Xradia MicroXCT

NASA Ames

11/01/2009-12/10/2009

Prepared by Luke Hunter

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1 Executive summary

Between 11/01/2009 and 12/09/2009 a demonstration of the MicroXCT was conducted at Xradia, Inc. in Concord, Ca. For the demonstration, the NASA-Ames supplied three carbon fiber material samples. NASA wished to examine the samples to determine specific information about the orientation and assembly of the fibers.

NASA specifically requested the following from the demonstration:

- Image each sample with a larger field of view (4X or 10X) and a high magnification (20X or 40X) to visualize the contact frequency and orientation of the fibers in the transverse and planar directions

Sample A was imaged using the 10X and 20X, providing varying levels of resolution and field of view. Samples B and C were imaged using the 10X objective and the 40X objective, providing information from a moderate field of view as well as our best resolution. The fiber orientation is clearly seen in all the results. Much greater detail of individual fiber orientation and interaction is apparent in the higher resolution images, 20X and 40X.

During this demonstration we were able to highlight:

- MicroXCT's capability to image low contrast material.
- MicroXCT's capability to provide artifact free images
- MicroXCT's capability to provide high quality images for product development
- MicroXCT's capability of providing high resolution images for feature measurements
- Useful software features like virtual cross-sectioning, virtual de-layering, and 3D visualization.

2 Introduction to Xradia

Xradia is a technology leader in 3D computed tomography systems. Our customers span across the scientific research, semiconductor, bio-medical, and energy fields.

The Xradia product lines

MicroXCT –

- Fast 2D and 3D imaging and defect localization
- Spatial resolution down to 1.5 μm with fully automated data acquisition
- Non-invasive, visualization at micron level with sub-micron feature recognition
- High contrast imaging for low Z materials and biological samples with Xradia's PhaseEnhanced™ optics
- Programming for multi-region CT scanning of a sample for unattended operation
- Large working distance for experimental set up for high resolution, time-lapse imaging of functional devices and dynamic events

Nano XCT –

- Hi resolution 2D and 3D imaging and defect localization
- Spatial resolution down to 100nm with fully automated data acquisition
- Non-invasive, visualization at nano level with <100nm feature recognition
- Highly efficient condenser and zone plate optics for optimal utilization of X-ray source
- X-Pose technology using Zernike phase imaging for increased contrast

3 Demo setup

This demonstration was done using one of Xradia's MicroXCT-200 computed tomography systems. The overall system is shown in Figure 1. Figure 2 shows the inside of the system with a sample loaded and ready for tomography.

General configuration and objective lenses in place on the demo **MicroXCT:**

1. 150 kV x-ray source: 40 -150 kV and 4 - 10 W range or
2. 90 kV x-ray source: 40-90 kV and 4-8 W range
3. 2X, 4X, 10X and 20X objective lenses (best spatial resolution ranges from ~12 μm to ~1.5 μm)
4. 2048 X 2048 CCD camera

Figure 1: MicroXCT system

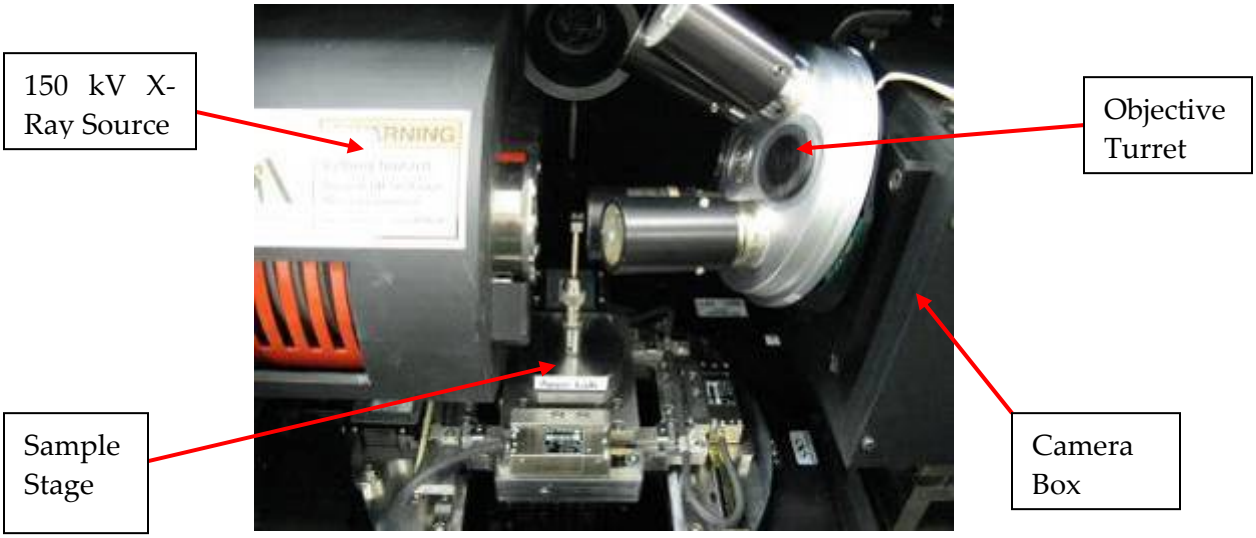


Figure 2: Sample loaded inside the standard MicroXCT-200

Each sample was trimmed down to a small piece and lightly glued to a thin aluminum rod. The rod was then mounted in our standard pin vise holder. An example of how a sample was mounted is shown in **Figure 3**.

The system parameters used for examining the samples can be found in Table 1. Due to the low x-ray absorption for all the materials imaged in this demo we chose to use low energy x-rays. Sample A was imaged using our 10X and 20X, while samples B and C were imaged with our 10X and 40X objectives.

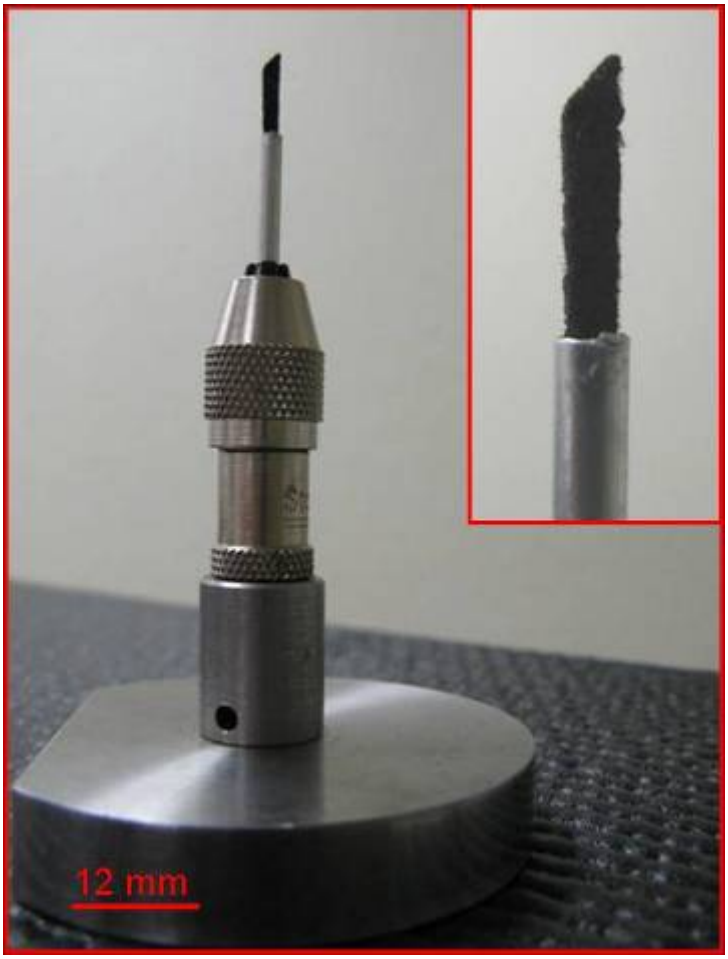


Figure 3: This figure shows an example of how the samples were mounted. Shown is sample 3 glued into a thin aluminum rod and mounted in our standard pin vise holder.

Table 1: Scan Parameters

Sample	Obj.	Pixel size(µm)	FOV (mm)	Energy (kV)	Power (W)	# of views	Time/view (sec)	Total acq time
Sample A	10X	2.4	2.5 X 2.5	40	10	1610	3	3.5 hr
Sample A	20X	1.2	1.2 X 1.2	40	10	1610	15	9 hr
Sample B	10X	2.2	1.2 X 1.2	40	8	805	2	1.5 hr
Sample B	40X	0.56	0.5 X 0.5	40	6	1610	10	7.5 hr
Sample C	10X	2.26	2.3 X 2.3	40	8	1610	3	3.5 hr
Sample C	40X	0.55	0.5 X 0.5	40	8	1610	6	5 hr

4 Imaging Details

The following CT images were obtained by taking 360° tomographies. During reconstruction the projection views were filtered using a standard Gaussian filter. This is done to reduce noise without significant degradation of resolution. The XMReconstructor software outputs a file format viewable with our TXMViewer software. The time from start of reconstruction to examining the data in the viewer is typically less than 15 minutes. The TXMViewer software allows the user to examine three orthogonal planes as well as a 3-dimensional view. Users can also create cross section and delayering movies. **Supplemental to this report, virtual cross section, de-layering, and 3D movies for this demo are available.**

Sections 4.1 and 4.2 details the results from imaging sample A.

Sections 4.3 and 4.4 details the results from imaging sample B.

Sections 4.5 and 4.6 details the results from imaging sample C.

Please refer to the figure captions in each section for specific details about the different images shown.

4.1 Sample A 10X

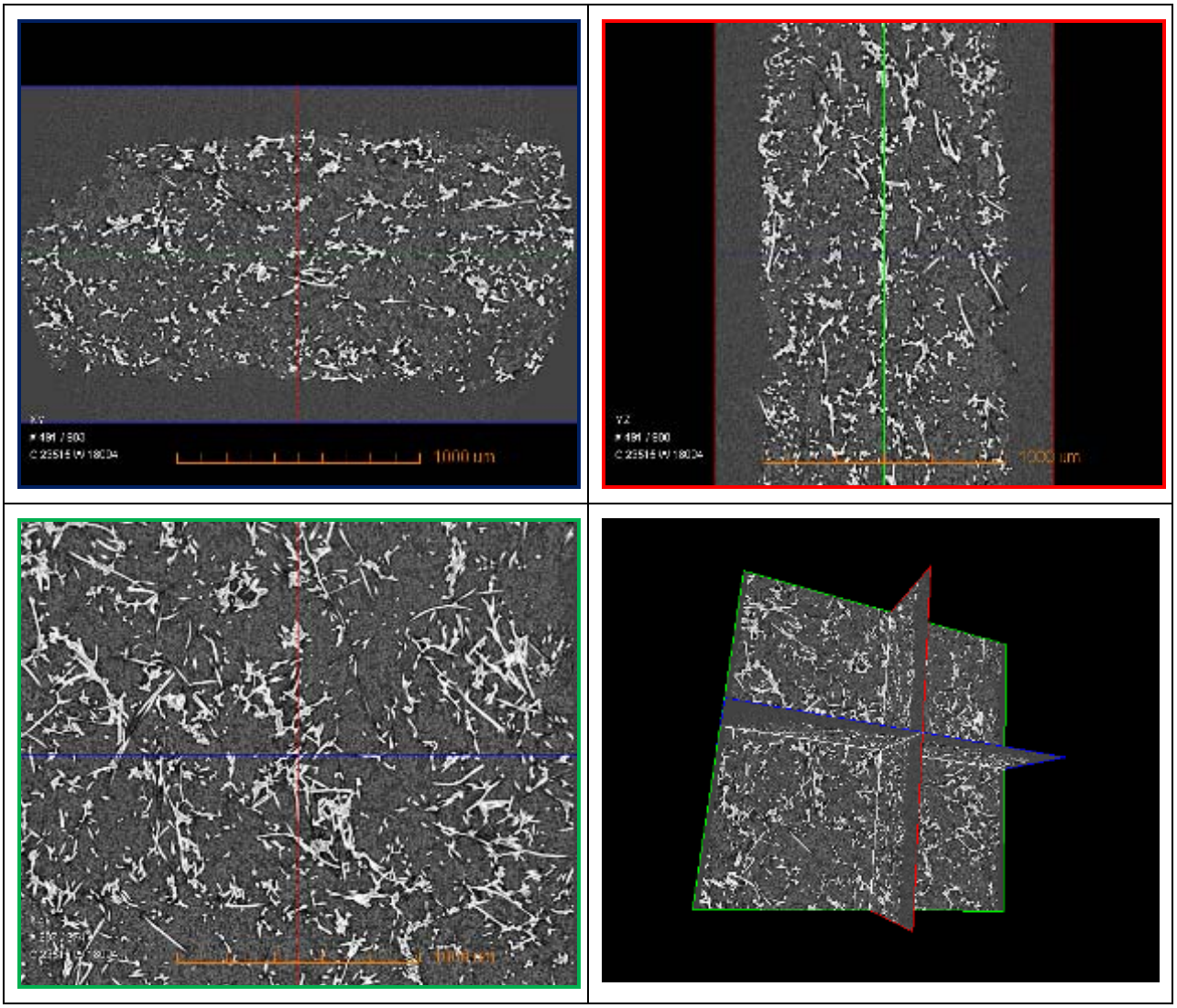


Figure 4: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image which should help explain the relation of the slices to one another.

