A Dendroarchaeological Analysis of the Moffatt Stick

Amanda B. Young, Ben Phillips, Andre Robichaud,
Colin P. Laroque, James Ehrman, Adam Karpowitcz and Mark Presley

MAD Lab Report 2010-18

Mount Allison Dendrochronology Laboratory,
Department of Geography and Environment,
Mount Allison University

Table of Contents

Abstract

The particular situation of the hand-carved Moffatt hockey stick makes it unique among old hockey sticks in that it has a ring pattern evident to allow crossdating of the stick against a known master chronology. Added to this, the particular way in which the stick was carved from one solid piece of timber left evidence that the perimeter of the tree is near the outside of the shaft of the stick. An analysis of the ring-widths was conducted and two paths were measured from the butt of the stick (42 and 43 years long). A local sugar maple chronology was developed from the Pottles Lake region of Nova Scotia where the stick originated and a crossdate of 1815 was achieved against a time period where limited sample depth exists in the master chronology. Added to this date are seven rings that can be seen on the rounded portion of the butt, and six more rings where tangential wood illustrates that material was carved away. These additional rings add up to a minimum outside date for the wood of 1828, with additional rings needed to get to the wood/bark interface. We estimate that there was an additional seven to ten rings present. Although the sample sizes are low for the crossdates and further research will continue to strengthen the pattern match, the dendrochronological data fit well with the archival details suggesting the stick was originally made for WM "Dilly" Moffatt sometime in the 1830s. This evidence would suggest that this is the oldest "hockey" stick known to exist in Canada.

Introduction

In the winter of 2009, the Mount Allison Dendrochronology Laboratory (MAD Lab) was contacted by the owner of the Moffatt Stick to see if we could assist in helping to discern the date of a stick he owned. Although the object was unusual, and probably difficult to date, we agreed to conduct an initial assessment.

Figure 1. The owner (standing) behind Amanda Young (sitting), during the initial scans of the butt of the stick. Initial scans indicated that there were potentially enough rings visible to retrieve an overall pattern of radial growth from the stick.

An overall plan of scientific inquiry was formulated for this history mystery. Establishing the date of the stick would be difficult, but given enough time and some luck, the MAD Lab decided to attempt the work. The plan was broken down into four stages. The Mad Lab needed to establish a radial-growth pattern from the rings from the stick itself. Statistically, a higher number of rings is best, but the absolute minimum was set at 30. The second phase of the plan called for the MAD Lab to create a master chronology of the radial-growth pattern of the trees growing near the site where the wood used to create the stick was harvested. The third phase was to check the layers of paint and varnish. The layers of paint could be used to help tell the story of the history of the stick. To test against an attempt at a forgery, we wanted to try to establish that a consistent "time" sequence of paint was layered on the stick. Finally, all of the evidence would be put together to try to establish as close as possible the date that the stick was created.

Establishing the ring pattern on the stick

Since the artifact could possibly be of high monetary value, we were unable to destructively sample the object, so we were limited to sample only what we could see. After a quick visual inspection and some buffing, it was clear that the rings on the butt end of the stick were the only place that a radial growth pattern might be achievable. Our first step was to invert the stick on a flat bed scanner (Figure 1) and to take a high-resolution image of the flattened butt end (Figure 2 and 3). Once the stick image was in digital form, we could enhance and degrade various parts of the image to get the ring boundaries as clear as possible by altering the contrast and sharpness of the image.

Two operators working independently traced out the ring boundaries and then measured a path of ring widths (with an accuracy of 0.01 mm) on the image using the software package WinDendro (Figure 2 and 3). The ring boundary patterns were overlapped by a third researcher and the ring boundary assessment patterns were compared (Figure 4). There was good overall visual agreement on the ring pattern, with the weakness being at the edge of the stick where the butt end of the stick starts to round (Figure 4). However, the measurement paths were deemed to be similar enough, and the two measurement patterns were compared (Figure 5).

The measurements of the two independent paths share a good common signal and overall similarity. The first path established 42 measurable rings, while the second path distinguished 43. The ring measurements were subsequently averaged together and used as the stick ring pattern in subsequent analysis.

