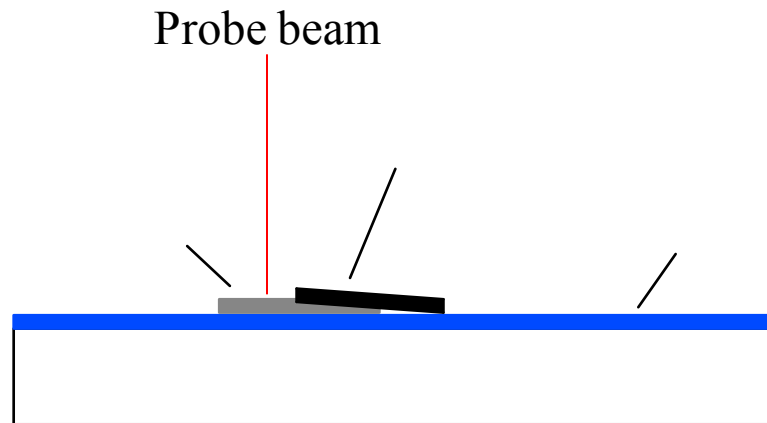


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# Summary of Shroud FTIR Analysis

# Data Collection - Infrared Spectroscopy

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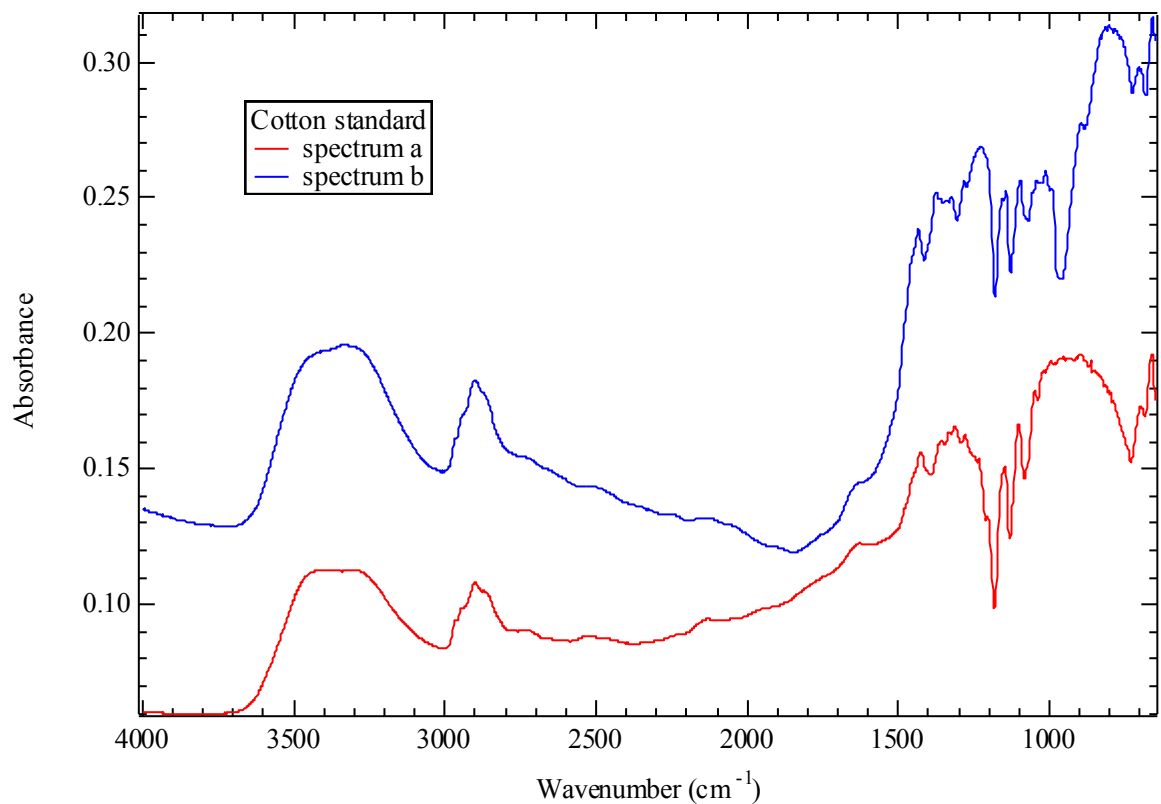


Analysis was performed using an FTIR microscope in reflectance mode, sampling at most a few fibers per spectrum

Several (4-6) spectra were obtained at each chosen position along the length of the thread

# Cotton Standard

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Spectra are characterized by:

