

Dendroarcheological Investigation of the Joggins Fossil Cliff Mine Workings, Nova Scotia



Sarah L. Quann, Amanda B. Young, and Colin P. Laroque
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Mount Allison Dendrochronology Laboratory,
Department of Geography and Environment,
Mount Allison University

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Abstract

The Joggins Fossil Cliffs are a popular UNESCO World Heritage Site located on the Bay of Fundy, Nova Scotia. The Fossil Cliffs contain evidence of early British and Acadian mining operations in the form of pit props from the mine shafts. These beams have been exposed over the years through constant coastal erosion by the Bay of Fundy Tides. Throughout the summer, the Mount Allison University Dendrochronology Laboratory (MAD Lab) sampled these exposed beams. A preliminary site overview was conducted in early June and two sampling days followed: June 15 and July 18, 2009. During these two days, 56 samples were collected from 11 clusters of beams. They were separated into two groups based on their position on the cliff; an upper level and a lower level. Once brought back to the Lab, they were dated against a master chronology of red spruce (*Picea rubens*). The cut dates for the upper group average around 1854 and around 1858 for the lower group. These dates correspond to the historical time period when mining by the British was underway and it can be concluded that it was they who mined both the upper and the lower shafts based on the cut dates of the samples.

Introduction

The Joggins Fossil Cliffs were made famous in 1842 after the discovery of fossils dating back to the Carboniferous Period or “Coal Age” by Sir William Dawson and Charles Lyell. The cliffs are located in Nova Scotia, along the Cumberland Basin. Seams of coal are easily discernable between rock layers along the 14.7 km of protected cliff face. Joggins was named a UNESCO World Heritage Site in July of 2008, due to its geological significance. The cliffs have been of an interest to both British and Acadian settlers since the discovery of the exposed and readily available coal in 1686 (Falcon-Lang 2008). Acadians were the first to mine the coal in the cliffs in 1696 until the British took over in 1713 (Falcon-Lang 2008). Fighting between Acadian and British forces ensued, and in the aftermath, mining was actively discouraged by the British in the area for approximately 90 years (Falcon-Lang 2008). Mining operations began again in 1847 by the British. When these mines were eventually abandoned, the wooden pit props supporting the tunnels were left behind. The shafts ultimately collapsed and are now being exposed by erosion from the tides. It is unknown when the current shafts that are visible and being exposed along the Fundy Seam were constructed, or who constructed them, the Acadians or the British.



Figure 1 – An image of the Joggins Cliffs from the beach. Wooden pit props can be seen exposed along the cliff following the bedding plane.

In order to determine when the mine shafts were constructed and who made them, a dendroarcheological investigation was conducted. Dendroarcheology is the field in which archeological ruins are sampled and dated using dendrochronological techniques.

Dendrochronology is the science of using the patterns in tree rings to provide information about the past growing environment. Dendroarchaeology uses the patterns in the tree rings to date a portion of the archeological ruin. The current research combined the historically documented time periods of Acadian and British mining activities to determine which of the two was mining at the sample sites near the Joggins Centre. It builds on a pilot study conducted previously by the MAD Lab in November of 2008. This project was assisted by Dr. Howard Falcon-Lang of the University of Bristol, UK and conducted by the MAD Lab research team.

Study Site

The UNESCO Joggins Fossil Cliffs are located in Nova Scotia along the east side of the Bay of Fundy in the Cumberland Basin (Figure 2). The cliffs stretch over 14 km and are up to 30 m in height. Mine workings are exposed along the Fundy coal seam from the cliff top at 45° 42.239' N latitude, 64° 26.532' W longitude to the bottom at 45° 42.206 N latitude and 64° 26.615 W longitude (Figure 2). Samples were taken from the mine workings along the cliff face over two sampling trips conducted on June 15th and July 18th. Samples were taken from eleven groupings of beams, from the two heights (Figures 3 and 4).