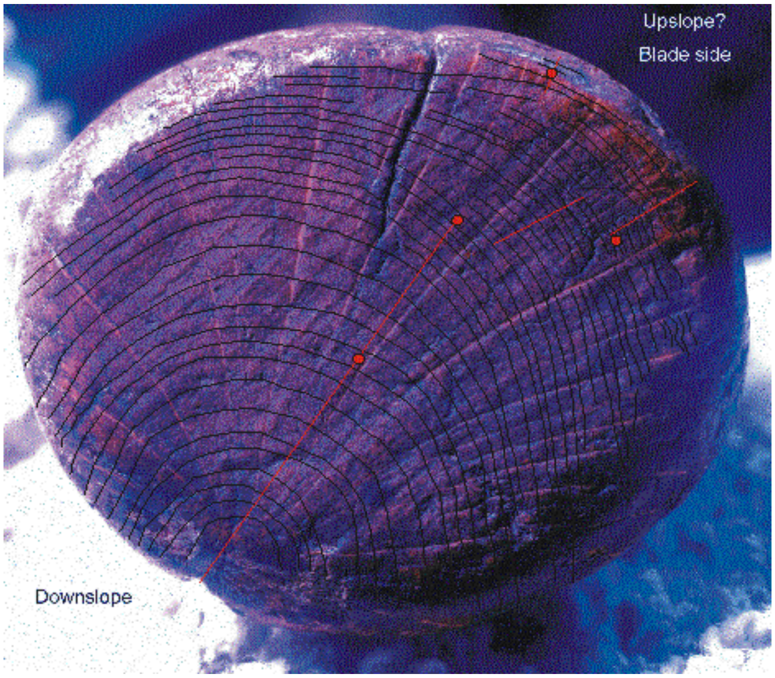

Figure 2. The red line indicates the direction of the first independent path sampled and measured. Overall rings patterns were drawn on the butt in the black lines on the stick in a graphics program.

Figure 3. The red line indicates the direction of the second independent path sampled and measured. Overall rings patterns were drawn on the butt in the black lines on the stick in a graphics program.

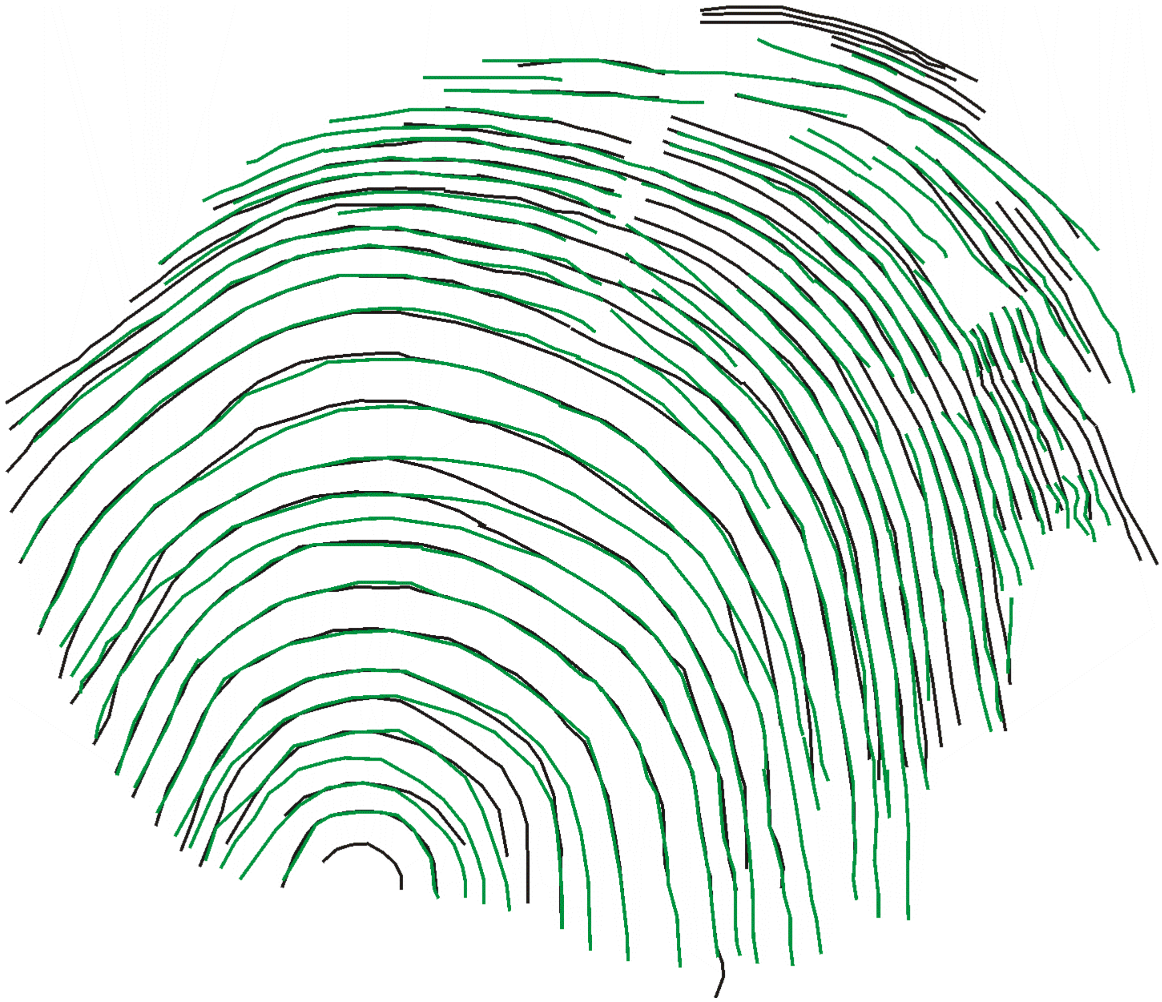

Figure 4. The black and the green lines indicate the comparison of two independent paths visualized by two different researchers. The paths were drawn by using different contrast and light intensities, and then overlapped to help visualize how consistent the ring patterns could be distinguished on the butt end of the stick