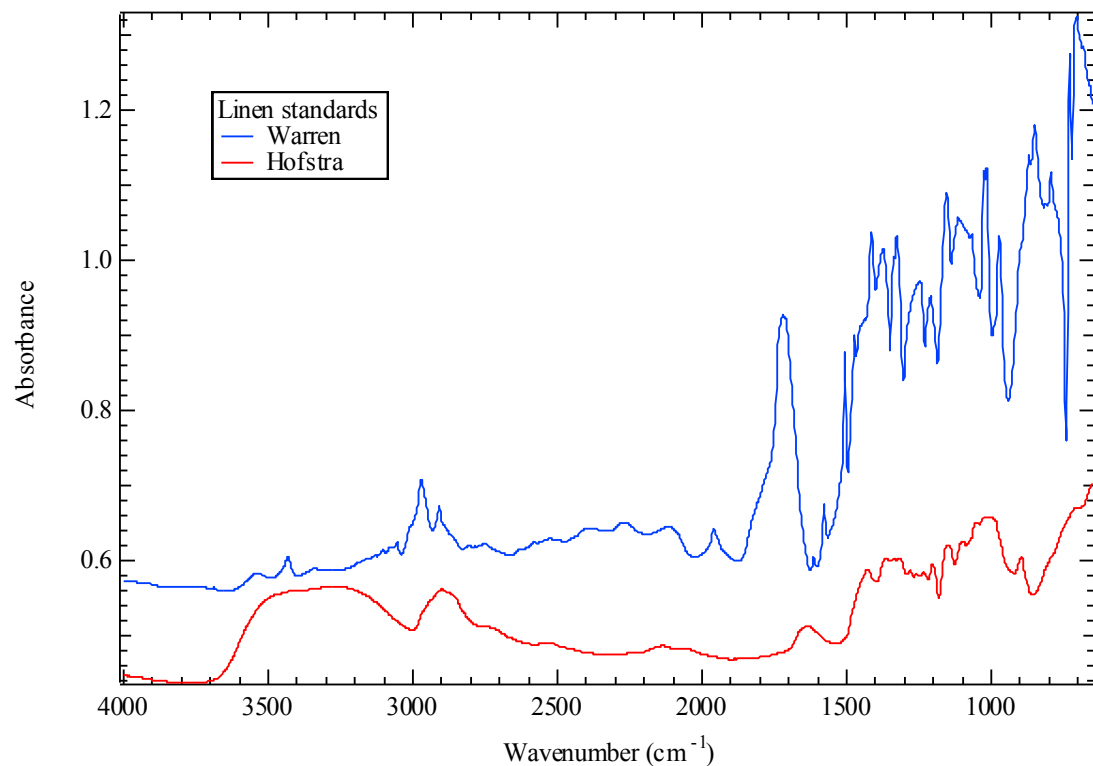
Broad distribution of  $sp^3$   $CH_n$

Broad -OH

Little/no C=O

Some significant spectral differences are observed for data obtained from different regions of the sample

