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Differentiating Aspen and Cottonwood in Prehistoric Wood from Chacoan Great House Ruins

David Tennessen

Department of Anthropology, University of Minnesota, Minneapolis, Minnesota 55455, U.S.A.

Robert A. Blanchette

Department of Plant Pathology, University of Minnesota, St Paul, Minnesota 55108-6030, U.S.A.

Thomas C. Windes

National Park Service, U.S. Department of Interior, Santa Fe, New Mexico 87504-0728, U.S.A.

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Accurate taxonomic identification is an essential part of archaeological wood analysis. However, making identifications more precise than the genus level is usually not possible since species within the same genus typically possess very similar cellular morphology. This paper describes a method for distinguishing aspen (*Populus tremuloides*) from cottonwood (*Populus fremontii, Populus angustifolia, Populus acuminata*) in samples of wood collected from the San Juan Basin in northwestern New Mexico and southwestern Colorado. This method is then applied to archaeological wood samples from the Anasazi great house at Aztec Ruins National Monument in Aztec, New Mexico. The results of this study demonstrate that quantifiable differences do exist between aspen and cottonwood species and that the technique can be used to separate archaeological specimens of *Populus* wood.

Keywords: ARCHAEOLOGY, ARCHAEOLOGICAL WOOD, WOOD IDENTIFICATION, WOOD ANATOMY, CHACO CANYON, AZTEC RUINS, CHACOAN GREAT HOUSES.

Introduction

The analysis of wood from archaeological sites holds great potential for providing information about the past. Dendrochronology has been used successfully for decades to provide precise dating of archaeological sites (Douglass, 1935; Schweingruber, 1993). More recently, analysis of archaeological wood has been used to provide important information about raw material production (Windes & Ford, 1996; Windes & McKenna, 2001), resource availability (Fitzhugh, 1996) and land use and deforestation (Kohler & Matthews, 1988). Even investigations on deteriorated wood have provided useful information on wood species used, degree of preservation, and past environmental conditions (Blanchette, 2000; Blanchette *et al*., 1994). Regardless of the kind of information being sought, an essential step in the analysis of wood from an archaeological context is identification.

The taxonomic level to which identifications are possible depends on a number of factors including the species being examined and the size and condition of the specimen. Typically, wood identifications are made to the genus level. Identifications to species are very difficult if not impossible since the different species within a genus usually display very similar cell morphology. In order to address some anthropological questions, however, it may be necessary to determine from which tree species a sample of archaeological wood originated.

An example of a case where precise, species level identifications are important is the analysis of wood from Anasazi sites in the San Juan Basin of northwestern New Mexico. Large amounts of wood from a variety of species were used in the construction of Anasazi great houses (Lekson *et al*., 1988), including members of the genus *Populus*. In New Mexico, *Populus* is represented by a number of species in different sections of the genus. These include one species of

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aspen, *P. tremuloides* from section Leuce, and two species of cottonwood, *P. fremontii* from section Aigeros and *P. angustifolia* from section Tacamahaca. In addition, a hybrid species of cottonwood, *P. acuminata* (*P. angustifolia* × *P. fremontii*) also occurs.

Although their ranges overlap, aspen and cottonwood may occur in very different habitats (Harlow *et al*., 1996). Aspen does not currently grow in the immediate vicinity of great houses in the San Juan Basin, but species of cottonwood are common along the rivers, tributaries, and washes adjacent to where many great houses are located. It has been suggested that the regional vegetation has remained approximately the same over the past 2000 years (Betancourt, 1984), and certainly ethnobotanical remains recovered from Anasazi sites reveal that local resources are little changed from today.