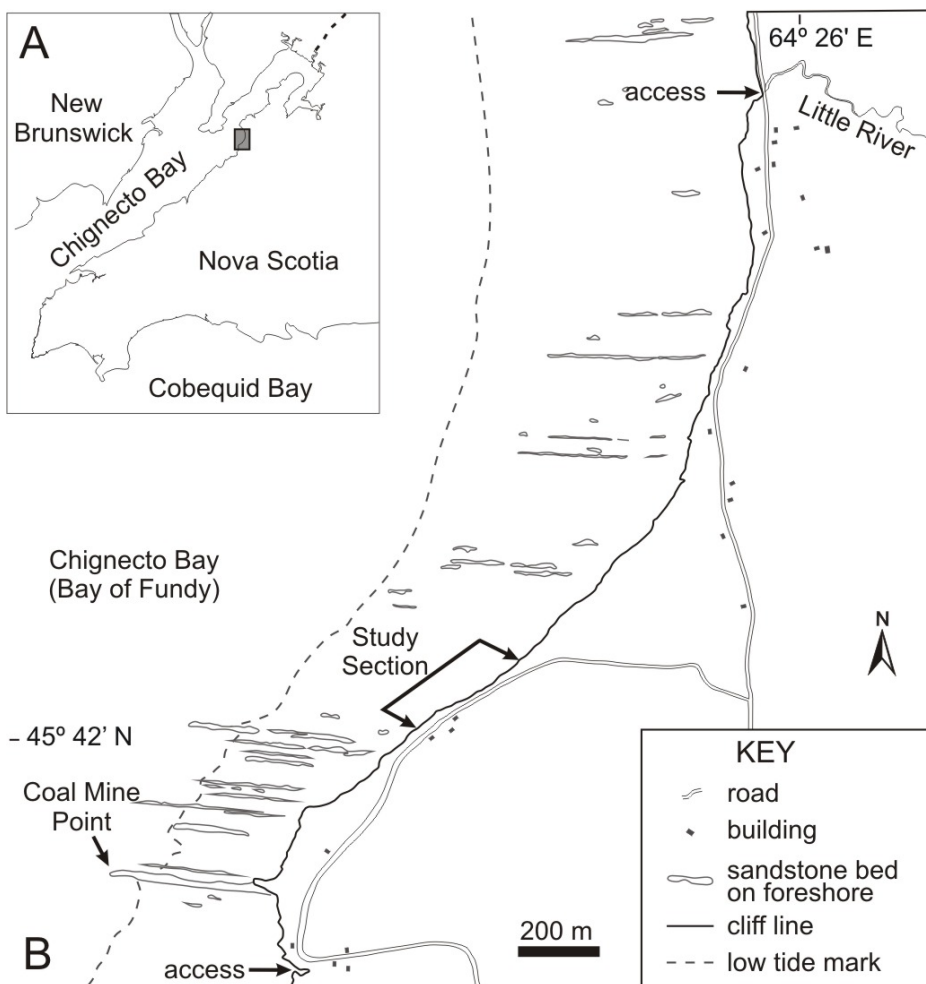


Figure 2 – The location where study sampling took place along the coal seam exposure.

Methods

Sampling ranged over a distance of approximately 161 metres. The MAD Lab labeling code for the project was 09ES000 and each beam sampled was given an individual code. The location from which each sample was taken was recorded by observers above and below the cliff. A GPS sampling point was taken at each location from above the cliff, as well as sketched onto a site map. From below, an observer triangulated the sampling location and measured the height and distance of the cliff from a base station, as well as the height of each sampling location, to aid in mapping the samples. Within the 09ES000 set, clusters of beams were given an additional label; from J1 to J11. These were separated into a bottom group (J1, J2, J3, J4, J5, J6, J8, J9, and J10), while J4B, J7, and J11 were considered the top group (Figure 4).



Figure 3 – A photo mosaic of the cliff face from which the samples were taken. Sampling began on the far upper left (north) and went to the lower right of this photo (south). The two levels of mine shafts follow the grain of the rock layers (black lines).