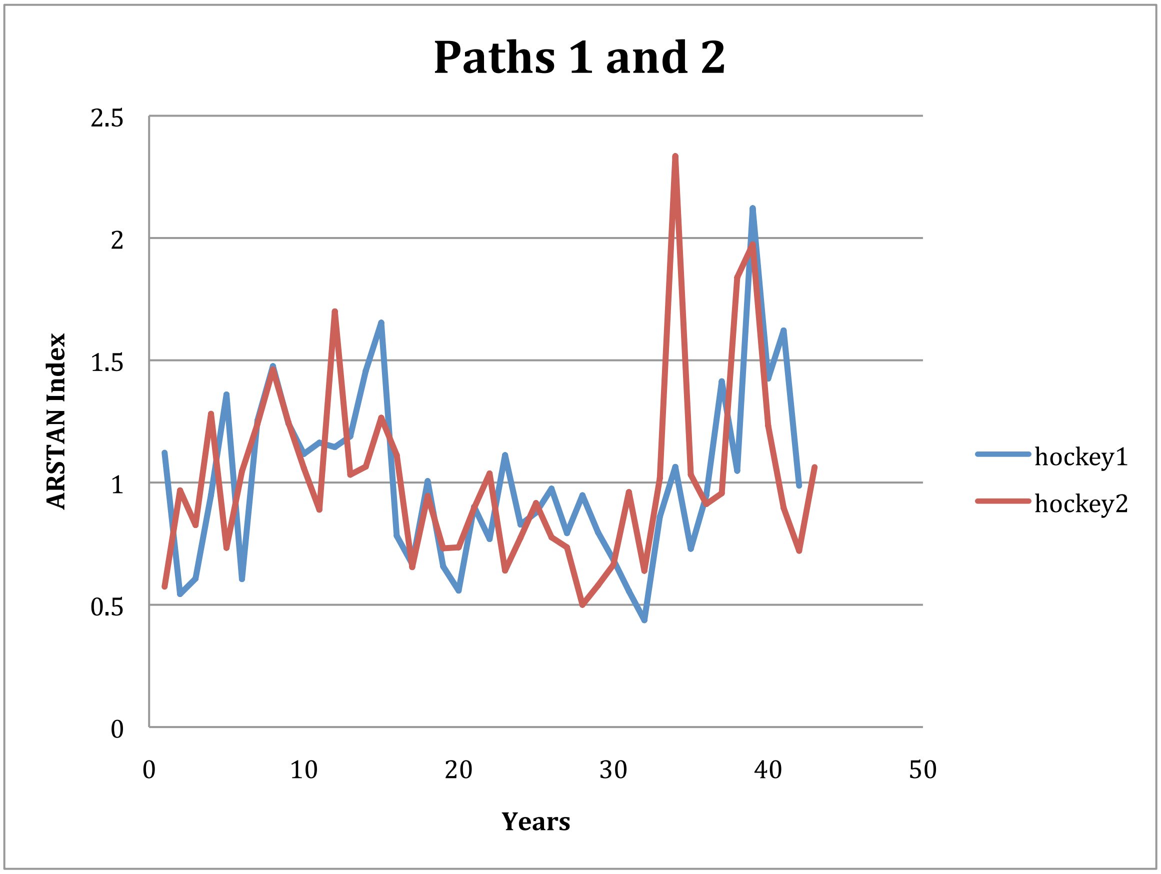

Figure 5. The two lines indicate the two independent paths with their associated measurements (accuracy of 0.01 mm) taken from the butt end of the stick. The two paths illustrate good agreement in overall shape.

Establishing the Master Chronology

In the summer of 2009, four locations around Pottles Lake, NS were sampled (Figure 6, Table 1). Previously the wood of the stick was established as sugar maple (*Acer saccharum*) , and so old sugar maple were sought. They proved very hard to find, but eventually 33 individual trees were found to try to establish a living chronology as far back in time as possible. Standard 5.1 mm increment borers were used to extract samples from the living trees without damaging them. The extracted samples were stored and labeled in plastic drinking straws, and transported back to the Mad Lab for analysis.

