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TECHNICAL NOTE

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Estimation of Postmortem Interval (PMI) as Revealed Through the Analysis of Annual Growth in Woody Tissue

ABSTRACT: The discovery of human remains lying across a black spruce (*Picea mariana*) leader (branch) that subsequently grew up around the remains provided an opportunity to use the growth ring pattern to estimate the postmortem interval (PMI). As these remains were discovered in an advanced state of decomposition in October of 2000, and it was clear that relevant insect evidence was not forthcoming, this novel approach to estimating PMI was proposed. The asymmetrical growth of the leader resulted in a correspondingly asymmetrical pattern of its growth rings. As the date of cutting the leader was known, it was possible to evaluate the asymmetrical growth pattern to provide an estimation of PMI. Fine polishing of the cross section and computerized quantification of ring widths enabled an estimation of the displacement of the leader, and hence the time the decedent's body was so positioned. By charting the ring-width differential for the leader, it was concluded that the displacement occurred sometime between July of 1993 and May of 1994. The actual date of disappearance was confirmed to be August 24, 1993.

KEYWORDS: forensic science, forensic botany, postmortem interval, dendrochronology

The analysis of plants in forensic contexts, known as forensic botany, is recognized as a potentially valuable source of information (1,2). Traditional analyses of botanical evidence include stomach contents analysis for last meal determination and digestion for postmortem interval estimation (PMI), pollen analysis for geographic locality, fungal analysis for PMI and locality, algae, including diatoms, for location, and DNA for linking plant remains to a suspect, scene, or victim (1). In one famous instance, a portion of the ladder used in the Lindbergh kidnapping case was anatomically compared on the basis of the grain, or tree rings, and demonstrated by Arthur Koehler as having been part of a floorboard in Hauptmann's attic (3).

Plants are ideal indicators of time. Interspecies variation and climatological considerations result in variations in growth patterns and rates. Timing may be indicated through the presence of leaves, flowers, fruits, growth of branches, pollination, and even the shedding of leaves (1). The recovery and associated succession of species in disturbed areas may also be used as indicators of recent disturbance. The decomposition and accumulation of leaves in outdoor contexts may be a valuable indicator of larger spans of time. However, the application of tree ring analysis as a means of estimating PMI has not been prominently noted in the professional literature. Further, forensic anthropologists, who are usually consulted in such cases, may not be aware of the analytical avenues offered by forensic botany in order to arrive at an estimation of PMI.

The analysis of annual growth rates in tree rings, the discipline of dendrochronology, has traditionally been used as both a management tool in forestry and to infer past climates by those chronicling climatic change. Archaeologists have also taken advantage of this method for dating archaeological sites in the American Southwest. The growth of any individual ring depends not only on the environmental conditions at a given time but also on mechanical stresses such as slope, snow creep, or partial wind-throw. Each of these conspires to displace the stem from the vertical. The response of a tree to such displacement is to develop "reaction wood" that produces a ring that is not uniform all the way around the stem. The resulting rings become elliptical due to the greater growth on one side of the stem than the other owing to an increase in localized cambial activity. In the case of conifers, the greater growth occurring on the lower side of the stem is referred to as "compression wood." This growth is analogous to a buttress placed against a leaning wall. In deciduous trees the same result is achieved by means of greater growth on the upper side of the stem. This is termed "tension wood" and is analogous to the stay on a mast or guy on a tent pole.

The discovery of a clothed, but highly decomposed, human body in a forest setting provided the opportunity to test estimating the PMI through growth ring analysis. At the time of death the body fell on a young black spruce (*Picea mariana*) leader (terminal shoot) that subsequently grew up around the body in an attempt to regain its normal vertical growth. This technical note outlines how the analysis of growth rings, in this context, was key in the estimation of PMI. The potential for the analysis of woody plant material as an aid to estimating PMI in forensic contexts is also presented.

