POSTGLACIAL TIMBERLINE FLUCTUATIONS, LA PLATA MOUNTAINS, SOUTHWESTERN COLORADO

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ABSTRACT

A paleoecological study of the La Plata Mountains was initiated to develop further a dated and continuous environmental sequence for the San Juan River headwaters to which discontinuous archaeological and alluvial data from the Four Corners region might be compared. Routine pollen analysis of a 4-m core from a subalpine meadow adjacent to Twin Lakes, 3290 m (10,790 ft), including 11 radiocarbon dates and pollen ratios, provides the chronology of climatic change as reflected by postglacial timberline fluctuations. The timberline was lower than that of the present about 9800 BP, then advanced upward at least twice to higher elevations prior to 6000 BP. The timberline retreated to lower elevations shortly after 4000 BP; this retreat was followed by another significant advance upward about 2500 BP. Mining, logging, and grazing, which began in the 1870s, may be represented by a sharp decrease in the relative frequencies of Pinus and Picea pollen, with subsequent secondary succession represented by increased Ranunculaceae and Salix pollen and then a return to conifer pollen dominance. These changes may also result from a significant lowering of the timberline within the last few hundred years.

INTRODUCTION

Palynology has been recently utilized in the reconstruction of prehistoric timberline fluctuations in the Colorado Front Range, central Colorado (Maher, 1972), the San Juan Mountains, southwestern Colorado (Maher, 1961; Andrews et al., 1975), and the Chuska Mountains, northwestern New Mexico (Wright et al., 1973). The record obtained from a 4-m peat core from a subalpine meadow near timberline in the La Plata Mountains 25 km northwest of Durango, La Plata County, Colorado (Figure 1), further enables construction of a 9800-year climatic chronology as reflected by timberline fluctuations (Petersen, 1975). This record was obtained in order to establish a continuous-dated paleoecological sequence for the La Plata Mountains and San Juan River headwaters, and thus to provide a framework to which discontinuous archaeological and alluvial data could be compared.

STUDY AREA

GEOLOGIC SETTING

The La Plata Mountains, southwestern Colorado (Figure 1), protrude into the eastern edge of the Colorado Plateau. This forested upland rises abruptly from the lowermost part of the succession of relatively dry plateaus, mesas, and canyons that extend into New Mexico, Arizona, and Utah. Part of the southern Rocky Mountains, the La Platas lie about 30 km southwest of the main San Juan Mountain front. All principal peaks lie within a 165-km² area and several exceed 3660 m (12,000 ft) in elevation; Hesperus Mountain (4030 m; 13,232 ft) is the highest. A laccolithic mountain group, the La Platas are

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Figure 1. Map of a portion of the La Plata Mountains, southwestern Colorado. Pollen collection sites are indicated by arrows and selected archaeological sites by squares.
carved from a domal uplift of Paleozoic and early Mesozoic sedimentary strata intruded by Tertiary igneous stocks, dikes, and sills (Eckel et al., 1949, p. 1). Igneous rock forms the high outlying ridges of Helmet Peak and the Hogback (Atwood and Mather, 1932, p. 67).

Our core was obtained from the meadow adjacent to Twin Lakes (NE¼ SE¼ NE¼, sec. 18, T 37 N, R 11 W, La Plata, Colo., Quad.). Twin Lakes (3290 m; 10,790 ft) is actually a single lake divided by a strip of vegetation (Figure 2). It is located in a depression near the headward end of an old landslide which is one of three described by Atwood and Mather (1932, p. 155) as modifying the ridge between Sharktooth Peak and Burro Mountain. The ridge is primarily Mancos Shale (dipping 25°W) capped by flat-lying intruded porphyry (Atwood and Mather, 1932, p. 155; Eckel et al., 1949, p. 118). The slide resulted from slippage in the direction of dip.

The Twin Lakes drainage area is small. A regular drainage pattern has not yet established itself on the slide and there are no streams feeding the lake. Twin Lakes is less than 1 m deep and the outlet is less than 1 m above the present lake level.

**Glacial History**

Atwood and Mather (1932, pp. 81, 83, 129, 144) recognize three Pleistocene glaciations in the La Plata Mountains. The cirque shape and elevation of Echo Basin (Figure 1) suggest the Cerro, or earliest, glaciation; a large moraine on the bench 2.5 km down valley at 3050 m (10,000 ft) is assigned to the Durango, or second glaciation. In the La Plata River Valley there are two moraines on opposite sides of the valley at 2745 m (9000 ft) representing the Durango glaciation. A third moraine in the valley bottom diverts the La Plata River and is assigned to the latest, or Wisconsin glaciation. Near the confluence of the north and south forks of the West Mancos River are several Wisconsin lateral moraines with their terminal deposit down valley at 2620 m (8600 ft).