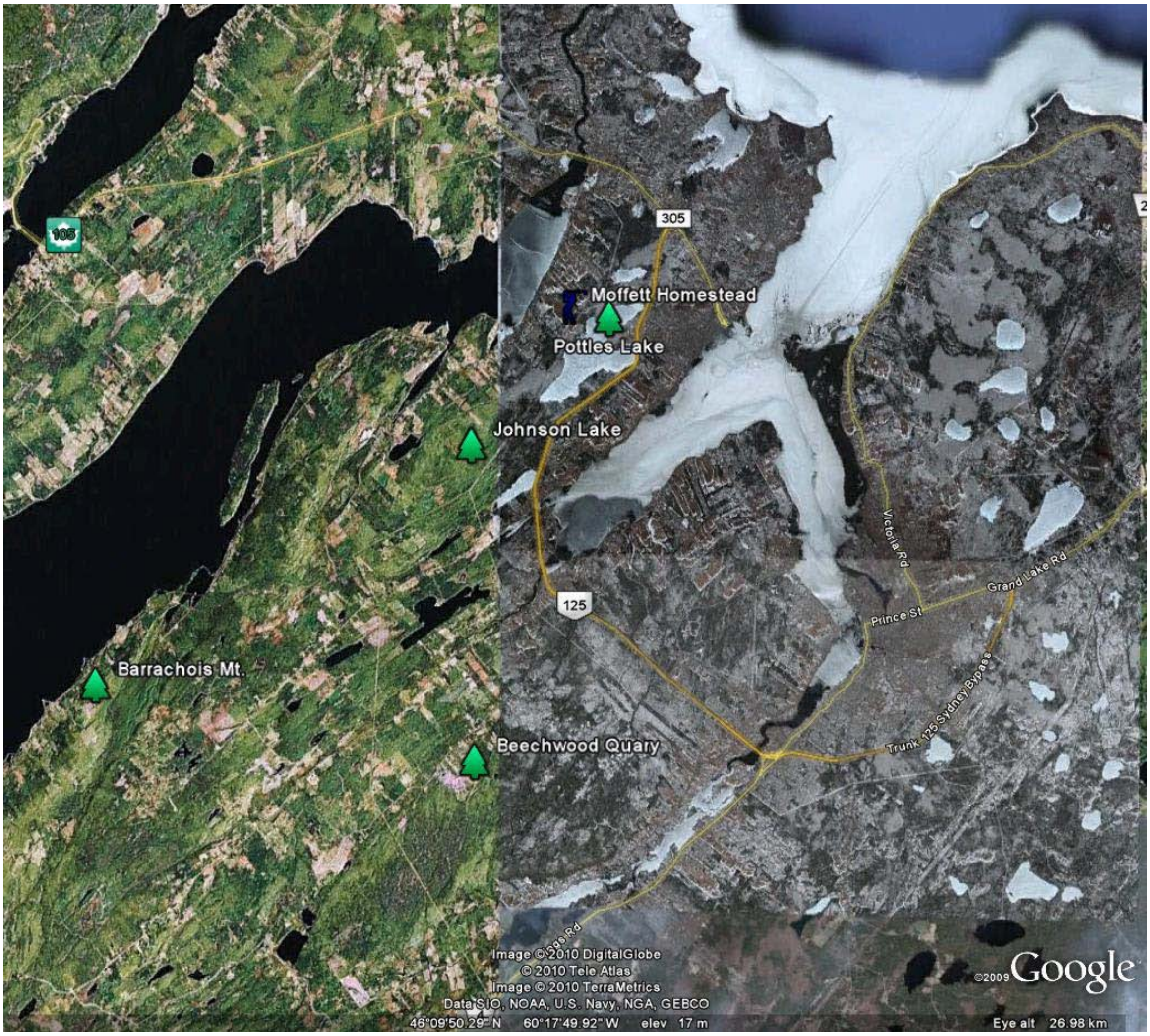

Figure 6. The location of the four sites where living sugar maple (*Acer saccharum*) were sampled in the Pottles Lake region. The sites sampled were Beechwood Quarry, Johnson Lake, Pottles Lake, and Barachois Mountain.

Table 1. A crossdating COFECHA summary Table for samples in the study. Note all samples with correlations above 0.3281 are significant above the 99% confidence interval.

Site	MAD Lab Code	Interval	# of Cores	# of Trees	Series Correlation
Beechwood Quarry	09FLE00	1761-2009	28	14	0.438
Johnson Lake	09ARLE00	1811-2009	9	6	0.256
Pottles Lake	09ASLE00	1919-2009	10	5	0.574
Barrachois Mt.	09ATLE00	1813-2009	8	8	0.487

Once in the lab, each of the samples were glued into slotted mounting boards and sanded evenly with increasingly finer sand paper (80-600 grit), and then buffed in order to bring out the cellular structures and to make the annual rings more visible. A Velmex measuring system was then used to count and then measure the rings to determine the width of each with an accuracy of 0.001mm.

Using the program COFECHA, each individual ring-width series was statistically analyzed and a time series was created. In this step, the samples were pattern matched against each other in order to create a chronology, which covered a time period beginning with the 2009 sampling year. These new chronologies were standardized to have a mean of one by using a negative exponential curve in the program ARSTAN (Holmes 1986). This standardization was completed to allow samples from trees of different ages to be compared via a graph representing the overall growth patterns of the trees from the four sites.

Paint and Varnish Layers

A visual examination of the stick's paint and varnish layers under a 60X microscope discerned five distinct deposits (Figure 7). These layers seemed to be consistent in order across the entirety of the stick. Small flakes from within the travelling case, and also some selected from the stick itself were taken with permission of the owner. The selected flakes were brought to the Mount Allison Digital Microscopy Facility (http://www.mta.ca/dmf/) and prepared for an Energy Dispersive Spectrum (EDS) X-ray analysis in the Scanning Electron Microscope (SEM).

Collected paint chips were mounted onto polished graphite support stubs using colloidal graphite. A number of chips were mounted so that the various colors of finish (black, red, red/brown, green, yellow/white) were oriented on the top surface of the chip for optimum EDS analysis. One chip was sufficiently thick and robust as to allow mounting on edge in the hopes that analysis of layers in this orientation would reduce the likelihood of x-ray contributions from other paint layers below that exposed on the surface (Figure 8).

