Journal of California and Great Basin Anthropology
Vol. 7, No. 2, pp. 202-224 (1985)

Lichen Dating of Alpine Villages in the White Mountains, California

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As has been remarked periodically within the pages of this journal, chronology continues to be a basic concern in contemporary archaeological research (Bettinger 1980; Thomas 1981). This is so despite general consensus that our ultimate purpose in archaeology is not merely to place things in time but to understand culture process: it is simply that many interesting cultural processes are envisioned as operating in a temporal dimension, from which it follows that the data needed to understand them must generally be temporally ordered.

Unfortunately, in relation to demand, the battery of affordable and yet reliable chronometric techniques at the disposal of the archaeologist is relatively limited. Radiocarbon is still the technique of preference, particularly given recent innovations in sample preparation and counting methods. Its routine use is, however, precluded by the relatively high cost per assay, anywhere from \$200 to \$400. Techniques less expensive, on the other hand, either suffer from uncertainties surrounding underlying natural processes (e.g., obsidian hydration) or are applicable only in special circumstances (e.g., dendrochronology).

Dating techniques that rely on data from the cultural as opposed to the natural world, e.g., seriation and cross-dating, are similarly limited in their range of potential application. In the Great Basin, for instance, time-sensitive projectile point shapes have long provided the basis for regional chronologies, yet there are within this area many kinds of sites that resist dating by this means – rock art, hunting blinds, and stone alignments of other kinds, to name only a few.

These problems are not likely to disappear anytime soon. Theoretical developments on a variety of fronts make it clear that the kinds of archaeological phenomena that must be investigated and interrelated to form reasonably comprehensive interpretations of given points in time are exceedingly diverse and therefore unlikely to yield to any single chronometric technique. Given these circumstances, the prudent archaeologist will seek to use as many techniques as possible, balancing their costs, reliability, and breadth of potential application. It is partly our purpose here to illustrate the use of a technique, lichenometry, that has until now enjoyed use principally in glacial geology but that would seem to deserve consideration in archaeology as well. As with any other chronometric technique, lichenometry has both advantages and disadvantages. We are certainly not holding it up as a panacea; it is hardly that. It is, however, a largely untapped source of information that should prove useful in developing comprehensive archaeological chronologies for some regions.

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This is not intended as a primer in lichen dating; readers seeking such would be far better served by a careful study of the references cited. It is our intention, rather, to present lichen dates for some sites in eastern California, to evaluate the reliability of these dates and the problems surrounding their interpretation, and, more briefly, to assess their implications for prehistoric developments in this region. In tackling this relatively specific problem we illustrate some of the basic advantages and disadvantages of lichen dating in archaeological contexts. We begin with a summary review of the sites being dated and the problem to which their dating is relevant.

ALPINE VILLAGES IN THE WHITE MOUNTAINS

Surveys and excavations in the White Mountains of eastern California have recently revealed the presence of previously unsuspected villages at elevations of between 3,170 and 3,850 m. Strikingly reminiscent of Alta Toquima Village, located at an elevation of 3,350 m. on Mount Jefferson in central Nevada, briefly reported by Thomas (1982), these settlements are characterized by extensive surficial artifact scatters consisting of both chipped and ground stone implements, subsurface midden deposits up to a half-meter in depth, and, most distinctively, by large rock rings or circles that evidently served as footings for roofed structures, most of which were probably dwellings.

A total of ten such villages located between 1982 and 1985 are presently under study.[1] One of these has been intensively excavated; the subsurface deposits of the others have been tested to a more limited extent and controlled surface collections have been obtained from each one.

The data presently in hand preclude definitive interpretation but it seems fairly certain that these sites were occupied by families or groups of families who engaged in both plant and animal procurement in the White Mountain Alpine Tundra. An abundance of cultural debris and well-built structures and features of other kinds would seem to indicate fairly lengthy periods of residence, perhaps six weeks to two months, most likely between late spring and early fall. Lacking sophisticated cold-weather technology, for which there is evidence in neither the ethnography nor the archaeology of this region, the locations at which these sites occur would in most years be essentially uninhabitable for any prolonged period from mid-fall to mid-spring.

THE PROBLEM

Though it would be of basic interest under any circumstance, the dating of these sites takes on critical importance in relation to recent proposals of changing land-use patterns in eastern California and their relationship to changes in adaptive patterns throughout the Great Basin. In brief, Bettinger and Baumhoff (1982) have suggested that the late prehistoric spread of Numic-speaking peoples from southeastern California northward and eastward into the Great Basin was made possible by an adaptive shift. According to this model an earlier pattern emphasizing group mobility and the use of preferred resources, particularly large game, was replaced by one of more restricted movement and more intensive use of less-preferred local resources of lower quality, particularly seeds. The adoption of the latter pattern about one thousand years ago by groups in eastern California is seen to have had a variety of consequences. In particular, it sustained high population densities, promoted population growth, and carried special competitive advantages as groups embracing it began to encroach on the lands of those wedded to the earlier adaptive form that depended on less intensive land use. These and other circumstances are held to have precipitated the so-called "Numic Spread."

Thomas (1982) noted that Alta Toquima, an alpine village some 240 km. away from the ones in the White Mountains, was perfectly compatible with the Bettinger and Baumhoff (1982) model of the Numic spread. Preliminary results of investigations there tended to link that village with a pattern of residential alpine occupation centering on intensive mixed plant and animal procurement that sprang up roughly between A.D. 1000 and A.D. 1300, replacing an older pattern in which large game was taken on short-term forays.

The adaptive shift tentatively identified in central Nevada seems to repeat itself in the White Mountains. Although the surface scatters of most White Mountain alpine villages are dominated by projectile points dating earlier than A.D. 600 – evidently a consequence of later artifact scavenging and earlier use of these locations for hunting camps and stands – the contents of all structures excavated so far are dominated by projectile points and ceramics more recent than that. Further, transect surveys undertaken in 1984 showed that time-sensitive artifacts dating earlier than A.D. 600 were distributed throughout the alpine zone in a manner suggesting transient use by hunting parties; those dating later than A.D. 600 were confined primarily to villages, linking them with a more intensive form of land use in which plant procurement and processing figured prominently. Thus, the evidence from the White Mountain villages tends to suggest a basic change in the use of the alpine zone of exactly the kind and at exactly the time predicted by Bettinger and Baumhoff (1982).

This preliminary assessment can, of course, be questioned on a variety of grounds but it is particularly problematical in the matter of dating, the issue with which we concern ourselves for the balance of this discussion.

DATING THE WHITE MOUNTAIN ALPINE VILLAGES

Apart from time-sensitive artifacts that seem to place them between A.D. 600 and historic times, the White Mountain villages are potentially susceptible to dating by a variety of techniques including tephrachronology, dendrochronology, obsidian hydration, and radiocarbon. Each of these is being actively pursued and promises to yield excellent information in the future, yet none currently offers unequivocal evidence as to the age of these sites and the few dates they have generated are in conflict with evidence from our excavations.

Tephrachronology

A single, sometimes discontinuous, layer of white, aphyritic tephra occurs in varying thicknesses and at varying depths below the surface at five of the ten sites excavated. This tephra must derive from the Inyo-Mono Craters chain 70 km. to the northwest (cf. Kilbourne, Chesterman, and Wood 1980) and very likely marks a single event since these sites are in such close proximity to each other and appear roughly contemporaneous. Low strontium content revealed by X-ray fluorescence of volcanic ash found within a structure at one site (Rancho Deluxe) suggests origin in the Mono Craters (Paul Bouey, personal communication 1984; cf. Wood 1977a). Unfortunately, neither the chronology nor the chemistry of the many ashes deriving from these vents is sufficiently well understood to permit the dating of the White Mountain villages, however, it is probably one of three aphyritic Mono Craters ashes that have been dated at 40 B.C., A.D. 760, and A.D. 1310, respectively (Sieh, Wood, and Stine 1983; Wood 1977a, 1977b). Where their stratigraphic relationship to this ash layer can be ascertained, time-sensitive artifacts tend to discount the possibility that the earliest of these three Mono Craters tephras is the one represented. The dates of either of the two younger tephras are in accord with associated cultural materials and with the chronological placement that has been proposed for these alpine villages.