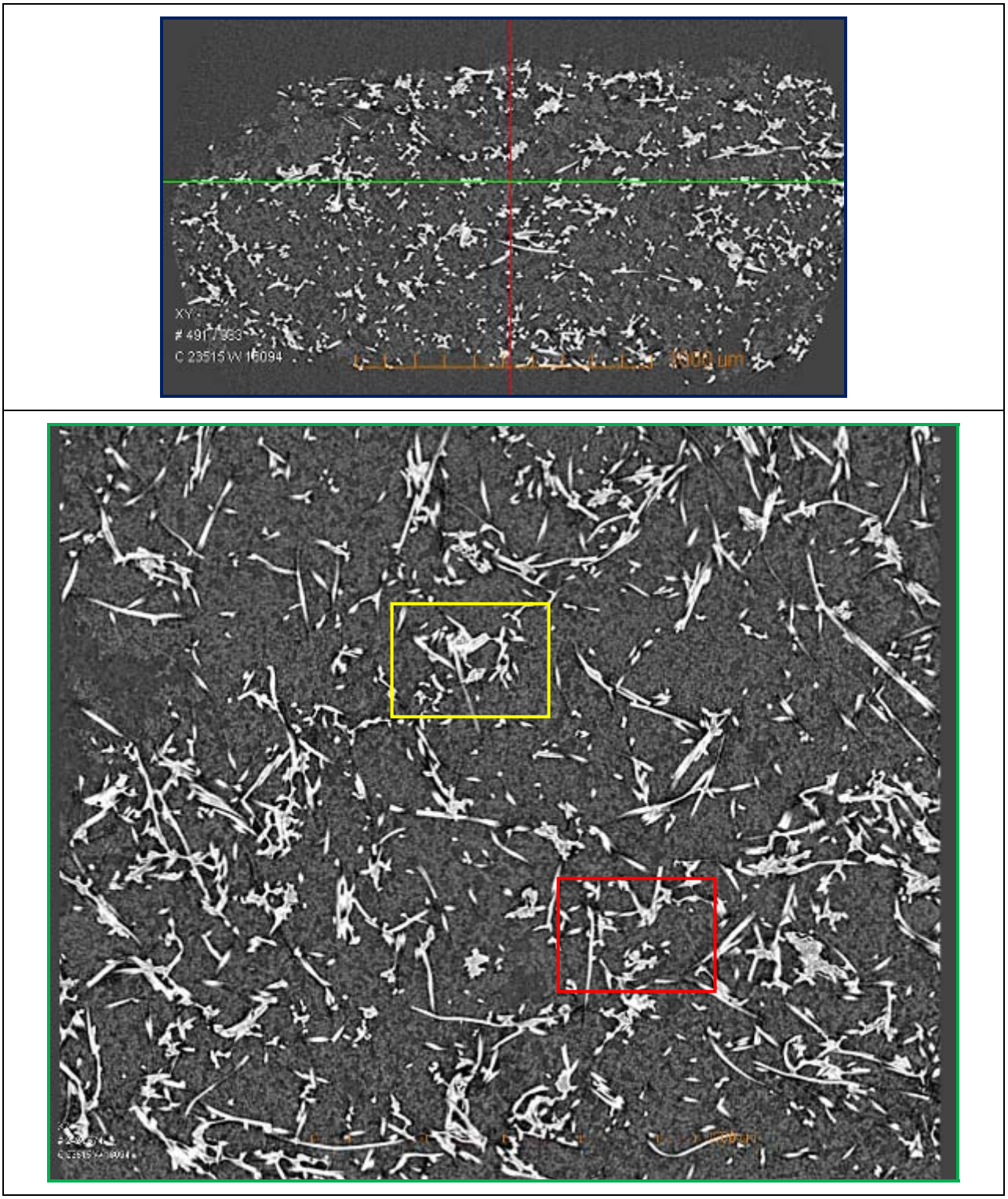


Figure 5: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

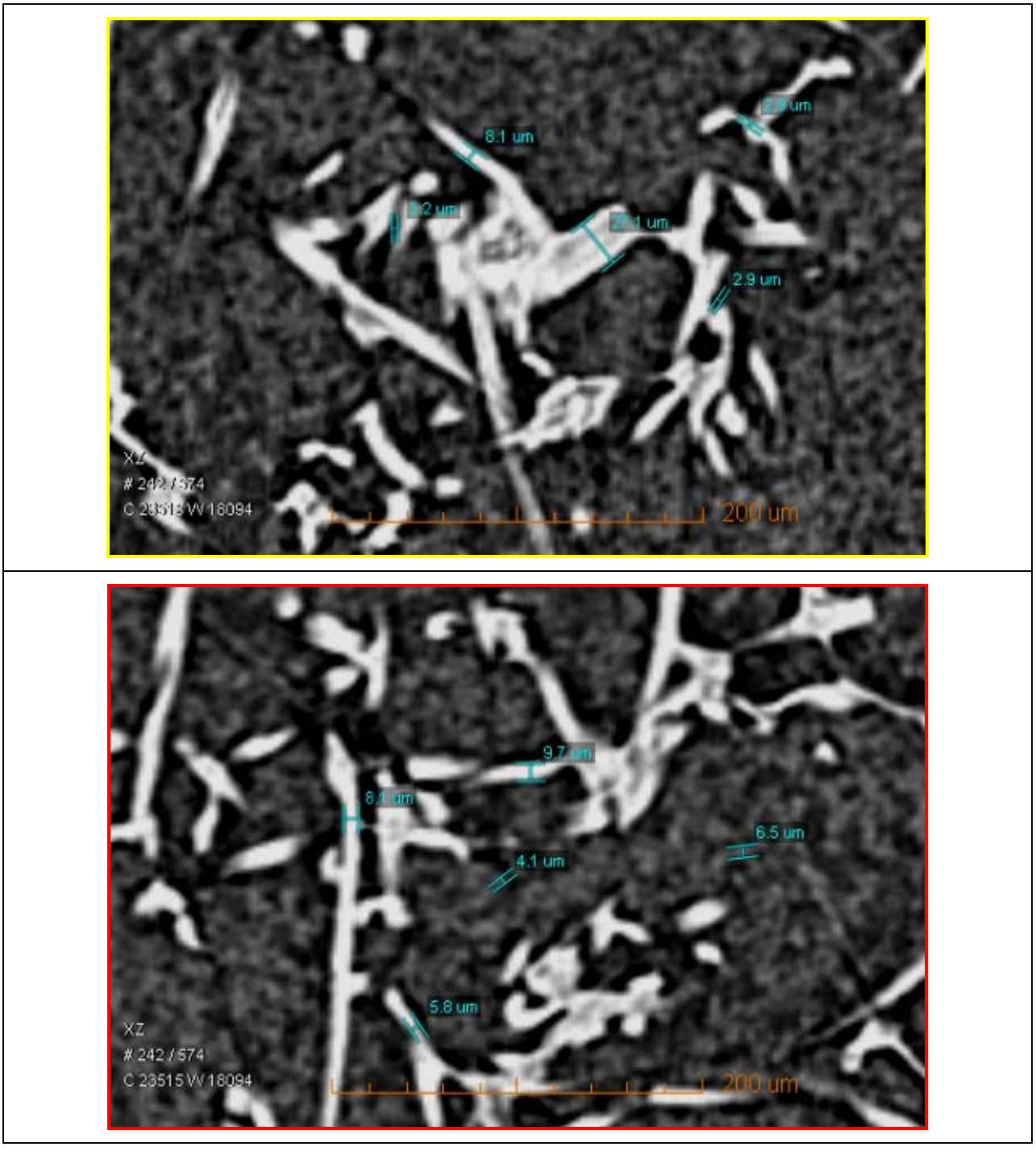


Figure 6: Detailed views of the areas in the yellow and red boxes in the previous figure.

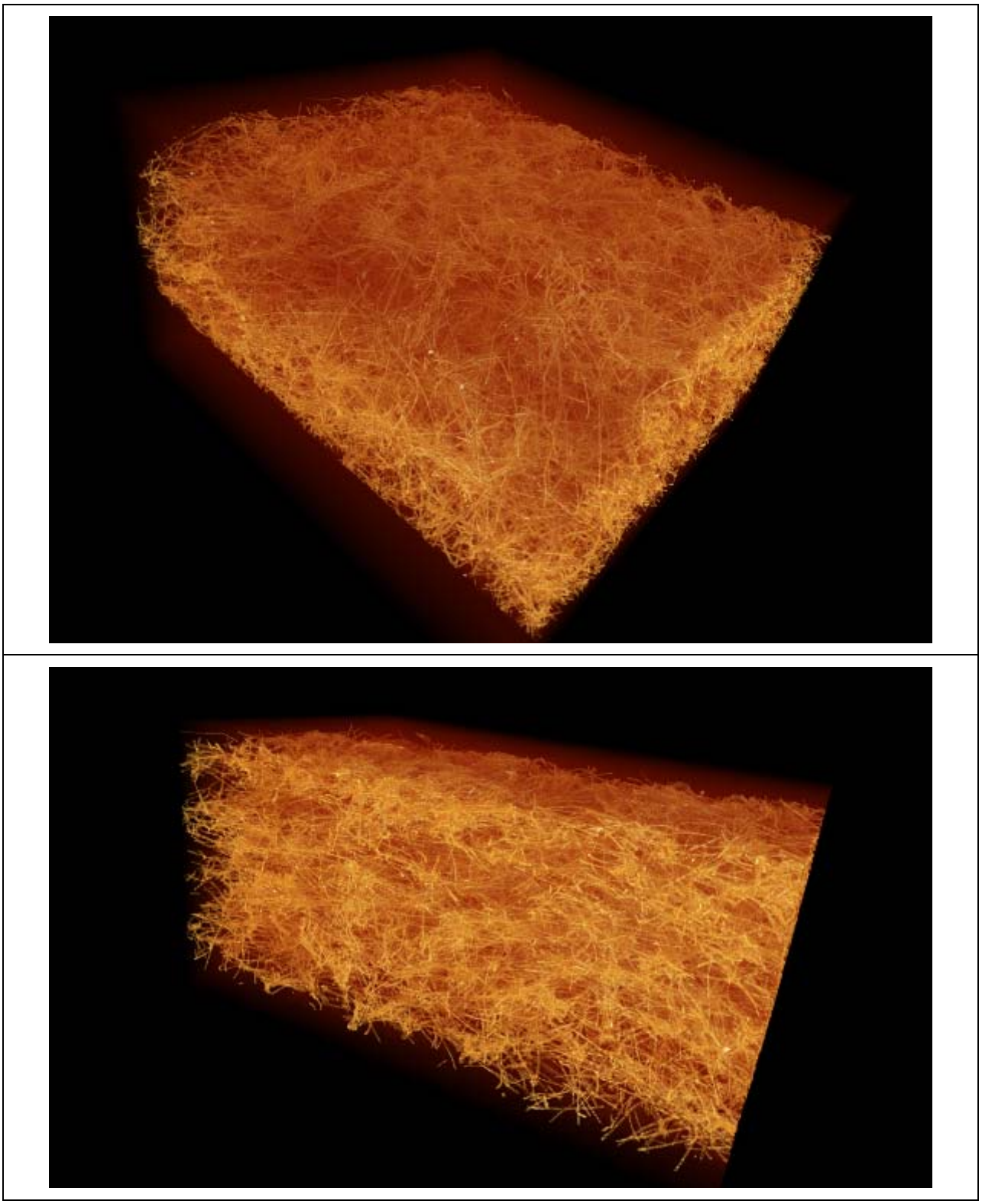


Figure 7: 3D rendered views of the imaged region.