# Linens Standards



Data from modern linen standards are highly dependant on processing

Unprocessed linen is characterized by

Strong C=O

Sharp CH<sub>n</sub> stretch bands

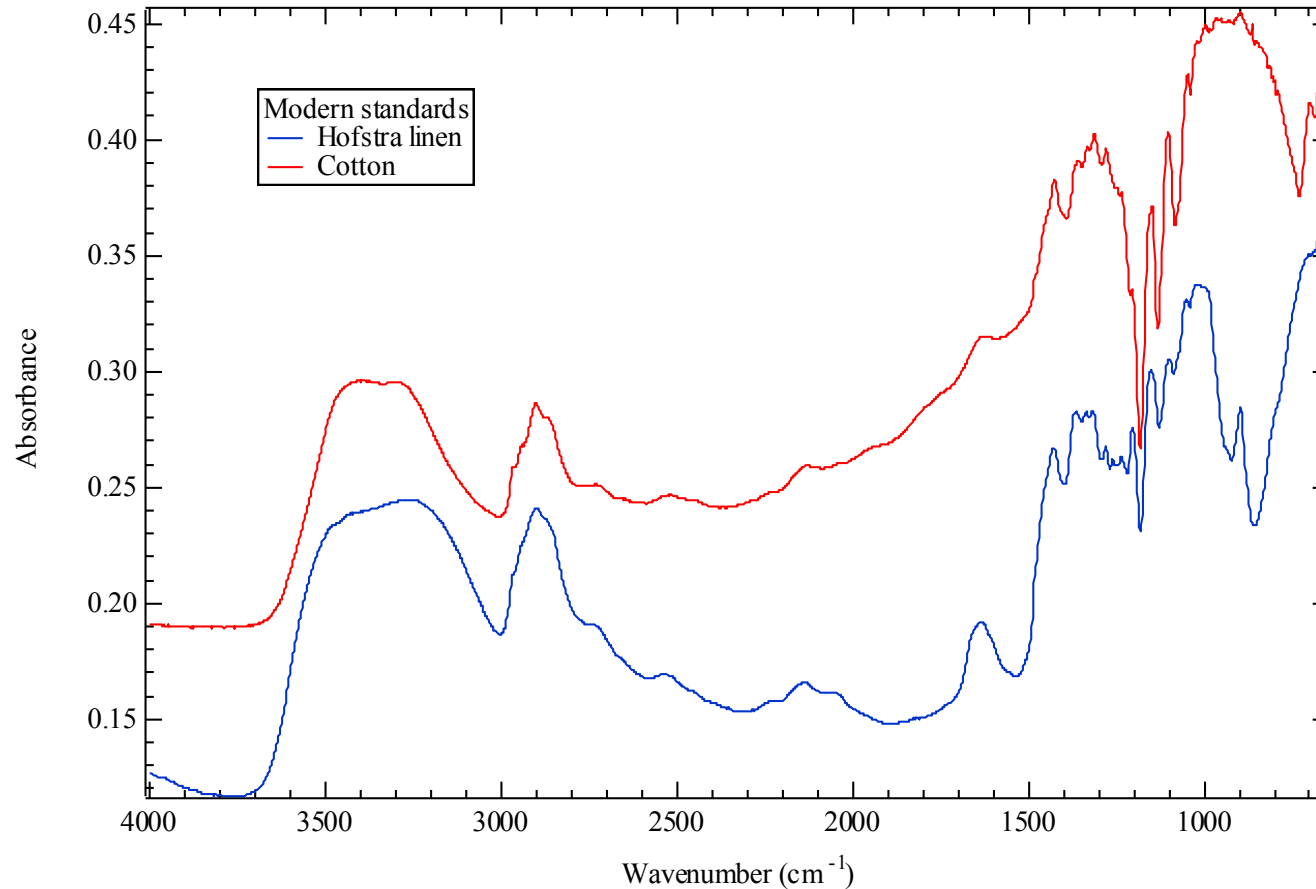
sp<sup>3</sup> -CH<sub>3</sub> and >CH-

Weak, but sharp, -OH

Processed linen is much more similar to cotton. In this case the C=O peak has been eliminated.