Obsidian Hydration

Obsidian from various sources constitutes the greatest proportion of the chipped stone assemblages at these sites and hydration-rind measurements should ultimately provide an accurate basis for dating them. We have yet to establish a cold-climate rate for any of these glasses, however, and absent this the technique cannot now provide information of the kind needed. This notwithstanding, the scarcity of workable stone in the alpine zone evidently occasioned extensive artifact scavenging by village inhabitants. This is likely to skew hydration-rind measurements and obscure the true dates of individual assemblages until very large samples have been processed.

Radiocarbon and Dendrochronology

Charred tree stems and branches are quite common in both the open deposits and the structures that have been excavated. These would seem to invite dating not only by radiocarbon but also by dendrochronology since a well-established tree-ring sequence is available for the White Mountains (Ferguson 1969; LaMarche 1974). The vast bulk of nearly all samples is bristlecone pine (*Pinus longaeva*), which is legendary not only for its longevity but also for its resistance to decay and demonstrated ability to remain preserved several millenia after death (LaMarche 1973). Since relic stands of bristlecone dominated by ancient living and dead individuals are the largest source of firewood readily available in the alpine zone, radiocarbon assays and dendrochronological dates on the wood or charcoal of this species are likely to be anomalously old except in the case of very thin stems that would tend to weather and decay more rapidly. Examination of large lots of material and careful screening of samples for suitable specimens should avoid this problem, but such time-consuming analysis has only begun.

A more immediate solution is to date samples of only comparatively short-lived species, sagebrush (*Artemisia tridentata*), for example. Two such samples, secured from deeply buried, rock-lined hearths in structures at two different sites have been submitted for radiocarbon assay. Surprisingly, both yielded essentially modern dates, that is, younger than A.D. 1800 (UCR-1715, -1716). Each of the structures in question produced at least some historic material, predominantly glass beads, but their lower components, from which these samples were recovered, lacked such items and were presumed to predate Euroamerican contact.

The Inyo-Mono highlands featured prominently as aboriginal strongholds during the Indian wars in the early-to-mid 1860s (Chalfant 1933: 217, 224-225) but it is improbable that the bulk of alpine village occupation is as recent as these two radiocarbon dates suggest. Accordingly, we must presume that they are quirks of sampling, that something is wrong with one or both samples – perhaps rootlet contamination – or, what seems most likely, that hearths within these structures were continually churned and reworked by aboriginal groups over long periods and so contain material much younger than the cultural deposits at equivalent depths immediately adjacent to them. However we choose to explain these dates, they do little to clarify the chronology of the White Mountain alpine villages.

Given the clouded picture emerging from

attempts to establish a working chronology for these alpine villages by other means, lichenometry – the dating of cultural features by the size of the lichens growing on them – has several obvious advantages. First, the dates obtained apply to structural remains exclusively, therefore they refer primarily to residential occupations rather than to the broader range of more transient activities that did not require the construction of elaborate stone features for which these locations could have been (and in most cases clearly were) used, temporary camps and ambush locations, for example.

Second, the technique is comparatively undemanding as to the circumstances where it can be used, being applicable to virtually all structural remains throughout the alpine zone of the White Mountains. This is in marked contrast to radiocarbon, dendrochronology, obsidian hydration, and tephrachronology, all of which are vulnerable to vagaries of preservation and sample size – so much so that one cannot assume ahead of time that any one will serve in a particular case.

Third, lichen dating is relatively quick and cheap. Unlike techniques whose application is necessarily limited by cost in time or dollars, large suites of lichenometric dates can be obtained without undue expenditure of either. Since the samples are large, the problem of statistical error is lessened and erroneous dates are more readily identified.

Fourth, and perhaps most importantly in the present case, lichenometry does not rely upon samples from excavated contexts. Structures can be lichen dated prior to excavation (indeed, it is best done before they are disturbed by excavation) and thus tentatively separated into age classes that can be individually sampled by excavation. In a related sense, when identification is uncertain on other grounds, we have found the technique especially useful in distinguishing cultural from natural features.

Background

An archaeologist was among the first to propose the use of lichens as a tool for dating (Renaud 1939), but modern lichenometry was developed and has been most frequently applied by glacial geologists (Beschel 1950, 1961; Benedict 1967; Curry 1969; Innes 1985), especially in the last two decades. Successful archaeological applications are few in number (cf. Benedict 1975, 1981) and even some of these have been concerned primarily with the dating of glacial/periglacial deposits as a means of paleoclimatic reconstruction (Benedict 1981).

The basis for the technique lies in the slow and more-or-less regular pattern of growth displayed by certain long-lived crustose lichens. *Rhizocarpon* has been the subject of broadest study (cf. Benedict 1981; Innes 1985), but several other taxa have been shown to provide useful data as well. In the White Mountains two species, *Rhizocarpon bolandari*, a dark brown lichen, and *Rhizocarpon alpicola*, a dark green lichen, are sufficiently common to provide a basis for dating. Two others (*Caloplaca elegans* and an unidentified form tentatively referred to as *Rhizocarpon*) are present but too rare to be useful.

Remarkably hardy in certain respects, lichens are killed by adverse fluctuations in temperature, moisture, and sunlight (Benedict 1967; Innes 1985). A simple change of exposure may have this effect, especially in marginal environments. In glacial and periglacial settings, snow cover, proximity to ice, or transport in glacial ice are major causes of lichen mortality (Curry 1969). Upon climatic amelioration or ground stabilization, new colonies are established on surfaces voided of older lichen and on previously uncolonized surfaces that come to rest in favorable positions. These lichen growths, or thalli, may then be said to date the cessation of glacial/periglacial activity or substrate movement.

Human activity can also alter lichen substrates enough to affect growth and colonization. The repositioning of stones in the course of feature construction will kill existing lichens that happen to be placed face-down or in unfavorable aspects. At the same time this exposes previously uncolonized boulder surfaces to favorable orientations. It often happens, however, that this is insufficient to remove all the older thalli. In these cases, the observed distribution of thalli diameters is generally uneven, usually evident in the contrast between the smooth distribution of the size classes that represent the smaller new colonies and the more broken distribution of those that represent the larger survivor colonies. Benedict (1985; cf. 1975) reports that only 2.6% of the thalli measured on a wall built as part of a Colorado hunting complex had survived its construction; similar features elsewhere in the Colorado Front Range display comparable survival rates ranging between 0.8% and 2.5% (Benedict 1985).

In agreement with Benedict (1985), our research showed that very few lichen colonies survived on stones used to build structures at the White Mountain villages. The mean size of the five largest thalli (see below) found on these features is invariably much less than that of those found in surrounding boulder fields. As suggested for the Colorado hunting feature reported by Benedict (1975), it may be that the pre-existing thalli were heavily shaded or entirely covered by roof or wall coverings. Alternatively, they may have been unable to withstand the excessive heat, smoke, or dust associated with the use of these features. As this matter is taken up in detail below, we will note here only that lichen thalli growing on both aboriginal and historic structures in the White Mountains appear to be as homogeneous with respect to size, and therefore age, as those that have been studied in Colorado.