4.2 *Sample A 20X*

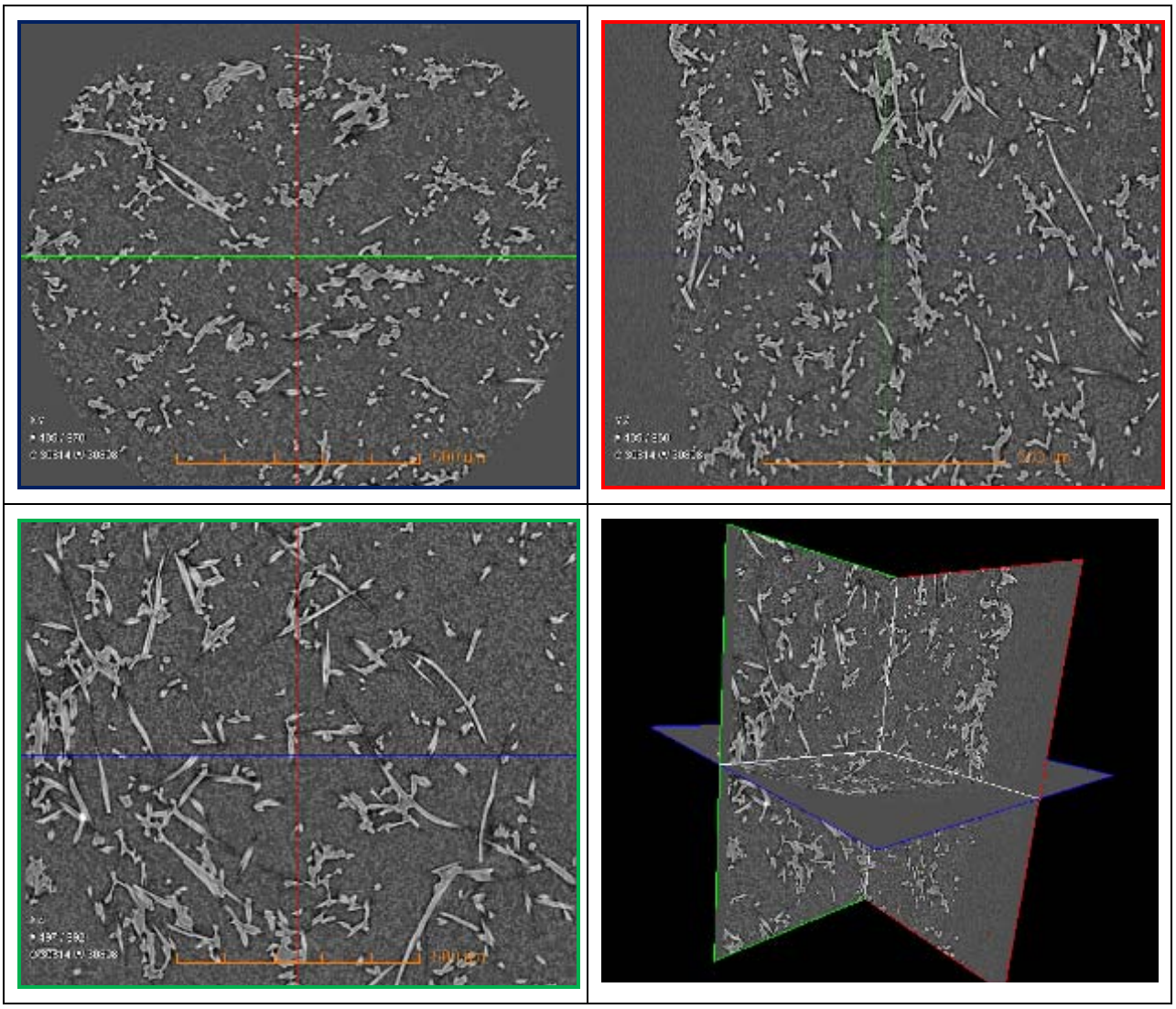


Figure 8: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

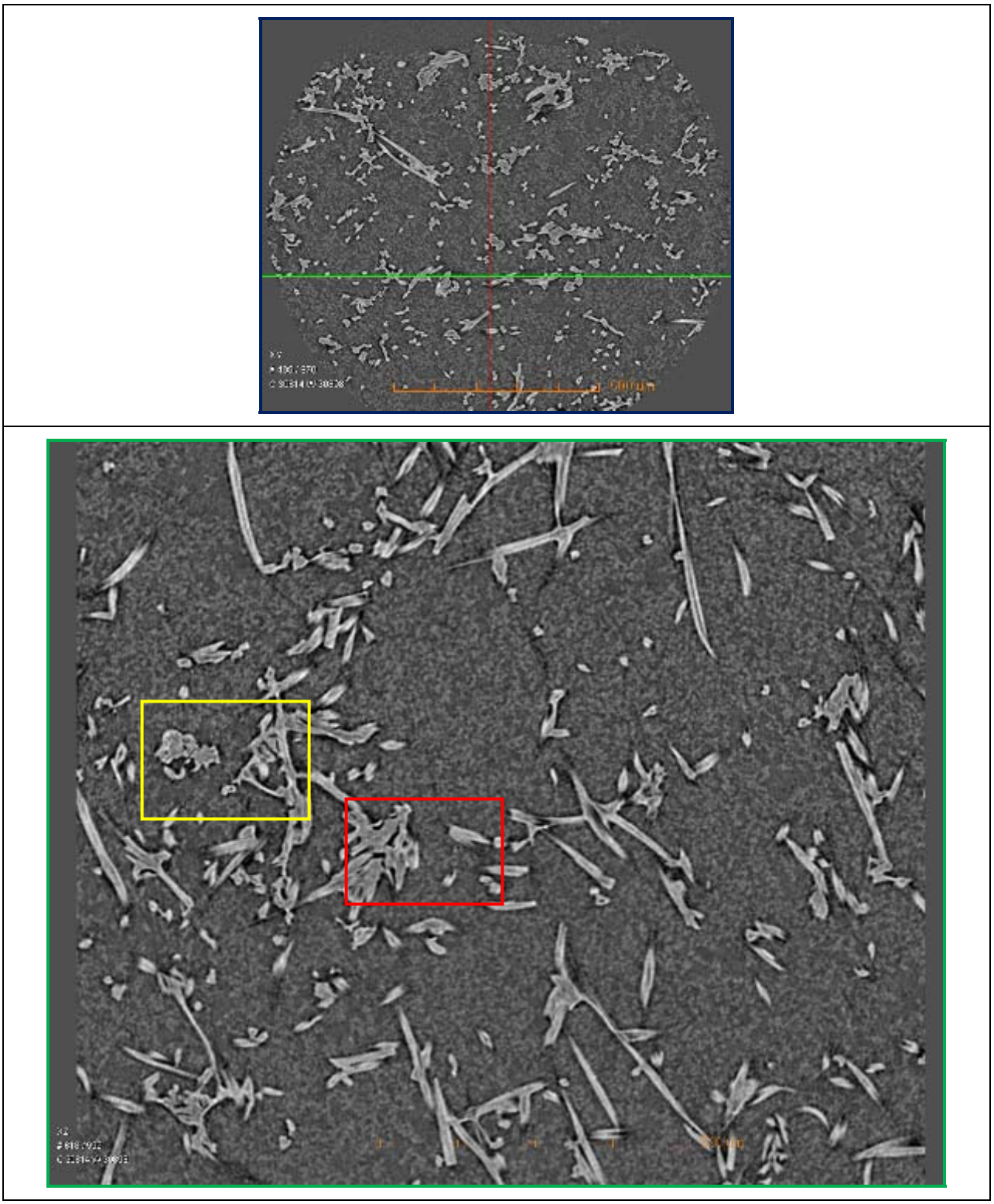


Figure 9: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

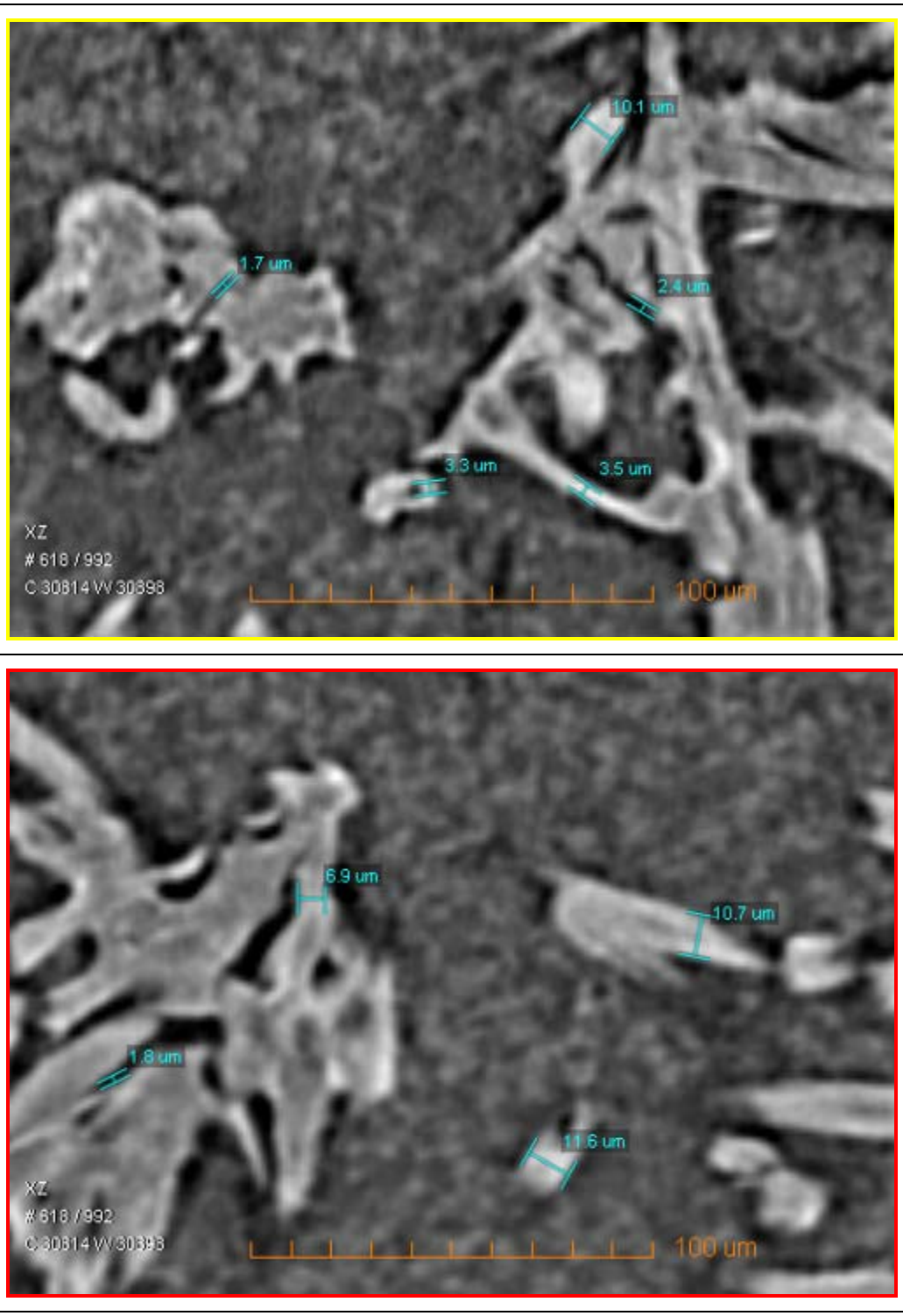
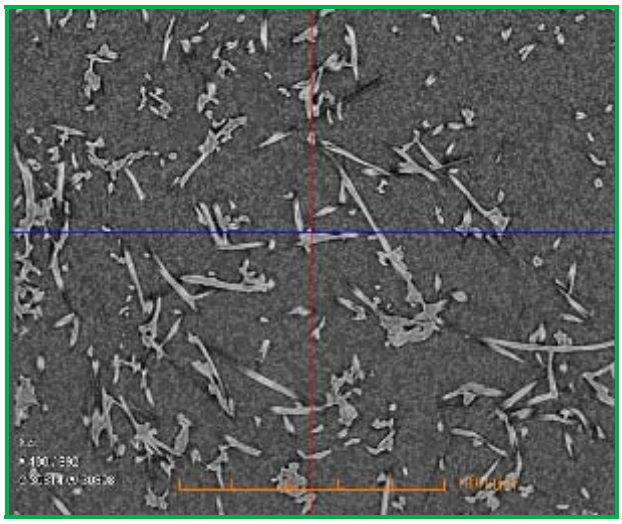


Figure 10: Detailed views of the areas in the yellow and red boxes in the previous figure.



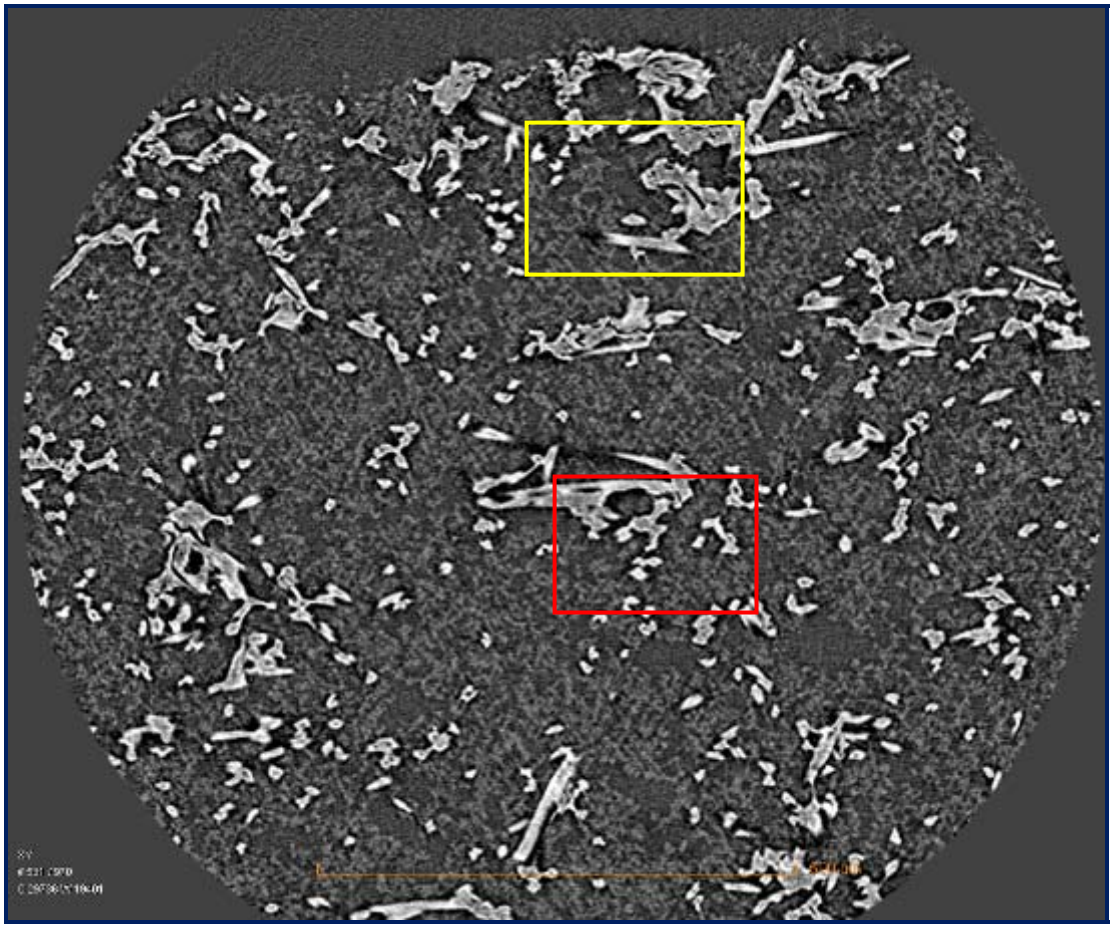


Figure 11: The blue line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

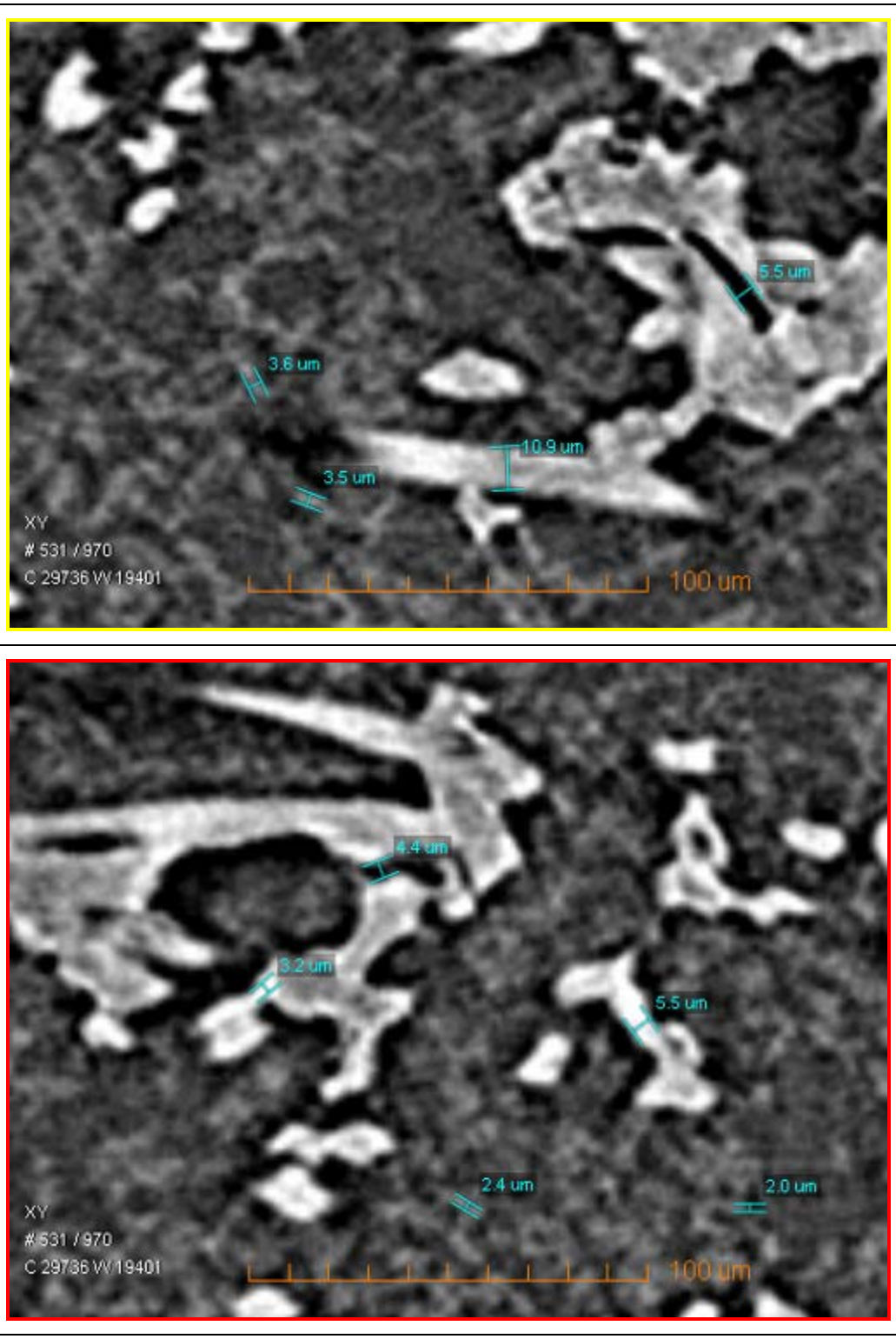


Figure 12: Detailed views of the areas in the yellow and red boxes in the previous figure.

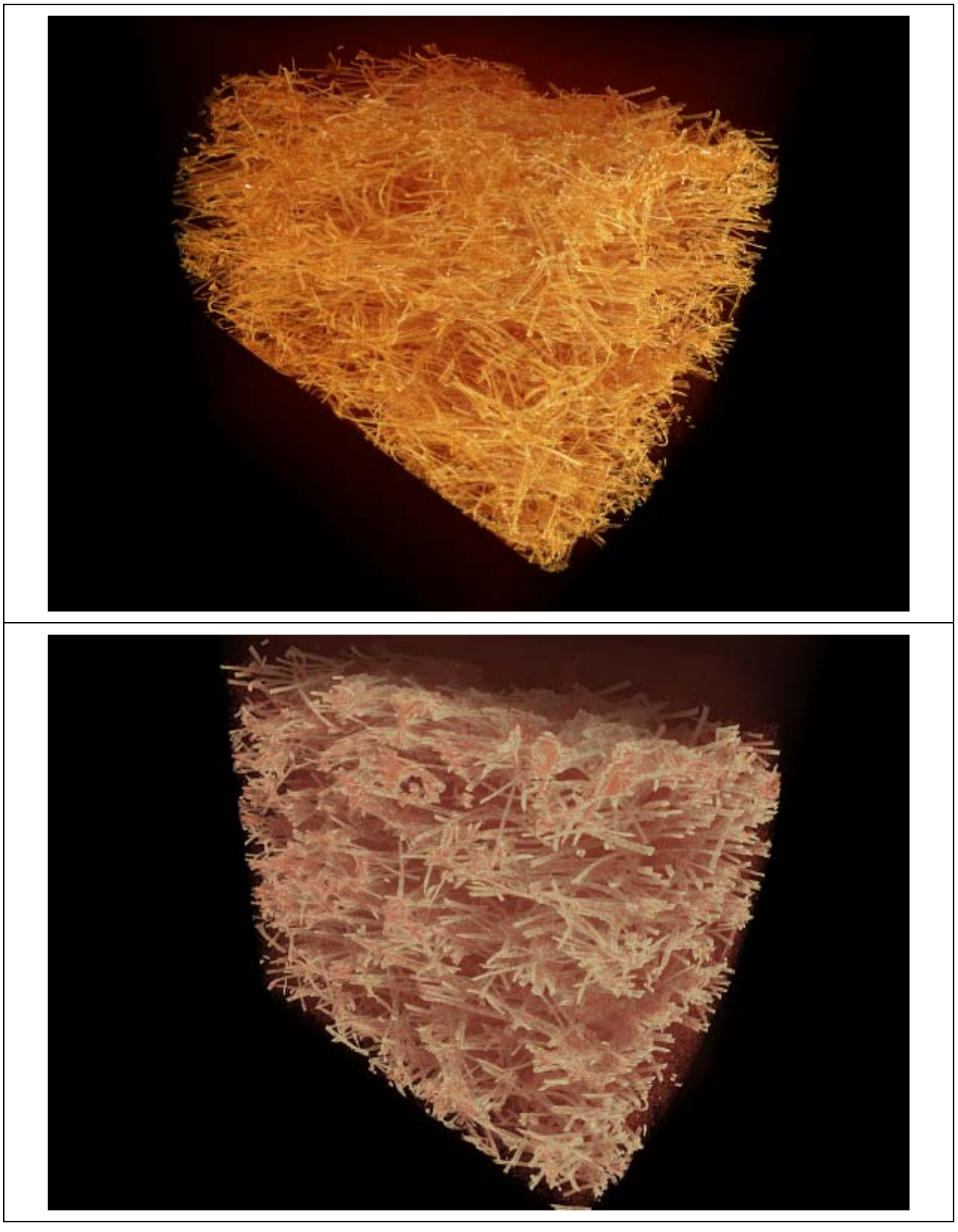


Figure 13: 3D rendered views of the imaged region.