Navigation to areas of interest for EDS required that the samples be coated with ~10 nm gold for stable SEM imaging. SEM views were correlated to color images taken from the dissecting microscope prior to coating. Analyses were conducted using a JEOL JSM-5600 SEM equipped with an Oxford Inca 200 EDS system and light element detector. X-ray spectra were collected using a 100 s (dead-time corrected) acquisition from 0 to 10 kV into 1024 channels using 15 kV accelerating voltage. The electron beam was rastered over the area of interest at magnifications ranging from 500 to 10,000X, depending on size and homogeneity of the features of interest.

Individual spectra of each paint/varnish layer were collected and provided for chemical paint chip analysis (Figure 9).

Figure 7. An example of an area of the stick surface under high magnification. Cracked and chipped pieces of the paint and varnish layers are clearly visible. In this image, four different layers demarcated by colour can be distinguished.

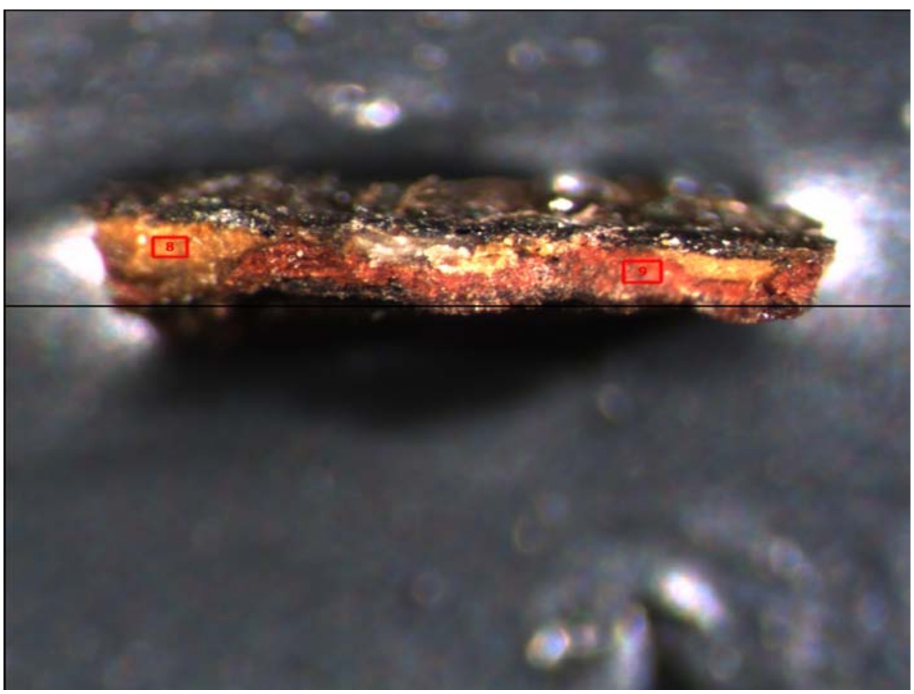

Figure 8. A mounted piece of a paint chip ready for Scanning Electron Microscope (SEM) analysis. The target areas (marked by the numbers 8 and 9 in the red boxes), were selected in regions of individual chips where the layers were deemed to be more pure in characteristics.

