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A RE-EVALUATION OF THE POSTGLACIAL VEGETATION OF THE LARAMIE BASIN, WYOMING-COLORADO

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ABSTRACT.— Previous work by Wells in the Laramie Basin suggested that a coniferous forest/woodland covered the basin floor in the recent past (until the latest Holocene). We have found no evidence for this woodland and suggest instead that these scattered woodlands along sandstone outcrops and their immediate margins are outliers of the montane forest of the Medicine Bow Mountains, existing in their apparently anomalous locations due to favorable microenvironments set up by the topography and substrate.

During the past two years, we worked at various sites in and surrounding the Laramie Basin in an attempt to collect sufficient information with which to reconstruct postglacial vegetation (and environment) change for the region. The basin's unique geography as one of the few high-altitude basins surrounded by the Rocky Mountains, and the knowledge that a periglacial climate existed here in pre-Holocene times (Mears 1981), encouraged us to seek postglacial paleoclimatic data from not only upper elevations in the mountains (as done traditionally in the Rocky Mountains), but for the basin itself. Faunal, soil, and geomorphic studies here (Hager 1972, Reider et al. 1974, Grasso 1979, Reider and Burgess, in prep.) point to late Pleistocene and Holocene environmental change. In addition, a 116-year-old record of meteorological data is available for the basin, which will aid any climatic reconstructions attempted.

Upon visiting the Sand Creek region of the Laramie Basin (Fig. 1), we were delighted to find an abundance of fossiliferous material, including in situ dead trees (macrofossils) and *Neotoma* (woodrat) middens, as well as living trees that appeared to be at least several centuries old. Both living and dead trees were restricted to the sandstone outcrops and their immediate margins, these outcrops principally lithified sand dunes of the Pennsylvanian Casper Formation (Fig. 2).

It later surprised us when we read in the papers of Wells (1970a, 1970b) on the postglacial vegetation of the Laramie Basin that he believed these trees had in recent times (the latter half of the Altithermal and perhaps part of the Neoglacial) covered the entire floor of the Laramie Basin. Knowing both the ecological requirements of these conifer species (*Juniperus scopulorum* Sarg.— Rocky Mountain juniper; *Pinus flexilis* James—limber pine; and *P. ponderosa* Laws.— ponderosa pine) and the relatively minor degree of climatic change in the Holocene compared to the Pleistocene, we considered Wells's hypothesis not plausible. Instead,

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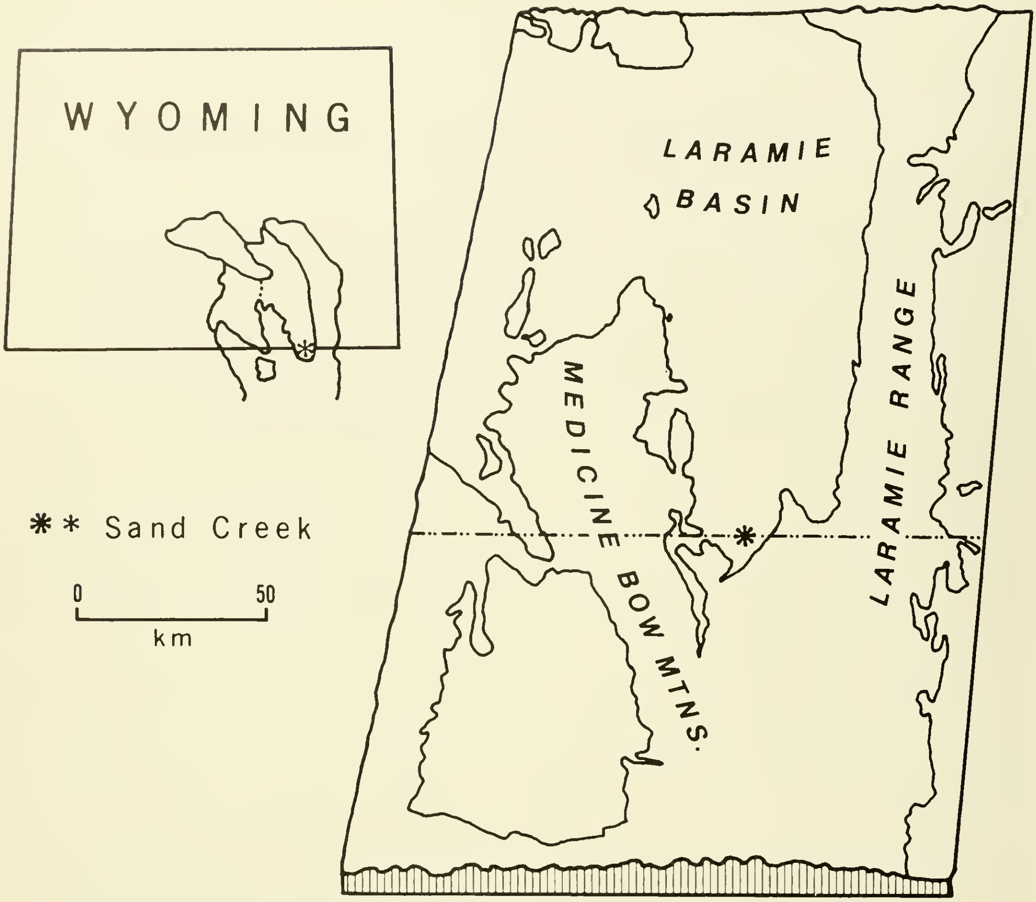