4.3 Sample B 10X

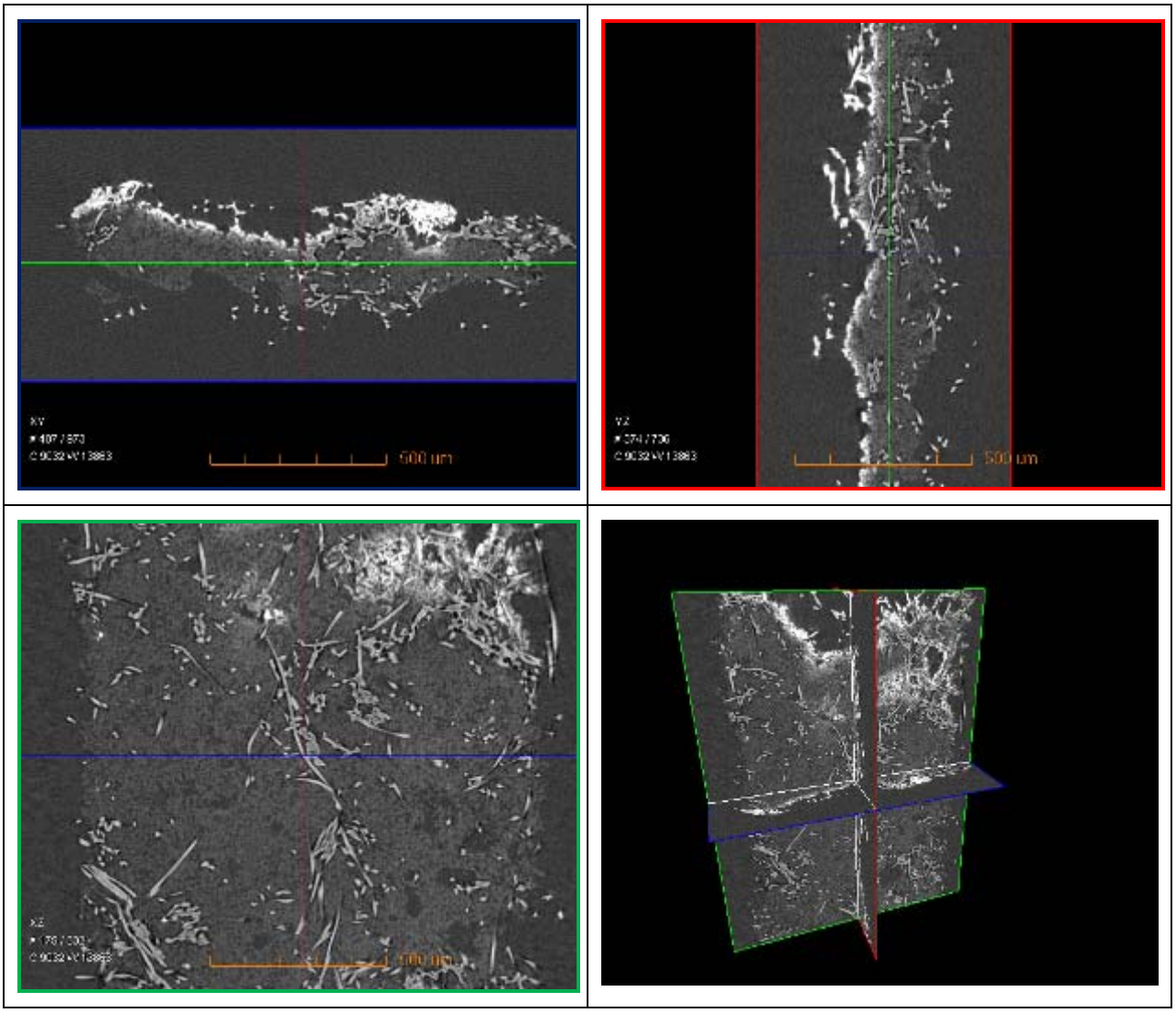


Figure 14: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

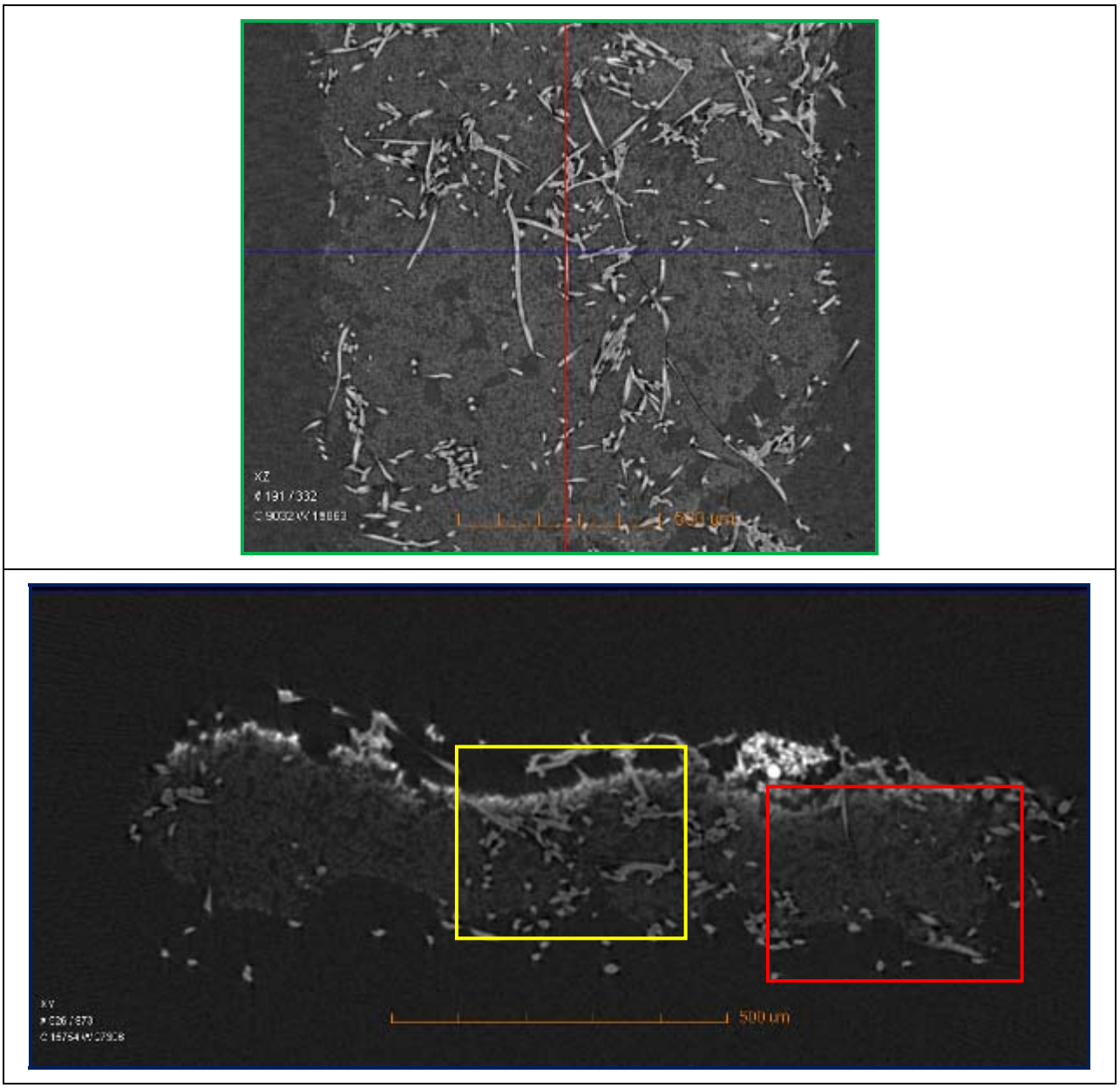


Figure 15: The blue line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

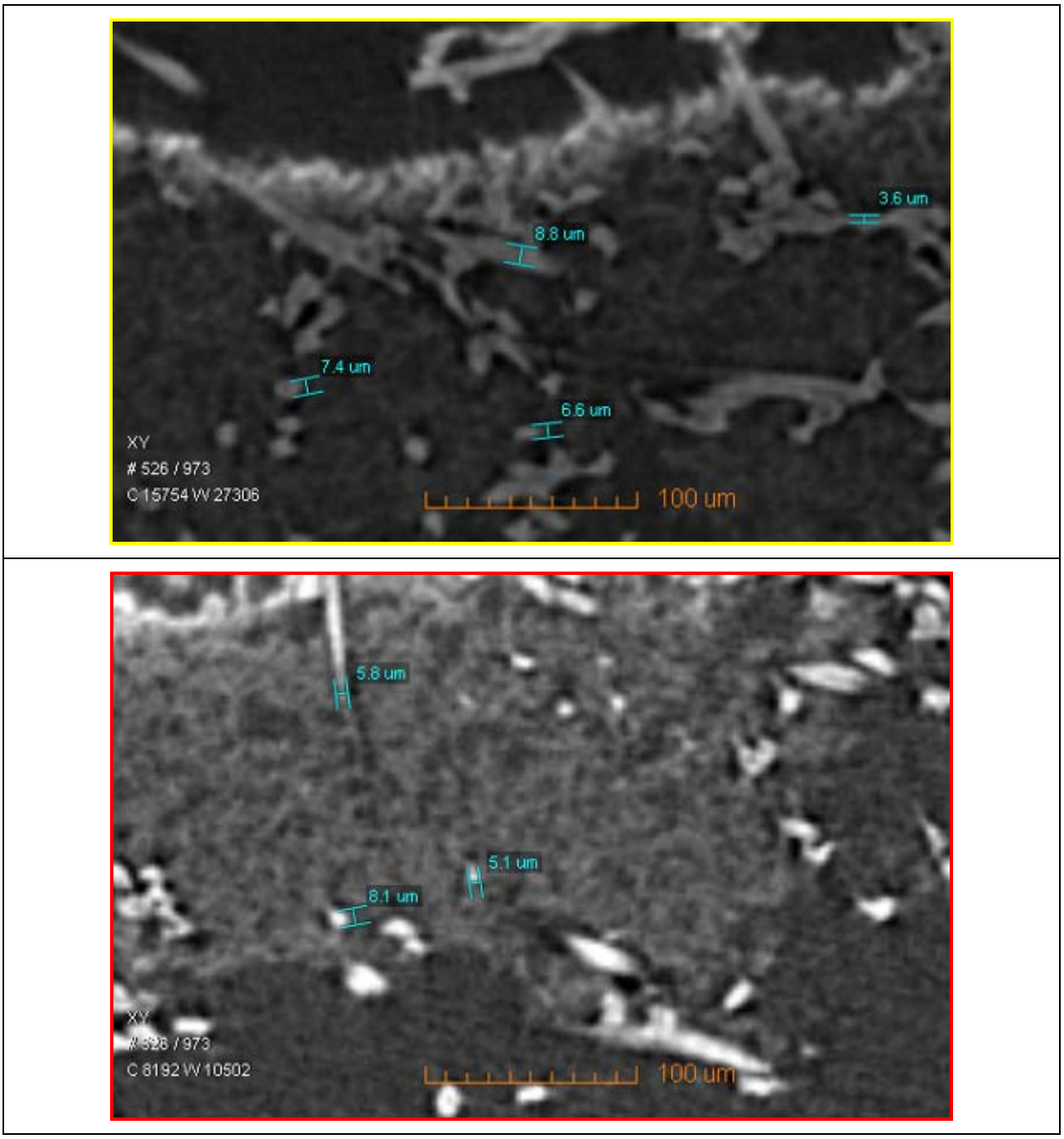


Figure 16: Detailed views of the areas in the yellow and red boxes in the previous figure.