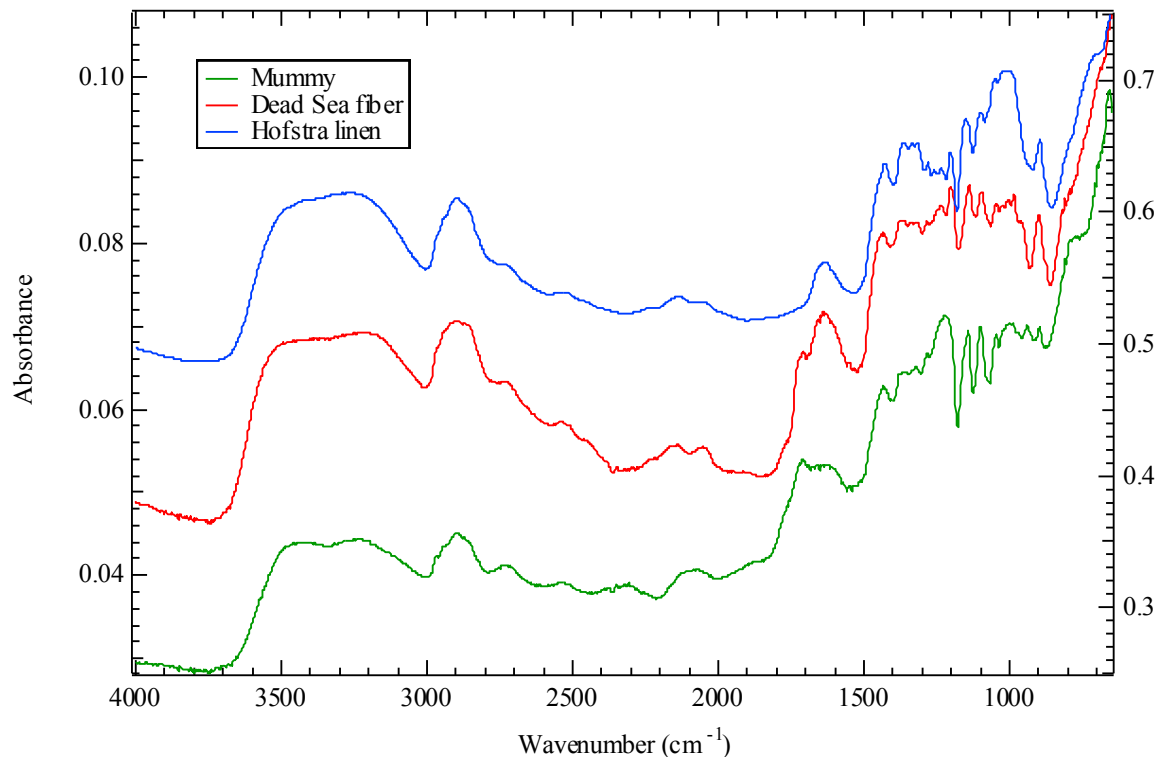
# Cotton vs. Linen

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These spectra show the similarities between modern cotton and modern processed linen

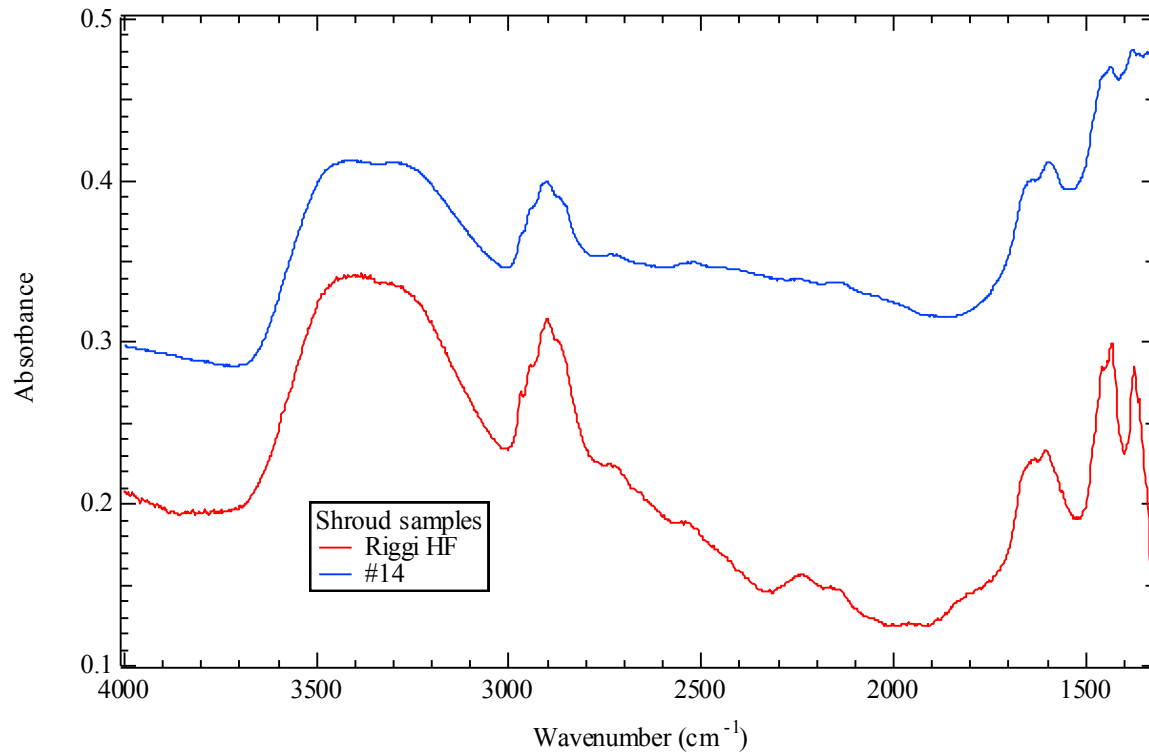
# Ancient Linen Samples



The ancient linen samples are quite similar to the modern processed linen sample. The primary difference is that the ancient samples retain strong C=O absorption, a feature that seems to be associated with unprocessed linen but not cotton. One may speculate that the ancient samples had no/minimal processing, and that the similarities to the modern processed linen sample are in fact due to aging effects.