Joggins Site Outline

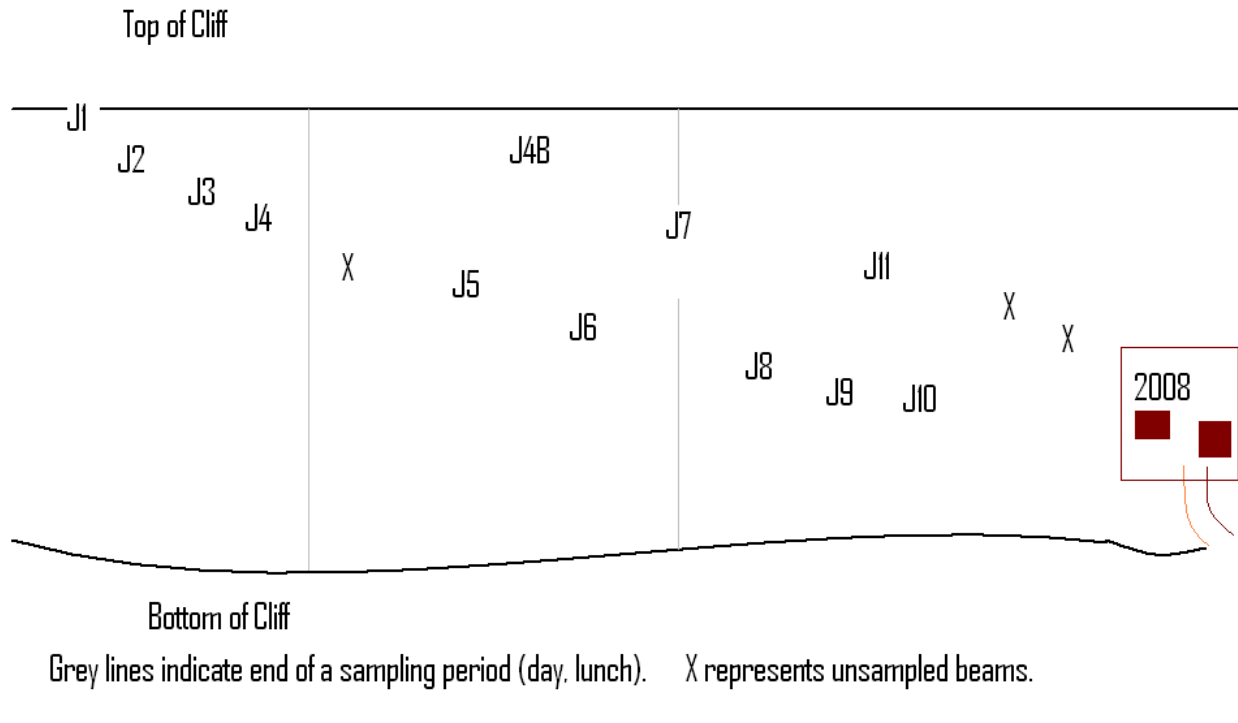


Figure 4 - This sketch represents the areas from which the samples were taken. J1-J11 indicate the sampling sites and “X” marks places that beams were present and exposed along the cliff but were not sampled. The red box contains the sampling sites from a previous year, November 2008.

The pit prop beams of the mine shafts from which samples were taken were embedded in the cliff face. To retrieve them, crew members were belayed from the cliff top by using a rope anchor system. All applicable safety gear was used such as harnesses, ropes, helmets, and overalls. Once at the level of the beams, samples were identified, labelled and debris was removed from around the wood. Samples were then taken by lowering a saw down to the members of the MAD Lab on the cliffs edge where a cross-section was collected of each sample, and it was sent back up using a bag and rope system. Samples and their condition and location were noted.



Figure 5 - Two crew members were belayed from the top of the cliff to collect samples. They were anchored into position and were belayed by an experienced MAD Lab crew member. A cluster of beams is located on the far right of the photograph in the black circle.

Once the samples were collected, they were brought back to the MAD Lab in Sackville, NB. Samples were cut into 8 centimetre thick sections using a band saw and then were finely sanded to make the rings clearer and more easily distinguishable. Each sample had two paths measured across the most sound portions of the disc. These paths were at an angle of no less than 90 degrees from each other. Rings were measured using a Velmex measuring system attached to a microscope to measure the distance between each ring to 0.001 mm, and to obtain the ring counts. A measurement pattern floating in time was therefore created for each sample. While each sample was under the microscope, species specific cellular wood characteristics were noted.

A master red spruce (*Picea rubens*) chronology spanning from 1624 to 2006, as well as the sampling chronology available from the previous study were used to cross-date the samples' ring widths. Cross-dating is a method of pattern matching a tree's growth signal of unknown age to that of a known pattern (Figure 6). A red spruce chronology was used because the samples collected in the study were primarily spruce (54 of 56); the two that were not spruce were eliminated from further analysis. Samples less than 30 years old were also eliminated due to the fact that they might fit well into a number of time periods and so they were not deemed to be able to be accurately dated.