Fig. 1. Map of Sand Creek study area in the Laramie Basin of Wyoming-Colorado.

topography and microenvironmental conditions could have favored a more vigorous woodland (as evidenced by population and individual sizes) on the outcrops sometime in the past.

We therefore decided to critically reevaluate the paleoenvironmental data for the Sand Creek area. This involved examining a larger area than apparently done by Wells (pers. comm. with local ranchers) and also an attempt to tie the botanical data in with other paleoenvironmental studies conducted in the region. The completion of this project awaits radiocarbon dates and further dendroclimatic reconstructions. It is our hypothesis that these scattered woodland stands are outliers of the montane forest of the Medicine Bow Mountains, existing in their apparently anomalous locations due to favorable microenvironments set up by the topography and substrate, and not relicts of a former forest over the basin floor as hypothesized by Wells.

Methods

The methods we have used to solicit information as to the nature and degree of change of past environments at Sand Creek involve gathering various paleoecological materials. As we have yet neither found fossil soils in this immediate area, nor analyzed animal remains found in the *Neotoma* middens, we confine our discussion to the botany and paleobotany of the area.

Extensive hiking and collecting was done in the area outlined in Figure 1 to determine the spatial and temporal extent of conifers in this region. Dead and living individuals were mapped, along with *Neotoma* middens (both

Fig. 2. Study site 1 at Sand Creek (Wells' primary site). The landscape here is characterized by lithified sand dunes of the Pennsylvanian Casper Formation. The tree in the middle of the photo is a Rocky Mountain juniper (*Juniperus scopulorum*) approximately 1000 years of age.

fossil and contemporary). Although collecting has been completed at many of these sites, materials are still being obtained. In addition, the vegetation, regenerative capacity, microclimatic setting, geology, and soils of the sites were recorded.

Initial tree-ring and midden analyses, following the traditional methods of Stokes and Smiley (1968), Fritts (1976), and Wells (1976), have been conducted. Studies on the regenerative capacity of the conifer populations follow the methods outlined by Elliott (1979). We present our initial findings here. We believe these findings are important for those attempting to reconstruct Holocene climatic change for the Western USA, because they offer a radically different conclusion than that presented by Wells (1970a, 1970b). Also, for anyone undertaking recent paleoenvironmental studies, it becomes increasingly important to have a thorough understanding of the life strategy and ecological requirements of the species investigated, and also of the local geography of a site, if one is to accurately reconstruct a climatic record.