Differentiating aspen from cottonwood in samples of wood from Anasazi great houses could provide valuable information about environmental change and shifts in socio-economic strategies related to wood harvesting and construction (Windes & Ford, 1996; Windes & McKenna, 2001). Aztec Ruins, a cluster of Chacoan great houses built in the early AD 1100s, has one of the largest samples of prehistoric wood left of any site in the American Southwest. The West Ruin, which provided the vast majority of materials for this study, still contains about 6000 pieces of visible wood. The majority of this is *Populus* sp. used for door and ventilator lintels and for secondary roof support beams. Builders of great houses in Chaco Canyon, 80 km due south of Aztec, procured 10s of 1000s of beams for construction from around the periphery of the San Juan Basin 60–90 km away (e.g., Betancourt, Dean & Hull, 1986; Dean & Warren, 1983; Windes & McKenna, 2001). The availability of cottonwood stands along the nearby Animas River, a mere 300 m away, however, would have provided the logical source for the prolific use of *Populus* sp. in the West Ruin. Yet, some non-local species of ponderosa pine and spruce or firs were also used in construction at the West Ruin, with the nearest present stands about 18–24 km away. Thus, we cannot be certain that some or all of the *Populus* sp. in the West Ruin is cottonwood without species-level identifications. The differences are profound, with cottonwood being locally abundant but aspen stands located some 50 km or more away. Aside from a shift in labour investments and harvest strategies, the differences in procurement could mark different organizational capabilities. In addition, the unique cluster of conifers constructed in the initial room suites in the West Ruin suggests that *Populus* sp. might also be informative as to room use and differences in social status or groupings.

The anatomy of wood tissue in both aspen and cottonwood is very similar (Hoadley, 1990; Panshin & DeZeeuw, 1970) which makes species level identification in archaeological samples problematic (Figures 1 & 2). Both woods are characterized by a diffuse porous to semi-ring porous distribution of vessels, simple perforation plates within vessel elements, alternate intervessel pitting and homogenous uniseriate rays. Previous anatomical studies have suggested that some species of cottonwood (*P. balsamifera, P. deltoides, P. trichocarpa*) from both the Aigeros and Tacamahaca sections tend to have larger vessels than aspen (Hoadley, 1990; Panshin & DeZeeuw, 1970). To determine if there is a difference in vessel size between aspen and cottonwood from the San Juan Basin, modern samples of aspen and cottonwood were obtained from northwestern New Mexico and southwestern Colorado and detailed measurements of the first-formed earlywood vessels were made. Data obtained from these modern woods were then compared to vessel sizes of prehistoric *Populus* wood samples obtained from different rooms in the Aztec West Ruin great house in Aztec, New Mexico.

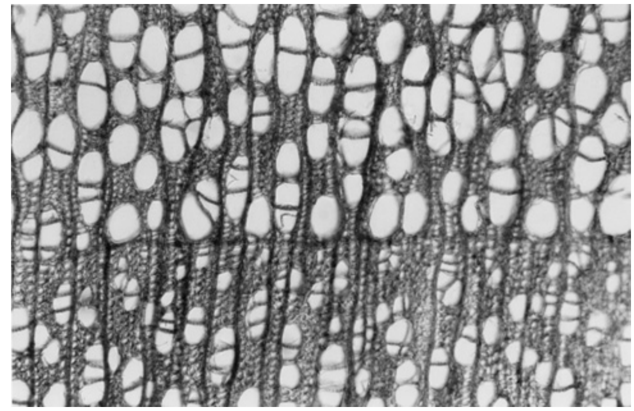

Figure 1. Cross-section of cottonwood comparative sample at 100 × magnification.

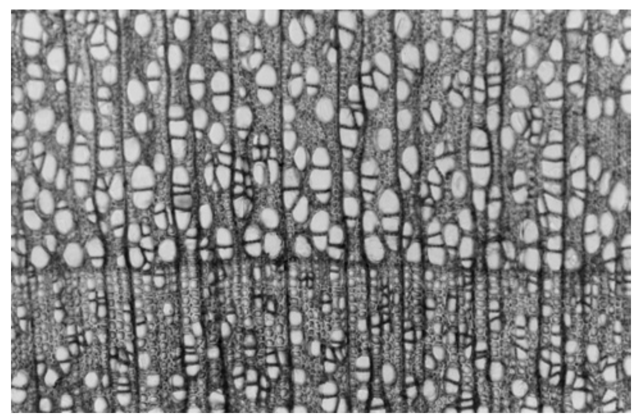

Figure 2. Cross-section of aspen comparative sample at 100 × magnification.

