sediments or mineral accretions can provide a more robust framework.

When integrating results from multiple dating techniques, several factors must be considered. These include the statistical limitations of each method, the potential for cross-verification among different dating results, the effects of environmental and contamination factors on the dating processes, and the reliability of the statistical methods used to analyze and interpret the data. Each method's results must be scrutinized for consistency and checked against known archaeological sequences to ensure their accuracy and reliability.

Furthermore, it is essential to address the calibration of dating techniques, such as radiocarbon dating, where known statistical errors must be factored into the final age determinations. The calibration processes can introduce additional uncertainties, particularly when combined with other methods that may have their own inherent errors. Therefore, the interpretation of rock art dating results must be conducted with a critical eye, considering both the technical aspects of the dating methods and the broader archaeological and environmental contexts in which the art is situated.

The literature extensively covers the geomorphic applications of lichenometry, particularly in subpolar and alpine conditions where rock art is less common, potentially skewing perceptions of its applicability. Its popularity among geomorphologists is due to its effective time range, which is most reliable for the last millennium, extending a few centuries back. Despite indications that it could date up to 9000 years BP under optimal conditions (Miller and Andrews 1133-1138), general consensus limits its accuracy to about 500 years (Innes, "Use of an aggregated Rhizocarpon" 183). This makes it useful for recent glacial deposits. Although most rock art falls within this range and some are associated with lichens, lichenometry's high reliability, falsifiability, simplicity, and cost-effectiveness should make it widely used. Surprisingly, it has only recently become a common method among researchers.

Historically, lichenometry has been employed to date Late Holocene timescales within archaeological literature. Historically, lichenometry was first used for dating in the archaeological literature (Cooper 197; Fink 138; Smith 1-5). The method attracted attention in 1958 by Roland Beschel, who documented the growth rates of lichens by measuring their diameters on tombstones in Innsbruck, Austria. These studies laid the groundwork for subsequent research that has expanded the application of lichenometry worldwide to date various geological and man-made surfaces such as river channels, flood deposits, lake shorelines, and moraines (Bradwell and Armstrong 311; Benedict, "A Rewiew of Lichenometric" 143; Armstrong and Bradwell 4).

Lichenometry is widely used for dating rock and rock-derived surfaces. Bradwell and Armstrong (311) demonstrated its efficacy for dating diverse geomorphic features such as river channels, flood deposits, lake shorelines, high beaches, seismic events, rockfalls, talus formations, and moraines. Numerous studies (Bradwell and Armstrong 319; Locke et al. 1-3; Innes, "Lichenometry" 188; Matthews, "Lichenometric dating" 187; Nash 274; Noller and Locke 262; Benedict, "A Rewiew of Lichenometric" 144; Armstrong and Bradwell 4-5; Trenbirth 1-5) have validated and refined this method, highlighting its versatility and reliability in geochronological research.

The "direct dating" of rock art requires meeting two criteria: a clear physical relationship between the artwork and the dating criterion, and scientifically testable hypotheses about their chronological relationship (Bednarik, "Characterization of Petroglyphs" 1-2). This excludes purely iconographic interpretations, as these rely on untestable correlations between perceived forms and unrelated cultural iconography.

A variety of measurement and statistical techniques have been employed to acquire lichenometric data, including methodologies for determining the longest axis of lichen (Anderson and Sollid 2; Bornfeldt and Osterborg 3), averaging the dimensions of the longest and shortest axes (Erikstad and Sollid 85) measuring the shortest axis (Locke 5), and calculating the overall surface area of the largest lichen thallus. The resulting lichenometric dating curves are generally parabolic, indicating a decrease in growth rate as the lichen ages. These curves can be correlated with rock art in two distinct manners:

a) If an incision has been made over an existing lichen thallus on a rock surface, the lichen underneath can provide a terminus post quem date, marking the earliest possible date of the incision, as the presence of the lichen impedes further growth in the area covered.

b) Conversely, if a lichen grows over or adheres to the surface of a petroglyph, it establishes a terminus ante quem reference, suggesting the latest possible date for the artwork. However, this application requires specific environmental and biological conditions to ensure accuracy (Bednarik, "The dating of rock art: a critique" 1215).

Lichens typically exhibit extremely slow growth rates, implying that even a relatively small, circular lichen formation might represent a considerable age. In Arctic regions, for instance, map lichens such as "Rhizocarpon geographicum" and related species demonstrate annual radial growth measured in mere fractions of a millimeter (Stanton et al. 4). By reliably determining the average radial growth rate of these lichens, researchers can measure the diameter of the largest lichen thallus on an exposed rock surface and thus estimate with reasonable precision the duration for which the surface has been exposed to lichen colonization. This estimation provides a minimum age for the surface.