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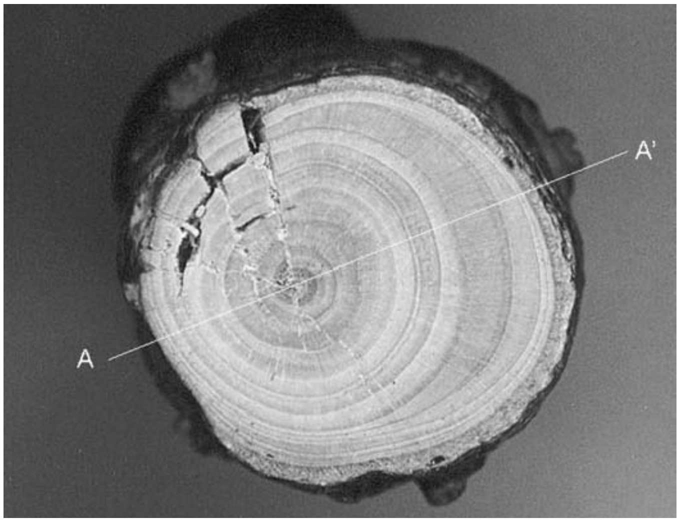

FIG. 1—*Cross section of black spruce terminal shoot cut from beneath a human corpse. Measurements of ring widths were made across diameter A–A′.*

Methods

The investigating team saw fit to have the remains of the body and all woody plant material lying beneath and around the body, moved to the Forensic Osteology Laboratory (FOL) at Laurentian University for further study. A branch of black spruce upon which the body had fallen had continued to grow and its terminus had regained its normal, vertical growth form. The base of the branch, at the point where it had been cut by the investigating team in the field, was carefully re-sawn with a razor saw to provide a flat cross section and then the surface finished to a fine polish by an established dendrochronological technique (4,5). This involves sanding the wood surface with sand paper of progressively finer grit size as follows: 80, 120, 180, 240, 320, 360, 400, and 600 grit. From 80 to 240 grit, the paper was backed with a flat wooden block. For the finer grades the paper was backed by a pencil eraser 6 cm long and 2 cm wide. The advantage of the eraser is that its "give" allows the paper to conform to any ripples in the wood. The section is considered to be ready for analysis only when individual cells may be observed with a $\times 10$ power hand lens.

Ring widths were measured by means of an image analysis system that consisted of a Cohu solid-state video camera (Model 4815) mounted on an Olympus SZ40 binocular dissecting microscope and coupled to a computer system consisting of two monitors, one for viewing the image and the other to enable use of the JAVA (Jandel Inc.) software to perform the actual measurements and to transform the data. Calibration of the optical system was achieved using a high-quality centimeter scale and ring widths were measured to the nearest 0.01 mm. The deposition of compression wood, in the years following disturbance of the branch upon which the body had fallen, resulted in ring widths that were markedly different on the inner and outer side of the branch. Ring widths were measured across a diameter that ran through the pith from the narrowest to the widest section of the stem, section A–A′ in Fig. 1.

Results

The presence of many black spruce needles attached to the clothing of the deceased was noted when the body was examined at the FOL at Laurentian University. A terminal shoot of black spruce with needles attached provided the material necessary for a positive identification.

Black spruce is unique among North American conifer species in that it exhibits layering of lateral branches. Owing to a habit of growth in which the lowermost branches arch down towards the ground, it is not uncommon for the lowest point of the arch to touch the ground, become covered with leaf litter or peat moss, and for the branch to establish a root system at that point. Over a period of decades this process can occur a number of times away from the original tree stem and leads to a growth form that foresters refer to as "Candelabrum Black Spruce" (6). The importance of this growth pattern is that the opportunity for the body to fall on a relatively young black spruce terminal shoot or leader in such an environment was very much improved and led to the opportunity to use botanical material to estimate PMI.

Ring width measurements (Fig. 2) across section A–A′ (Fig. 1) reveal that growth was generally greater in the early years of its growth, 1987–1996, than subsequently, revealing little in regard to when its vertical orientation was disrupted by the displacement caused by the body of the deceased.