While many of the cirques, which are common above 3500 m (11,500 ft), contain protalus ramparts and rock glaciers, there is no snowline in the La Platas today, and only a few sheltered drifts may last into August. Some drifts in Tomhawk Basin were semipermanent in 1935 to 1937 (Eckel et al., 1949, p. 4). Carrara and Andrews (1973) present radiocarbon-supported data indicating absence of glacial ice from the San Juan Mountains for the past 8500 years. They also believe that many of the rock glaciers developed immediately after deglaciation and have remained active until today. A large rock glacier on the north slope of Hesperus Mountain (Figure 3) was described as a landslide by Atwood and Mather (1932, p. 155).

**Modern Climate**

Summer precipitation usually occurs from convective storms associated with air masses originating from the Gulf of Mexico. Pacific air masses provide winter precipitation. At Mancos, Colorado (2145 m; 7035 ft), maximum precipitation occurs during July and August and mini-
Figure 3. West Mancos River Canyon. Colorado blue spruce and oak (foreground), ponderosa pine (lower center), Douglas-fir (right side of canyon), and aspen (most of the distant upland areas) communities occur within this view taken eastward from Transfer Campground at 2680 m (8800 ft) toward Hesperus Mountain (center), late August 1973.

Table 1
Climatic data from southwestern Colorado

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation (m)</th>
<th>Annual precipitation (cm)</th>
<th>Mean January temp. (°C)</th>
<th>Mean July temp. (°C)</th>
<th>Length of record (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf Creek Pass</td>
<td>3245</td>
<td>106.3</td>
<td>-7.4</td>
<td>+11.4</td>
<td>15</td>
</tr>
<tr>
<td>Silverton</td>
<td>2870</td>
<td>61.7</td>
<td>-8.5</td>
<td>+12.9</td>
<td>53</td>
</tr>
<tr>
<td>Telluride</td>
<td>2670</td>
<td>60.4</td>
<td>-5.8</td>
<td>+14.8</td>
<td>50</td>
</tr>
<tr>
<td>Ouray</td>
<td>2360</td>
<td>51.4</td>
<td>-2.3</td>
<td>+18.4</td>
<td>14</td>
</tr>
<tr>
<td>Vallecito Dam</td>
<td>2335</td>
<td>62.8</td>
<td>-5.4</td>
<td>+18.2</td>
<td>18</td>
</tr>
<tr>
<td>Ft. Lewis</td>
<td>2320</td>
<td>47.7</td>
<td>-5.0</td>
<td>+17.6</td>
<td>40</td>
</tr>
<tr>
<td>Mesa Verde</td>
<td>2155</td>
<td>46.4</td>
<td>-1.2</td>
<td>+22.7</td>
<td>37</td>
</tr>
<tr>
<td>Durango</td>
<td>2025</td>
<td>45.8</td>
<td>-3.7</td>
<td>+19.4</td>
<td>66</td>
</tr>
<tr>
<td>Cortez</td>
<td>1885</td>
<td>33.5</td>
<td>-2.5</td>
<td>+21.8</td>
<td>29</td>
</tr>
</tbody>
</table>

aData are from U.S. Dept. of Commerce, Weather Bureau (1964).

bData are from U.S. Dept. of Commerce, Environmental Data Service (1972).

mum precipitation occurs during June (U.S. Dept. of Commerce, Weather Bureau, 1964, p. 17). Baker's (1944, p. 246, Figure 19) data for the headwaters of the San Juan River and its tributaries indicate that the July mean temperature decreases 0.7°C per 100 m increase in elevation. Climatological data from some southwestern Colorado stations are presented in Table 1; these illustrate reduced temperature and increased precipitation with increasing elevation. Although there are no records for the La Plata Mountains, Wolf Creek Pass, (3245 m; 10,640 ft), located 120 km to the east on the Continental Divide, provides an approximation for Twin Lakes (3290 m; 10,790 ft).