For example, the age of rock surfaces can be gauged by measuring lichen thalli on surfaces adjacent to historically inscribed tombstones or directly on images carved into rock. However, during surface surveys, it has been observed that in certain regions, tombstones are often destroyed or constructed from soil, lacking inscribed dates, which complicates the application of this method for determining absolute ages.

Lichen Species Selection

The selection of lichen species employed in chronological estimations is predicated upon the sufficient prevalence of individual specimens within the study area (Mottershead 96-97). Armstrong and Bradwell 5) have meticulously cataloged a total of 27 distinct crustose lichen species for application in lichenometric analyses. The most frequently utilized species among these is Rhizocarpon geographicum, a saxicolous (rock-dwelling) lichen known for its slow growth rate, longevity, and extensive distribution (Loso and Doak 223). There is a well-established correlation between the growth area of a lichen and its age, as illustrated in Figure 1. This relationship is critical for accurately determining the age of lichen-covered surfaces, facilitating precise and reliable lichenometric dating.

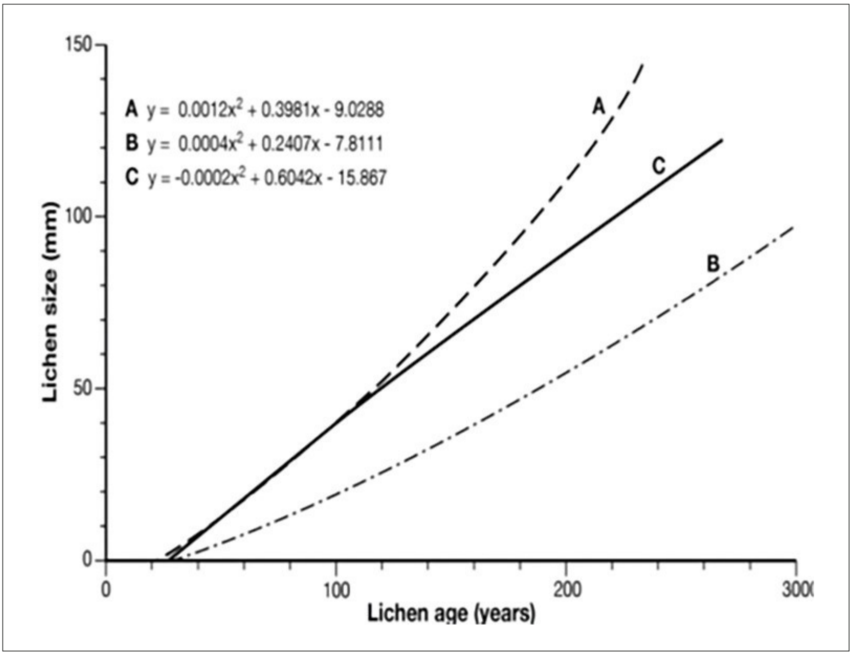


Figure 1. Demonstration of a direct relationship between lichen growth area and lichen age (Trenbirth and Matthews 20).

Measurement Techniques

The measurement of lichen thallus growth is accomplished by rapidly, inexpensively, and accurately measuring a large number of lichen thalli (Armstrong 315-320). Two commonly measured parameters for crustose lichens are area and diameter, with the most common being the diameter of nearly circular thalli. In practice, the diameter of non-circular thalli can be defined as the longest axis, the shortest axis, or the average of both. For example, Trenbirth and Matthews ("'Little Ice Age' glacier" 19) measured the longest axis of lichens using precision instruments (Photo 1). Lichen diameters are also measured using a ruler (Phillips 95-96); Bradwell and Armstrong, 315), digital calipers (Lowell et al. 313), and by tracing the outline of thalli (Miller and Andrews 1135; Haworth et al. 290).

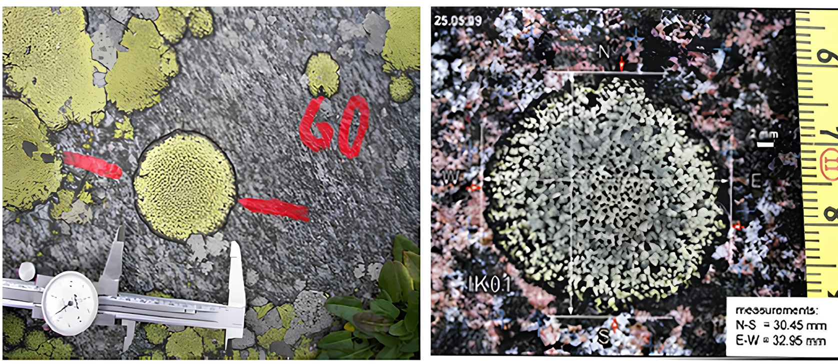


Photo 1. Measuring lichen diameter with precision instruments (Trenbirth and Matthews 23).