RESULTS

The present distribution of trees and tree species is shown in Figure 3. Multiple monospecific and mixed species stands occur along this semicontinuous sandstone ridge extending out from the southwestern Medicine Bow Mountains. The lower forest limit here is 2,500 m, with woodland patches reaching elevations of 2,300 m.

It is important to note that the lowest trees surviving here are not on the floor of the basin proper, but are restricted to the sandstone outcrops (Fig. 4) or their immediate margins. The dead trees (macrofossils) reported by Wells and found by us occupy the same topographic position as the living conifers, where winter snowdrift and summer runoff can supply them with the necessary moisture for survival in this marginal environment (Fig. 5).

It is interesting to note that two of the fallen fossil junipers plus two standing dead stumps in the area are much larger than any living junipers in the area today (Fig. 6). As this species is apparently at its lower mois-

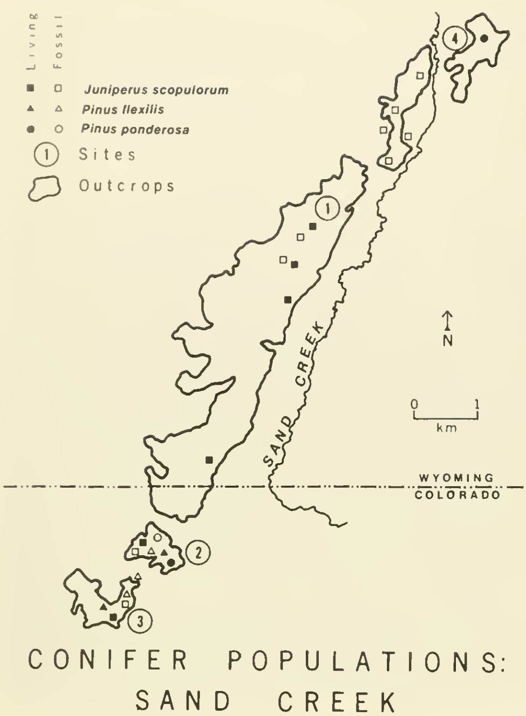

Fig. 3. Distribution of living and fossil (in situ dead) trees in Sand Creek study area. Findings in woodrat middens are not included here. Sandstone outcrops extend from the Medicine Bow Mountains to their southwest, decreasing in elevation toward the northeast.

ture, but not temperature, limit today (Fowells 1965), it seems reasonable to speculate that more moisture (either due to increased precipitation or decreased temperatures/evapotranspiration) was available during at least part of the past life spans of these trees.

This hypothesis is also supported by the fact that no mixed stands of ponderosa pine and juniper (as evidenced in some of the fossil middens) exist here today. Stands of limber pine and juniper do exist, along with mixed stands of all three species and pure stands of juniper or ponderosa pine. Fossil midden equivalents of all stand types mentioned here except the monospecific stands are found.

All three species are successfully sexually regenerating today in each stand in which they occur. This is witnessed by the presence of both viable seed (cones) and juveniles.

It proves difficult to make any type of rigorous statement in reference to the age structures of the tree populations here. This is due not only to a lack of radiocarbon dates for each dead tree (macrofossil), but primarily because both dead and apparently also living trees have been removed from this area for use as fence posts, firewood, etc. Many of the cut junipers we have found were harvested for "cedar table tops" in the 1920s (pers. comm., F. Lilly to B. Mears 1980), a fact that is distressing to paleoecologists trying to reconstruct the history of a site. Cross-dating of the tree rings in mature junipers is also extremely difficult; however, limber and ponderosa pine are easily cross-datable.

Juveniles of all three species, ranging from a few to 50 years in age, are abundant. All age classes (standard 10-year groups) of ponderosa pine are found for the last few hundred years, with no individuals over 350 years old (as yet found) surviving today. Ponderosa pine macrofossils (both in situ dead trees and smaller macrofossils in middens) are infrequent, though we have found cones and seeds at site 1. Limber pine is found up to several hundred years old, with some individuals approaching 1,000 years in age. In situ limber pine macrofossils are common at sites 2 and 3; some of these dead trees were also much larger than those living today. Sampling of these macrofossils is not yet complete.