Table 1. Modern aspen and cottonwood samples used for determining differences in anatomical structure

Sample location	Species	Number of samples	Mean pore area (μ^2)
Tafoya Canyon	Aspen	8	1840·03
Sandia Mtns	Aspen	3	1461·51
Colorado	Aspen	10	2114·78
White Mtns	Aspen	3	1462·54
La Plata	Aspen	6	1418·03
Aspen mean			**1834·80**
Chaco Canyon	Cottonwood	6	2894·98
Animas River	Cottonwood	10	2610·52
Cottonwood mean			**2717·19**

Methods

Comparative samples

Thirty samples of modern aspen and 16 samples of modern cottonwood were obtained for comparative purposes from a variety of locations in New Mexico, Colorado and Arizona (Table 1). Aspen samples were collected from Tafoya Canyon, New Mexico (n=8), the Sandia Mountains, New Mexico (n=3), Dolores (n=10) and La Plata (n=6) counties, Colorado and the White Mountains, Arizona (n=3). Cottonwood samples were collected from along the Chaco Wash in Chaco Canyon adjacent to Pueblo Bonito (n=6) and along the Animas River adjacent to the Aztec Ruins (n=10). Wood was obtained from the trunk or branches of trees with approximately the same diameter as the archaeological wood found in the Aztec Ruin great house.

Archaeological samples

Fifty-one archaeological samples were recovered from latillas (secondary roof beams) and door and ventilator lintels at Aztec West Ruin great house in Aztec, New Mexico (Table 2). Archaeological specimens were collected during sampling carried out for the Chaco Wood Project (Windes & McKenna, 2001) and were obtained by sawing pieces from beams or by coring. To faciliate analysis, samples were organized by their field identification numbers into seven groups; 900s, 1000s, 1100s, 1200s, 1400s, 3000s and 4000s. All specimens in the 900s and 1400s groups were recovered by coring, while the remainder of the archaeological specimens was obtained by removing small sections from latillas.

Sample preparation

Thin sections of the transverse plane were made from each modern and archaeological specimen. These sections were mounted on a glass slide for observation using a compound light microscope. In addition, radial sections were made for each archaeological specimen to confirm that the wood was *Populus*. One archaeological specimen, 1128, was identified as *Salix* sp. based on the presence of upright ray parenchyma cells and was removed from further analysis.

Table 2. Samples of wood from latillas (secondary roof beams) and door/ventilator lintels at West Ruin Great House, Aztec Ruins National Monument, Aztec, New Mexico used for analyses

Number	Size (μ^2)	Probability that unknown specimen is aspen
1471	896·36	0·991695252
1473	952·74	0·990144603
1436	1089·57	0·985087991
1472	1125·56	0·983378308
1435	1211·95	0·978449569
1011	1347·47	0·967714528
1006	1370·75	0·965409938
1442	1416·70	0·96038737
1474	1421·55	0·959818116
1470	1455·28	0·955637061
1007	1494·98	0·95018436
981	1509·86	0·947981348
1231	1518·05	0·946729822
980	1562·85	0·939366785
998	1568·84	0·938312916
992	1708·27	0·908443338
1476	1778·60	0·888872223
4813	1780·66	0·888247187
1232	1785·78	0·886680376
1230	1822·52	0·87486707
996	1888·40	0·851046062
3540	1963·60	0·819417363
978	1966·89	0·817920838
1177	1988·05	0·808065134
1061	2002·72	0·800996715
1146	2048·27	0·777812432
3359	2069·11	0·766581241
1090	2112·60	0·741896047
1475	2134·89	0·728603098
994	2138·83	0·726209248
1155	2144·02	0·723035927
3596	2368·32	0·567653113
3337	2432·71	0·518736636
3338	2438·48	0·514321459
3336	2478·37	0·483773841
1097	2547·37	0·43134792
3594	2617·00	0·379961757
3340	2694·23	0·325995139
3715	3092·66	0·124858539
3713	3103·96	0·121123997
3711	3147·57	0·107603572
3714	3161·78	0·103493365
3592	3227·18	0·08632201
3716	3333·47	0·063859387
3341	3376·01	0·056495985
3591	3733·50	0·019630712
3593	3871·25	0·012959005
3539	3921·89	0·011117124
3335	5199·13	0·000224425
3712	5563·59	0·000073474

In order to prepare thin sections, a small piece was cut from each comparative and archaeological specimen. The segments cut from each specimen were in turn cut into smaller pieces, which typically measured

1·5 × 1·5 × 0·5 cm. Before sectioning, the small wood segments were softened by boiling for up to 2 h depending upon the condition of the specimen. Modern samples required boiling for the longest time, while decayed or degraded archaeological samples were only boiled for approximately 0·5 h.