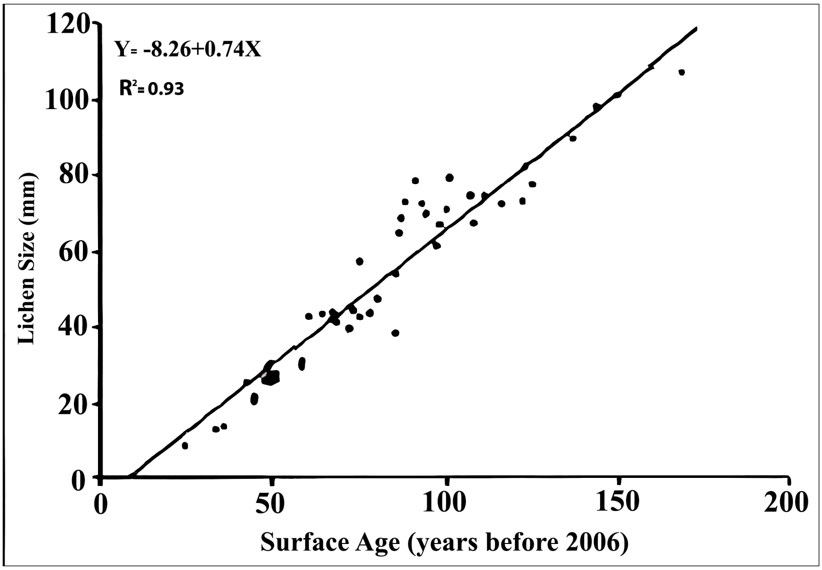
The area of lichens can be utilized to calculate their growth rates, which is a key aspect in lichenometry, a method used to estimate the age of rock surfaces. Before the advent of computer software, early researchers like (Rydzak 2-3) employed manual techniques to track lichen growth. They would trace the outlines of lichen thalli (the body of the lichen) on plastic sheets and monitor their growth over time (Figure 2). This was done by measuring the surface areas of each traced thallus using graph paper. From these measurements, they calculated annual growth averages (Armstrong 310).

A common approach in lichenometry is to date a substrate using the largest thallus present, as it typically represents the longest period of uninterrupted growth. Matthews ("Lichenometric dating" 188) proposed that using the largest thallus, especially when coupled with measurements from a broad surface area, can provide more accurate and realistic dating results. This method allows researchers to estimate growth over time and thus, indirectly date rock surfaces or archaeological features where the lichen is found. The accuracy of these estimates, however, can be influenced by environmental factors such as climate and pollution, which affect lichen growth rates. Therefore, combining data from the largest thalli with a wider sampling area helps to account for variability and yields more reliable results.

Indirect Lichenometry

This method involves identifying substrates with known ages and measuring the lichens growing on them (Mottershead 96). Measurements of lichens from surfaces with known ages establish a correlation between lichen size and surface age (Matthews, "Lichenometric dating" 186). Anthropogenic surfaces like tombstones (Innes, "Use of an aggregated Rhizocarpon" 184), stone walls (Benedict, "Recent Glacial History" 818), mine waste heaps (Karlén 30), abandoned farms (Caseldine 111-112), monuments (Werner, 131), and natural surfaces dated with tree rings (Noller and Locke 262) are used as control points in indirect lichenometry. It can also date historical documents (Anderson and Solid 30-38). Commonly, age determination involves measuring the largest lichen or averaging lichen diameters or radii. Hughes (1595) measured Aspicilia calcarea. Attempts to approximate the Earth's surface age involve averaging sizes and ages of the five largest lichen species found on tombstones and monuments (Photo 2, Figure 2).

Photo 2. The use of lichens in determining the age of the earth (Brodo et al, 2001).



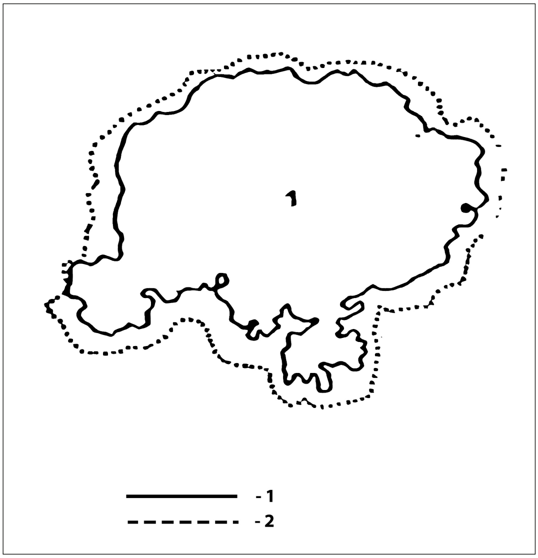


Figure 2. Determining the age of the surface by calculating the average size of the five largest lichen thalli (50 samples), gathered from measurements taken on monuments and tombstones with known ages (Hughes 2007).