Vegetation
Rocky Mountain vegetational zonation is determined primarily by elevation and secondarily by exposure, aspect, and local microclimatic and edaphic factors (Daubenmire, 1943, pp. 386-387). Vegetational distribution in the La Plata Mountains is similar to that described by Maher (1961, pp. 16-20; 1963, pp. 1488-1490) for the Animas Valley region of the San Juan Mountains. Extensive mining, logging, and grazing which began in 1873 undoubtedly altered the natural vegetation (Eckel et al., 1949, pp. 3, 5, 51; Larsen and Cross, 1956, pp. 3-4). Comparison of modern vegetation with a photograph of La Plata City (2865 m; 9400 ft) taken May 6,
FIGURE 4. Two photographs of La Plata City, 2865 m (9400 ft), La Plata River Canyon. The upper photo, taken May 6, 1894, during active mining, shows sparse conifers on the mountain slopes above the city. The lower photo was taken July 25, 1974, 79 years later, and shows reinvasion of aspen-dominated forest following abandonment of heavy mining activity. View is toward the northwest and Babcock Peak (center). The 1894 photograph is from Golden Treasures of the San Juan, copyright 1961 by John D. Marshall and Temple H. Cornelius, reprinted with permission of The Swallow Press.
1894 (Marshall and Cornelius, 1961, p. 67), shows that trees were sparse on the mountain slopes northwest of La Plata City during active mining in the region (Figure 4). Burnt Ridge was burned sometime between 1875 and 1895, and is still largely bare of trees (Eckel et al., 1949, p. 5). An abandoned lumber camp is located 1 km northeast of Beef Pasture (Eckel et al., 1949, p. 118), and the Twin Lakes area recently has been logged.

With increasing elevation, one encounters the following indicator species and vegetation types. Pinyon (Pinus edulis) and juniper (Juniperus spp.) woodland extends up to about 2290 m (7500 ft). Ponderosa pine (Pinus ponderosa) and oak (Quercus gambelii) extend to 2740 m (9000 ft) with Douglas-fir (Pseudotsuga menziesii) and aspen. Aspen is the most abundant tree in the La Plata Mountains, and extensive aspen groves occur on the large upland areas. North-facing canyon slopes bear dense Douglas-fir forest with Colorado blue spruce (Picea pungens), white fir (Abies concolor), ponderosa pine, and aspen in favorable locations (Figure 3).

A mixed conifer forest extends to almost 3050 m (10,000 ft) with Douglas-fir, Engelmann spruce (Picea engelmannii), white fir, subalpine fir (Abies lasiocarpa), and aspen. A dense forest of Engelmann spruce and subalpine fir extends to timberline (upper forest limit) at about 3540 m (11,600 ft). The alpine zone, above 3540 m, is dominated by grass, sedges, herbs, and low willows. Dwarf Engelmann spruce and subalpine fir extend to tree line (krummholz limit), at about 3610 m (11,850 ft), in the ecotone between forest and tundra.

FIELD AND LABORATORY PROCEDURES

Overlapping cores were taken from the meadow at the southeast edge of Twin Lakes with a 5-cm-diameter modified Livingstone piston sampler. Extruded cores were measured, wrapped in plastic film and boxed in wooden trays for transport to cold storage at Washington State University.

The 4.11-m Twin Lakes core (Table 2) is composed of peat except for 18 cm of silty clay at the base. A well-preserved drift peat, composed largely of Picea needles and cone scales, overlies the basal clay. The silty peat layer at 1.92 to 2.02 m is distinctive; it is slightly higher in silt content and lighter in color than the rest of the core. The least fibrous peat in the core, it is described as “felted” in Table 2 (Troels-Smith, 1955, p. 55).

The core was sampled at 5-cm intervals. The

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00-0.05</td>
<td>Sedge peat; reddish brown (5YR 4/4); nonhumified; very fibrous; medium rootlets; diffuse lower boundary.</td>
</tr>
<tr>
<td>0.05-0.40</td>
<td>Sedge peat; reddish brown (5YR 4/4); slightly humified; moderately fibrous; medium to fine rootlets; gradual lower boundary.</td>
</tr>
<tr>
<td>0.40-1.92</td>
<td>Sedge peat; red (10R 4/6); moderately humified; Picea needles common; grading down from very fibrous to moderately fibrous; rootlets rare; abrupt, smooth lower boundary.</td>
</tr>
<tr>
<td>1.92-2.02</td>
<td>Silty peat; light brownish gray (10YR 6/2); highly humified plant detritus; felted; fine rootlets abundant; clear, smooth lower boundary.</td>
</tr>
<tr>
<td>2.02-2.40</td>
<td>Peat; dark reddish brown (5YR 4/4); moderately humified; very fibrous; diffuse lower boundary.</td>
</tr>
<tr>
<td>2.40-2.80</td>
<td>Peat; dark reddish brown (5YR 4/4); moderate to highly humified; slightly fibrous to felted; diffuse lower boundary.</td>
</tr>
<tr>
<td>2.80-3.75</td>
<td>Peat; dark reddish brown (5YR 4/4); moderately humified; very fibrous; abrupt, smooth lower boundary.</td>
</tr>
<tr>
<td>3.75-3.93</td>
<td>Drift peat; dark reddish brown (5YR 4/4); moderately fresh and nonhumified; Picea needles, twigs and cone scales abundant; abrupt, smooth lower boundary.</td>
</tr>
<tr>
<td>3.93-4.11</td>
<td>Silty clay; dark grayish brown (10YR 4/2); partially decomposed rock fragments (less than 1 cm diameter) present.</td>
</tr>
</tbody>
</table>