# Shroud Samples #14 and “Riggi”

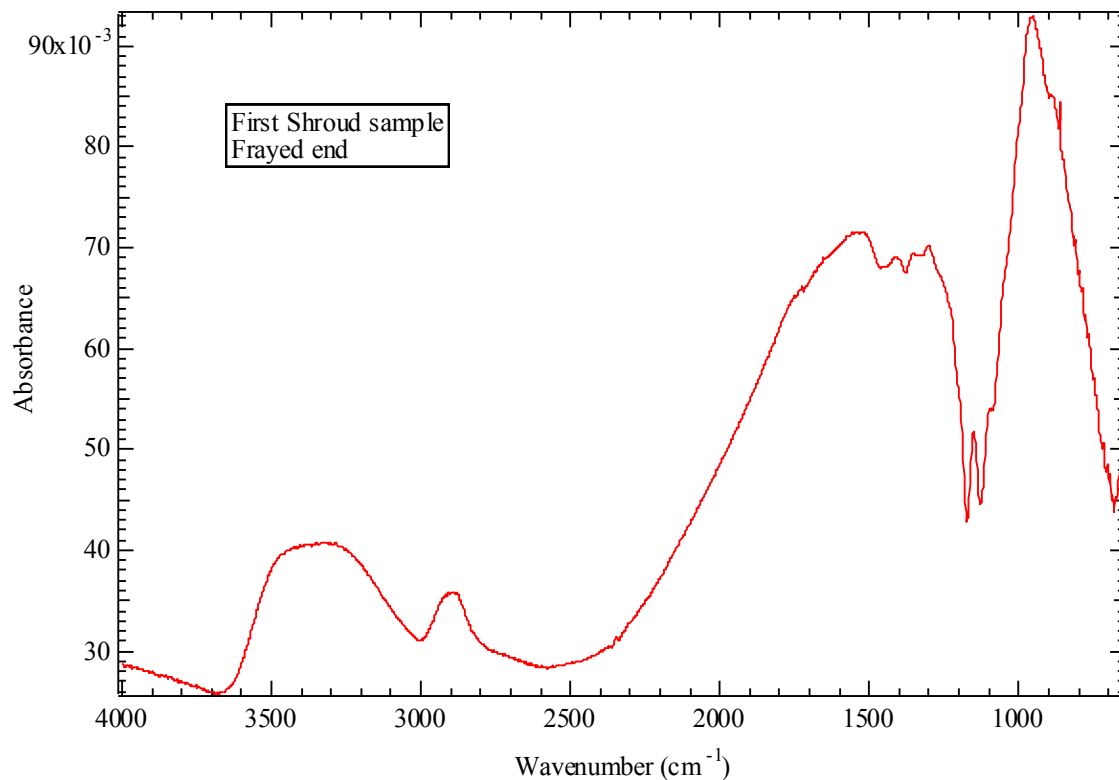
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These Shroud samples are most comparable to the modern processed linen sample. Note however the absence of C=O absorption. This makes it much more difficult to definitively identify the material as linen vs cotton.

# First Shroud Sample I

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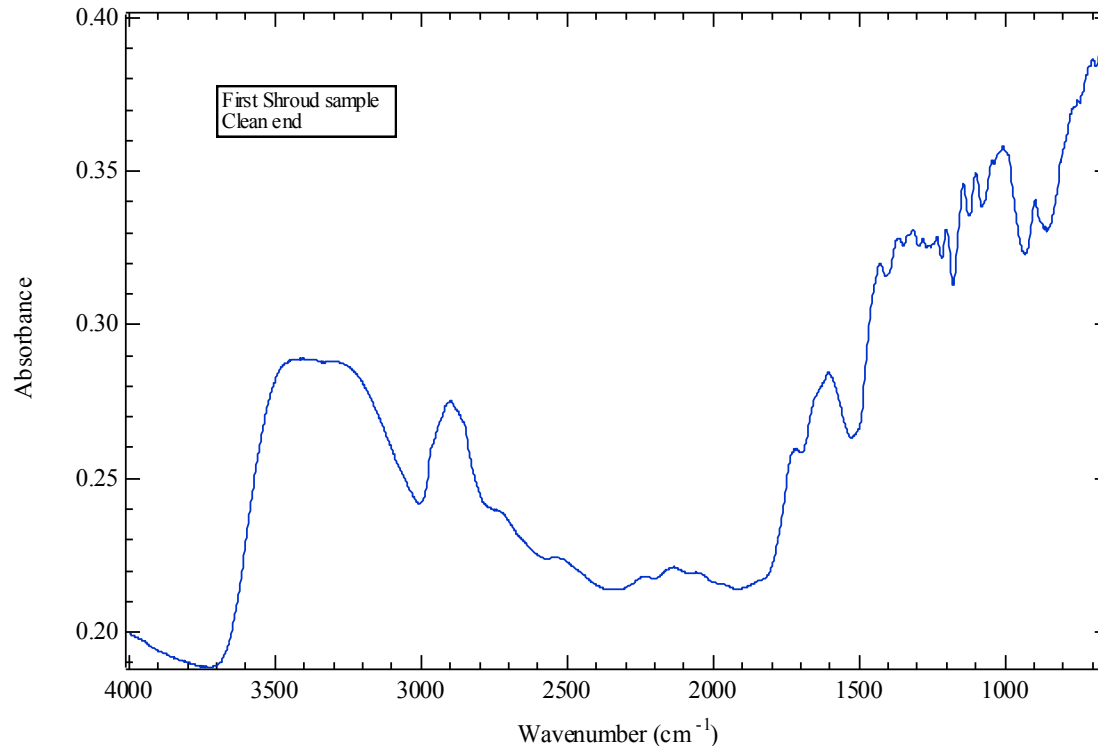