In 2003, O'Neal and Schoenenberger undertook a comprehensive study within the Washington and Northern Oregon locales of the United States, aiming to ascertain the growth rates of the lichen species Rhizocarpon geographicum and to establish a correlation between lichen proliferation and the chronological age of rock surfaces. Evaluating the precision of such methodologies presents a significant challenge. Nonetheless, Matthews ("'Little Ice Age' glacier" 13-15) conducted a comparative analysis utilizing indirect lichenometry to assess the age of lichens found on gravestones and historical artifacts with established dates. His findings indicated a marginal discrepancy, with an approximate variance of ±6 years relative to the overall age, attributable to the rapid expansion and growth rates of lichens. However, the absence of lichens on certain rock formations can often be ascribed to the specific ecological needs of the lichens and to prevailing adverse environmental conditions that inhibit their growth.

Direct Lichenometry

In the direct approach to lichenometry, systematic and repeated observations of individual lichens over an extended period are necessary. Accurate assessment of growth rates requires a longitudinal study spanning at least one to several years, meticulously recording growth dynamics. A growth curve is then constructed based on measurements from lichens of various sizes. Crustose lichen species, with slower growth rates, are often preferred for their more stable long-term data.

In their seminal work, (Armstrong 309) and, (Bradwell and Armstrong 319) synthesized the findings from 13 distinct studies, revealing considerable variability in the estimated average annual diameter growth rates of lichens, which ranged from 0.08 mm/year to as much as 1.47 mm/year. The relationship between the size of the lichen and its estimated age is typically represented graphically, illustrating comparative data across three distinct regions as shown in (Figure 1).

Further advancing the field, (Trenbirth and Matthews 20) specifically focused on determining the annual growth rates of species within the "Rhizocarpon" genus. Their research methodology was notably selective, favoring lichens that exhibited circular growth patterns on stable rock surfaces and were not subject to competition from other lichen species.

Measurements were precisely conducted using calipers to ensure accuracy. The study documented that the average annual growth rates for lichens from this genus across 47 observation stations varied between 0.43 mm/year and 0.87 mm/year.

Established lichen growth rates have significant implications for determining the approximate ages of historical monuments, inscriptions, and seismic events in environments conducive to lichen growth. The methodology involves measuring lichen growth area on a substrate and dividing the data by the established annual average growth rate to estimate surface age (Trenbirth and Matthews 21-24). This approach enhances the accuracy and reliability of lichenometric dating, contributing to broader geological and archaeological chronologies.

Material and Method

The methodology of this research was structured into four distinct phases. In the initial phase, the prevalent indirect approach for age determination was employed, necessitated by the absence of regional monuments or tombstones that could serve as reference points for the lichen species identified for this study. The second phase involved meticulous site selection; an area replete with historical paintings and figures was chosen, aligning with the study's objective of age estimation.

The third phase focused on the selection of lichens. This involved identifying and selecting lichen species deemed most appropriate for age determination, based on a thorough review of the literature. The criteria for selection prioritized species that are long-lived, crustose, and predominantly found in the region, ensuring relevance and consistency with the ecological context of the study area.

The final phase involved measuring lichen areas with a systematic approach to accurately delineate their extents. Transparent acetate sheets were used to trace boundaries and areas, and a millimeter grid method was employed for quantification. This technique accommodates the variability in lichen growth patterns influenced by environmental factors such as nutrient availability, moisture levels, temperature, and light exposure. The rigorous methodological framework aims to ensure precise and reliable age determinations derived from lichenometric analysis (Bednarik, “Finger lines” 34) .

In the study, environmental factors were carefully controlled as they can affect lichen growth rates. Parameters such as humidity, temperature, light levels, and pollution play a significant role in the growth rates of lichens. During fieldwork, areas with similar environmental conditions were selected to minimize the impact of these factors on growth. Additionally, weather records for the periods during which lichen growth rates were measured were examined, and particularly rapid growth periods (spring and summer) were evaluated with these conditions in mind. Thus, the aim was to minimize potential deviations in the results caused by environmental influences.