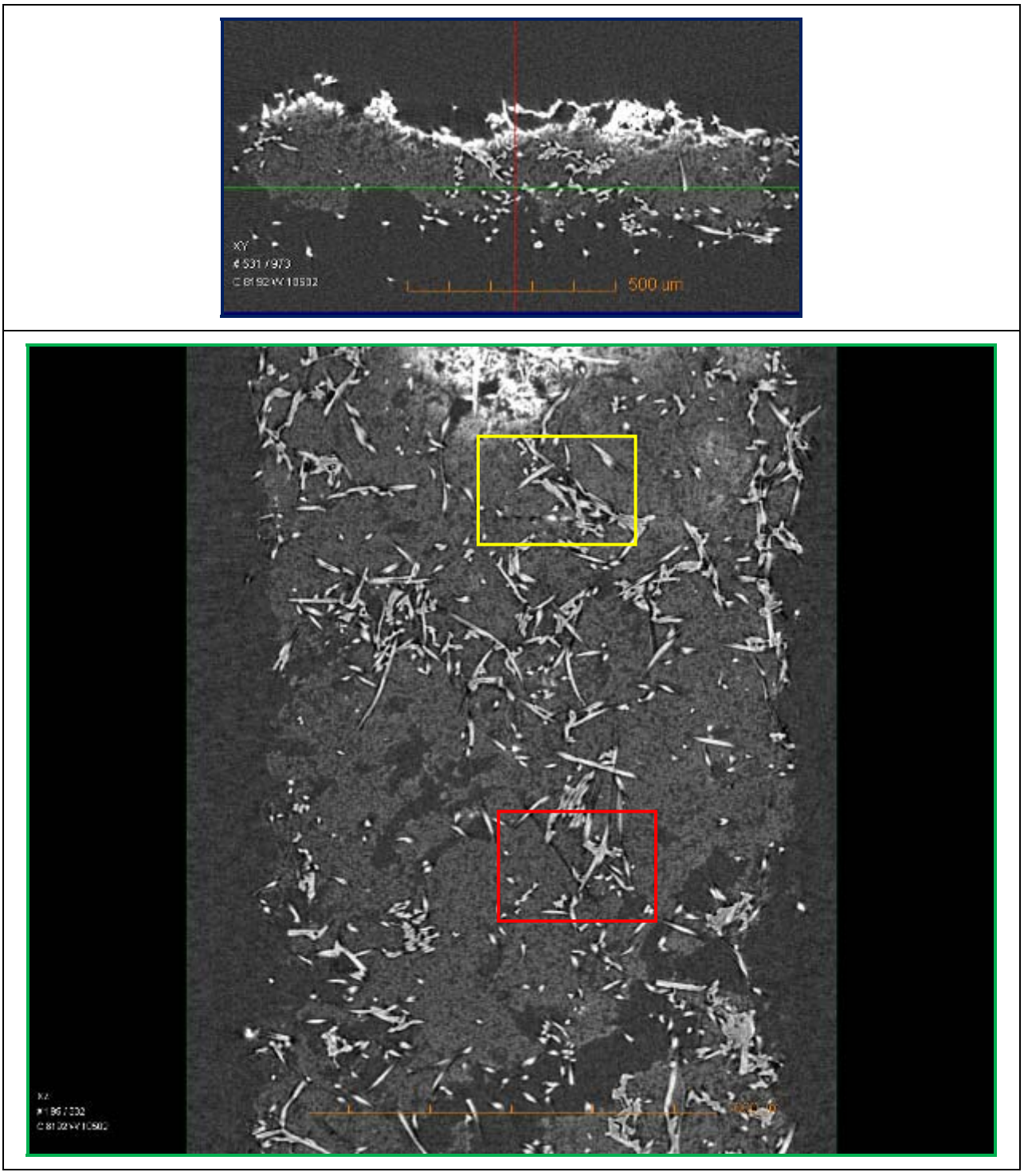


Figure 17: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

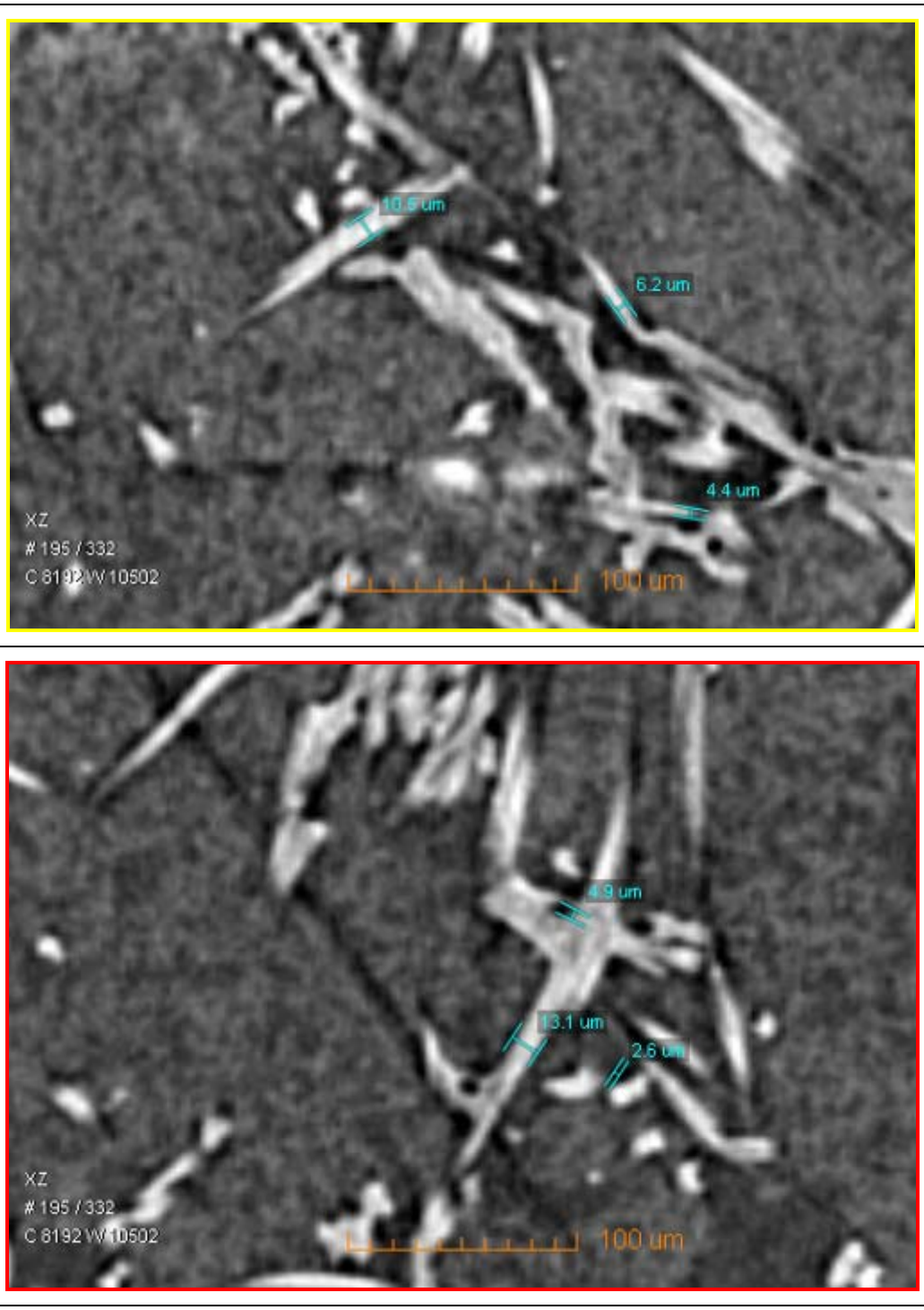


Figure 18: Detailed views of the areas in the yellow and red boxes in the previous figure.

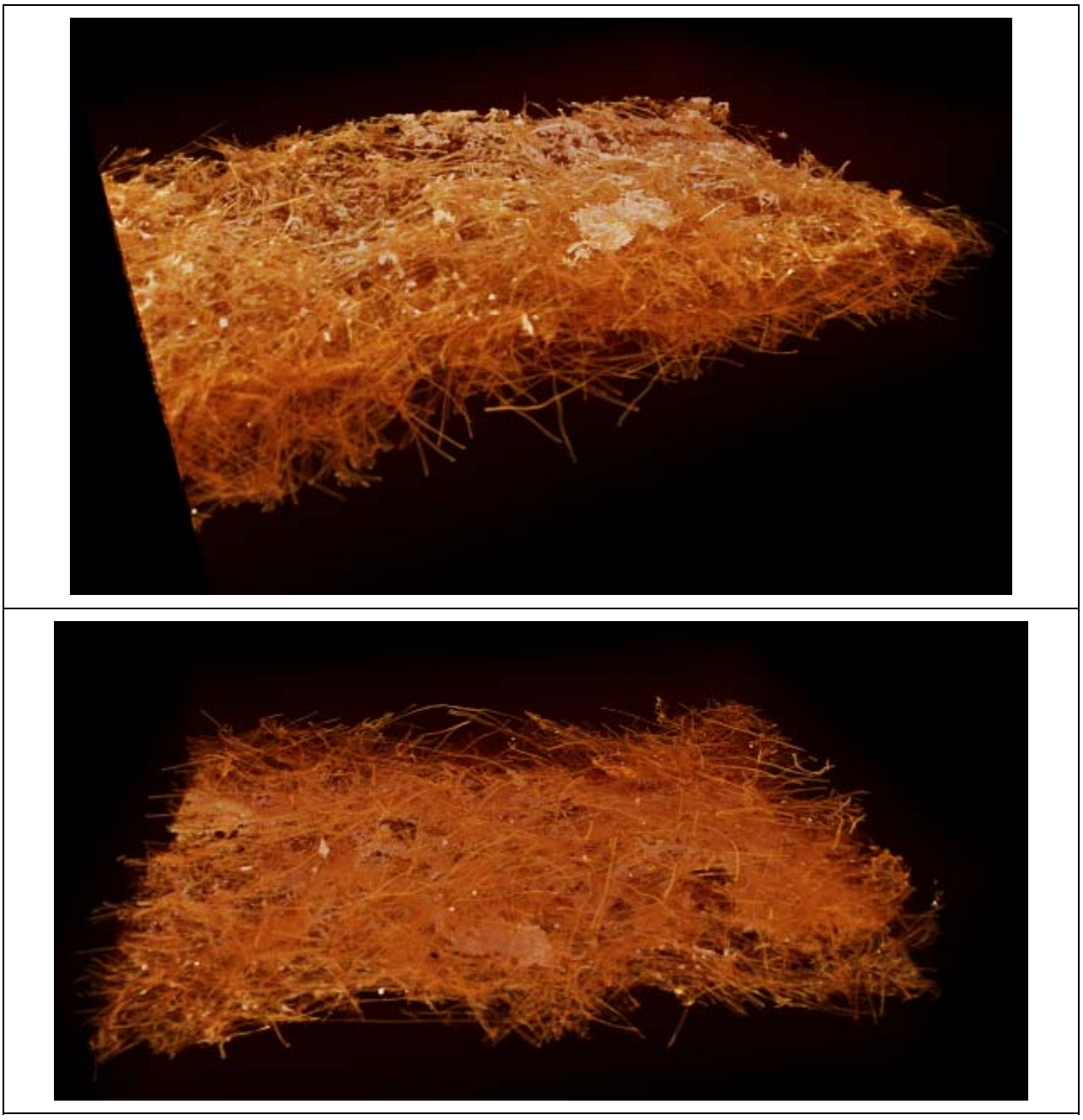


Figure 19: 3D rendered views of the imaged region.