This spectrum is typical of those obtained at the frayed end of the sample. It is difficult to say for sure if there is a distinct C=O peak or not.



# First Shroud Sample II

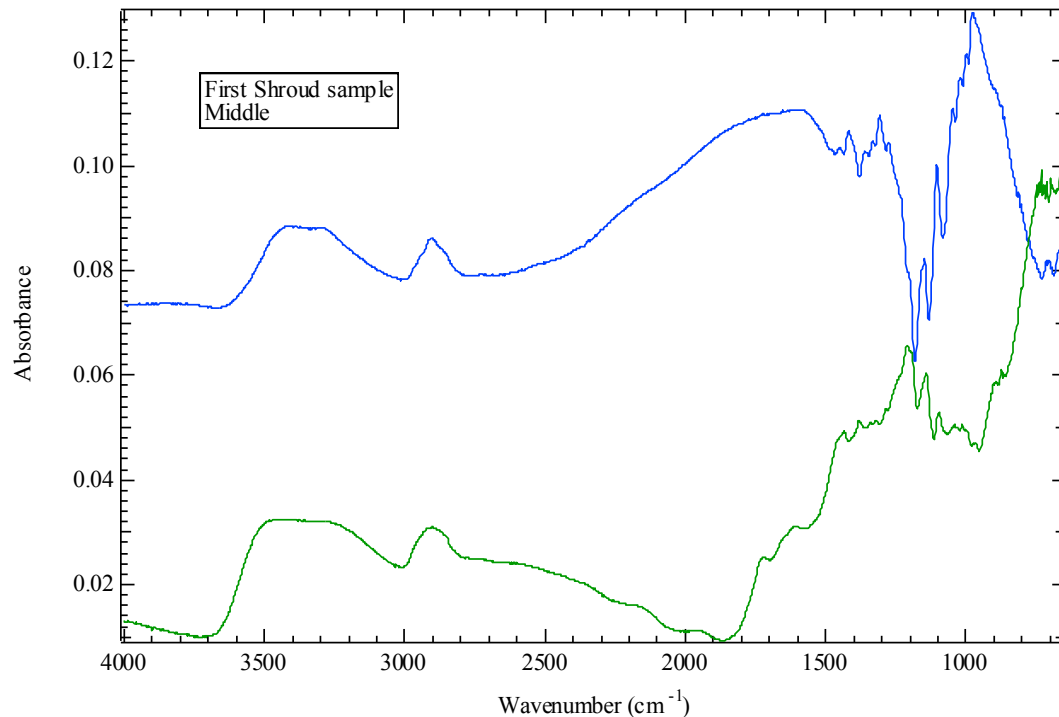
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This spectrum is typical of those obtained at the clean end of the sample. It is very similar to data obtained from the ancient linen standards, with the presence of a distinct C=O peak.