Lichen species for the study were collected from specific locations within the rocky terrain of Örnök village, Issyk-Kul. They were gathered with their substrates using appropriate methods and quantities and transported to the herbarium of Kyrgyz-Turkish Manas University, Faculty of Science, Department of Biology. After drying under room conditions, they were prepared as herbarium specimens, and diagnoses were conducted using various sources (Poelt and Vĕzda 1; Purvis et al. 1; Aslan 145). Care was taken to collect the entire thallus, and detailed notes on thallus colors, sunlight/shade conditions, and substrates were recorded and referenced during diagnosis.

In sample identification, various reagents that react with specific lichen substances were employed, alongside Stereo and Research microscopes. These chemical reagents consist of: K: 10% Potassium hydroxide solution; C: 3% Sodium hypochlorite solution; P: Paraphenylenediamine’s saturated solution in 96% alcohol; I: A few iodine crystals dissolved in 70% Ethyl alcohol.

Some of the most critical factors influencing the selection of the study region include: a) the occurrence of extensive lichen colonization on the rocky terrain surrounding the lake basin, b) the region’s suitability for sustaining small-scale animal husbandry to meet economic demands, and c) the enduring reliance of the local nomadic lifestyle on prevailing climatic conditions. Consequently, the evolution of human habitation and progress in the region has been intricately linked to historical climatic patterns and ecosystem dynamics. For instance, fluctuations in the water level of Lake Issyk may surpass several meters, surpassing those observed in marine contexts. Such alterations or temperature differentials could exert significant impacts on the region's ecosystem and wildlife.

Some research has documented a decline in lake levels between 1927 and 2000, followed by a subsequent increase after 2000 (Romanovsky 45) However, alterations in glacier flow within the Tien Shan Mountains have played a significant role in prompting the migration of human communities throughout the region's extensive history. Furthermore, contemporary settlements in Central Asia, along with their millions of inhabitants, remain heavily dependent on glacier water resources. As such, any decrease or loss in glacier area volume remains a significant concern for countries in Central Asia (Takeuchi et al. 28).

For instance, glacial chronological studies have revealed that the glaciers in the Tien Shan significantly expanded during the Last Glacial Maximum, approximately 19,000 years ago, and commenced a gradual retreat around 11,000 years ago. The present glaciers are predominantly remnants of the last glacial dissolution (Grosswald et al. 274). Consequently, in light of climate change, there is an opportunity to derive specific arguments concerning the extent of its influence on human life and the artistic comprehension of the rock ecosystem.

In various locations and study sites, traditional methods have dated rock art, often to the Middle Ages and, in some cases, to the Scythian period (Tabaldiev and Zholdoshov 111). New research conducted around Issyk Kul also indicates that rock painting developed from the beginning of the Bronze Age to the Middle Ages (Özgül 64; A. Ceylan 5-6; N. Ceylan 44). Horse-human petroglyphs depicting battle or hunting scenes in Örnök and other Central Asian regions are generally attributed to the Middle Ages, where horsemen are shown with attire, armor, and long hair, and horses are depicted as armored (Hudyakov and Tabaldiev 14; Akmatov 10). These depictions are similar to those where the lichenometric method was applied. Archaeological studies by (Miklashevich 63-65) from 1988 to 1995 classified petroglyphs into five periods: 1) Bronze Age, 2) Late Bronze to Iron Age, 3) Scythian/Saka Age, 4) Usun Age, 5) Middle Ages.

The study area, situated to the north of the Issyk-Kul region in Kyrgyzstan, is locally known as Küngöy Ala-Too (Küngöy; meaning sunny, temperate, warm, Ala-Too; Ala Mountains/Tian Shan). Our surface surveys in the region revealed rock arts and burial complexes dispersed in distinct areas across the lake, suggesting human habitation in the region since ancient times

Findings

Lichenometry is the most cost-effective and widely applicable tool for estimating surface ages, requiring minimal training and no advanced instruments. The ubiquity of lichens on rocky surfaces further enhances its utility. It serves as a valuable alternative dating method, used both independently and alongside other techniques. Despite the use of methods like radiocarbon analysis and luminescence dating for rock art (Bednarik, "The dating of rock art: a critique" 1225-1226), lichenometry has been underutilized in this context. This study aims to estimate the ages of figures on rocks in Issyk-Kul region, Örnök village.

During the project process, the indirect lichenometry method was employed using lichens, aiming to determine the approximate age of the ancient shapes and figures on the rocks. In this phase, samples were collected by identifying the lichen species *Pleopsidium flavum* (Bellardi) Körb., which met distinct, dominant, and abundant criteria suitable for age determination, at 7 different stations on the rocks where the figures were found. Lichen diagnoses were conducted in the laboratories of the Biology Department of the Faculty of Science at Kyrgyz-Turkish Manas University using lichen diagnosis methods, relevant sources, stereo microscopes, and light microscopes.