Apart from the natural and cultural phenomena known to kill or disturb lichens noted above, plant growth, if it is sufficiently tall and dense, can eliminate or slow the growth of extant lichen cover and discourage the growth of new thalli by shading them (Benedict 1967). Individuals of shrubby species are seldom long lived and it is sometimes difficult to ascertain whether previous plant growth has affected lichen colonization and development. Alpine plants of the White Mountains, however, are seldom tall or dense and at only one site (Enfield) is there reason to suspect that shrub growth has been vigorous enough to adversely affect lichen development.

Within a particular species, measurement of the diameters of the largest thalli attached to a given substrate is sufficient to indicate its age relative to another similarly measured for the same species. To establish a chronology measured in years (i.e., an absolute dating) requires in addition an established growth curve for the lichen species in question. This gives the age of the lichens, to which is added an estimate of the amount of time needed for their establishment on the substrate being dated. Under especially favorable circumstances, particularly along streams and moist spots, colonization may occur in as little as 10 years (Curry 1969). Where conditions are more xeric or the substrate is initially less stable, on the other hand, colonization may require between 20 and 50 years – and longer than this if the substrate is smooth and polished (Benedict 1967). Aboriginal features in the White Mountains were built with unmodified (i.e., undressed) field stones and boulders that, like boulders in glacial and periglacial features within the range, were probably colonized about 50 years following episodes of disturbance, except where other circumstances militated against this (see below).

Construction of Growth Curves

Since little is known about either the growth rates or growth mechanisms of lichens in general, the development of a growth curve requires a series of benchmark substrates that have been dated both lichenometrically and by some other means, typically by historical records or radiocarbon assay. A suite of these benchmarks is required, with, at a minimum for a well-established curve, substrates that represent its beginning, middle, and end. Strictly speaking, a curve developed in this manner is valid only for one species and only for the limited environmental range where the study is conducted. *Rhizocarpon geographicum* is by far the most widely used species, world-wide, and most studies using other species compare against it. Unfortunately, *R. geographicum* is very rare in our study area, which necessitates the use of *R. alpicola* and *R. bolandari.* As shown in Table 1, mean thalli diameters for these two species were found to be statistically indistinguishable when computed separately for: (1) the individual populations of structures present at the seven sites where both taxa are represented; (2) all the remaining cultural features that were measured taken as a group; and (3) the boulder fields surrounding these villages taken as a group. Overall, out of 60 individual cases in which both were present on the same substrate (cultural or natural), *R. alpicola* exhibited the largest mean in 36 (60%) and *R. bolandari* in 24 (40%). On this basis it is reasonable to assume that the growth rates for the two species are roughly comparable within the White Mountains and, thus, that a single growth curve will suffice for both until better data become available. As noted below, however, in all calculations where dating is involved the two species are distinguished and treated separately.

Table 1

COMPARISON OF MEAN THALLI DIAMETER FOR *R. BOLANDARI* AND *R. ALPICOLA*

Substrate	*R. bolandari* (mm.)	*R. Alpicolas* (mm.)
Structures/Sites		
Crooked Forks	31.7	33.6
Enfield	18.4	18.0
Midway	31.2	31.3
Shooting Star	16.8	20.3
Rancho Deluxe	22.3	24.5
Pressure Drop	13.9	14.2
Site 12640	30.1	29.4
Miscellaneous Features	26.2	27.0
Boulder Fields	58.6	58.4

Though it is the subject of much current work, the Holocene chronology of the White Mountains is not well documented. Consequently, our curve, developed by Oglesby (MS), lacks the requisite benchmark substrates within this study area except in its initial portion, which is anchored by historic structures of known age: shepherd cabins and a stone corral. Constructed between about 1890 and 1930 by immigrant French shepherds who used the White Mountains as summer rangeland (D. Powell, personal communication 1985), these features provide important evidence regarding rates of lichen colonization and growth in the period immediately following colonization. Three radiocarbon assays pertaining to lichen-dated substrates obtained subsequent to the development of the curve are in general agreement with it but not considered a sufficient basis for its correction at this point (see below).

Lacking better independent chronological control locally, our curve appeals to evidence gathered by Innes (1985) and Benedict (1967), which suggests that, to a first-order approximation correcting for altitude, *Rhizocarpon* in general and *R. geographicum* in particular follow the same general growth pattern in continental environments worldwide. This is shown by the close correspondence between the growth curves of Benedict (1967), on the one hand, and those of Curry (1968) and Scudari (1983), on the other; dates given by these curves differ by only 10% - 15% even though they were developed

Table 2
LICHEN DATES FOR HISTORIC SUBSTRATES

Site	Feature	Lichen Diameter Mean (mm.)	Lichen Diameter Maximum (mm.)	Lichen Date	Date*
Corral Camp South	Corral	5.6	8	1885	ca. 1900
Rancho Deluxe	Cabin	6.0	8	1885	ca. 1900
Pressure Drop	Cabin	8.0	9	1875	ca. 1900
Site 12640	Cabin	5.3	8	1900	ca. 1900

*Estimated from historic accounts (cf. Wehausen 1983).

Table 3
RADIOCARBON DATES FOR LICHEN-DATED SUBSTRATES IN THE WHITE MOUNTAINS

Site/Structure	Lichen Date	Radiocarbon Date
Site 12640		
Structure 2	A.D. 1535 - 1635*	A.D. 1420 - 1650 (340 +/- 60 B.P.; UCR-2189)
Crooked Forks		
Structure 2	A.D. 1260 - 1410*	A.D. 1340 - 1485 (490 +/- 70 B.P.; UCR-2176)
Structure 3	A.D. 1135 - 1285	A.D. 1315 - 1520 (490 +/- 100 B.P.; UCR-2180)

*Structure exterior.

Note:
Radiocarbon dates given as 95% confidence intervals in calendar years (Klein et al. 1982).

for study locations 1,500 km. apart. Curry and Scudari worked close to our area (roughly 50 km. away), but at lower elevations (ca. 2,500 m.) and in sheltered, more mesic environments. Benedict worked about 1,450 km. away, but at similar altitudes and in similar but slightly more mesic environments.

The lichen growth curve we used is an interpolation of growth curves developed by Benedict (1967) for *Rhizocarpon geographicum* in the Front Range of Colorado, Curry (1968) for *Acarospora chlorophana, Rhizocarpon superficiale,* and *R. lecanorium*, and Scudari (1983) for *R. alpicola* and *R. bolandari* in the Sierra Nevada of California. Using the evident similarity in world-wide growth rates for *Rhizocarpon* and the close match between the well-established curves of Benedict, Curry, and Scudari, we have "split the difference," tending to slightly favor Benedict's curve since it was developed at a similar altitude. As shown in Table 2, dates given by this somewhat arbitrary curve agree very closely with the known ages of the historic features in the White Mountains. The lack of independently dated substrates representing its intermediate and older portions makes our curve very tentative and empirical in nature and, hence, subject to possible, but probably small, changes. As mentioned above, three radiocarbon assays are currently available for lichen-dated substrates in the White Mountains. From this small sample correspondence between the lichen date and radiocarbon date for the same surface appears reasonably close, though there is some suggestion that the long-term growth rate is faster than we have calculated it (Table 3). For the moment, however, these data do little more than suggest the curve yields dates that are approximately correct within the last 600 years. It would be unwise to compute a new curve from this evidence alone, especially since the radiocarbon dates themselves have yet to be interpreted fully. Chronological information generated in subsequent phases of archaeological research at these villages will substantially increase the precision of our growth curve and hence the lichen dates for these sites. Again, we emphasize that this curve is tentative and requires further refinement. Whatever its ultimate configuration, however, the dating suggested here will remain unchanged ordinally (that is, the order of events will be preserved).