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Figure 5. Pollen diagram from Twin Lakes, La Plata Mountains, southwestern Colorado.
fossil and surface samples were screened through 100-mesh screens for macrofossil separation and prepared for pollen analysis. Samples were mounted in silicone fluid (2000 centistokes) and were examined at 400× magnification. At least 300 pollen grains, excluding Cyperaceae, were counted in each sample. Pollen and spore identifications were checked against the reference collection at Washington State University.

With the exception of Lycopodium annotinum, microfossils were poorly preserved in the 4.05- and 4.00-m samples. Lycopodium spores are relatively resistant to oxidation (Havinga, 1964, Table 3). Pollen preservation above 3.95 m was excellent. Results of the analysis are presented in Figure 5. A summary diagram was prepared for Picea, Pinus, Other NAP, Cyperaceae, and three ratios using weighted, three-level moving averages. Weight was given by doubling the value of the second level and dividing the sum by four to obtain the average (Figure 6). Eleven radiocarbon dates are given in Table 3; two of these (5575 ± 185 BP and 6030 ± 295 BP) are inconsistent with depth. Therefore, replicate samples from the same stratigraphic positions within a different 10-cm-diameter core were dated. The original two samples (SI-1555 and SI-1757) were small and required dilution, whereas the latter two were large enough to provide dates on individual lipid, humate, and residue fractions. Dates on all of these fractions were in close agreement. The Washington State

![LA PLATA MTS, COLORADO TWIN LAKES, 3290 Meters Summary Diagram](image-url)

**Figure 6.** Summary pollen diagram from Twin Lakes, La Plata Mountains, southwestern Colorado. Pollen percentages and ratios are plotted using weighted, three-level moving averages, \( x = (a + 2b + c)/4 \); ratios are plotted about the mean of all 80 samples. Ratio curves in agreement to the left of the mean indicate a retreat downward of timberline, an increase in tundra area, and lower mean July temperatures in relation to the 9800 radiocarbon year mean. Agreement to the left of the mean indicates the opposite.
University date (av. WSU-1515, 1520, 1523) for 2.17 to 2.23 m agrees with the Smithsonian determination (SI-1757) for the same level, whereas the 2.52 to 2.58 m sample (av. WSU-1516, 1529) is about 1100 years older than the Smithsonian date (SI-1555). We accept the WSU dates because the initial sample was much larger, dates on the various fractions are consistent, and the date is consistent with depth. The WSU dates for the two levels discussed are plotted on the pollen diagrams (Figures 5 and 6).

SURFACE POLLEN SAMPLES

Plants and modern pollen surface samples were collected from four sites in August 1973 (Figure 1). Surface pollen percentages are given in Table 4. Lake bottom sediments were collected near tree line from the larger of two shallow, rock-bottomed, unnamed lakes at 3610 m (11,840 ft) in Rush Basin (S 1/2 NE 1/4, sec. 32, T 37 N, R 11 W, La Plata, Colo., Quad.; Eckel et al., 1949, Plate 7). Spruce (Picea engelmannii) and willow (Salix brachycarpa) occur near the lake (Figure 7). Common herbs include Bistorta bistortoides, Artemisia scopulorum and, in wet places, Caltha leptosepala. Two showy Compositae, Arnica mollis and Helenium

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**Figure 7.** The larger of two rock-bottomed, unnamed lakes in Rush Basin, 3610 m (11,840 ft). A modern pollen sample was collected from sediment in this shallow lake surrounded by alpine tundra with willow and Engelmann spruce krummholz (foreground). The view is toward the north, August 25, 1973.