The identified lichen species, *Pleopsidium flavum* (Bellardi) Körb., was depicted on acetate sheets to represent surface areas from seven different stations, for illustrative purposes. Different pens were used to draw lines indicating four different periods, which were unrelated to growth areas. Growth areas were promptly calculated in millimeters and recorded in the table. Subsequently, four drawings were made at three-month intervals, repeatedly illustrating the lichen shapes. The growth zones occurring during these periods on lichen thalli were identified and determined using the millimeter grid method. By averaging lichen growth monitored over 12 months, the annual average growth was calculated to be 8.427. Additionally, the largest lichen thalli on the identified rocks were measured, revealing a lichen area of 24.940 mm.

Firstly, in order to obtain more reliable results, the total surface area of *Pleopsidium flavum* (Bellardi) Körb. determined from seven different stations was calculated as 24.940 mm using the millimetre measurement method. Then, a total of 28 measurements were taken with quarterly periods and the growth areas and their averages in these periods were determined as 2, 3.142, 2.857, 0.428, respectively. By adding these average measurements, the average annual growth rate of the lichen species used for age determination was determined to be 8.427. Finally, by dividing the previously calculated value of the total surface area of 24.940 mm of the lichen species *Pleopsidium flavum*, which is the closest and largest to the figures in the region, by the annual average of 8.427 mm, it was understood that the figure on the rock was 2.959 years old (Table 1; Figure 3-4).

Table 1
Seasonal and annual average growth rates for the *Pleopsidium flavum* lichen species by station

Station Number	**Sample Coordinates**	**Total Lichen Area (mm)**	**Growth from February to April (mm)**	**Growth from May to July (mm)**	**Growth from August to October (mm)**	**Growth from November to January (mm)**	**Annual Growth Rate (mm)**
1	42°36'21" N 76°54'48" E	6	1	3	3	-	7
2	42°37'32" N 76°51'15" E	139	2	3	3	-	8
3	42°36'21" N 76°54'48" E	75	2	3	2	1	8
4	42°37'51" N 76°51'07" E	143	3	4	3	-	10
5	42°37'52" N 76°51'48" E	131	2	3	3	1	9
6	42°38'16" N 76°51'45" E	111	2	3	3	-	8
7	42°38'11" N 76°50'40" E	39.5	2	3	3	1	9
Average Total			2	3,142	2,857	0,428	8.428

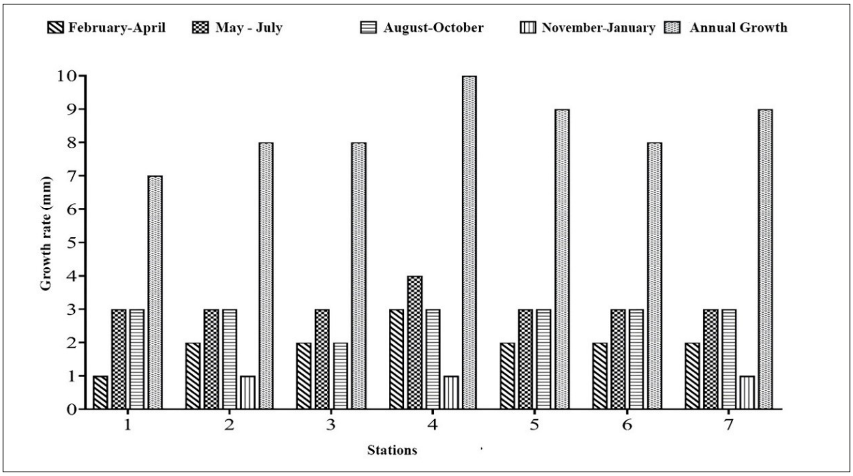


Figure 3. The average quarterly and annual growth rates of the Pleopsidium flavum lichen species determined by station

Figure 3 shows that the most thriving periods for the identified lichen species are 2, 3, 1, and 4, corresponding to spring and summer. Lichen growth is primarily influenced by moisture, wind, temperature, water, light, nutrients, and clean air. Lichens, lacking true roots, stems, or leaves, acquire essential nutrients from surfaces through cell gaps. Growth is most pronounced in spring and summer, with suitable rates for these periods. Annual average growth rates for age determination sum the growth rates of four periods. Ranked from largest to smallest growth rates by station are 4, 5, 7, 6, 3, 2, 1, influenced by proximity to water, moisture, and nutrient levels. Bird fertilizers on larger rocks notably impact lichen growth rates.