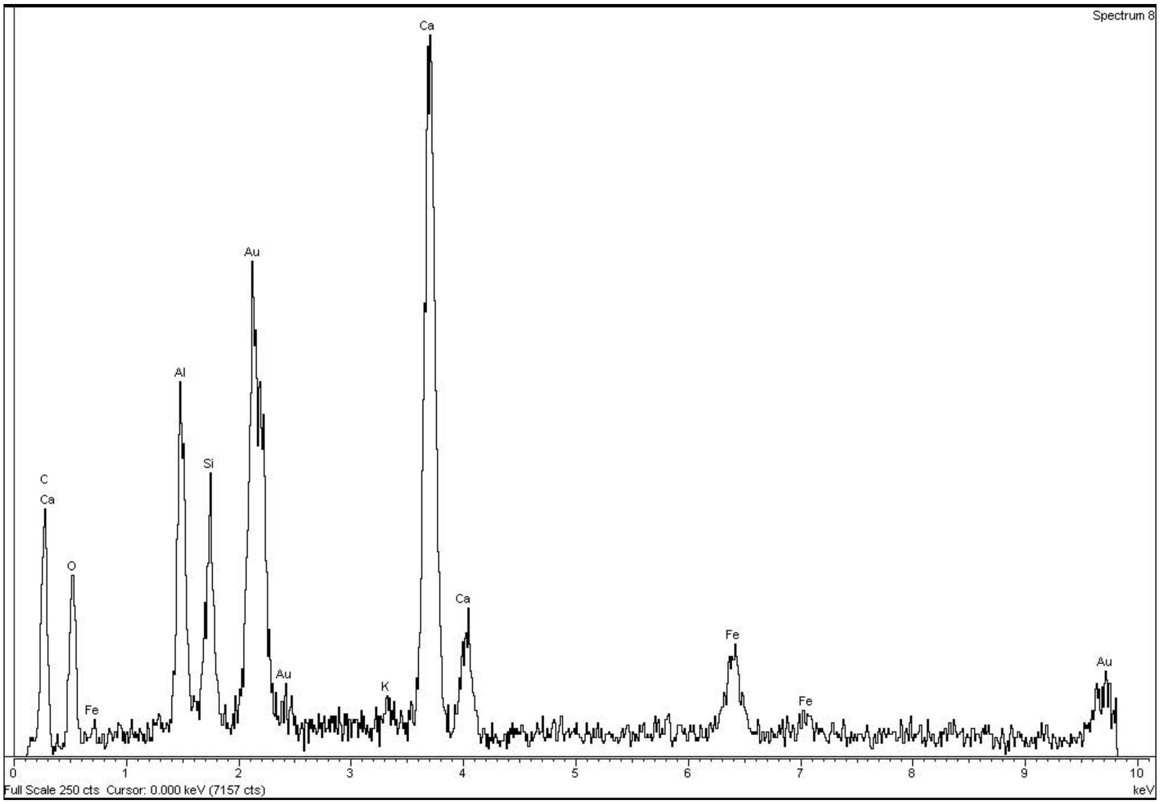

Figure 9. The chemical signature of the mounted piece of a paint chip from the Scanning Electron Microscope (SEM), Energy Dispersive Spectrum (EDS) X-ray analysis. This graph is the spectral array from the target area #8 (see Figure 8), which illustrates a high concentration of calcium (probably in the form of CaCO3).

The subsequent analysis of the chemical and paint textures confirmed the presence of five chemically distinct layers (Table 2). The sequence from bottom to top was as follows:

Layer 1, a dark brown layer of coarsely ground reddish and black pigments, appears to be directly on wood. The chip is composed of natural "red earth" pigment based on iron oxides combined with charcoal.

Layer 2 is a yellowish-white layer that is fairly thick. This layer is a combination of chalk (calcium carbonate) and yellow earth pigment, known in the paint industry as "yellow ochre".

Layer 3 is a red layer consistent with the presence of red, iron-containing earth. These pigments are usually common clays in combination with other minerals, sometimes subjected to high temperature to obtain a redder colour, such as for example "burnt sienna". The apparent presence of lead in this layer may come from an addition of "red lead" (minium, Fe3O4), again a very common pigment, or may come from the lead drier in the oil binder. Metal salts were almost always added to the oil to accelerate drying/hardening. Lead was the oldest drier, later cobalt and manganese became more common. Actually, other layers could contain the lead drier as well. Another very common lead pigment is "lead white" (lead carbonate), which could have been added to the red paint in small quantity for a brighter effect.

Layer 4 is a reddish brown layer, which appears to be a mix of common red or brown earth pigments, containing iron, maybe darkened with some charcoal pigment. The presence of manganese suggests so called "umber", another natural earth pigment.

Layer 5 was seen on the upper most surface of the stick and seen as specks and patches of green. The chemical composition of the 5^{th} layer suggests probably a so called "green earth" paint - a naturally occurring common earth pigment, or a synthetic organic green, perhaps bulked with barium or calcium sulfate/carbonate. The green appears to be quite intense suggesting a synthetic colourant, but this may be misleading, as the greens will stand-out in the presence of the duller, reddish background, so the green earth is still a possibility. Note the green is the last (top) layer and may be quite new.

More exact identification of the pigments could be done by other techniques, but they would likely not contribute any new information as to the age of the stick. All the identified pigments are common through time (with the exception of the upper-most synthetic green). Since the wood of the stick appears quite cracked and damaged *under* the layers of paint, it is very likely it was originally un-painted and "refinished" with paints later, with probably tens of years between application sequences.

Table 2. Layers and chemical signatures of the individual layers distinguished by the SEM EDS analysis.

Layer	Colour/comment	Chemical Signature
Layer 1	-Dark brown -On wood	natural "red earth" pigment based on iron oxides
Layer 2	-Yellowish-white -Fairly thick	"yellow ochre” calcium carbonate based
Layer 3	-Red layer	"red lead" (minimum, $Fe3O4$)
Layer 4	-Reddish brown	"umber“ manganese presence
Layer 5	-Green	“synthetic organic green” barium or calcium sulfate/carbonate

Crossdating the Stick

The four live sugar maple chronologies are illustrated in Figure 10. They all have a good visual and statistical match, but like most chronologies, their weakness is in the earliest years where sample depth is limited. The stick measurements were crossdated against the live chronologies with one suggested pattern match (Figure 10). The pattern match fits into the earliest portions of the live chronologies, and ends in 1815.