4.4 Sample B 40X

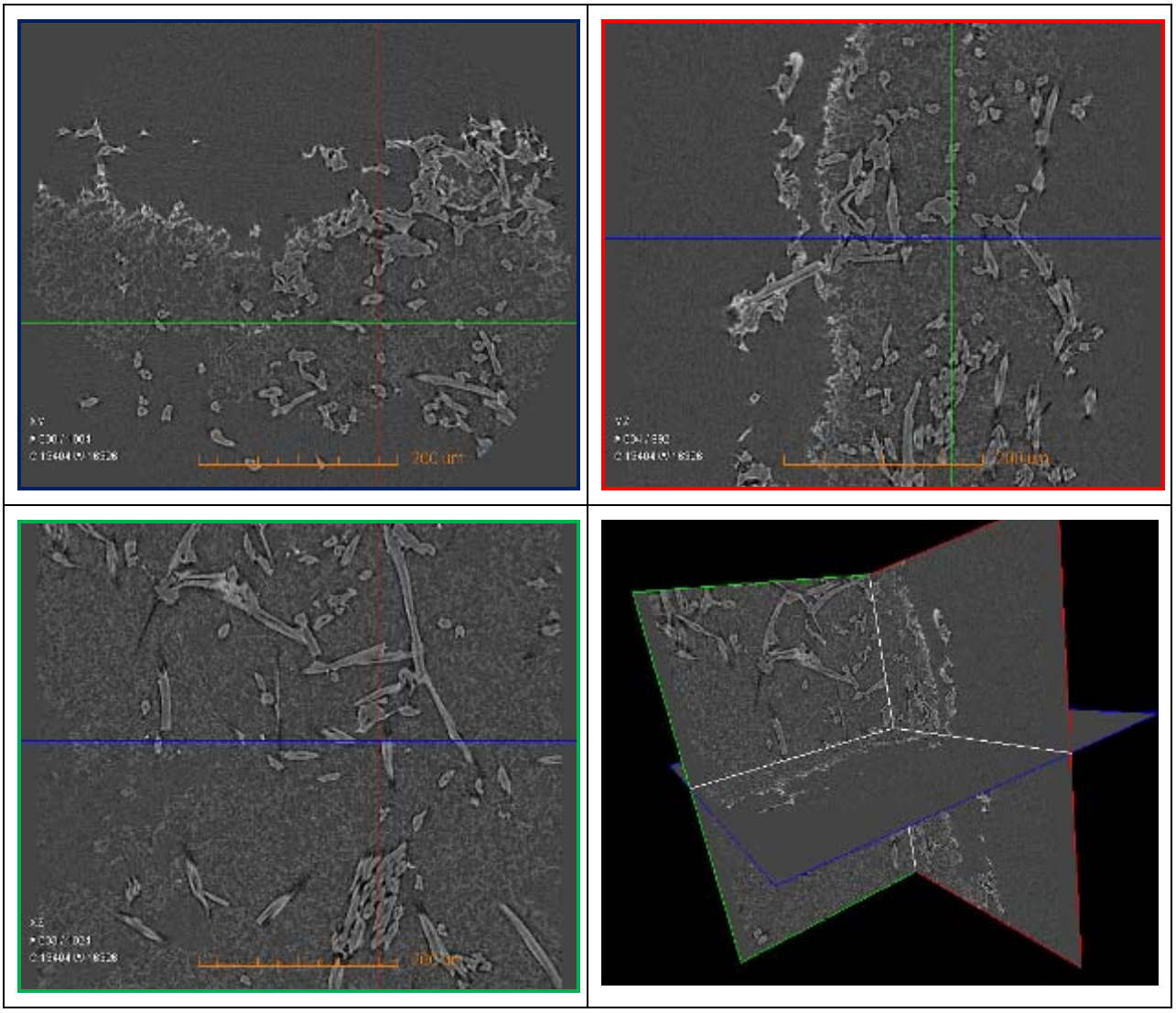


Figure 20: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

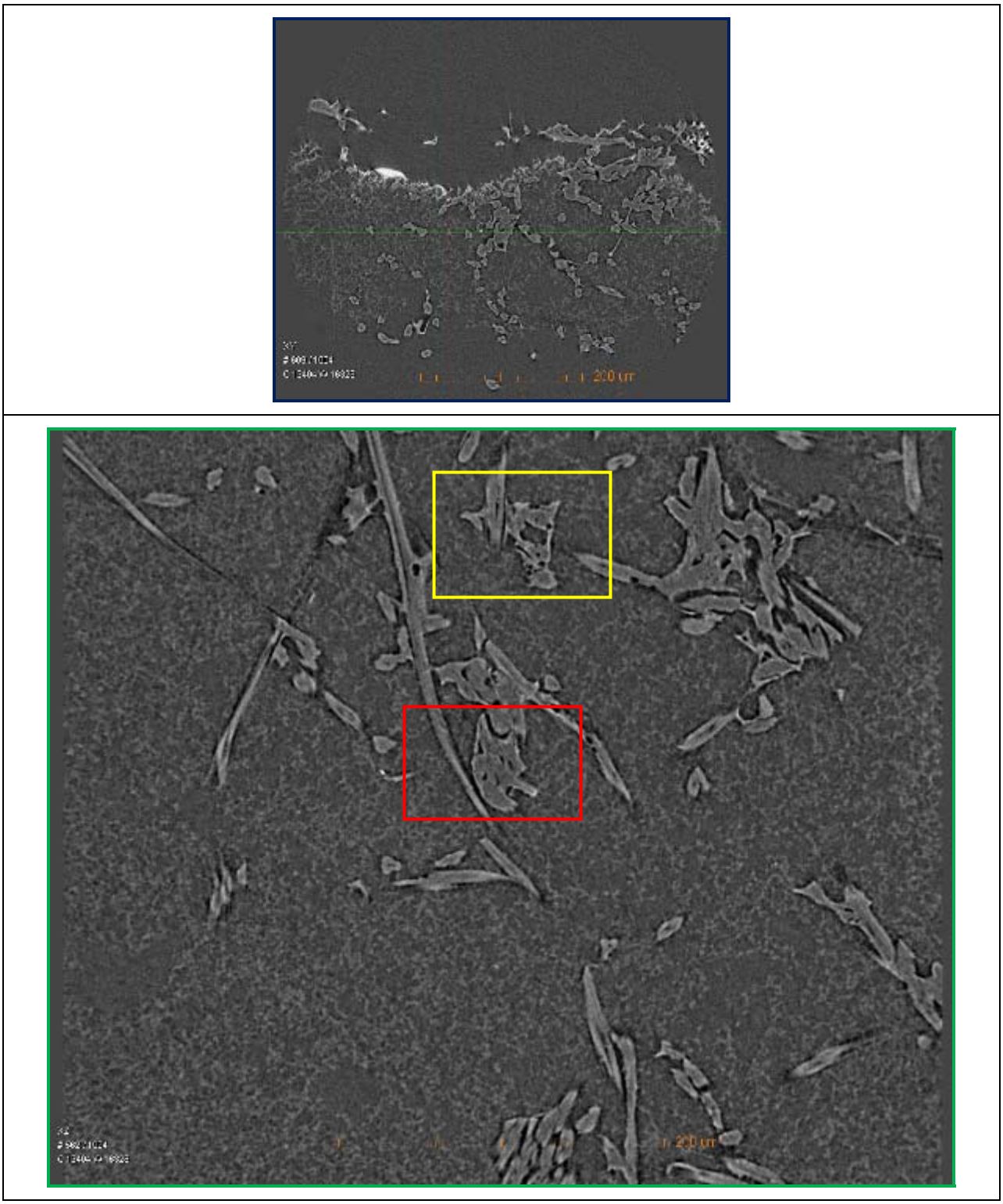


Figure 21: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

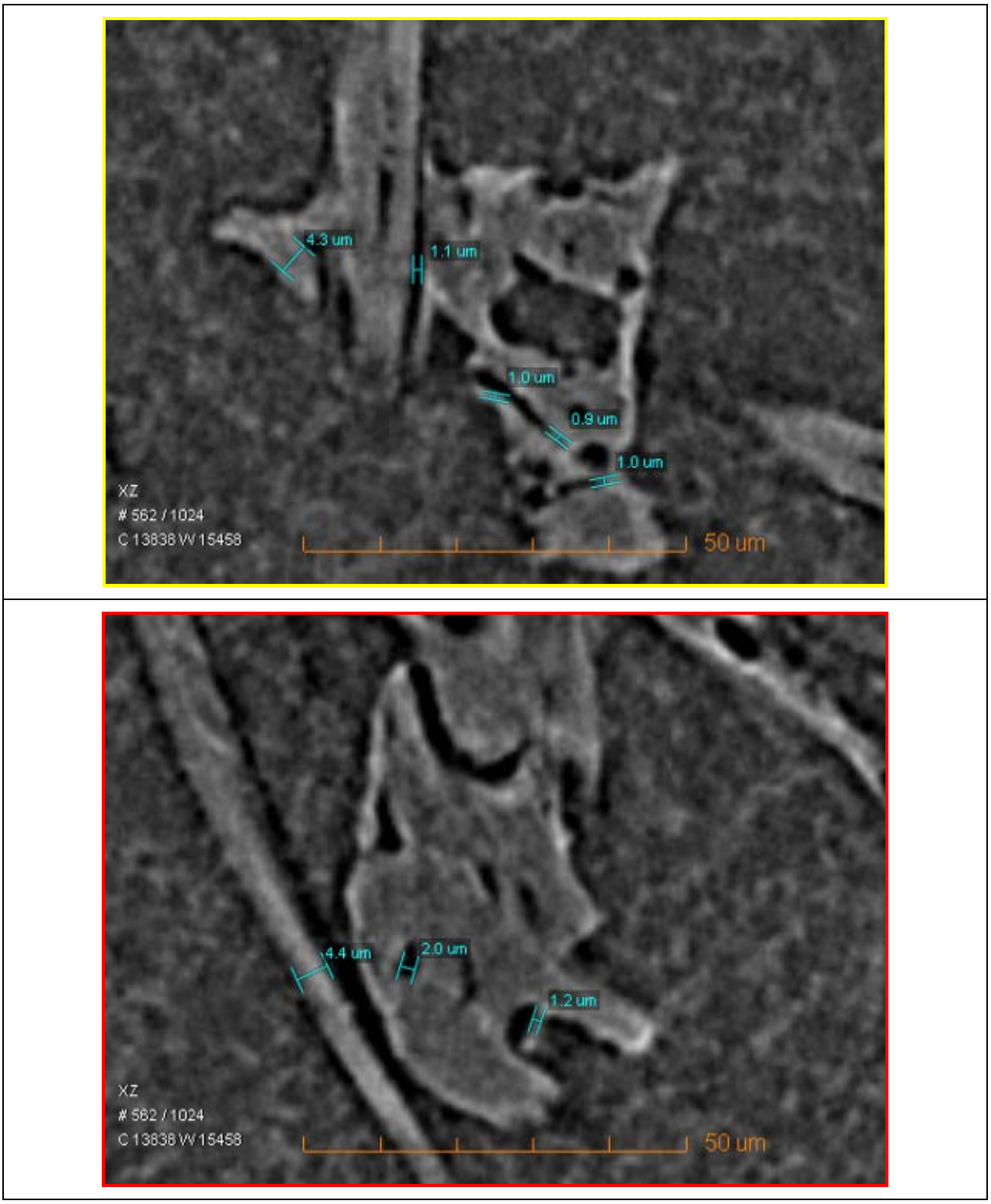


Figure 22: Detailed views of the areas in the yellow and red boxes in the previous figure.

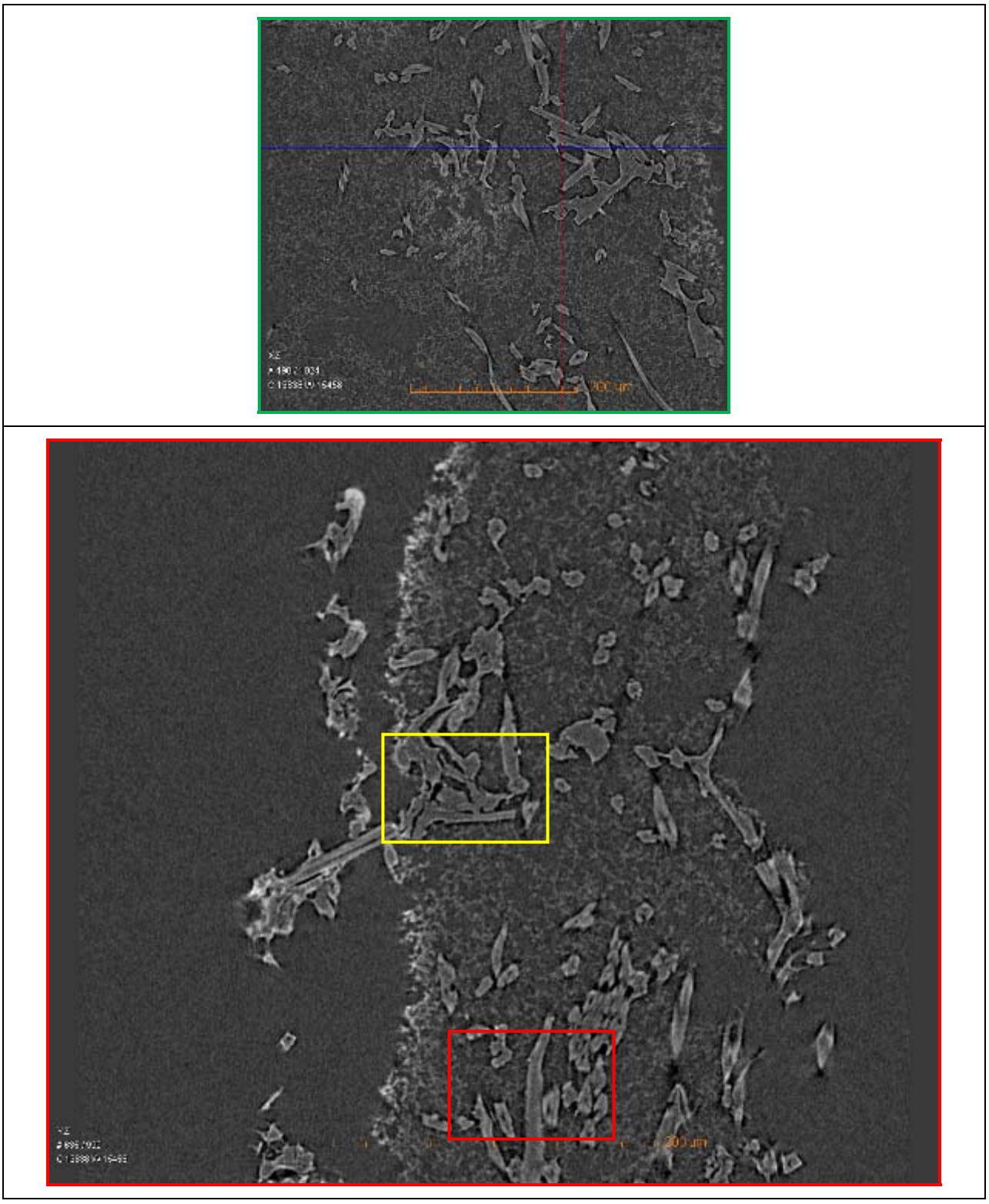


Figure 23: The red line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

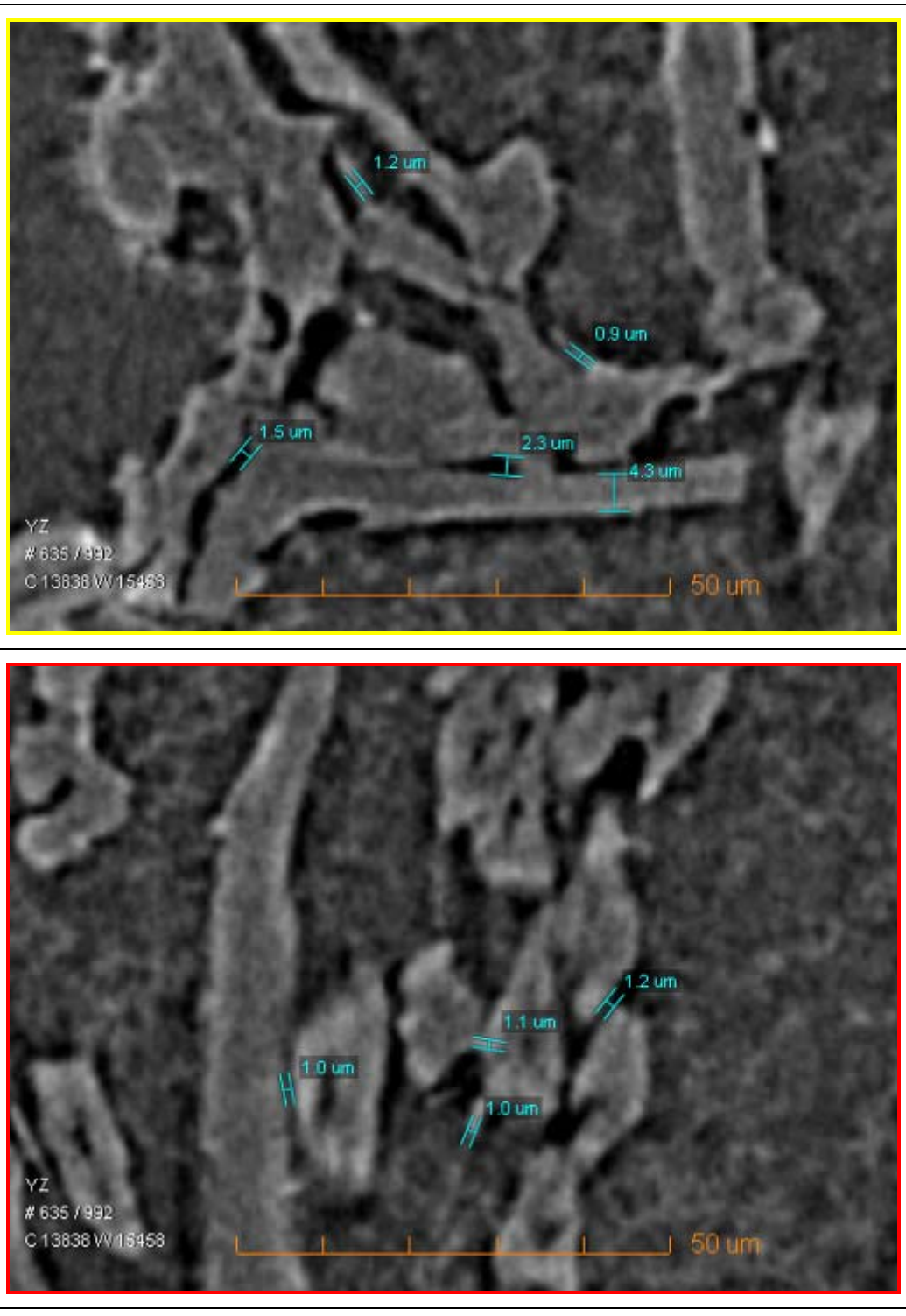


Figure 24: Detailed views of the areas in the yellow and red boxes in the previous figure.

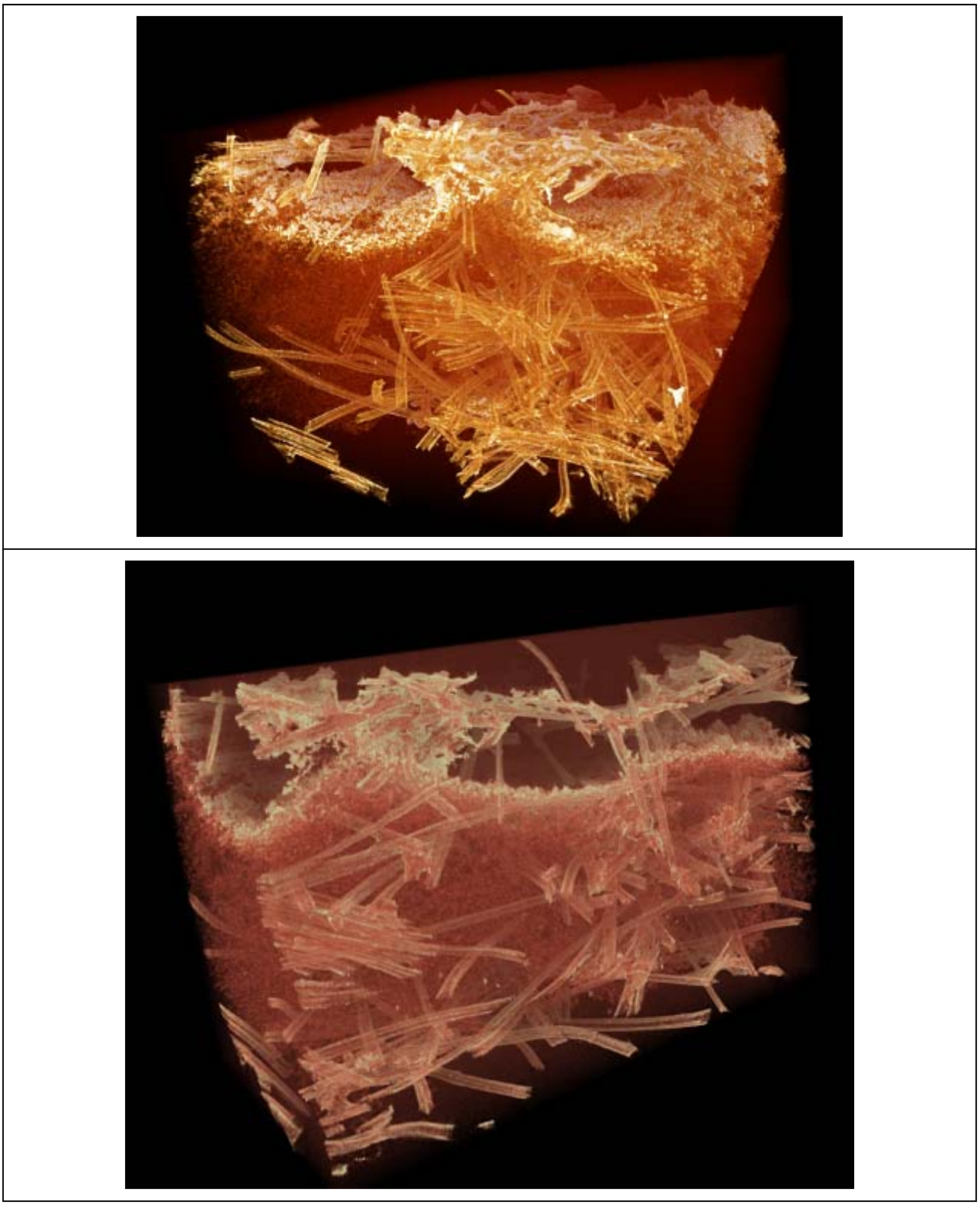


Figure 25: 3D rendered views of the imaged region.