Lichen thalli appear to go through two distinct growth stages during their lifespan (Innes 1985; Lock et al. 1979). The first stage, the so-called "great growth period," is an interval of rapid development following initial colonization. This growth describes a roughly exponential curve and for *Rhizocarpon* seems to last about 100 years. Subsequent growth is much slower and essentially linear in rate. Our curve assigns a growth rate (in terms of thalli diameter increase) of about 0.14 mm./year for the first 100 years, about 0.04 mm./year for the next 675 years, and about 0.03 mm./year after that. Dates can be assigned by referring to Table 4.

Table 4

WHITE MOUNTAIN LICHEN GROWTH RATES

Mean Thalli Diameter (mm.)	Date of Substrate
5	1910 A.D.
6	1900
7	1895
8	1885
9	1875
10	1860
11	1810
12	1785
13	1760
14	1760
15	1735
16	1710
17	1685
18	1660
19	1660
20	1635
21	1610
22	1585
23	1560
24	1535
25	1510
26	1485
27	1460
28	1435
29	1410
30	1385
31	1360
32	1335
33	1335
34	1310
35	1285
36	1260
37	1235
38	1210
39	1185
40	1160
45	960
50	760
55	585
60	385
65	185
70	15 B.C.
75	165
80	315
90	465
100	815

Note:
Dates rounded to nearest 25-year (B.P.) increment and mean lichen diameter to nearest millimeter.

The error estimates given with our dates represent possible sampling errors and uncertainties inherent in performing lichenometry rather than errors associated with the growth curve itself. Even assuming a perfectly known growth rate, these potential errors would exist. The error estimates are empirical and semiquantitative and are based on the reproducibility of results. Innes (1983) and others (e.g., Lock et al. 1979) have shown that, under the best of circumstances, the chronometric estimates resulting from lichenometric analyses are reproducible to about 5% to 10%. That is, estimates produced by two different workers or the same worker at two different times will be within 5% to 10% of each other. The error here is due primarily to: (1) subjective differences in interpreting actual site locations; (2) the virtual impossibility of completely scouring every side of every rock to ensure that the five truly largest thalli are found; and (3) small errors associated with measuring diameters of thalli only roughly circular. Younger dates imply smaller thalli which are more subject to potential variation;

as dates get older and thalli larger, the potential errors, while in the same absolute range, grow less significant. Thus, keeping in mind the results of Innes (1983) and others (Lock et al. 1979), we assign a semiquantitative error of ±50 years for the first 500 years, an error of ±75 years for the next 500 years, and an additional error of ±100 years for each subsequent 1,000-year block.

Lichen growth rates are known to vary as a consequence of rock type (Benedict 1967; Curry 1969) and since rocks of vastly contrasting mineralogy are featured within and among individual boulder fields in the White Mountains, lichen growth was measured on different rock types at several locations to determine the magnitude of this effect. Lichen substrates at seven of the ten sites are either granitic or metasedimentary boulders that, when compared in the same localities, exhibit thalli the mean diameters of which are statistically indistinguishable at confidence intervals greater than or equal to 90%. To assure the greatest possible uniformity between the data obtained from these sites, measurements were obtained from granodiorite boulders whenever possible. Lichen substrates at the three remaining sites are predominantly dolomite, which was observed to sustain substantially fewer examples of *R. alpicola* and smaller thalli in both *R. alpicola* and *R. bolandari* than metasedimentary boulders in the same fields. Multiplying the diameters of the largest thalli growing on dolomite boulders by 1.5 is sufficient to correct the latter.

Procedure

At each of the ten sites every cultural surface feature, prehistoric and historic, dwelling or not, was examined and the diameters of the ten largest thalli of both *R. alpicola* and *R. bolandari* were measured (provided this many of each could be found). The mean of the five largest of each species was computed separately for each and the corresponding age for the larger of the two means was determined from the White Mountain lichen growth curve (cf. Innes 1984; Lock et al. 1979). Adding to this the estimated lapse of 50 years required for thalli colonization following disturbance gives the lichen date for the substrate (feature). Dates computed by this method are naturally younger than those obtained using the method of Curry (1968) and Benedict (1967), which employ maximum (rather than mean) thalli diameter. Specifically, when computed in the manner discussed above for the ten White Mountain sites under study, mean thalli diameter averages about 88% of maximum thalli diameter (Table 5). This agrees reasonably well with Innes (1984) who, on the basis of much larger samples, reported mean thalli diameter averaged between 90% and 92% of maximum thalli diameter. Our interpolation of the Benedict and Curry curves includes sufficient errors of approximation to outweigh differences of this order and so ignores the small, systematic discrepancy between the results obtained by our method and theirs.

Table 5
MEAN THALLI DIAMETER AS A PERCENTAGE OF MAXIMUM THALLI DIAMETER

Site	Value*
Crooked Forks	81.3%
Enfield	94.4%
Raven Camp	80.3%
Corral Camp South	88.1%
Corral Camp North	83.0%
Midway	88.3%
Shooting Star	89.8%
Rancho Deluxe	87.3%
Pressure Drop	86.5%
Site 12640	88.8%

*Values computed as:
mean diameter/maximum diameter x 100.

No attempt was made to date features with fewer than three thalli and the dates for those with fewer than six are regarded (and noted as being) tentative. Thalli less than 75% of the diameter of the next largest example on the same substrate were discounted as later colonists. Conversely, thalli more than 125% of the diameter of the next largest example on the same substrate were interpreted as survivors predating construction and thus discounted when dating the features on which they occurred. These were present in only 12% of the structures examined and never with more than one example (cf. Table 7). Bedrock milling features were excluded from the study because their smooth substrates resist lichen colonization and are more prone to removal of established thalli.

Lichen thalli growing on boulder fields adjacent to each site were also measured to establish the most recent period of local periglacial activity severe enough to remove extant lichen growth. This effectively dictates the oldest dates potentially obtainable by lichen dating at each site since, along with those growing in the boulder fields, lichens growing on existing cultural features would have been removed at these times. In each case, the lichen dates indicated for these boulder fields are considerably older than lichen dates indicated for adjacent cultural features. Conversely, lichen dates indicated for historic structures are with few exceptions younger than those indicated for aboriginal structures at the same site.

Results

Reported in Table 6 are average maximum thalli diameters and corresponding substrate dates for a total of 50 aboriginal features presumed to be dwellings, ten aboriginal features of other kinds, eight Euroamerican features, and the surrounding boulder fields for all ten White Mountain alpine villages. Features for which no reliable data could be obtained are listed as ND (no data). Where they differ, thalli measurements and dates for exterior and interior wall surfaces of the same structure are given separately. In all such cases where this difference is greater than 75 years, the lichens growing on exterior walls are older than those growing on interior walls. More complete data are presented in Table 7, which includes all individual readings used to calculate the means for both lichen species (where available), whether or not the species was used to date that substrate, and all anomalously large readings presumed to represent pre-construction lichens.

For reasons explained more fully below, exterior-wall dates are taken as dates of construction. Interior-wall dates, where they are significantly different from exterior-wall dates, are thought to represent the latest point at which a structure was occupied more than about five summers in succession. Figure 1 depicts the chronology of dwelling construction in 100-year increments for each site individually and all ten sites collectively over the 1,300-year interval during which construction is indicated by lichenometry.

A variety of circumstances, including the tentative quality of the White Mountain lichen growth curve, makes it unwise to assume great precision for these dates. At face value, however, they fix the greatest concentration of house construction at the White Mountain alpine villages between 800 and 300 years ago, or roughly between A.D. 1185 and A.D. 1685. At the extremes, the earliest structure (Structure 5 at Midway) is about 1,325 years old, while the youngest (Structure 1 at Shooting Star) is perhaps only 75 years old.