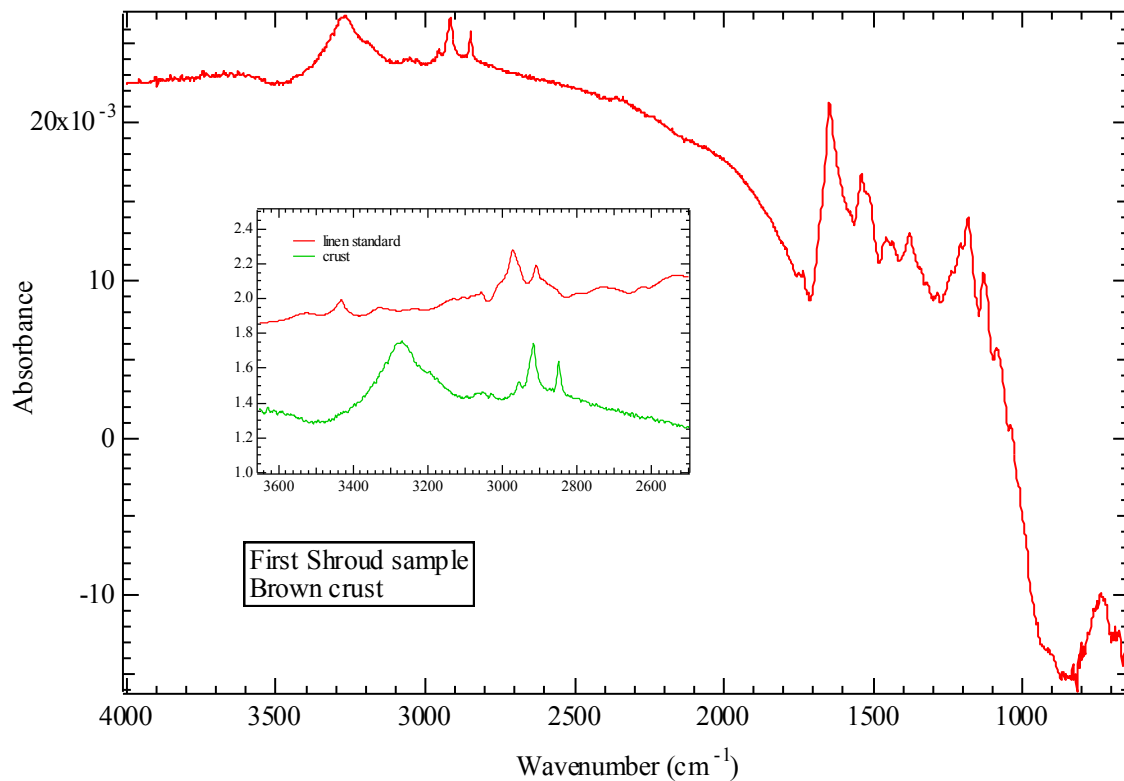
# First Shroud Sample III

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Data were also obtained from a number of individual fibers located in the middle of the sample, where the break occurred. Some spectra were similar to those obtained at the frayed end, others were similar to data obtained from the clean end. This could imply the splicing of two different types of fiber (this is where the resin-like material was). However **the data are not conclusive**, and it may be that the sample was simply affected to varying degrees by contamination from the resin.