**Figure 8.** Beef Pasture, 3060 m (10,040 ft). A surface pollen sample and a 4-m core were obtained from this 75-ha grass and sedge meadow surrounded by a mixed conifer forest. The view is of the eastern portion, looking southeast toward Hesperus Mountain (left background), August 26, 1973.
Table 3
Twin Lakes radiocarbon dates

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Laboratory Number</th>
<th>Date (years BP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40-0.49</td>
<td>SI-1754</td>
<td>2545 ± 75</td>
</tr>
<tr>
<td>0.85-0.95</td>
<td>SI-1755</td>
<td>2890 ± 75</td>
</tr>
<tr>
<td>1.40-1.50</td>
<td>SI-1347</td>
<td>4035 ± 60</td>
</tr>
<tr>
<td>1.75-1.85</td>
<td>SI-1756</td>
<td>4305 ± 85</td>
</tr>
<tr>
<td>2.15-2.25</td>
<td>SI-1757</td>
<td>6030 ± 295</td>
</tr>
<tr>
<td>2.17-2.23</td>
<td>av. WSU-1515, 1520, 1523</td>
<td>5860 ± 60</td>
</tr>
<tr>
<td>2.50-2.60</td>
<td>SI-1555</td>
<td>5575 ± 185</td>
</tr>
<tr>
<td>2.52-2.58</td>
<td>av. WSU-1516, 1529</td>
<td>6700 ± 80</td>
</tr>
<tr>
<td>2.90-3.00</td>
<td>SI-1758</td>
<td>8500 ± 90</td>
</tr>
<tr>
<td>3.40-3.50</td>
<td>SI-1759</td>
<td>8670 ± 80</td>
</tr>
<tr>
<td>3.80-3.90a</td>
<td>SI-1348</td>
<td>9765 ± 175</td>
</tr>
</tbody>
</table>

a Date on wood and spruce macrofossils, all other dates are on whole peat.

hoopesii, occur with a variety of low cushion plants on the rocky slopes above the lake, and their presence is probably reflected in the modern pollen rain. The Rush Basin pollen sample is characterized by nonarboreal pollen (65.1%); Artemisia (13%) is the most abundant pollen in this tundra sample. Long-distance-transported pine pollen (25%) is the most important arboresal pollen, while spruce (4.3%), which grows at the site, is poorly represented.

Twin Lakes, at 3290 m (10,790 ft), is 250 m (800 ft) below timberline. Open Engelmann spruce-subalpine fir forest surrounds the lake. Common understory plants that probably contribute to the modern pollen rain include Helenium hoopesii, Ligularia bigelowii, Delphinium barbeyi, Aconitum columbianum, Geranium richardsonii, and several grasses. The northwest-southeast-trending sedge meadow adjacent to Twin Lakes is 2 ha in area. The major sedge peat formers are Carex utriculata and C. micropetra. Caltha leptosepala is very abundant. Mosses include Aulacomnium palustre and Drepanocladus uncinatus. The coring site in the meadow near the edge of Twin Lakes is shown in Figure 2. The Twin Lakes surface pollen sample is characterized by arboreal pollen (76.9%), of which 26.7% is spruce.

Beef Pasture (SI/2 SW1/4, sec. 11, T 37 N, R 12 W, Rampart Hills, Colo., Quad.) is an open, 75-ha grass and sedge meadow at 3060 m (10,040 ft). The surrounding mixed forest includes aspen, Alnus tenuifolia, Douglas-fir, and spruce (Figure 8). Common understory plants

Table 4
Surface sample pollen percentages, La Plata Mountains, Colorado

|---------------|---------------|----------|----------|--------------|--------------|--------------|---------------|------------|---------|---------------|---------------|-----------|----------|----------|----------------|---------------|---------|--------------|-------------|-------------|----------------|
FIGURE 9. Chicken Lake, 2707 m (8880 ft). A surface pollen sample was collected from this shallow, marshy depression dominated by sedge and cattail and surrounded by aspen. Note the burned ponderosa pine remnant (center background). The view is toward the west, August 28, 1973.

probably contributing to the modern pollen rain include Chenopodium fremontii, Achilla lanulosa, Solidago multiradiata, Erigeron coulteri, E. speciosus, and several grasses. The major sedge peat formers are the same as at Twin Lakes. The Beef Pasture pollen count is similar to that of Twin Lakes except for lower percentages of long-distance–transported pine and the higher local nonarboreal pollen.

Chicken Lake (N\(\frac{3}{4}\), sec. 18, T 37 N, R 12 W, Rampart Hills, Colo., Quad.) is a shallow, marshy depression containing sedge and cattail at 2707 m (8880 ft). It covers 1 ha and is surrounded by a dense growth of aspen and oak with some ponderosa pine and Douglas-fir (Figure 9). The Chicken Lake pollen sample collected near the upper limit of ponderosa pine contains the highest Pinus and lowest Picea percentages.