After the specimens were softened, transverse sections were made using a razor blade. The cutting surface was lubricated with a 50% alcohol:50% glycerin solution. These sections were placed on glass slides, mounted in a few drops of the same alcohol/glycerin solution and covered with a cover slip. Multiple slides of each specimen were made, with each slide containing sections (usually four) from a single (1·5 × 1·5 × 0·5 cm) piece. Slides were then heated to drive off air bubbles, and the edges of the cover slip were sealed with Permount mounting medium (Fisher Chemicals, Fair Lawn, New Jersey).

Measurement of vessel area

Previous anatomical investigations have noted that the vessels of some species of cottonwood tend to be larger than those of aspen (Hoadley, 1990; Panshin & DeZeeuw, 1970). The method used here to differentiate aspen from cottonwood is based on differences between the two groups of species in mean area of the first-formed vessel elements in the earlywood. For this study, pore size was represented as area in cross-section, measured in square microns, rather than length and width. Taking a single measurement saved time and it was reasoned that area measurements should stay approximately the same even if the actual shape of the vessel was slightly distorted during the making of thin sections.

The area of earlywood vessels was measured using NIH Image, a program for the analysis and processing of images developed by the National Institutes of Health and available on the Internet (*http://rsb.info.nih.gov/nih-image/*). Using a Leitz Labor lux S compound transmitted light microscope with a Panasonic GP-KR222 digital video camera mounted on a 0·5 × camera tube, images of earlywood vessels were captured at 400 × and displayed on a Macintosh computer. Once images were captured and displayed, NIH Image was used to obtain vessel area. In order to record vessel area in square micrometers at this magnification, the scale was set at 2·058 pixels per micron. Manual area measurements were made by outlining the interior surface of selected pores using the freehand selection tool, then selecting the measurement command with the area measurement enabled.

Measurement protocol

In order to consistently measure the same features among different specimens, the following measurement protocol was used for both archaeological and modern wood specimens. Area measurements were made only on the first-formed earlywood vessels of an annual ring. These were defined as vessels in direct contact with the radially flattened cells that demarcate the edge of a growth ring. Vessels themselves were usually easily identified on the basis of their relatively large size. However, in some specimens, earlywood vessels appeared to be quite small. In these cases, the presence of intervessel pitting in vessel walls was helpful in distinguishing pores from the lumen of other cells. If cell identification could not be determined or if the pore was excessively distorted or damaged it was not measured.

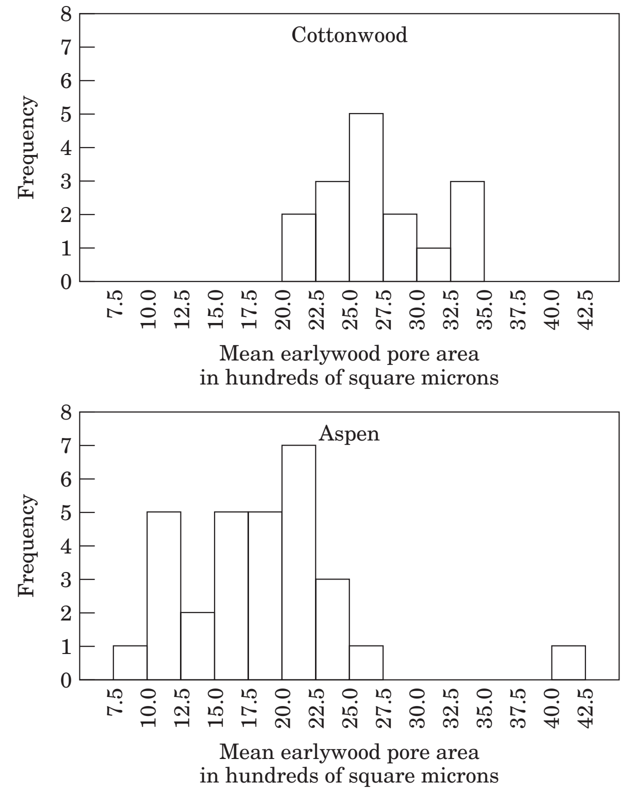

Figure 3. Frequency distributions of mean earlywood vessel areas for aspen and cottonwood.