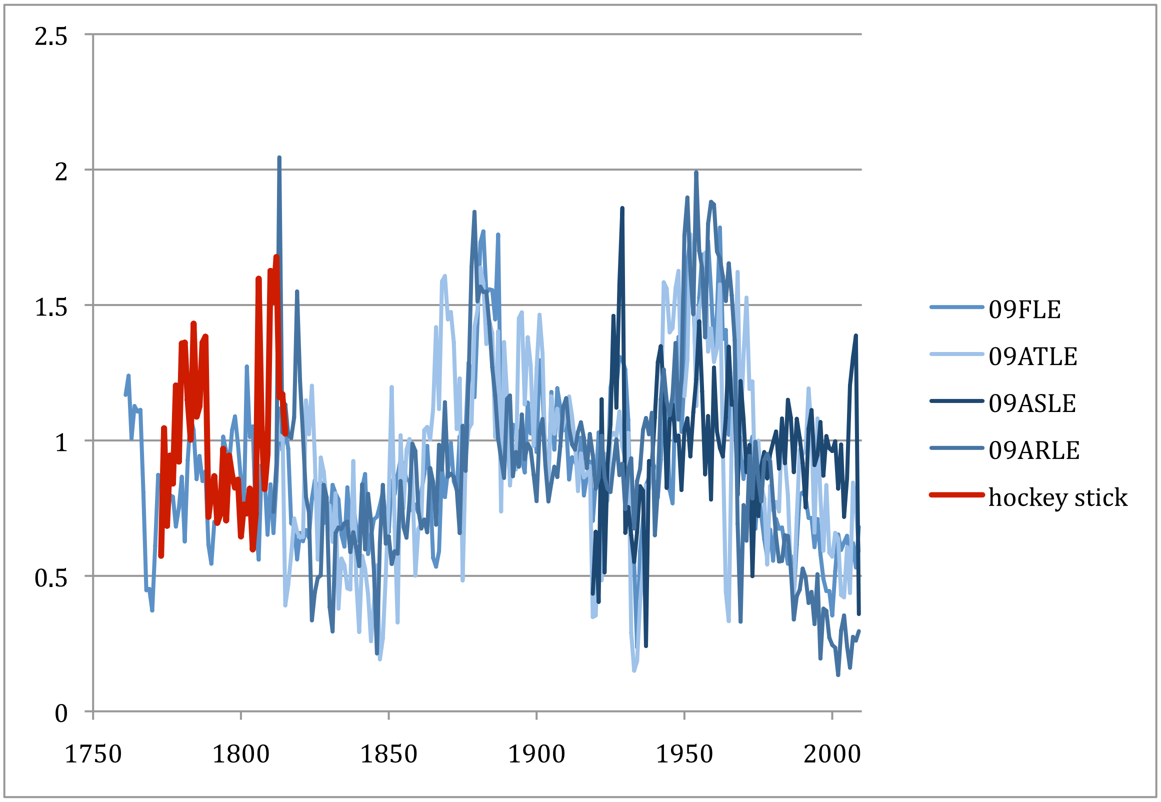

Figure 10. The crossdated chronology of the stick (red line) matched against the living samples of sugar maple collected from the Pottles Lake area in Cape Breton, NS.

Final Ring Count

The MAD Lab was able to distinguish 43 rings in the butt end of the stick. The tree must have been growing very slow under a canopy to have so many rings held within the small diameter of the stick. This 43-year sequence was only able to be pattern matched in one place in time, ending in 1815. This sequence is from the flattest part of the butt of the stick, but more rings are distinguishable on the curved portion of the stick's butt (Figure 11). Seven more rings are clearly visible on the curved portion of butt of the stick, but they cannot be measured with any accuracy as they follow a curved focal plane under the microscope. These additional rings move the minimum date of the wood up to 1822. Six additional tangential (side) rings are visible on the shaft of the stick until a remnant knot is encountered lower portion of the shaft. This additional ring sequence would moves the date of the wood up to 1828. Part of the knot is carved away on the stick, and judging by the knot architecture, we estimate that up to a further seven to ten rings must have been carved off to get to the wood/bark interface. Therefore our approximated year that the wood was cut is 1835 to 1838.

Figure 11. The crossdated ring pattern of the stick was acquired from the flat part of the butt of the stick. The final position in time was adjusted by adding the visible rings and tangential rings visible on the rounded parts of the shaft of the stick.

Conclusions

Paint and varnish chemistry indicates that the sequence of layers is consistent with common paints that existed through time for an object that would have been made in the mid- to late-1830s. The mid-layer position of the lead-based paint fits well for when lead-based paints were more commonly used (early 1900s). The top most placement of the synthetic paint (after the 1940s) also fits well with a stick that would have had nearly 175-years of use. The layers of material, in combination with the patina and natural cracking of the layers, indicate that the sequence of coatings would be very difficult to duplicate.

The wood properties indicate that the wood is sugar maple, and it was hand-carved out of one piece of lumber. After careful examination, we believe the stick was originally a small tree growing along side of a stream bank or cliff edge (Figure 12). It was probably on a site that had stability issues with its rooting structures, and so a naturally occurring j-sweep morphology, allowed the stick to be quickly carved, while the natural strength of the wood could be maintained in the stick. This procedure would have created a robust stick, capable of being used, while still maintaining its structural integrity for over 175 years.

Finally, there are initials carved in the blade of the stick (Figure 13), and by the paint wear pattern, the initials seem to be underlain by all five layers of paint. The initials are clearly "WM" and in the male linage of the stick owners, this would point directly to WM "Dilly" Moffatt (Table 3). Dilly was born in 1829, and if the stick were his, the timeline issued by this analysis would indicate that he was a 6-9 year old boy when he first received the stick.

Table 3. A list of the Moffatt family male lineage starting at Captain James Moffatt, the original Loyalist ship builder that settled in the Pottles Lake/Sidney area. The timeline was supplied to the MAD Lab by the stick owner.