The following pollen percentage trends can be seen in Table 4: (1) the highest Artemisia and NAP values occur in the tundra sample (Rush Basin), (2) the highest spruce and fir values occur in the spruce-fir forest samples (Twin Lakes and Beef Pasture), and (3) the highest pine values occur in the sample near the upper limit of ponderosa pine (Chicken Lake).

FOSSIL POLLEN PERCENTAGES

The reader can more easily follow this brief summary of the major changes in important pollen curves by referring to Figures 5 and 6. Twin Lakes, near the upper limit of spruce-fir forest, has been especially sensitive to minor changes in the distribution of Picea. Picea pollen fluctuates from a high of 49% at 2.45 m to a low of 4% at 1.25 m, but reaches only 28% within the basal drift peat (3.75 to 3.93 m) which is composed largely of spruce macrofossils.

Pinus pollen reaches 66% at 3.90 m (about 9800 BP). It then drops to about 40% as Picea pollen increases, and then Pinus fluctuates around 30% for most of the remaining profile. After declining to 12% at 0.05 m, Pinus increases to 39% at the surface. Ranunculaceae pollen is rare below 0.20 m, but reaches 13% at 0.10 m; it drops to 2% in the top two samples. The Ranunculaceae pollen fluctuations preceded those of Salix.

Artemisia pollen exhibits a negative relationship to Picea pollen. For example, the highest Artemisia (21%) occurs at 1.25 m with the lowest Picea (4%). This relationship is obvious in the summary diagram (Figure 6). Exceptions to this negative relationship occur at 3.90, 2.75, and 1.95 m with peaks in Pinus or Gramineae, and at 0.05 m when Salix is especially abundant (Figure 5). In Figure 6, Other NAP does not include Artemisia and Cyperaceae; its highest percentages are coeval with low Picea percentages.

Cyperaceae pollen is low in the basal clay (prior to 9800 BP), reaches 67% in the drift
peat, then decreases to 2.45 m (prior to 6000 BP). Between 2.35 and 1.40 m (about 4000 BP) Cyperaceae fluctuates between 5 and 53%, and above 1.40 m it is fairly stable except for decreases to 3% at 0.40 (about 2500 BP) and 0.05 m. Cyperaceae pollen increases to 23% at the surface.

Moss spores are exceptionally abundant above the basal clay where they reach 600% of total pollen. They then occur only occasionally until 0.10 m, where they begin a rapid increase to 40% of total pollen at the surface.

**INTERPRETATION**

**HISTORIC DISTURBANCE AND SECONDARY SUCCESSION**

The remarkable changes in conifer and NAP percentages above 20 cm may be the result of forest disturbance and secondary succession. The temporary decrease of conifer pollen percentages followed by increasing Ranunculaceae, other NAP, Salix, and conifer values to the present time may coincide with the events of rapid human population growth and decline. However, a major lowering of timberline within the past 300 years or so may also account for these changes, and it could be difficult to distinguish the effects of human disturbance following a major climatic event. Andrews et al. (1975, Tables 1 and 2) report a depression of tree line within the past 300 years for Hurricane Basin located 85 km north of the La Plata Mountains.

A 280 ± 80 BP (GaK-3859) date was obtained on a conifer branch from a buried woody-layer in a peat deposit located 50 m above present tree line.

The influence of settlement, mining, logging, and grazing should have been apparent by the 1880s and should have been most significant through the early 1900s (Figure 4). The first prospectors worked the head of the Mancos River in 1869 (Larsen and Cross, 1956, p. 3), and many of the mines in the La Plata Mountains were established between 1873 and 1909. During this time, over 200 mining claims were patented and hundreds of others recorded. Parrot City was established on the La Plata River in 1874, Mancos followed in 1880 and the town of La Plata (Figure 1), 7.5 km north of Parrot City, was founded in 1884. These towns thrived for a time, but by the 1930s, Mancos was the only one with more than a few families (Eckel et al., 1949, pp. 51-53).

**UPPER TREE LIMIT**

Without more information, it is difficult to interpret the history of specific palynomorphs in relation to past vegetation and climate. This is particularly true of many rare NAP as well as the abundant Cyperaceae and Bryophyta. However, we believe it is possible to relate the Twin Lakes pollen record to past timberline elevations through the use of modern surface sample comparisons. The La Plata Mountains are particularly suited to such an attempt because the total area above timberline and tree line would be greatly altered by a minor shift in their altitudinal limits (Figure 10). For example, a depression of only 110 m (360 ft) would double the plan area above present tree line.