# First Shroud Sample - Crust



Data from the brown crust  
were characterized by

$\text{sp}^3$  - $\text{CH}_2$ -

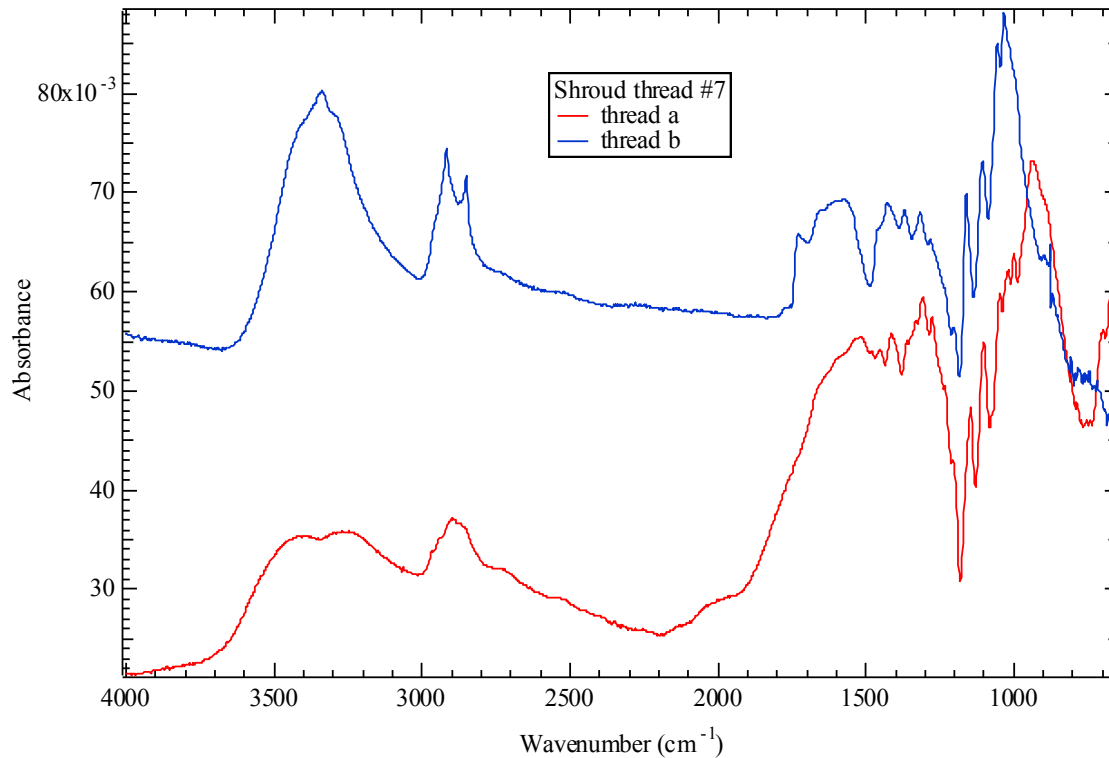
Olefinic C=C

Relatively narrow -OH

Terpene-based resin???

# Shroud Sample #7

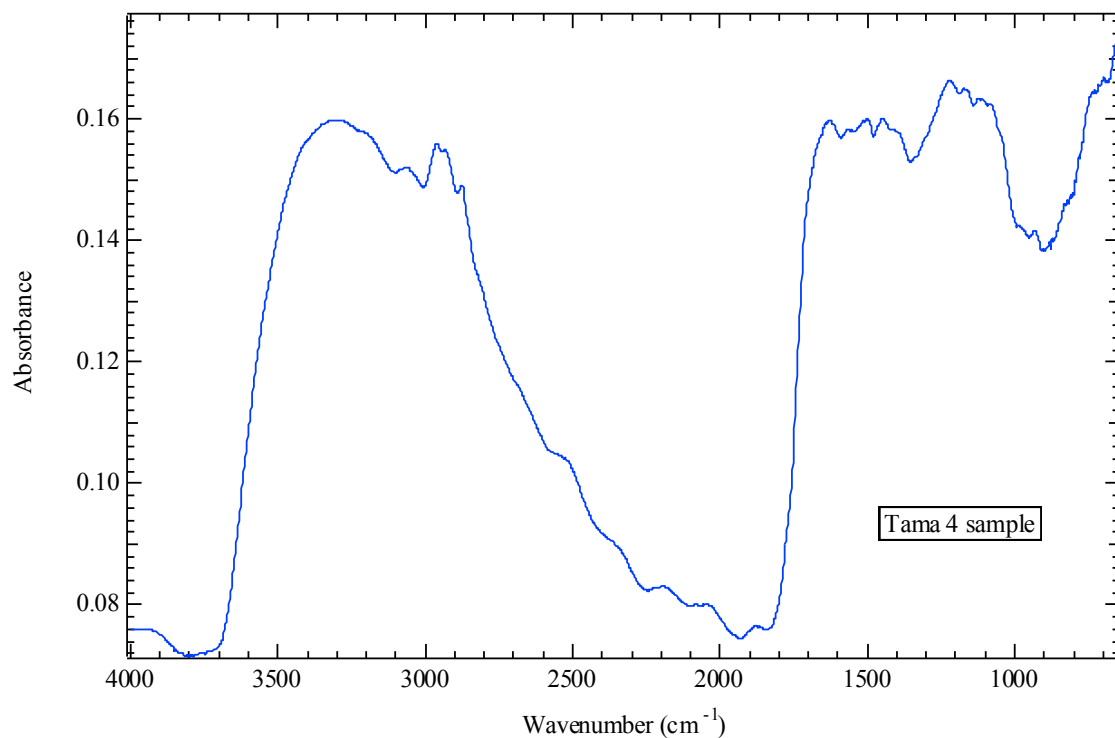
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Most spectra obtained from this sample are very similar to those obtained from the frayed end of the first sample. However, some fibers were clearly contaminated by the resin-like material

# Shroud Sample - Tama 4

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This sample appears much different from the others. The CH<sub>n</sub> band structure is much different, and -OH absorption is much broader and stronger. Not much can be said about this.

# Conclusion

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For modern samples, there are spectral features that differentiate unprocessed linen from cotton. However, processing/aging of linen can dramatically change its spectral characteristics. This makes it very difficult to conclusively identify an unknown sample.

Ancient linen standards are clearly strongly affected by aging. However the samples studied did retain the C=O absorption characteristic of modern unprocessed linen - a feature not observed in any of the cotton standards studied (nor in the literature).

The Shroud data were highly variable. Some fibers appeared very similar to the ancient linen standards. Others were more similar to modern cotton or processed linen. For the first sample examined, it is **possible** that the thread composition varied from one end to the other, consistent with the slicing hypothesis. However **the data can not be considered conclusive**.

The brown crust has spectral features that are consistent with a terpene-based resin.