HOLOCENE PERIGLACIAL ACTIVITY IN THE SAN JUAN MOUNTAINS NEAR CREEDE, COLORADO

ERIC P. JENSEN
CARLETON COLLEGE
DEPARTMENT OF GEOLOGY
NORTHFIELD, MN 55057

SITE CHARACTERIZATION:

Fisher Mountain is located twelve miles south of Creede, Colorado at 106° 56' W, 37° 40' N (see fig. 2). The mountain reaches a maximum elevation of 3921 m, and serves as the type locality for the Fisher Quartz Latite. This unit is comprised of a coarsely porphyritic ash flow tuff which was extruded 25.4 Ma in conjunction with the resurgence of the Creede Caldera during the late Tertiary (Steven and Lipman, 1973). Subsequent ice ages have carved several cirques and glacial valleys which are currently littered with Quaternary age glacial deposits. The north facing cirque, in particular, has a number of curious features composed of rock debris, which appear to be periglacial in origin. Several of these features have morphologies which suggest that they are rock glacier remnants. According to White (1979), all such rock glacier deposits in the San Juan mountains date to Late Pinedale (the period used to describe the onset of the late Wisconsin deglaciation). However, Carrara and Andrews (1973) and Morris (1987) have found evidence which indicates rock glaciers were also formed during the Neoglacial period of the late Holocene.

PURPOSE OF PROJECT:

The purpose of this project is to describe the morphologies of several of the features found in this cirque, and attempt to establish their approximate ages of formation. Using these dates, I have reconstructed the post-Pinedale climatic history of the north facing cirque on Fisher Mountain. Dating techniques utilized for this project include lichenometry and the following relative dating techniques: weathering rind thicknesses, degree of boulder angularity, overall lichen cover percentage and percentage of fresh material.

CHARACTERIZATION OF THE PERIGLACIAL FEATURES:

For this study, I examined the 10 largest and most obvious periglacial features in the cirque. For each feature I constructed a cross sectional profile, recorded material sizes and distributions, measured the length and width, and took general notes. White (1981), Madole (1972) and Benedict (1970) provide excellent descriptions of the local alpine periglacial facies, and these papers served as the basis for classifying these features. Of the 10 features, I have identified six as being rock glacier remnants, one as a protalus rampart, one as a rockfall talus cone and another as either a rock glacier remnant or solifluction lobe capped by a layer of rock debris. The remaining feature turned out to be a mudflow/debris deposit which was not periglacial in origin. However, this feature was very useful in that it provided a radiocarbon date which corresponded to a 29 mm maximum diameter of the lichen species *Rhizocarpon geographicum* found throughout the deposit. This helped me construct a calibration curve for lichenometry (to be discussed later). The remnant rock glaciers were further classified as lobate rock glaciers, tongue shaped rock glaciers or spatulate rock glaciers as defined by Wahrhaftig and Cox (1959).

THE USE OF LICHENOMETRY:

For lichenometry, a calibration curve was generated by utilizing data collected from the cirque itself and from data collected by other authors such as Carrara and Andrews (1973), Benedict (1967) and Andrews and Webber (1974) (see fig. 1). The lichen growth rate observed in the cirque is obviously slower than those recorded at other localities, due to the topoclimatic conditions and rock type present in the Fisher Mountain cirque (volcanic tuffs are notorious for their slow lichen growth rates according to Carrara and Andrews, 1973). The upper limit of the calibration curve was determined on the basis of the thallus diameters found on Late Pinedale moraines and till, while the lower range of the graph was constructed by using lichen growth rates observed on the tombstones in the Creede Cemetery. The break in the slope of the graph occurs at about 250 BP. This date corresponds to the period of colder climate known as the "little ice age" (or "Gannett Peak" event) which lasted from 350 BP to 150 BP. A talus deposit in the valley which appeared to have been covered by a Gannett Peak firn field had a maximum *Rh. geographicum* diameter of 29 mm. The 29 mm diameter was assumed to have an age of about 250 years, and serves as the point which defines the break in slope. This assumption will be subject to revision upon receiving the radiocarbon date. However, due to the fact that such a revision could only alter the calibration curve by several hundred years at most, it is likely to have little effect on the dates assigned to the features.

In constructing this curve, I have assumed that deglaciation of the cirque occurred at approximately 9,000 BP in accordance with Maher (1961), Andrews, *et al.* (1975) and White (1979). Andrews and Webber (1974) have stated that the *Rh. geographicum* has a lifespan which may exceed 9,000 years and can be used to date surfaces this old. Thus, the diameters of the largest *Rh. geographicum* thalli were assumed to be about 9,000 years old, and therefore late Pinedale in age. This assumption was supported by the results of this study.

Initially, I had planned to use four lichen organisms to conduct the lichenometry analysis: *Rh. geographicum, Leconara thomsonii* (a green foliose lichen), *Leconara sp.* (a green fruticose lichen) *and Parmelia sp.* (a grey crustose lichen). However, due to the inconsistent growth rates of the latter three lichens and lack of available data, all but the *Rh. geographicum* were used strictly as a relative dating technique. Note that two of the lichens were identified only by their genus, as further identification is unnecessary for the purposes of this study.