LaMarche (1973, pp. 649-652) and Daubenmire (1954, pp. 128-133) have reviewed the probable causes of upper tree limit and have concluded that net photosynthesis during the warmest part of the year is critical. Photosynthesis in high elevation conifers is limited to these warmer months and it must be adequate for annual respiration and foliage renewal require-
Upward advance of tree line requires seedling establishment and survival above the existing tree line, while retreat is caused by the death of established trees above a certain altitude. The upper tree limit is related to reproduction and net photosynthesis and the latter is temperature dependent. Since upper tree limited is controlled primarily by temperature, its history should provide a climatic chronology of regional significance.

Marr and Marr (1973) conducted a 2-year study of the Colorado Front Range forest-tundra ecotone. Their results showed a temperature decrease of 2 to 4°C, a wind velocity increase, and a precipitation decrease between forest and krummholz limit. Within this ecotone, the mean daily minimum and maximum temperatures for July were 8.8 and 11°C. Lindsay (1971, Table 1), in a 1-year study in the Medicine Bow Mountains, southeastern Wyoming, found that the July mean temperature in the timberline ecotone was 12.2°C, the mean minimum was 7.8°C, and the mean maximum was 16.7°C. For the White Mountains, California, LaMarche (1973, p. 650) estimated the mean maximum July tree line temperature at 14.7°C. Daubenmire (1954, pp. 128-129) reviewed a number of studies showing that timberline roughly coincides with the 10°C isotherm for the warmest month of the year (usually July).

Surface pollen counts from the La Plata Mountains (Table 4) agree with Maher's (1963, Figure 3) studies for the Animas Valley region, San Juan Mountains. His results show that *Artemisia* pollen percentages are highest above timberline, *Picea* percentages are highest between 2590 m (8500 ft) and timberline, and *Pinus* percentages are highest between 2135 m (7000 ft) and 2590 m, and again above timberline. These pollen distributions serve to distinguish tundra from spruce-fir forest.

Based on modern pollen surface samples, the following changes would be expected at Twin Lakes if timberline were to retreat to a lower elevation and the area of tundra were to increase: (1) *Picea* pollen percentages would decrease; (2) *Pinus* percentages would increase; (3) *Artemisia* percentages would increase; and (4) other NAP percentages would increase as a result of local production of tundra herb pollen. Alpine herbs are generally low pollen producers, and the relative increase in *Pinus*, *Artemisia*, and NAP probably includes pollen transported from lower elevations as well as pollen of local alpine species.

Conversely, if timberline were to rise, thereby reducing the total tundra area, the following changes would be expected at Twin Lakes: (1) *Picea* pollen percentages would increase; and (2) *Pinus*, *Artemisia*, and other NAP percentages would decrease.

**Selection of Ratios**

One problem in interpreting percentage diagrams is that the change in abundance of a single pollen type affects the percentages of all the others. This constraint may be overcome by using pollen ratios because the quotients are unaffected by changes in the relative frequencies of other pollen types. Maher (1963, Figure 4; 1972, Figure 6) compared the *Picea/Pinus* ratios with surface sample elevations in the San Juan Mountains and the Colorado Front Range, and he used the same ratio (Maher, 1961, Figure 15; 1972, Figure 7) to interpret past apparent elevations from fossil pollen records. The *Picea/Pinus* ratios in surface samples increase to a maximum value near timberline and then decrease above that elevation. Thus, for any one *Picea/Pinus* ratio, there are two characteristic elevations, one above timberline, and the other below (Maher, 1961, p. 72).

Because additional evidence is needed to distinguish between the two apparent elevations estimated from the *Picea/Pinus* ratios, two additional ratios were selected for Twin Lakes; these are *Picea + Abies + Pinus/NAP* and *Picea/Artemisia*. Surface pollen data for the La Plata Mountains indicate that with the retreat downward of timberline and the resultant increase in tundra area, the quotient of all three ratios should become smaller at Twin Lakes. Weighted, three-level moving averages of these ratios are plotted in Figure 6 about the mean of the ratios for the 80 samples of the Twin Lakes analysis.

Fluctuations about the mean of the three ratios (Figure 6) are in general agreement. When all three ratios are in phase, we interpret shifts to the left of the means as indicative of lower mean July temperature, a retreat of timberline to lower elevations, and increased tundra area in relation to the mean for the last 9800 radiocarbon years. Shifts to the right of the means would represent increased summer temperatures, a timberline advance upward, and decreased tundra area.
DISCUSSION

Our interpretation of the ratios and timberline history follows. Spruce macrofossils in the basal drift peat indicate that Twin Lakes was below tree line 9800 BP, but timberline was lower than the 9800-year mean until about 8600 BP (3.35 m). Timberline advanced to higher elevations than the mean at 3.20 m, and retreated downward to near the mean between 3.00 (8500 BP) and 2.60 m. Timberline again advanced upward at 2.50 m (6700 BP). Shortly after 4000 BP (1.24 m), timberline retreated to its lowest elevation since the bottom of the profile. Timberline advanced to a significantly higher elevation than the mean at 2500 BP (0.40 m).