Structure



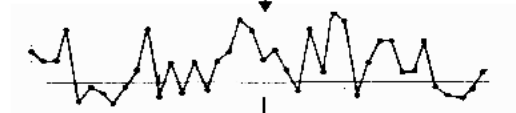
Sample



Path



Floating Chronology



Master Chronology

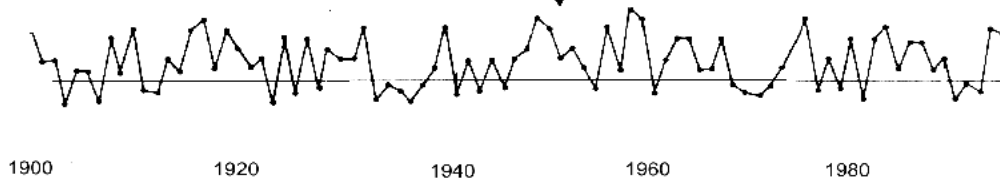


Figure 6 - Illustrates the method of cross-dating undated beams and comparing them to a master chronology. This comparison matches ring width patterns between the newly sampled floating chronology and the master chronology. This allows undated wood to be assigned an accurate cut date.

A statistical comparison between the floating and master chronologies was performed using the program COFECHA (Holmes, 1986a). COFECHA takes the new floating chronology and then compares it to the master to illustrate where in time each sample best fits. A correlation value is assigned to each sample based on how well it fits at the date where it is placed. A low or negative correlation means that the sample may need to be moved either up or down in time or that it differs because of environmental variability. A high value indicates that the sample pattern correlates well to the master chronology and to that specific time period.

A visual comparison was provided by using a program called ARSTAN (Holmes, 1986b). ARSTAN takes ring width data and standardizes it. Both the 09ES000 samples and the red spruce chronology were standardized in this way. Graphs containing these curves were created to observe their correlation to each other. A spreadsheet program was used to statistically create correlation matrices of the correlation values between sites. It was also used to look at the correlation between the reference chronology and the overall 09ES000 chronology.

Results and Discussion

Of the 56 samples collected, 38 were used to date the site. The group correlation for the 09ES000 set against the master is 0.364 (Table 1). It therefore correlates significantly to the master chronology. The group spans from 1728 to 1888. The correlation of the top level is 0.426 and that of the bottom is 0.389. They span 1728-1888 and 1729-1880 respectively. The sites have cut dates that range from 1849 to 1888. Samples from the top group tend to be younger and those from bottom group tend to be older.

Table 1 – Site information separated by cluster of beams, including correlation to the master chronology, dates of the samples, mean length of series, number of samples, and number of paths measured (* values above 0.3281 are significant at the 99% confidence interval).

| Site | Correlation* | Time Span | Mean Length of Series | # Samples | #Dated Paths |
|-------------|---------------------|------------------|------------------------------|------------------|---------------------|
| All | 0.364 | 1728-1888 | 72.8 | 38 | 75 |
| Top | 0.426 | 1728-1888 | 76.9 | 11 | 22 |
| Bottom | 0.389 | 1729-1880 | 71.2 | 27 | 53 |
| J1 | 0.350 | 1791-1859 | 46.7 | 3 | 6 |
| J2 | 0.301 | 1807-1868 | 43.0 | 3 | 6 |
| J3 | 0.308 | 1766-1849 | 79.0 | 2 | 4 |
| J4 | 0.441 | 1729-1880 | 116.6 | 4 | 8 |
| J4B | 0.474 | 1809-1859 | 38.5 | 2 | 4 |
| J5 | 0.269 | 1818-1867 | 41.0 | 2 | 3 |
| J6 | 0.415 | 1804-1866 | 52.2 | 3 | 6 |
| J7 | 0.565 | 1825-1867 | 39.0 | 1 | 2 |
| J8 | 0.377 | 1764-1874 | 73.7 | 5 | 10 |
| J9 | 0.302 | 1755-1861 | 86.0 | 3 | 6 |
| J10 | 0.399 | 1781-1862 | 65.0 | 2 | 4 |
| J11 | 0.406 | 1728-1888 | 90.7 | 8 | 16 |

Both the bottom and top groups correlated very well with each other and with the master chronology (Table 2). The results of this research were statistically significant. The correlation is also shown to be very high when the standardized curves are graphed against each other (Figure 7). The patterns of all the curves illustrate a strong consistency, leading to a firm conclusion that the wood has been placed in the proper context in time. A secondary bonus of the addition of the 09ES000 data to the MAD Lab data bank means that the new information will increase the depth and reliability of the red spruce chronologies for the region (Figure 8).