4.5 *Sample C 10X*

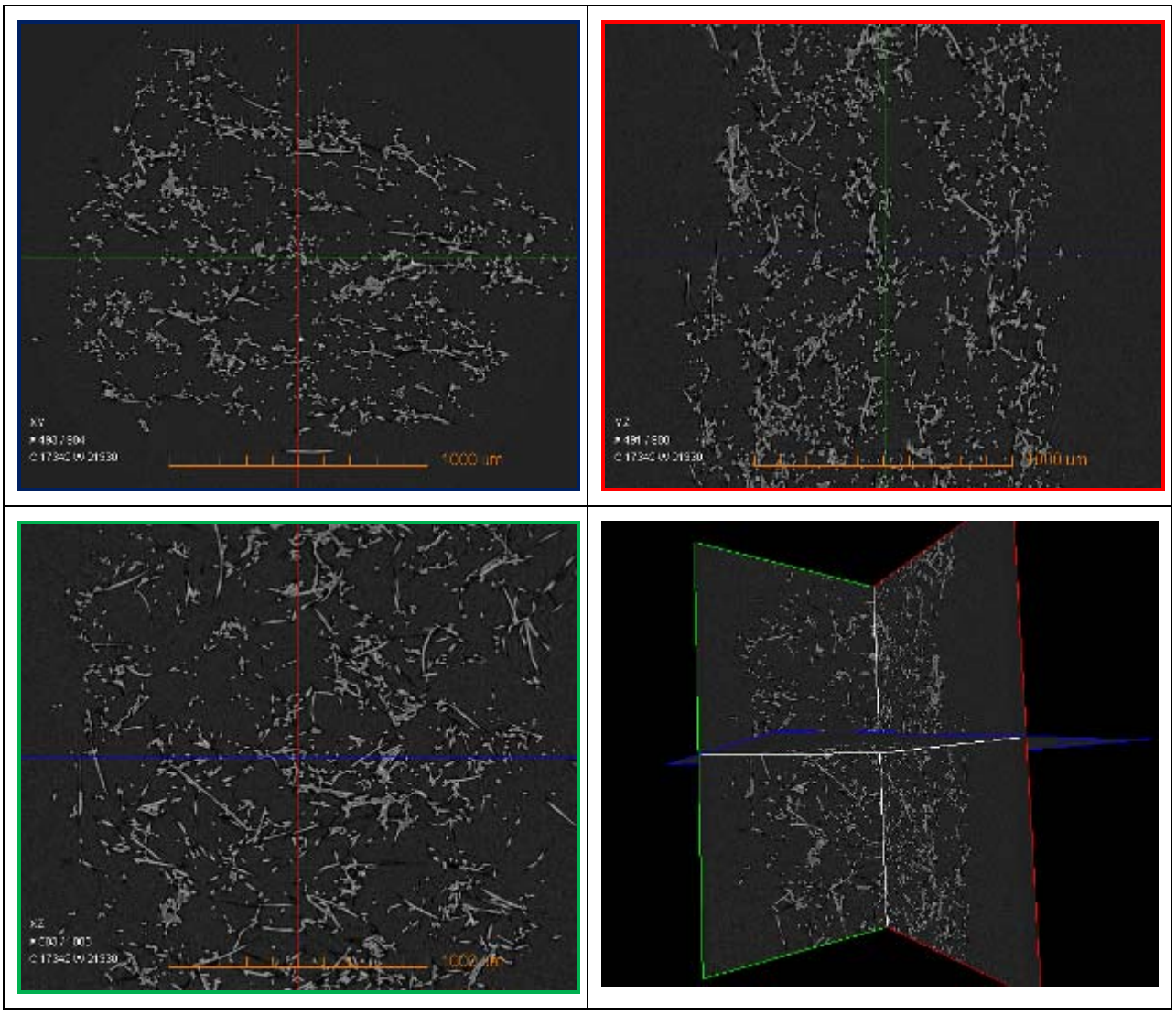


Figure 26: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

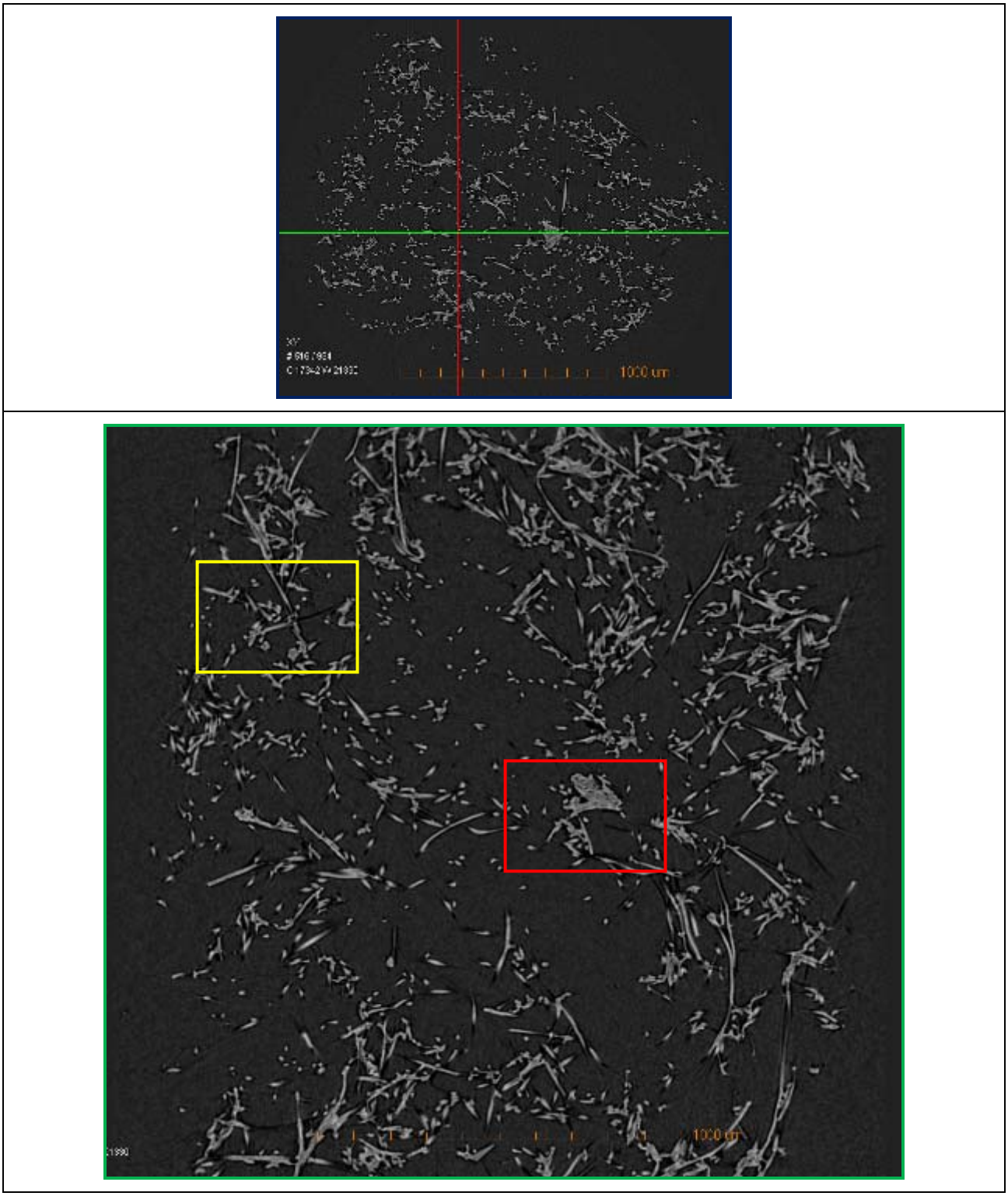


Figure 27: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

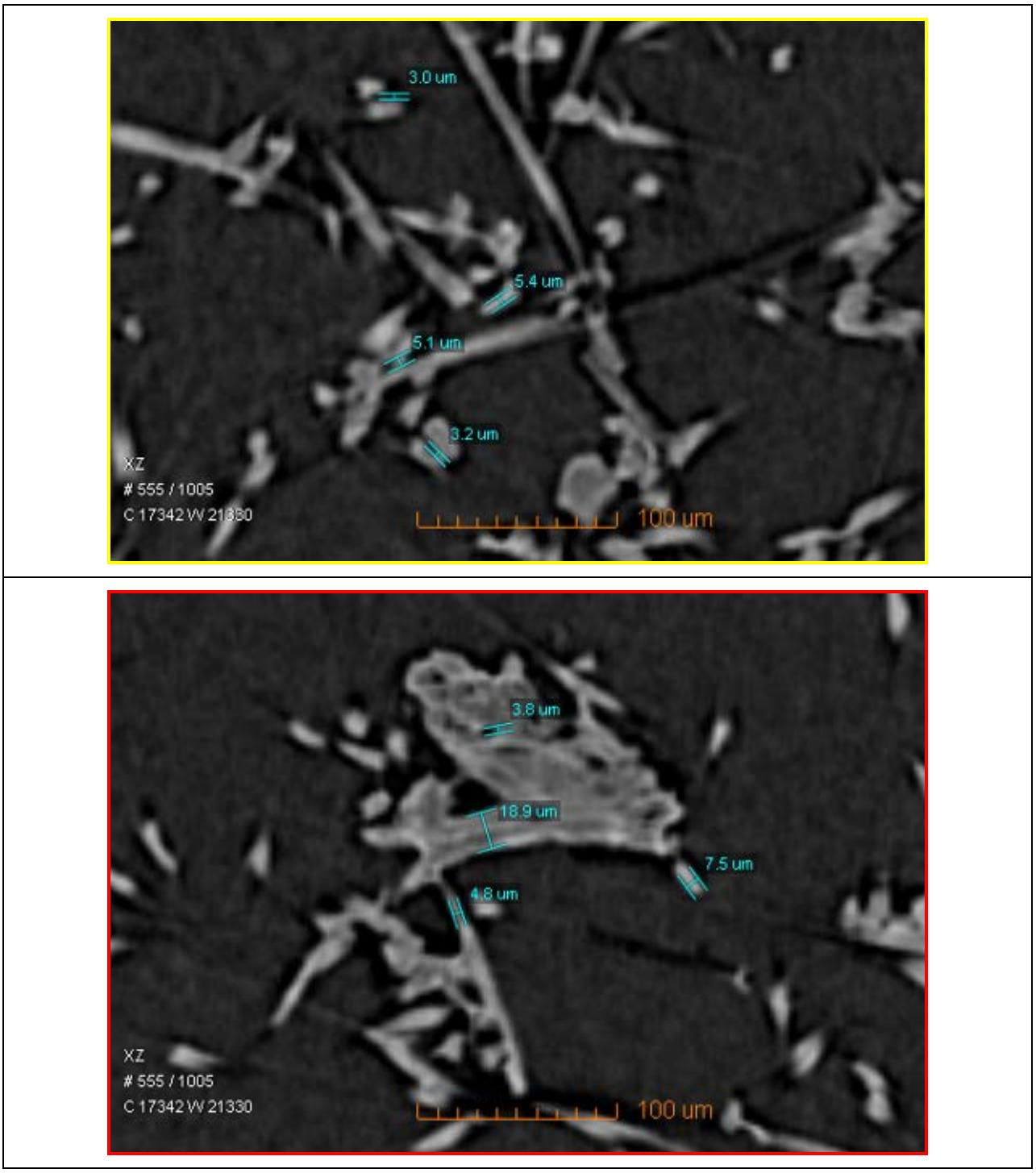


Figure 28: Detailed views of the areas in the yellow and red boxes in the previous figure.

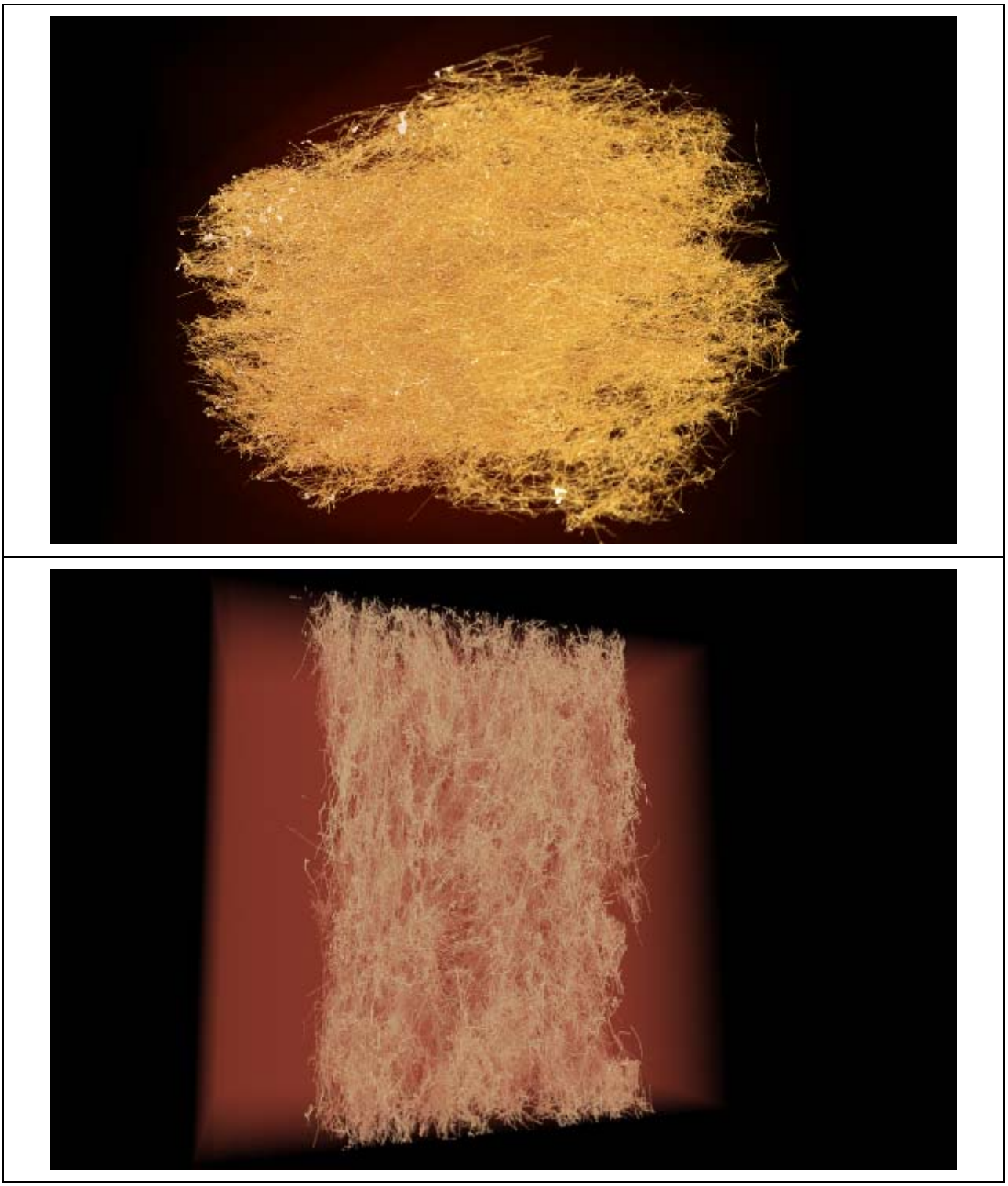


Figure 29: 3D rendered views of the imaged region.