Among the ten villages, Midway, with its oldest structure dating to A.D. 660, appears to have been the first occupied and is the only site at which all structures date prior to A.D. 1285. At three other sites, Site 12640, Corral Camp South, and Crooked Forks, house construction had begun by A.D. 1210. Construction continued until at least A.D. 1535 at both Site 12640 and Corral Camp South but ceased by A.D. 1335 at Crooked Forks, where only three dwellings were ever built. Pressure Drop, Rancho Deluxe, Corral Camp

Table 6

LICHEN DATES FOR ALPINE VILLAGES IN THE WHITE MOUNTAINS

Site/Feature	Type	Mean Lichen Diameter (mm.)		Approximate Substrate Date[1]
Crooked Forks				
Structure 1	Dwelling			
	Interior	34.6		A.D. 1285
	Exterior	33.0		A.D. 1310
Structure 2	Dwelling	33.0		A.D. 1335
Structure 3	Dwelling	38.0		A.D. 1210
Boulder Field	Natural	69.0		A.D. 35
Enfield[2]				
Structure 1	Dwelling	17.6		A.D. 1660
Structure 2	Dwelling	12.6		A.D. 1760
Structure 3	Dwelling (?)	18.8		A.D. 1660
Cabin	Euroamerican	ND		–
Fireplace	Euroamerican	ND		–
Fireplace	Euroamerican	ND		–
Boulder Field	Natural	ND		–
Raven Camp[3]				
Structure 2	Dwelling	22.0	(33.0)	A.D. 1335
Structure 3	Unknown	ND		–
Structure 4	Unknown	ND		–
Boulder Field	Natural	39.6	(59.0)	A.D. 435
Corral Camp South[3]				
Structure 1	Dwelling (?)	18.2	(27.0)	A.D. 1460
Structure 2	Dwelling			
	Interior	6.8	(10.0)	A.D. 1860
	Exterior	21.8	(33.0)	A.D. 1335
Structure 3	Dwelling	27.6	(41.0)	A.D. 1110
Structure 4	Dwelling	29.4	(44.0)	A.D. 1010
Structure 5	Dwelling	19.8	(30.0)	A.D. 1385
Structure 6	Dwelling			
	Interior	14.8	(22.0)	A.D. 1585
	Exterior	21.4	(32.0)	A.D. 1335
Structure 7	Dwelling (?)	17.6	(26.0)	A.D. 1485
Structure 8	Dwelling			
	Interior	16.0	(24.0)	A.D. 1535
	Exterior	22.8	(34.0)	A.D. 1310
Structure 9	Dwelling	17.0	(26.0)	A.D. 1485
Corral	Euroamerican	5.6	(8.0)	A.D. 1885
Boulder Field	Natural	66.4	(100.0)	815 B.C.
Corral Camp North[3]				
Structure 1	Dwelling	19.8	(30.0)	A.D. 1385
Structure 2	Dwelling	11.2	(17.0)	A.D. 1685
Structure 3	Dwelling	10.0	(15.0)	A.D. 1735
Structure 4	Dwelling	19.6	(29.0)	A.D. 1410
Boulder Slope	Natural	35.0	(53.0)	A.D. 660
Boulder Field	Natural	42.6	(64.0)	A.D. 235
Midway				
Structure 1	Dwelling			
	Interior	26.0 (?)		A.D. 1485 (?)
	Exterior	38.0		A.D. 1210
Structure 2	Dwelling			
	Interior	23.0		A.D. 1560
	Exterior	35.2		A.D. 1285
Structure 3	Dwelling			
	Interior	36.4		A.D. 1260
	Exterior	32.8		A.D. 1335

Table 6 (cont.)

Site/Feature	Type	Mean Lichen Diameter (mm.)	Approximate Substrate Date
Structure 4	Dwelling		
	Interior	33.2 (?)	A.D. 1335 (?)
	Exterior	38.4	A.D. 1210
Structure 5	Dwelling		
	Interior	23.2	A.D. 1560
	Exterior	52.4	A.D. 660
Structure 6	Dwelling		
	Interior	28.6	A.D. 1410
	Exterior	39.0	A.D. 1185
Structure 7	Dwelling	ND	–
Structure 8	Dwelling	37.8	A.D. 1210
Structure 9	Dwelling	35.2	A.D. 1285
Structure 10	Dwelling	ND	–
Boulder Field	Natural	93.6	615 B.C.
Shooting Star			
Structure 1	Dwelling	5.0	A.D. 1910
Structure 2	Dwelling	ND	–
Structure 3	Unknown	23.8	A.D. 1535
Rock Wall	Aboriginal	16.8	A.D. 1685
Boulder Field	Natural	67.0	A.D. 110
Rancho Deluxe			
Structure 1	Dwelling	18.0 (?)	A.D. 1660 (?)
Structure 2	Dwelling	33.6	A.D. 1310
Structure 3	Dwelling	27.5	A.D. 1435
Structure 4	Storage (?)	18.5	A.D. 1660
Structure 5	Dwelling	27.8	A.D. 1435
Structure 6	Storage (?)	28.2	A.D. 1435
Structure 7	Dwelling	23.0	A.D. 1560
Structure 8	Dwelling	30.6	A.D. 1360
Structure 9	Dwelling	ND	–
Structure 10	Cairn	ND	–
Structure 11	Wall	ND	–
Structure 12	Euroamerican Cabin	6.0	A.D. 1900
Boulder Field	Natural	50.4	A.D. 760
Pressure Drop			
Structure 1	Dwelling		
	Interior	11.6	A.D. 1785
	Exterior	20.0	A.D. 1635
Structure 2	Dwelling		
	Interior	11.2	A.D. 1810
	Exterior	17.4	A.D. 1685
Structure 3	Dwelling	22.6	A.D. 1560
Rock Pile	Aboriginal (?)	14.0	A.D. 1760
Cabin	Euroamerican	8.0	A.D. 1875
Rock Wall	Euroamerican (?)	ND	–
Boulder Field	Natural	60.4	A.D. 385
Site 12640			
Structure 1	Dwelling		
	Interior	8.5	A.D. 1875
	Exterior	24.0	A.D. 1535
Structure 2	Dwelling		
	Interior	10.6	A.D. 1810
	Exterior	22.3	A.D. 1585
Structure 3	Dwelling		
	Interior	10.8	A.D. 1810
	Exterior	34.3	A.D. 1310

Table 6 (cont.)

Site/Feature	Type	Mean Lichen Diameter (mm.)	Approximate Substrate Date
Structure 4	Dwelling		
	Interior	23.4	A.D. 1560
	Exterior	36.6	A.D. 1235
Structure 5	Dwelling	40.0	A.D. 1160
Structure 6	Dwelling	35.0	A.D. 1285
Structure 7	Dwelling	31.3	A.D. 1360
Structure 8	Dwelling	38.0	A.D. 1210
Rock Wall	Aboriginal	32.5	A.D. 1335
Cabin	Euroamerican	5.3	A.D. 1910
Boulder Field	Natural	61.8	A.D. 310

Note:
The term "dwelling" refers to circular and semi-circular rock features presumed to have been used as roofed living spaces; "ND" indicates no reliable data.

[1] Dates calculated from mean lichen diameters rounded to nearest millimeter. Estimates of error are:

A.D. 1985	-	A.D. 1485	: +/- 50 years
A.D. 1484	-	A.D. 985	: +/- 75 years
A.D. 984	-	15 B.C.	: +/- 100 years
16 B.C.	-	1015 B.C.	: +/- 200 years

[2] Enfield is heavily overgrown with brush and its lichen dates are considered unreliable.

[3] Dolomite substrates for which the lichen dates have been corrected by multiplying the mean maximum lichen diameter by 1.5, the rounded result of which is shown in parentheses.