The *Rh. geographicum* is the most widely used lichen for the purpose of absolute dating. It has a notoriously slow growth rate which remains constant throughout most of its life (with the exclusion of the "great period" which lasts for the first 100-300 years of growth) and is fairly easy to identify due to its fluorescent lime green coloration and characteristic black dots. For each feature, the five largest *Rh. geographicum* thalli were measured and averaged. These averages were then compared to the calibration curve, and approximate dates of formation for the features were determined.

Several of the features exhibited recessional lobes or small deposits located proximal to the main body, which were treated as separate features. These "secondary" deposits may have formed during a later cooling event or could possibly represent a resurgence during the original deposition. Thus, a total of 16 "features" were dated. The results of this analysis are provided by fig. 3. The data points cluster into four distinct age groups, labeled A, B1, B2, C. The data point labeled as P represents the average of the data collected from the Pinedale features in the cirque.

What is particularly striking about the distribution of data points is the fact that the clusters show an excellent correspondence to the well-documented periglacial depositional events of the late Quaternary in Colorado. As summarized by Morris (1987) and Benedict (1967), these events are commonly referred to as 1) early Neoglacial (Temple Lake) 4500-2500 BP 2), middle Neoglacial (Audubon) 1900-1000 BP and 3) Little Ice Age (Gannett Peak) 350-150 BP. Thus, cluster C appears to correspond to the early Neoglacial event, cluster B1 to the Audubon event and cluster A to the Gannett Peak event. Period B2 presents sort of a problem in that it appears to have occurred several hundred years after the close of the early Neoglacial period. However, this deviation may be explained by the fact that lichenometry has an error which can be measured in the hundreds of years for the age range in question. Thus, the data points which comprise cluster B2 appear to belong to the late Temple Lake stade, or possibly the early Audubon (a difference of only 600 years separates these two events according to Miller, (1973)). A resurgence of periglacial activity in the later stages of the early Neoglacial cooling event is suggested by Miller (1973), who referred to such an event as Temple Lake II.

The accuracy of these results may be tested in two ways, by comparing this record to that produced by the relative age data, and by examining the record of talus production in the cirque to see if the periods coincide with periods of greater talus production. Such a record is provided by the extensive talus slope found along the southeastern margin of the cirque.

ANALYSIS OF THE TALUS SLOPE:

The talus slope is approximately 400 m long, 100 m wide and runs NNE - SSW, bordered to the east by the headwall of the cirque. The slope was divided into three regions: top, middle, and bottom. In each region, *Rh. geographicum* diameters and relative age data were collected at intervals of 22.5 m along the entire length of the slope. It is my assumption that periods of accelerated rates of talus production (which will occur as a response to periods of colder climate) would have been "recorded" in the form of consistent age groups found throughout the slope. I had previously noticed that the slope appeared to be "striped", with regions of different darkness. This difference in tonal quality appeared to be a reflection of the amount of lichen cover present in these areas, implying different ages of deposition. Thus, I felt that distinct events of accelerated talus generation would be reflected by the abundance of lichen thalli exhibiting diameters characteristic of that particular age. The frequency of occurrence of these thalli would be indicative of the magnitude of the event. However, it also must be considered that extensive periods of generation during normal climatic conditions would tend to cover these older events.

The lichenometry data collected for the talus slope are presented in fig. 4. Again, the data points plot into four distinct groupings which show excellent correlations not only to that shown by fig. 3, but to the Neoglacial cooling events. The relationships between the lichenometry dates and the previously established Neoglacial climatic chronology is difficult to ignore or explain as sheer coincidence.

However, a possible complication of the lichen data may result from firn field interference. That is, these Neoglacial cooling periods may have created firn fields which covered the features, thus killing the lichen organisms. When the firn field was removed by subsequent warmer temperatures, lichen once again would inhabit the features, but their ages would be indicative of the recession of the firn field, not the age of the talus. Such resetting has apparently occurred at least once in the cirque, where a remnant rock glacier was apparently covered by a Gannett Peak firn field. The resulting diameters of the *Rh. geographicum* were all characteristic of the Gannett

Peak event, and lichen "kill zones" (regions where lichen have been killed, leaving behind stained rings on the rock surfaces) were prevalent throughout the feature. However, the relative age data collected at this feature indicated a depositional age much greater than 250 BP. Thus, the lichenometry data must be compared to the relative age data to ensure that such correlations have not been produced by anomalous lichen data.

RELATIVE AGE DATA:

Five types of relative age data were taken: lichen diameters of all four species of lichen mentioned above, weathering rind thicknesses, boulder angularity, general appearance of each feature, lichen cover percentage and fresh material percentage. The boulder angularity and overall appearance were expressed together as a qualitative grade assessment on a scale of 1 to 5, 5 being given to features which exhibit the characteristics of Pinedale material and 1 begin given to material produced at the present time. Lichen cover percentages included the area of "kill zones", thus removing the interference of firn fields. Finally, calibration curves for the lichen were not applied, but the diameter was assumed to be proportional to age.