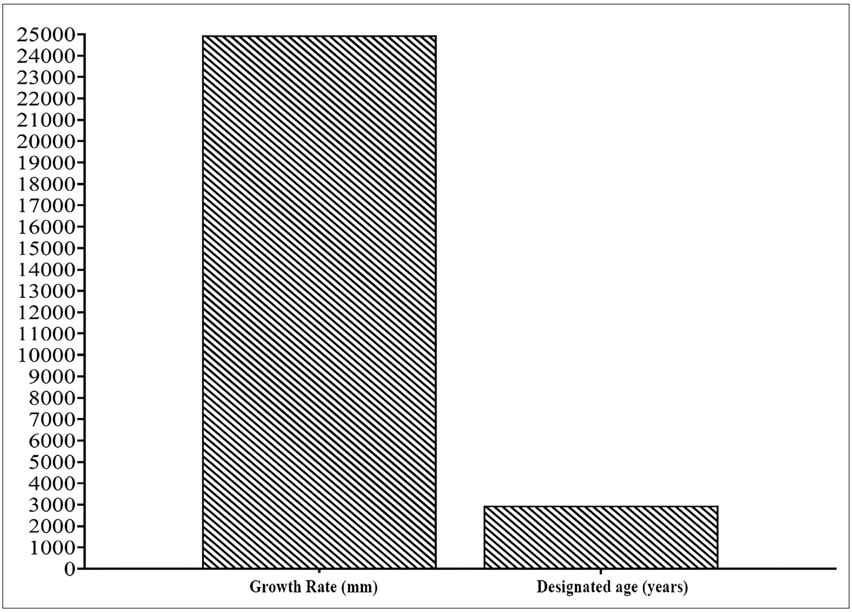
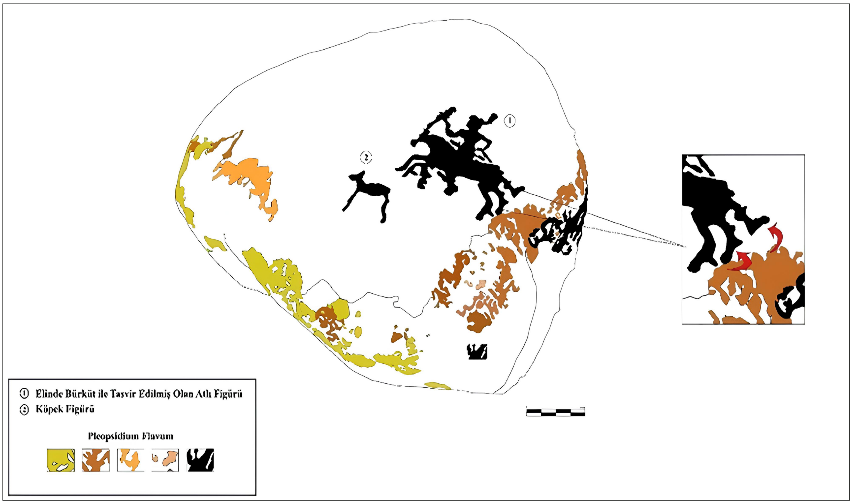


Figure 4. The total growth area and determined age of the closest and largest *Pleopsidium flavum* lichen species to the figures

Upon examining Figure 4, it becomes evident that the average growth of the largest lichen species found on or nearest to the figures is 24.940 mm. When this figure is divided by the annual average growth rate, it reveals that this growth occurred over a span of 2.959 years. Considering that a clean rock is typically chosen for important paintings, the presence of lichen covering part of the hind leg of the horse in the figure at station number 7 suggests that this figure predates the growth of lichen (Appendix A). In other words, the figure was created first, and then lichen developed on it. It's worth noting that lichens are crucial pioneer organisms in ecological succession and can therefore be utilized in age determination (Nash 1-2; Hale 5; Zeybek 92-93).

Photo 3. The lichen-covered rock containing the hunter figure



Drawing 1. Sketch of the Rock with the Hunter Figure Covered in Lichen

Conclusion

The initial organism to emerge in a barren area or on a rock surface is lichen. It's widely recognized that lichens play a crucial role in soil formation and serve as pioneering organisms in ecological succession, the gradual process of development. Thus, by studying lichens, which tend to appear first in nearly any setting or environment, the actual ages of the figures can be determined with minimal variation, on average.