Table 7
INDIVIDUAL LICHEN MEASUREMENTS[1] BY SITE, FEATURE, AND LICHEN SPECIES

Site/Feature/Substrate		Five Largest Thalli (mm.)					Mean (mm.)	Anomalies (mm.)
Crooked Forks								
Structure 1								
Interior	B	32	29	22	20		25.8	
	A*	41	35	34	32	31	34.6	55 mm.
Exterior	B	38	30	30	24		30.5	
	A*	41	32	31	30		33.5	
Structure 2	B	40	30	30	30	28	31.6	
	A*	39	35	31	30	30	33.0	
Structure 3	B*	42	41	37	35	35	38.0	
	A	36	35	33	32	31	33.4	
Boulder Field	B*	71	70	70	69	65	69.0	
	A	65	60	60	60		61.3	
Enfield								
Structure 1	A*	20	18	18	16	16	17.6	
Structure 2	A*	14	13	12	12	12	12.6	
Structure 3	B	20	20	19	18	17	18.8	
	A*	22	20	18	17	17	18.8	
Raven Camp								
Structure 2	B*	28	21	21	20	20	22.0	
Boulder Field	B*	41	40	40	39	38	39.6	
Corral Camp South								
Structure 1	B*	19	18	18	18	18	18.2	
Structure 2								
Interior	B*	8	8	6	6	6	6.8	
Exterior	B*	24	23	22	18		21.8	
Structure 3	B	22	22	22	20	20	21.2	
	A*	32	31	30	24	21	27.6	

Table 7 (cont.)

Site/Feature/Substrate		Five Largest Thalli (mm.)					Mean (mm.)	Anomalies (mm.)
Structure 4	B	23	21	21	21	20	21.2	39 mm.
	A*	34	34	30	26	23	29.4	
Structure 5	B*	24	20	19	18	18	19.8	
	A	18	17	16	16		16.8	30 mm.
Structure 6								
Interior	B*	18	16	14	14	12	14.8	
Exterior	B*	24	23	22	20	18	21.4	
Structure 7	B*	20	18	18	16	16	17.6	
Structure 8								
Interior	B*	18	18	16	12		16.0	25 mm.
Exterior	B*	26	24	22	22	20	22.8	
Structure 9	B*	20	18	16	14		17.0	
Corral	B*	8	6	6	4	4	5.6	
Boulder Field	B*	72	68	65	65	62	66.4	
	A	72	68	62	58	50	62.0	
Corral Camp North								
Structure 1	B*	25	20	19	18	17	19.8	
Structure 2	B*	14	12	11	11	8	11.2	
Structure 3	B*	13	11	10	8	8	10.0	
Structure 4	B*	21	21	20	19	17	19.6	
Boulder Slope	B*	37	37	36	33	32	35.0	
Boulder Field	B*	45	43	42	42	41	42.6	
Midway								
Structure 1								
Interior	A*	30	25	25	25	25	26.0	
Exterior	B*	45	40	40	35	30	38.0	
	A	35	35	25	25		30.0	
Structure 2								
Interior	B	20	17	16	16	15	16.8	
	A*	27	24	24	20	20	23.0	
Exterior	B	31	30	27	23	20	26.2	
	A*	36	36	35	35	34	35.2	
Structure 3								
Interior	B	35	34	31	31	30	32.2	
	A*	40	38	35	35	34	36.4	
Exterior	B*	35	35	34	30	30	32.8	
	A	37	32	31	30	29	31.8	
Structure 4								
Interior	B	30	29	28	28	23	27.6	
	A*	36	35	33	32	30	33.2	
Exterior	B	36	35	35	32	31	33.8	
	A*	40	40	39	37	36	38.4	
Structure 5								
Interior	B	13	12	11	10	8	10.8	24 mm.
	A*	28	24	24	24	16	23.2	
Exterior	B*	65	52	50	50	45	52.4	
	A	39	39	38	34	33	36.6	
Structure 6								
Interior	B	34	28	26	25	24	27.4	
	A*	31	30	29	27	26	28.6	
Exterior	B*	40	40	39	38	38	39.0	
	A	27	25	25	24	20	24.2	
Structure 8	B	40	38	36	35	33	36.4	
	A*	45	40	38	35	31	37.8	
Structure 9	B*	38	35	35	34	34	35.2	
	A	30	30	30	29	28	29.4	
Boulder Field	B*	105	98	95	90	80	93.6	
	A	88	78	75	72	72	77.0	

Table 7 (cont.)

Site/Feature/Substrate		Five Largest Thalli (mm.)					Mean (mm.)	Anomalies (mm.)
Shooting Star								
Structure 1	B*	6	5	5	5	4	5.0	
Structure 3	B	22	22	21	20	20	21.0	
	A*	31	28	20	20	20	23.8	
Rock Wall	B	15	14	12	12	10	12.6	
	A*	18	18	16	15		16.8	
Boulder Field	B*	70	68	65	65		67.0	
	A	52	50	50	49	48	49.8	
Rancho Deluxe								
Structure 1	B*	22	18	17	15		18.0	
Structure 2	B	30	29	27	25	24	27.0	
	A*	38	35	33	32	30	33.6	
Structure 3	A*	28	28	27	27		27.5	
Structure 4	A*	20	18	18	18		18.5	45 mm.
Structure 5	B	28	24	21	20	20	22.6	
	A*	31	30	28	27	23	27.8	
Structure 6	A*	31	30	30	25	25	28.2	
Structure 7	B*	25	25	23	21	21	23.0	
Structure 8	B	25	22	21	20	20	21.6	
	A*	34	31	30	29	29	30.6	
Structure 12	B*	8	7	5	4		6.0	
	A	6	5	3	3		4.3	
Boulder Field	B	50	50	48	48	45	48.2	
	A*	57	52	50	48	45	50.4	
Pressure Drop								
Structure 1								
Interior	B*	16	12	10	10	10	11.6	
Exterior	B	16	14	13	13	12	13.6	
	A*	20	20	20	20		20.0	
Structure 2								
Interior	A*	13	12	12	10	9	11.2	
Exterior	B*	20	18	17	16	16	17.4	
Structure 3	B*	26	24	22	21	20	22.6	
	A	25	22	22	19	18	21.2	
Rock Pile	B	18	16	12	11	10	13.4	
	A*	16	16	12	12		14.0	
Cabin	B*	9	8	8	7		8.0	15 mm.
Boulder Field	B	60	54	52	52	52	54.0	
	A*	70	68	60	54	50	60.4	
Site 12640								
Structure 1								
Interior	B*	10	10	8	6		8.5	
Exterior	A*	30	24	22	20		24.0	
Structure 2								
Interior	B*	11	11	11	10	10	10.6	
Exterior	B*	28	25	20	20		22.3	
Structure 3								
Interior	B*	15	11	10	10	8	10.8	
Exterior	B	35	32	31	28	27	30.6	
	A*	40	35	34	28		34.3	
Structure 4								
Interior	B	23	23	22	21	20	21.8	40 mm.
	A*	28	25	22	21	21	23.4	
Exterior	B*	46	38	34	33	32	36.6	
	A	40	37	35	34	34	36.0	
Structure 5	B*	42	41	40	39	38	40.0	
	A	37	32	31	30	29	31.8	

Table 7 (cont.)

Site/Feature/Substrate		Five Largest Thalli (mm.)					Mean (mm.)	Anomalies (mm.)
Structure 6	B	38	37	35	32	31	34.6	
	A*	38	38	36	32	31	35.0	
Structure 7	B	32	30	30	30	28	30.0	
	A*	37	32	28	28		31.3	
Structure 8	B	39	38	33	32	32	34.8	
	A	41	40	40	37	32	38.0	
Rock Wall	B	35	33	32	30	28	31.6	
	A*	33	33	32	32		32.5	
Cabin	B*	6	6	5	4		5.3	
Boulder Field	B*	66	65	60	60	58	61.8	
	A	64	58	58	55	52	57.4	

[1] All measurements on grandiorite for Crooked Forks, Midway, Rancho Deluxe, Pressure Drop, and Site 12640, on metasedimentary rock for Enfield and Shooting Star, and on dolomite for Raven Camp, Corral Camp South and Corral Camp North.