In order to express quantitatively the results of the relative age data, I developed a method of evaluating the data statistically. This method accounts for the reliability of the dating mechanisms, and reduces the effects of anomalous data (such as lichen diameters influenced by firn fields). A detailed explanation of this system is inappropriate at this time due the limited space, so only the results will be presented (see fig. 5 and 6). The relative ages of the features are represented along a scale from 1 to 100, 100 being the oldest and 1 being the youngest.

CONCLUSIONS:

Fig. 5 shows the data collected from the periglacial features. Again, the data points are clustered into three distinct groups, A, B and C, which probably correspond to the three separate cooling events. The data point P represents the data collected from the Pinedale features, and shows a substantial separation from the other points. The degree of separation from the Pinedale data supports the conclusion that these events correspond to the three step Neoglacial periglacial chronology of Colorado. Perhaps the most intriguing aspect of this graph is the clustering of the "secondary" deposits into event B, indicating that some of the features created during the C period were reactivated in period B. This evidence supports a similar conclusion reached by Morris (1987).

Figure 6 shows the relative age data collected from the talus slope, and also displays three distinct clusters which apparently correspond to the clusters in figure 5. These groupings are suggestive of periods of higher talus production, as would be expected during such cooling events. That all four graphs should produce such correlations to the Neoglacial climatic history of Colorado is hard to explain by coincidence. Thus, it is my conclusion that the periglacial features used in this study were all created during the "little ice ages" of the late Quaternary.

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Fig. 1

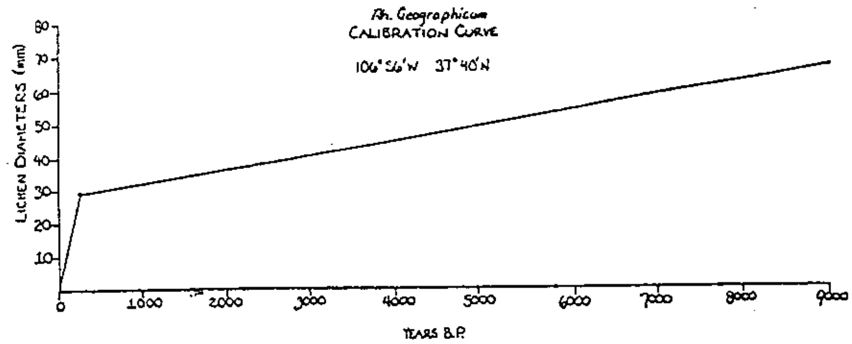

Fig. 2 Location of Fisher Mountain

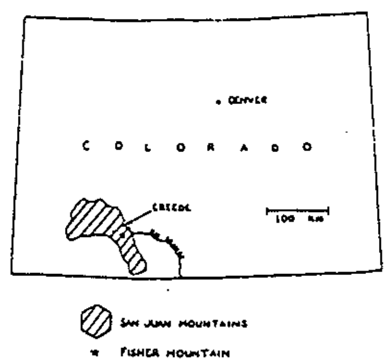

Fig. 3

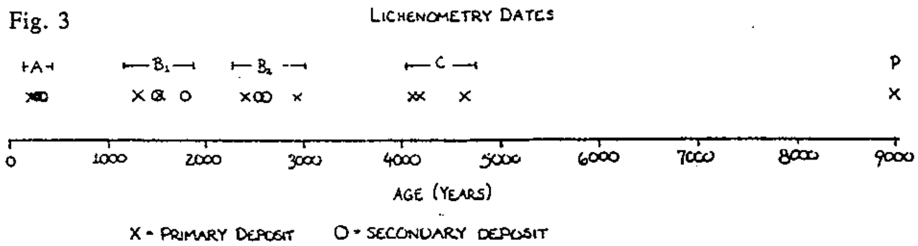

Fig. 4

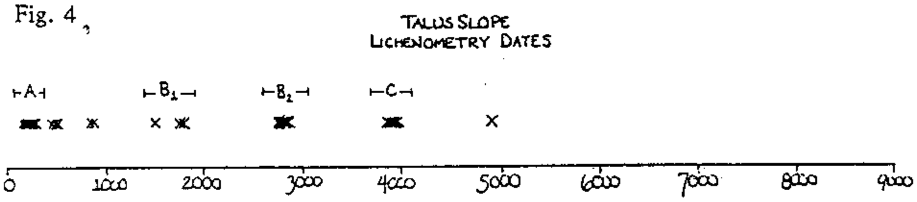

Fig. 5

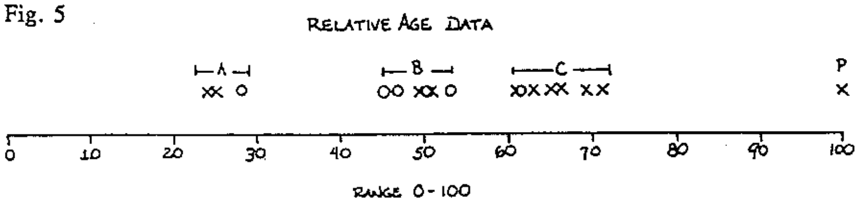

Fig. 6