In order to better visualize the eccentric growth that is clearly visible in Fig. 1 the ring width difference for each ring was obtained by subtracting the ring width on the left-hand side of the center from the ring width of the same ring on the right side of the center (Fig. 3). The years 1987 through 1992 demonstrate normal variation in ring width, likely reflecting environmental conditions. The year 1994 shows a dramatic increase in ring width difference with the side on the right of center—the side away from the body—laying down

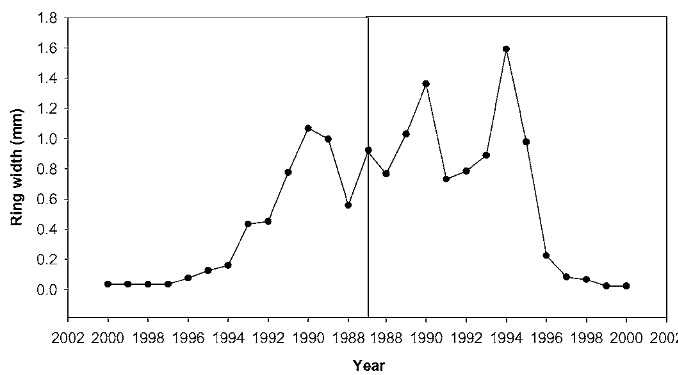

FIG. 2—*Chart of individual ring-width measurements, in millimeters, across section A–A′, as taken from black spruce cross section shown in Fig. 1.*

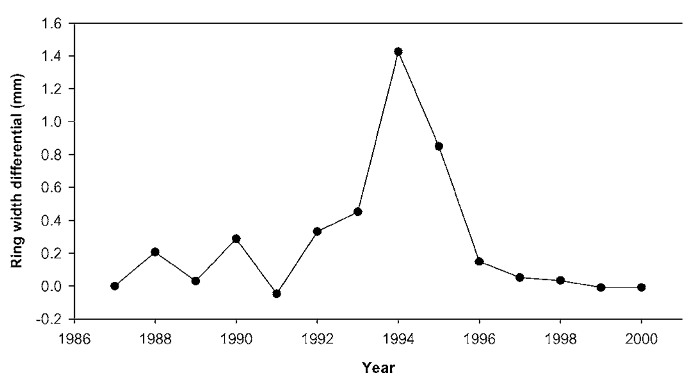

FIG. 3—*Chart of ring-width differential, measured in millimeters, for section of black spruce stem shown in Fig. 1.*

more wood with respect to the same rings on the left of the center. In 1995, 1996, and 1997 there was a progressive decrease in ring width difference after which, until the branch was cut in late 2000, there was essentially no difference in ring width from one side of the stem to the other.

Discussion

The dramatic increase in ring width difference that began in 1994 (Fig. 3) was a response of a branch that had been displaced horizontally from the vertical at the time of the death of the victim. The above-ground parts of all plants grow upwards towards the light, or counter to the force of gravity, a habit referred to as antigeotropism (7). If a normal-growing shoot is placed horizontally certain cell organelles called statoliths sink to the lower side of the cells and, by applying pressure to the endoplasmic reticulum, trigger greater elongation of cells on the lower side by changing the concentration of the plant growth substance (i.e., indole acetic acid). This asymmetry continues until the shoot once again regains verticality.

Figure 3 clearly demonstrates the reaction of the shoot away from the body to a maximum in 1994 and then a reduced rate as the shoot became more erect until 1996, when no further change was noted as the shoot was once again growing vertically. Eccentricity was first noted in the 1993 growing season but one must question whether the difference in growth from one side of the stem to the other lies outside of natural variability. The growth differential in 1994 is unmistakable and suggests that the stem/shoot had been displaced sometime between the end of the 1993 growing season and the beginning of the 1994 growing season.

The body was found clothed in a snowmobile suit, which suggested that the weather had already turned cold. Nevertheless, a conservative estimate of time of death was between July of 1993 and May of 1994. Upon investigation it was found that cause of death was suicide rather than homicide and the deceased was registered as missing on August 24, 1993.

Conclusion

Although the circumstances that led to the body falling on a young shoot of a particular species of tree must be considered serendipitous, the results from the investigation demonstrate the potential for living plant material to be used as an important source of forensic evidence under certain circumstances. This particular case emphasizes the need for an investigating team to consider whether or not botanical material might be of value in their investigation.

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