By comparison, Maher's (1961, Figures 14 and 15) fossil *Picea*/*Pinus* ratios from Molas Pass Bog, near Molas Lake, indicate a retreat of timberline from a high of 200 m above that of the present to at least 120 m below that of the present at 4940-300 BP (LJ-539; Hubbs et al., 1963, p. 271). Maher (1961, Figure 16) infers a concurrent lowering of July mean temperature from a high of 1.7°C above that of the present to a low of 2.7°C below that of the present.

Andrews et al. (1975, Figures 7 and 8, Tables 2 and 3) report pollen analyses, *Picea*/*Pinus* pollen ratios, and the occurrence of spruce macrofossils from a 2.15-m peat core from Hurricane Basin, northern San Juan Mountains. The coring site (3600 m) is located 50 m above present tree line. Four radiocarbon dates were obtained from a second core and exposed buried conifer wood. Stratigraphy and macrofossils were used to estimate their position in the analyzed core. The *Picea*/*Pinus* ratios for 33 samples indicate that timberline was lower than its present elevation at the base of the core (prior to 8300 BP) and it advanced upwards three times to at least present elevations. Spruce and conifer macrofossils indicate that there were trees adjacent to the coring site during part of the times of higher timberlines. The *Picea*/*Pinus* ratios indicate that the first advance upward of timberline occurred about 8500 BP, followed by retreat of timberline to lower elevations for a short time. Timberline advanced upward a second time sometime after 8300 BP and remained at least at present elevations until sometime after 3500 BP. Timberline again retreated to lower elevations prior to 1300 BP and remained there until the time of the 10-cm pollen sample. Above this sample, and prior to the top surface sample, tree line advanced a third time to higher elevations, at least high enough for conifer wood (dated at 280 BP) to be deposited in the peat 50 m above present tree line.

The results reported here are from the first exploratory research required to establish a continuous dated paleoecological sequence for the La Plata Mountains. Another pollen core has been taken from Beef Pasture near the lower limit of the spruce-fir forest. A date of 10,565±135 BP (SI-1554) was obtained from basal woody peat (4.50 to 4.60 m depth). Since the lower altitudinal limits of plant distributions are strongly influenced by moisture (Daubenmire, 1943, pp. 365-368), analysis of the Beef Pasture core should complement the Twin Lakes temperature record with information on past effective moisture.

Both Twin Lakes and Beef Pasture cores exceed 4 m in length. These rapid deposition rates will allow finer chronological control of evidence for minor vegetational changes. Such detail will be valuable in evaluating climatic causes of pueblo occupation and abandonment, and will also allow comparison of forest history with dendroclimatic data from Mesa Verde (Fritts et al., 1965) and other western sites (Fritts et al., 1971; Krebs, 1972; LaMarche, 1974; LaMarche and Stockton, 1974).

CONCLUSION

The analysis of a 4-m peat core from a subalpine meadow at 3290 m (10,790 ft) elevation in the La Plata Mountains, southwestern Colorado, is a further attempt to establish a continuous dated sequence for the San Juan River drainage. Pollen percentages and ratios show that Twin Lakes has been sensitive to minor vegetational changes including those recently induced by lumbering, mining, and grazing, as well as temperature-controlled timberline fluctuations for the past 9800 years. Major timberline advances upward occurred about 8500 BP and 6700 BP. A major retreat downward of timberline occurred shortly after 4000 BP, and another major advance upward occurred at 2500 BP. Studies of the Twin Lakes peat and other similar La Plata Mountains deposits are continuing.

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ACKNOWLEDGMENTS

This study was supported, in part, by funds from San Juan Valley Archaeological Project, Cynthia Irwin-Williams, Director. We thank Owen K. Davis, Fred Nials, Eugene M. Hattori, and Lisa G. Bostwick for field and laboratory assistance; Mary Ann Mehringer and Madge Gleason for aid with the manuscript and illustrations; William A. Weber for plant identifications; Robert Stuckenrath and John C. Sheppard for radiocarbon dates; and Louis J. Maher, Jr., for comments on the manuscript.

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Ms submitted July 1975