Table 2 – Correlation matrix showing correlations between the standardized data of parts of the sample group against each other and against the master chronology.

| | 09ES000 | LOW | TOP | MASTER |
|---------|---------|------|------|--------|
| 09ES000 | 1 | - | - | - |
| LOW | 0.85 | 1 | - | - |
| TOP | 0.87 | 0.40 | 1 | - |
| MASTER | 0.39 | 0.23 | 0.50 | 1 |

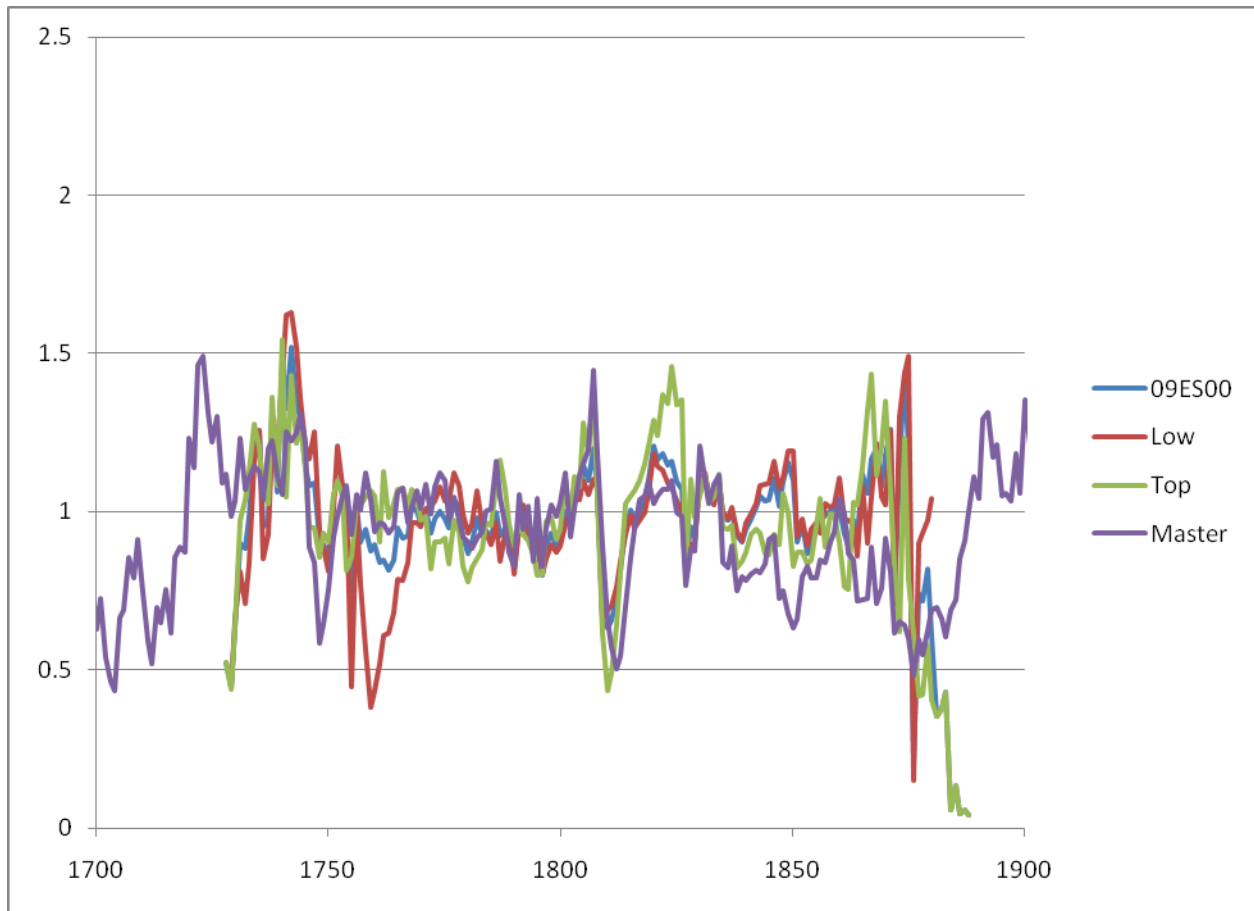


Figure 7 – A comparison of the standardized ring width patterns for the entire 09ES000 chronology, the bottom, the top, and the master chronology. The x-axis is the common time frame that the chronologies share, while the y-axis is a standardized index value, where 1 is average growth, and above and below 1 are above and below average growth.