In order to prevent measuring the same vessel more than once, measurements were only made on one thin section per slide. One hundred vessels were typically measured on each comparative specimen. Fifty vessels were typically measured on each archaeological specimen. Excessive biodeterioration or poorly cut sections made it impossible to count 50 vessels for five of the archaeological samples: 996 (n=48), 1007 (n=43), 3594 (n=29), 3712 (n=45), 3713 (n=48). The area measurements for individual vessels were entered on a spreadsheet and mean vessel area was then calculated for each comparative and archaeological specimen.

Analysis

Generating frequency histograms for the average earlywood vessel area of the modern samples of aspen

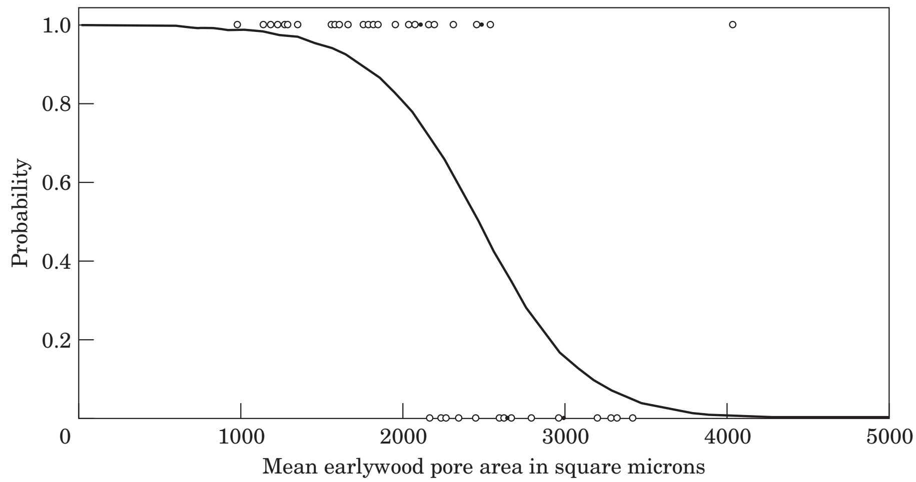

Figure 4. Probability that a specimen is aspen based on mean earlywood vessel area.

and cottonwood revealed overlapping distributions with approximately similar shapes, although the aspen comparative samples included a single anomalously large value (Figure 3). Assuming that these distributions are representative, Figure 3 strongly suggests that unknown specimens with an average vessel area less than 2000·00 square microns are aspen. However, the identification of unknown specimens with average vessel areas larger than 2000·00 square microns is more ambiguous. Specimens with an average vessel area larger than 2750·00 square microns are probably cottonwood, although the presence of the outlying aspen value suggests that very large average vessel areas are possible for aspen. Specimens with average vessel areas between 2000·00 and 2750·00 fall into the overlapping portions of the two distributions and could be either species.

Logistic regression analysis provides a method of determining the probability that an unknown *Populus* specimen is aspen or cottonwood. This method is used in the study of dichotomous populations that share overlapping distributions for some trait. Logistic regression analysis produces coefficient estimates (B_0 and B_1) that can be used to determine the probability that unknown specimens belong to one of the two populations. This probability is determined by inserting the coefficient estimates into the equation below along with the value of the trait (in this case mean pore area) of the unknown specimen.

$$p = 1/1 + e^{-[B_0 + B_1(\text{mean pore area})]} \qquad (1)$$

It was decided to let p in the above equation equal the probability that an unknown sample was aspen. Aspen comparative samples were assigned a response variable with a value of one, while cottonwood comparative samples were assigned a response variable with a value of zero. The mean vessel areas of modern aspen and cottonwood specimens and their associated response variable values (one or zero respectively) constituted that data set that was analysed using logistic regression.