Notes:

Asterisk (*) denotes species used for substrate lichen date.

A = *Rhizocarpon alpicola*

B = *Rhizocarpon bolandari*

North, and Enfield are somewhat more recent, all of their houses having been built between A.D. 1310 and A.D. 1760. The dates for Enfield are probably too young, however, since brush growth has disturbed the lichens there. A single dwelling at Raven Camp dates to about A.D. 1335. The only dwelling that could be dated at Shooting Star seems to have been built around A.D. 1910 which, though very recent, is compatible with a glass bead found on the surface of that site; another structure of undetermined function there, however, hints at the possibility of residential use as early as A.D. 1535.

DISCUSSION

There are currently very few sources of chronological data against which the lichen dates presented here can be checked. We have already noted that time-sensitive artifacts recovered from structures and midden deposits at these villages place them between A.D. 600 and historic times, which is in keeping with the chronology suggested by lichenometry.

Tephra recognized in the deposits of five of the villages is potentially another source of independent chronological evidence. As suggested above, this is probably one of two recent Mono Craters tephras, the first of which resulted from an eruption about A.D. 760, the second from an event about A.D. 1310 (Sieh, Wood, and Stine 1983; Wood 1977a, 1977b). The date of the older tephra, should it prove to be the one in question, would suggest that the dates obtained through lichenometry are too young, though not grossly in error. This more ancient tephra, however, is seldom coarser than 1.0 mm. more than 10 km. from its vent (Wood 1977a), while the White Mountain tephra, some 70 km. from that vent, is regularly coarser than that and contains lapilli up to 5.0 mm. in diameter.

This favors identification of the White Mountain tephra as the younger of the two most recent Mono Craters tephras, the date of which (A.D. 1310) fits neatly within the range of lichen dates obtained for these villages. The match is particularly close for those sites where excavation has been sufficient to disclose the general stratigraphic position of this tephra within the cultural deposit. At Pressure Drop, for which the oldest lichen date is A.D. 1560, the tephra occurs immediately below the very base of

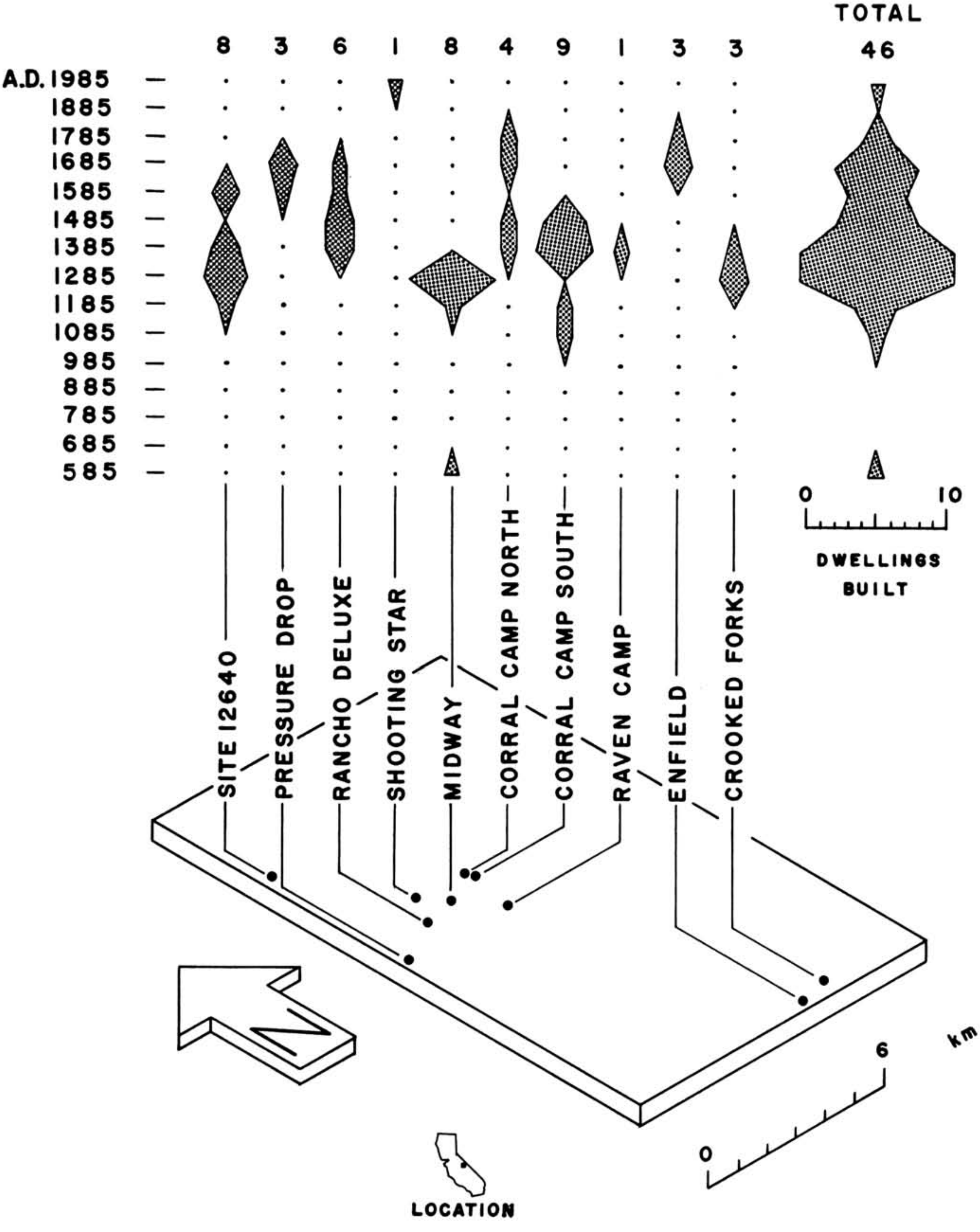

Fig. 1. Distribution of lichen dates for the construction of dwellings in White Mountain alpine villages.

the cultural deposit, while at Midway, where the oldest lichen date is A.D. 660, it occurs near the top of the cultural deposit; and at Corral Camp South, where the earliest date is A.D. 1010, the tephra appears toward the base of the cultural deposit, but clearly above its very bottom.

This does not assure the accuracy of the lichen dates. The stratigraphy of these alpine villages is not yet fully understood. Moreover, should the White Mountain tephra turn out to be the A.D. 760, rather than the A.D. 1310, Mono Craters ash and should our lichen dates turn out to be consistently about 600 years too young, exactly the same stratigraphic relationships between tephra and cultural deposit would hold. Even so, the correspondence between the lichen dates and the stratigraphic position of the tephra at different sites strongly suggests that our lichen chronology faithfully reflects the relative temporal ordering among alpine villages and therefore probably among individual features within those villages.

Granting that time-sensitive artifacts and buried tephra layers tend to indicate that the lichen chronology for the White Mountain villages is very likely correct in terms of relative sequence and may well be approximately correct as a time-scale measured in years, it will remain tentative until more is understood about the development of lichen growths on cultural features.

As already noted, the exact cause of lichen mortality in aboriginal structures of these alpine villages remains unclear. We ventured earlier that shading under walls and roofs or exposure to heat or smoke might be responsible. However, lichens established between 650 and 550 years ago on structures known to have been occupied in late prehistoric or early historic times (e.g., Structure 2 at Crooked Forks and Structure 3 at Rancho Deluxe) clearly show that thalli were able to colonize and continue to grow on structures that were occupied. At the same time, the many structures in which exterior thalli are significantly older than interior thalli indicate that lichens were more often successful in colonizing and maintaining growth on the exterior wall surface of a structure than they were in doing so on the interior wall surface of that same feature. This suggests that while extreme heat, smoke, and darkness within enclosed living spaces were sometimes sufficient to inhibit lichen colonization and growth, they lacked effect in unenclosed areas. It would seem then, that the White Mountain lichens are extremely sensitive to disturbances of the kind that accompanied house construction and somewhat less sensitive to disturbances associated with the use of these features as living areas.