Moffatt Family Genealogy – Direct Male Lineage		
Capt. James Moffatt	b. 1737 - d. 1810	Loyalist
John Moffatt	b. 1777 – d. 1839	Son of above
John Mumford Moffatt	b.1804 – d. 1868	Son of above
WM "Dilly" Moffatt	b. 1829 – d. ?	Son of above
Thomas A. Moffatt	b. 1837 – d. 1911	Sibling of above
Warren C. Moffatt	b. 1881 – d. 1963	Son of above
Charles M. Moffatt	b. 1916 – d. 2010	Son of above

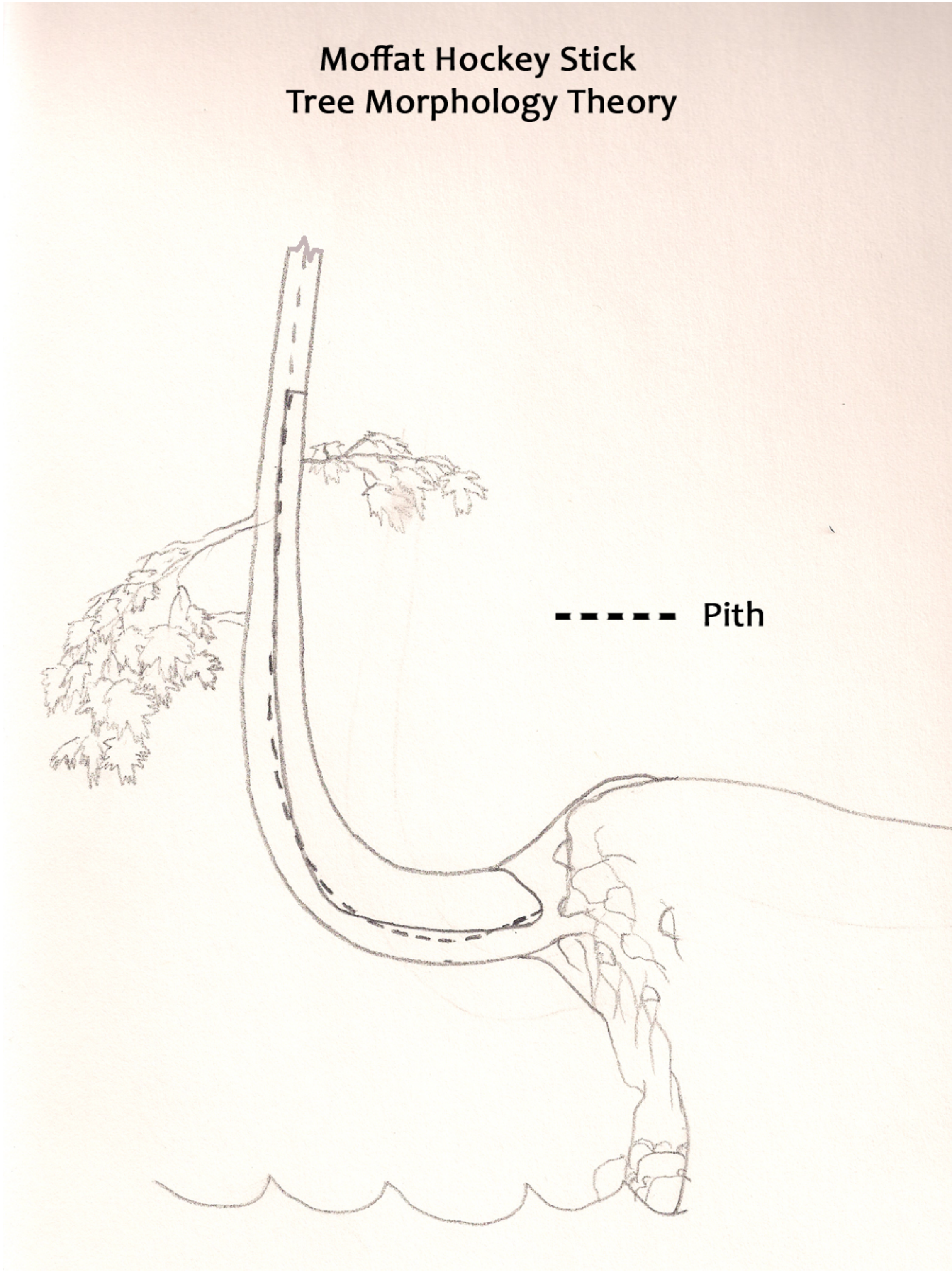

Figure 12. Based on the wood characteristics and the direction of the path of the pith, we believe the stick was originally a small tree, likely growing along a creek or cliff edge.

Figure 13. The stick with the initial “WM” carved in the blade of the stick. By the wear pattern of the paint layers around the initials, it seems that the initials are overlain by all five layers of paint discovered in the analysis.

References

Holmes, R.L., Adams, R.K., and Fritts, H.C. (1986). Users Manual for Program ARSTAN. In: *Tree-ring chronologies of western North America: California, eastern Oregon, and northern Great Basin* (eds R.L. Holmes, R.K. Adams & H.C. Fritts), pp. 50-65. Laboratory of Tree-Ring Research, University of Arizona, Tucson.