The findings of this study show similarities and differences when compared to lichenometry research conducted in regions such as Norway and Alaska. For example, studies on Rhizocarpon geographicum lichens in Norway have determined that annual growth rates vary between 0.43 mm/year and 0.87 mm/year (Trenbirth and Matthews 19-20). In our research, however, a higher growth rate of 8.427 mm/year was found for the species Pleopsidium flavum. This difference clearly highlights the impact of regional environmental conditions on lichen growth rates. Nevertheless, it is well-known that growth rates in lichenometry studies can vary widely, and it is therefore important to carefully interpret the data, taking into account region-specific environmental factors.

Upon examining Figure 4, it becomes apparent that the average growth of the largest lichen species found on or nearest to the figures is 24.940 mm. Dividing this figure by the annual average growth rate reveals that this growth occurred over a period of 2.959 years. It's well-known that when creating a painting on a rock where no lichen or other organisms are desired, a clean and bare rock should be selected. Furthermore, the presence of lichen covering part of the hind leg of the horse in the figure at station number 7 suggests that this figure was created before the lichen growth (Figure 4). In simpler terms, the figure was made first, and then lichen developed on it. This also indicates that the traditional methods used to estimate the age of rock arts in the region are well beyond their determined age, suggesting that this painting dates back to around 1000 BC, and other paintings found in the same area may have been created around the same period. In the measurements taken at the station, it was observed that lichen growth rates increase significantly during spring and summer. This is attributed to the rise in social activity in the region, which sits at an average altitude of 1600-1700 meters, during these seasons. Medieval written sources have mentioned that the region, suitable for transhumance, has abundant fauna for small-scale livestock farming, and the nomadic lifestyle has prevailed in this area for many years.

As noted in the studies by (Bernştam 51) and (Pomaskina 10-13) the rock arts in the region have been created over an uncertain period starting from around the 2nd millennium BC and extending to the present day. However, this study, conducted using the method we have established, has, for the first time, established a chronology through lichenometry, offering a more testable proposition for research in this field. Particularly, given that motifs such as figures wearing hats, wielding spears, and having hair have previously been dated to the Middle Ages, the age revealed in the study (2.959 years) suggests that, at least for the region, the Middle Ages began in the 1st century AD. This results in an approximate difference of 1000 years. This situation gives rise to a multifaceted paradox and debate over the criteria used for determining chronology.

This study provides a significant contribution not only in terms of dating rock art in Kyrgyzstan but also in re-evaluating the potential of lichenometry in archaeological research within a broader context. The findings show that lichenometry offers a more scientific and testable approach compared to traditional dating methods. Additionally, this method allows for a more accurate connection between the periods when the rock art was created and the environmental conditions. Future research with the wider use of lichenometry could yield more precise results regarding the chronology of regional rock art.

This is the first study in the field of rock art in Kyrgyzstan, and even in Central Asia, to utilize the lichenometry for age determination. Additionally, it has the potential to prompt a reassessment of the traditional methods for determining the age of rock art used in Kyrgyzstan. As a result, we anticipate that this study will set a precedent for other research in this field and make exciting scientific data more readily available and accessible.

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Contribution Rate Statement

The authors' contribution rates are as follows:
1. Author – 30% (Data analysis and fieldwork)
2. Author – 30% (Literature review and field research)
3. Author – 30% (Analogical study and fieldwork)
4. Author – 10% (Fieldwork)

Conflict of Interest Statement

There is no conflict of interest with any institution or person within the scope of this study. There is no conflict of interest between the authors.

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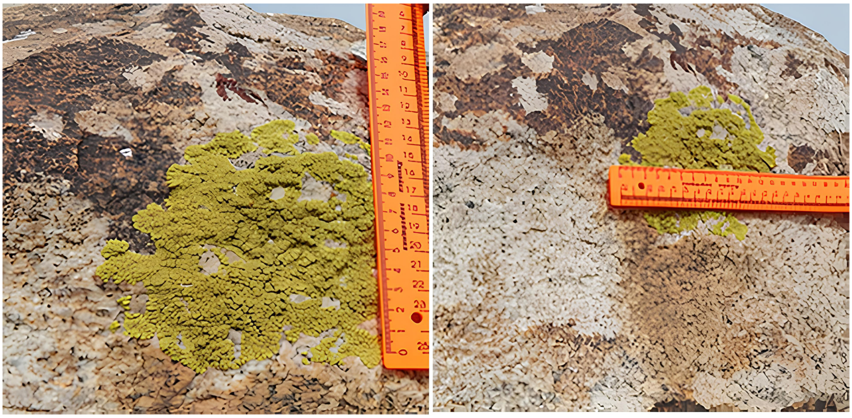
Appendices

Appendix A. The lichen sample used for age determination



Appendix B. Satellite image of the rock art site