We conclude from this that when stones were moved in the construction of foundations, the combined effects of reorientation, instability of the foundation until the newly placed stones settled, and, perhaps, dirt packing and covering placed over walls for added support, were enough to destroy virtually all extant thalli. Reorientation seems particularly deleterious to White Mountain lichens since it is exceedingly rare to find thalli large enough to be pre-construction survivors on historic shepherd huts, cabins, and corrals, which were neither unstable nor, insofar as we can tell, earth-covered. Summer aridity in the White Mountains, which receive only about 9 cm. of precipitation between June and August (Pace et al. 1971), may cause lichens there to be especially sensitive to reorientation. Whatever the explanation, that none of the lichen dates obtained for any of the cultural features examined approaches those for adjacent boulder fields which furnished the stone for their foundations makes us reasonably certain that few White Mountain lichens survive when a structure is built.

Shortly after construction, wall stabilization and partial erosion of any dirt covering present probably permitted colonization by new thalli not subject to extreme shading, heat, or smoke for several years in succession. Since these conditions do not characterize structure exteriors, lichens found there probably denote periods of construction.

Lichen colonization and growth might also have proceeded normally *inside* dwellings not regularly reoccupied, summer after summer, for an extended period. For these thalli, it is conceivable that the only lasting effect of a single season of occupation would be lost growth (we discount the possibility that brush and bough coverings left in place over abandoned dwellings would shade lichens for a sufficient period to kill them: unattended, it is unlikely these roofs would last even a single winter). We gather from this that it must be the cumulative effects of repeated occupation that sometimes discouraged lichen growth on interior walls, causing the lichen dates for these substrates to be younger than those for substrates on the exterior of the same structure.

It is unlikely that growth lost during seasons of occupation alone would be significant enough to account for the smaller size of interior thalli in these cases. More probably these discrepancies are attributable to unbroken strings of seasonal occupation that prevented lichen colonization in newly built structures or that eventually killed lichen growth within structures reoccupied after a period of disuse. If not in contact with moist soil, lichens can survive at least five years when deprived of direct sunlight (Benedict 1967: 821), a condition roughly akin to that experienced by thalli living inside a house occupied during their growing season. More study is clearly needed here but we can tentatively propose that consecutive seasonal occupations of a dwelling over a similar interval would be needed to erase existing lichen growths on its interior.

If this is so, then the lichen date for a structure interior corresponds either to its date of construction or to the last time it was occupied for something more than about five summers running. It would seem to follow that structures for which the interior and exterior lichen dates are essentially the same were never occupied with such frequency, while those for which these dates are significantly different must have been so at least once.

If correct, this line of reasoning would carry several interesting implications. In particular, it would suggest that structures with discordant exterior and interior dates might indicate the degree to which an individual site was reoccupied from year to year and the period within which this occurred. It is interesting to note in this regard that of the four sites (Midway, Site 12640, Corral Camp South, and Pressure Drop) where there were structures with different interior and exterior dates, three (Midway, Site 12640, and Corral Camp South) are among the largest alpine villages in the White Mountains. This is in accord with expectation provided we assume that large villages would tend to occur in optimal settings and be more likely to be reoccupied from year to year than smaller villages.

From these data it might also be argued that Midway was most regularly occupied between about A.D. 1185 and A.D. 1560 and less regularly thereafter. This is meant in the sense that the occupational spans (i.e., the span between the exterior and interior date of the same structure) of its most intensively used dwellings (i.e., those with significantly younger interior lichen dates) are concentrated in this interval, the spans of at least two falling at every point within it. By similar measure, Pressure Drop would seem to have been most regularly occupied between about A.D. 1685 and A.D. 1785, evidently by smaller groups than those at Midway. And in the same sense, Corral Camp South appears to have been most regularly occupied between about A.D. 1335 and A.D. 1585 and Site 12640 between about A.D. 1310 and A.D. 1810, both of them by groups that were apparently larger than used Pressure Drop but smaller than used Midway.

Unfortunately, the lichenometric data gathered in the course of our study are insufficient to sustain inferences as detailed as those above. The problem in doing so lies not in the precision of the technique but in the practical difficulty of defining the boundary between interior and exterior structure surfaces in the field, especially given the possibility of recent disturbance by grazing animals, and in obtaining the requisite sample of thalli measurements from the smaller number of substrate surfaces that are defined when a structure is subdivided. We are confident that where we were able to find significant differences in the dates suggested by thalli growing on the interior and exterior wall surfaces of the same structure these reflect intervals of intensive occupation along the lines noted above. We are not, on the other hand, equally confident that, where no clear temporal difference between the interior and exterior could be found, this signifies lack of intensive occupation. Accordingly, we cannot make assessments of the relative intensity of use between sites or between structures, such as those set forth immediately above.

CONCLUSIONS

If our preliminary inferences as to the nature of alpine village occupation are correct at least in a general way and if we are correct in presuming that the pattern of alpine land use reflected by these villages was preceeded by one characterized by short forays for the procurement of large vertebrates, then the lichen dates reported here are fully in accord with the model of Numic expansion set forth by Bettinger and Baumhoff (1982). Uncertainties about the White Mountain lichen-growth-rate curve and about the means by which old lichens are eliminated as a consequence of house construction and by which new thalli become established following construction and the degree to which thalli within a structure suffer from its occupation, however, all require that these dates be regarded with caution and as a preliminary, rather than final, chronology of alpine village occupation.

In broader perspective, the results of the White Mountain research suggest that lichenometry is potentially applicable to a wide variety of archaeological problems, both prehistoric and historic, in areas of higher elevation throughout California and the Great Basin. Curry (1968) and Scudari (1983) found the technique useful between 2,500 and 4,000 m. in the Sierra Nevada, which is probably the elevational range most suited to this approach. Pendleton and Thomas (1983), Thomas (1982), Delacorte (1985), and others have noted the difficulty of dating free-standing rock structures of various kinds that are regularly encountered within the Great Basin. Lichen dating offers one practical means by which this might be accomplished.

ACKNOWLEDGEMENTS

The lichenometric and archaeological research reported in this study was supported by National Science Foundation Grant BNS-8506972, by several University of California, Davis, Faculty Research Grants, and by a University of California White Mountain Research Station Student Research Grant. Paul Bouey, University of California, Davis, conducted X-ray fluorescence studies on volcanic ash from the Rancho Deluxe site. Doug Powell, Deep Springs College, provided data on historic land use in the White Mountains. Detailed comments and suggestions by James B. Benedict were especially helpful in revising the manuscript and we extend our thanks to him. We gratefully acknowledge, further, the expert editorial comments of Philip J. Wilke and the equally expert scientific advice of Debbie Elliot-Fisk.

NOTE

1. The ten sites discussed in this article are assigned trinomial designations in the California Archaeological Inventory as shown below. The site records are housed at the Eastern Information Center, Archaeological Research Unit, University of California, Riverside.

Site Name	**Trinomial**
Crooked Forks	CA-MNO-2191
Enfield	CA-MNO-2192
Raven Camp	CA-MNO-2193
Corral Camp South	CA-MNO-2194
Corral Camp North	CA-MNO-2195
Midway	CA-MNO-2196
Shooting Star	CA-MNO-2197
Rancho Deluxe	CA-MNO-2198
Pressure Drop	CA-MNO-2199
Site 12640	CA-MNO-2200

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