The actual analysis was carried out using Arc statistical software for regression analysis. This software was developed by the School of Statistics at the University of Minnesota and is available on the Internet (http://www.stat.umn.edu/arc/software.html). This analysis produced the following coefficient estimates:

$$B_0 = 7{\cdot}52917$$

$$B_1 = -0{\cdot}00306415$$

Inserting these coefficient estimates and the mean vessel area of an unknown sample into the above equation determines the probability that an unknown specimen is aspen. Because there are only two possible identifications, Equation 2 gives the probability that an unknown sample is cottonwood.

$$1 - p = \text{probability a specimen is cottonwood} \qquad (2)$$

The relationship between average vessel area and the probability that an unknown specimen is aspen is shown in Figure 4. Individual aspen and cottonwood samples are displayed as points distributed by mean vessel area with a probability of one or zero respectively. The curve joining the two groups of points represents the decreasing probability that a sample is aspen as vessel size increases. A mean earlywood vessel area of 2458·18 microns produces a 50% probability that a specimen is aspen (Figure 4). Specimens with a mean earlywood vessel area less than 2458·18 microns are probably aspen and specimens with a mean earlywood vessel area of more than 2458·18 microns are probably cottonwood. When the outlying aspen value was dropped from the analysis, a mean earlywood vessel area of 2336·43 microns produced a probability of 50%.

Results of Logistic Regression Analysis

Using logistic regression analysis, the probability that a given specimen was aspen was determined for the 50 archaeological samples. Table 2 displays this data arranged by decreasing probability. The majority of specimens ($n=35$) have a mean vessel area of less than 2458·18 microns and a probability of greater than 50%. These specimens are probably aspen. Sixteen specimens have a mean vessel area of greater than 2458·18 microns and an associated probability of less than 50%. This suggests that these specimens are cottonwood. Interestingly, all but one of the specimens with a probability of less than 50% belongs to the 3000s group of archaeological samples. Five specimens from the 3000s fall above the 50% probability line.

Conclusions

The measurements of earlywood vessel area made on modern samples of aspen and cottonwood, support the observation of Hoadley (1990) and Panshin & DeZeeuw (1970) that cottonwood tends to have larger vessels than aspen. Furthermore, this relationship between size and species appears to hold true for aspen and cottonwood native to the San Juan Basin. However, the presence of one modern aspen specimen with an extremely large mean vessel area indicates that this relationship is not fully understood. This individual may represent a hybrid *Populus* species with both aspen and cottonwood parentage. Additional samples of aspen and cottonwood have been collected to investigate this issue and to increase the precision of the statements of probability obtained through logistic regression analysis. Applying this relationship to the archaeological record through the use of logistic regression analysis demonstrates that quantifiable differences in mean vessel area do exist in archaeological samples and suggests differences in the use of *Populus* species at Aztec West Ruin. The identity of *Populus* varieties provides important clues regarding the selection and labour requirements of construction in Chacoan great houses. A great deal of care and effort was expended on the construction of some of the rooms within these structures. This suggests the special significance and importance of these rooms. For instance, the center core rooms at the Aztec West Ruins, constructed at about AD 1110–1113, show great care in the setting of the closing splints above the roof secondary beams and in the use of non-local wood for the roof primaries and secondaries. In addition, beam-end treatment (Windes & McKenna, 2001) indicates a remarkable amount of effort in finishing and displaying beam ends in the centre core rooms.

Populus secondaries are widely used at the site and might reasonably be expected to be cottonwood, which grows along the nearby Animas River and its tributaries. The identification of this wood as aspen, however, marks a shift in expedient behaviour by the great house builders, requiring procurement from some distance away from the site. Aspen also might have esthetic (e.g., a golden colour when aged) and strength qualities that cottonwood does not possess. The selection and specific functional use of aspen at Aztec and most other great houses that lie far from aspen West Ruin sources, indicates a labour investment that suggests the special importance of the rooms in which it was used. This may be supported by the use of other non-local woods (such as spruce and fir) in the same locations.

Based on this initial study, the analysis of earlywood vessel area appears to provide ethnobotanists with a relatively simple method for separating species of *Populus* used in the construction of Chacoan great houses. Continued investigations to identify the *Populus* species from other areas of Aztec West Ruin built at different times and from *Populus* wood used in other great houses of the region will undoubtedly provide new insights on wood species procurement and use by the Anasazi.

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