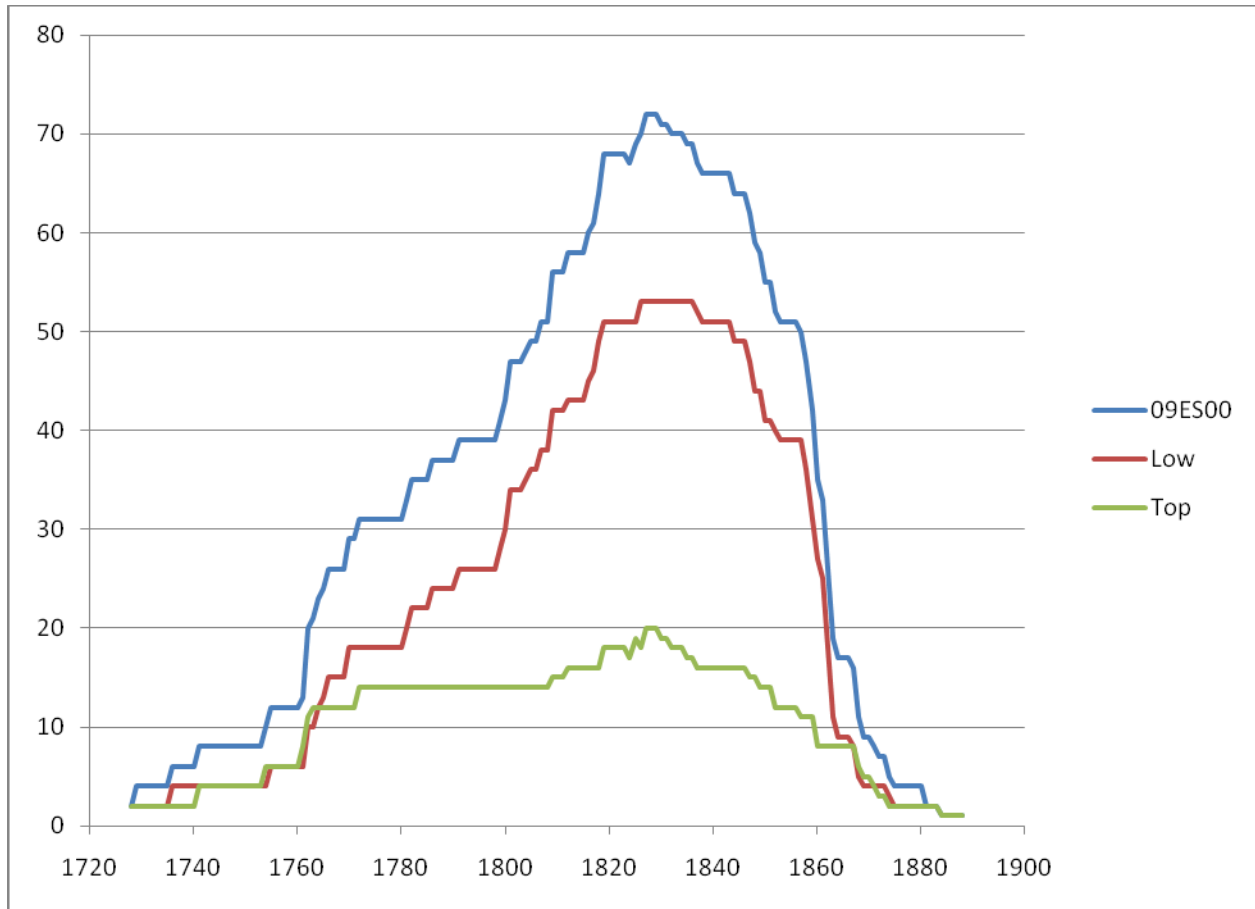


Figure 8 – Illustrates the time frame of the bottom, top and 09ES000 chronologies, as well as the additional sample depth they add to the MAD Lab data base for this time period.

Conclusions

The samples collected from the Joggins Cliffs illustrate a high correlation to the master red spruce (*Picea rubens*) chronology. From this, the 09ES000 chronology can be set in time. The floating chronology now spans from 1728 to 1888. The cut dates of the individual samples in 09ES000 are therefore established, and they range from 1849 to 1888, which corresponds to the historically known period of British mining. In the three top level sites, the cut dates of the samples become progressively older as they descend the cliff. In the bottom level, the cut dates vary across the slope, but do not follow a trend. This research has been effective in determining the cut dates of the pit props of the mine shafts and has determined them to originate from British mining activity.

References

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