Juniper appears to have had considerable difficulty through at least the last few thousand years (as documented by Wells's radiocarbon dates) with the establishment of an equilibrium population in this area. The living individuals today are primarily either several hundred to 1,000 years old or under 100 years in age. Juveniles tend to be clustered around singular dead or living mature individuals, which most likely served as the seed (mother) trees. Layering of juveniles from each other (but not from the larger trees) is also found. Occasionally, juveniles are found a great distance (over 1 km) from any possible seed trees. Few young adults are found, an age group in which the two pine species are abundant. Further dendroecological work with response functions for a species may help explain this difference.

One of the most intriguing facets of the Sand Creek sites is the tremendous variation in average tree-ring widths as one looks at living versus dead individuals. The ponderosa pines seem to have found a couple of sites at

Fig. 4. Trees at site 2. The majority of trees in this stand are situated on top of the sandstone outcrop, with individuals occasionally found along the margins. *Juniperus scopulorum*, *Pinus flexilis*, and *Pinus ponderosa* are all present here as both living individuals and fossils.

which they can exist with only occasional stress (as evidenced by very narrow rings every 30 to 40 years which are cross-datable); these individuals show wide, symmetrical crowning with consistently good growth and low mean sensitivities. In contrast, limber pine and juniper appear to have been under considerable environmental (climatic) stress, though this has not precluded the establishment of juveniles in recent times. Narrow rings and high mean sensitivities are common for both species here.

For comparative purposes, we present average ring-width data for several individuals of *Juniperus scopulorum* that we believe are representative of our samples. Whereas two measured, undated fossil trees have average ring widths of 1.09 and 2.38 mm, respectively, the largest living tree at Wells's site (our site 1) has an average ring width of 0.19 mm. One section of a large dead juniper cited by Wells with a radiocarbon date of 940 ± 105 BP (Gx-140F) on the outer wood has an average ring width of 0.17 mm; however, this value is derived from measurements on a branch cross-section and may therefore be expected to be smaller than those from the primary trunk. (All of the other measurements given are from main trunk cores and cross-sections.)

The above data show almost a 25-fold difference in ring-widths. As the living and fossil trees are found in the same habitats, this difference in growth must be attributed to a change in climate, with other environmental factors (topography, etc.) remaining constant. It is not attributable to intrapopulation or age differences.

Conclusion

It appears that Holocene climatic change in the Laramie Basin has been sufficient to trigger the death of conifers in the most marginal low-elevation sites. This is suggested by: (1) change in species composition of some of the lowest woodland stands, with only the most xeric tree species surviving this deterioration, (2) the death of individuals at the most marginal microclimatic/topographic locations, and (3) the decrease in ring width

Fig. 5a. Remains of fossil (dead) *Juniperus scopulorum* at the margin of a sandstone outcrop. This individual, like many in the area, has been partly harvested for lumber. Site 1.

Fig. 5b. Immature (not yet bearing seeds) *Juniperus scopulorum* along the margin of a sandstone outcrop between sites 1 and 2. This is a typical habitat for juniper regeneration. This individual is approximately 80 years old.

Fig. 6. One of two large, dead, fallen junipers at site 1. A cross-section through the midpart of this tree has been cut out, most likely for a table top. Presence of small branches on this individual attest to the fact that it has probably not been dead for more than a few hundred years.

(average growth rate) of the mature conifer populations.

We have found no evidence that a coniferous woodland or forest ever existed over the floor of the Laramie Basin in the Holocene (or even Pleistocene, though this latter time period is out of the scope of this study). It does appear, however, that more and occasionally larger individuals of the extant conifer species did exist on the sandstone outcrops and at their immediate margins in the early Neoglacial and perhaps late Altithermal.

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