4.6 Sample C 10X

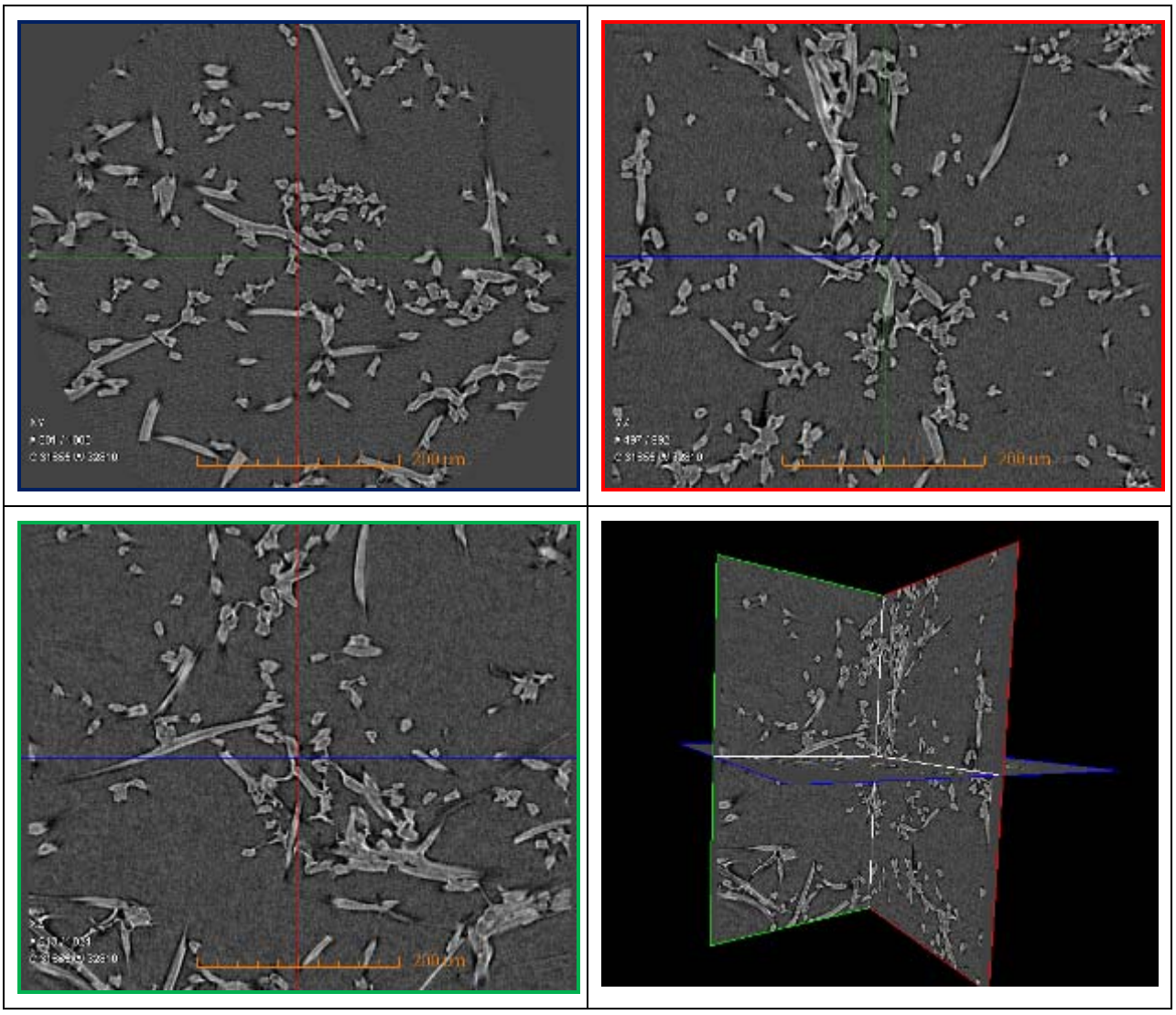


Figure 30: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

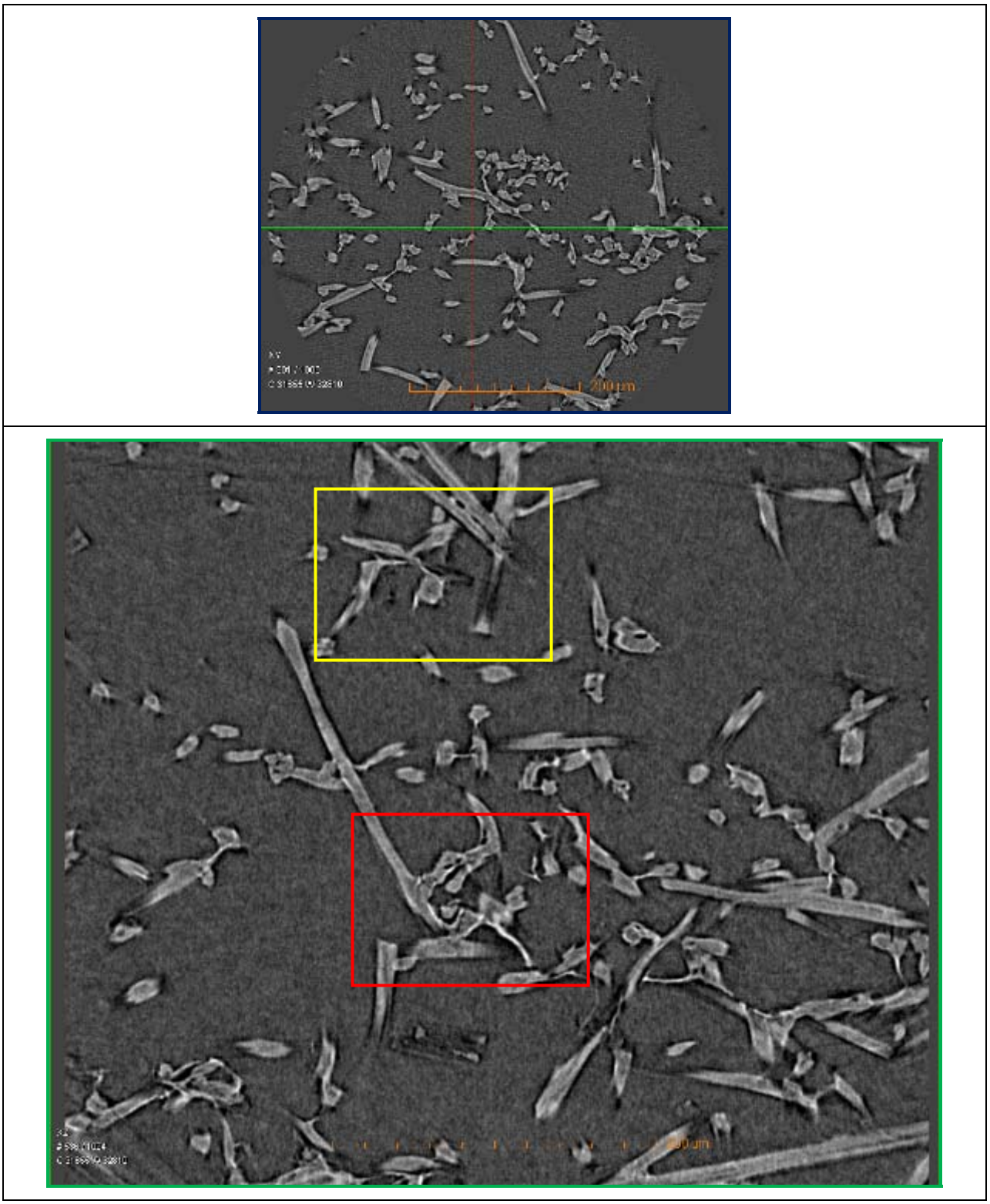


Figure 31: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

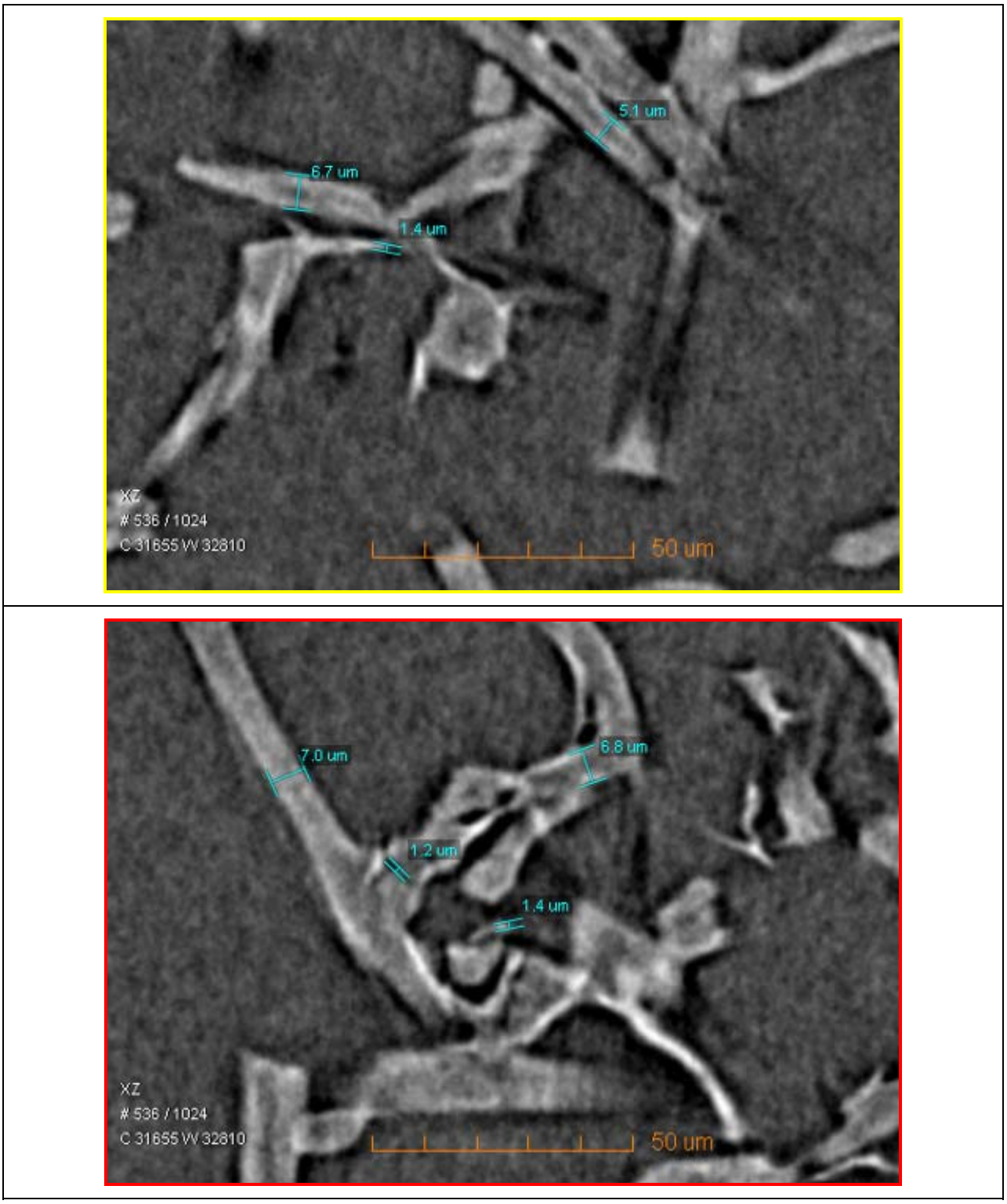


Figure 32: Detailed views of the areas in the yellow and red boxes in the previous figure.

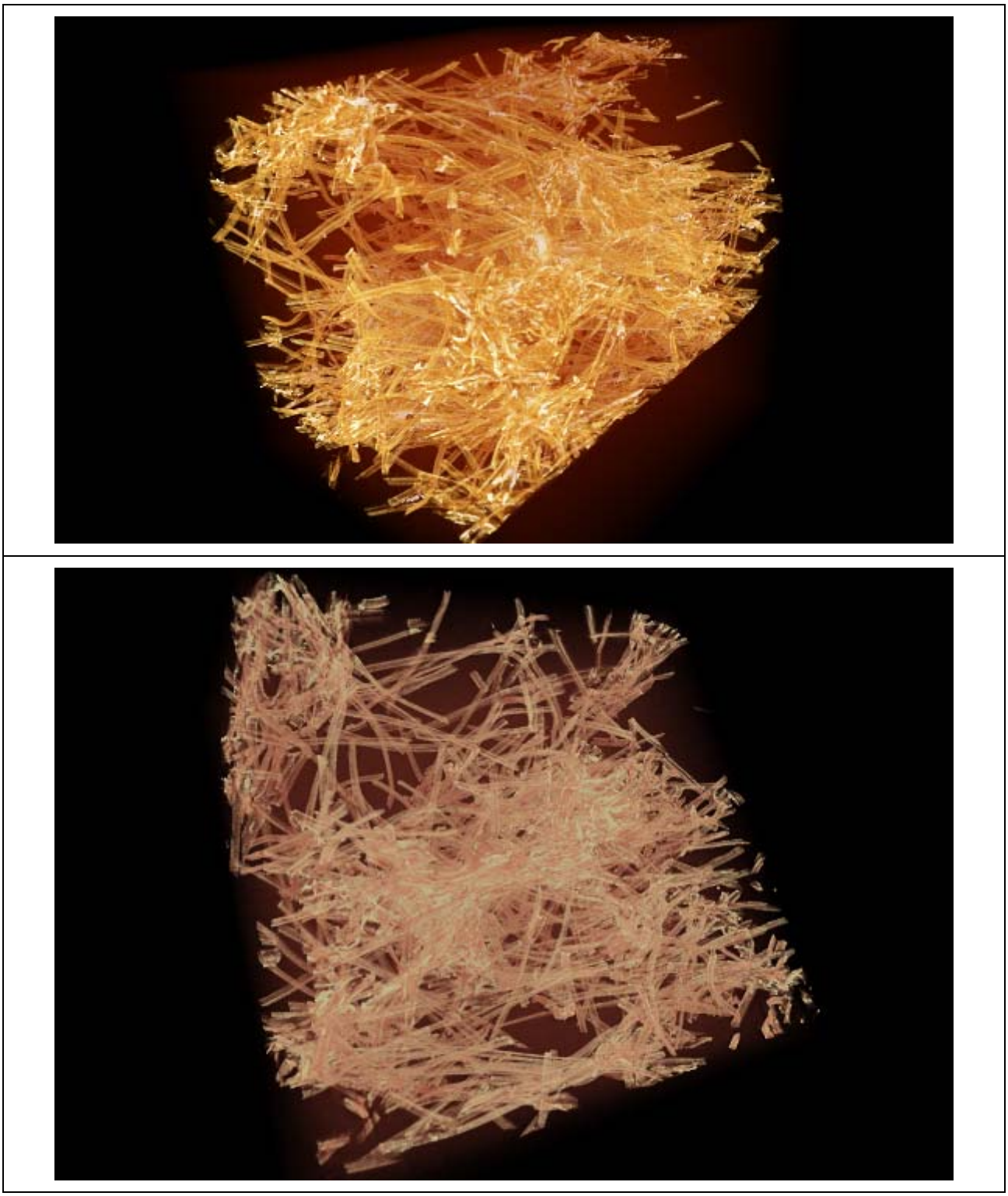


Figure 33: 3D rendered views of the imaged region.

4.7 Sample C 10X

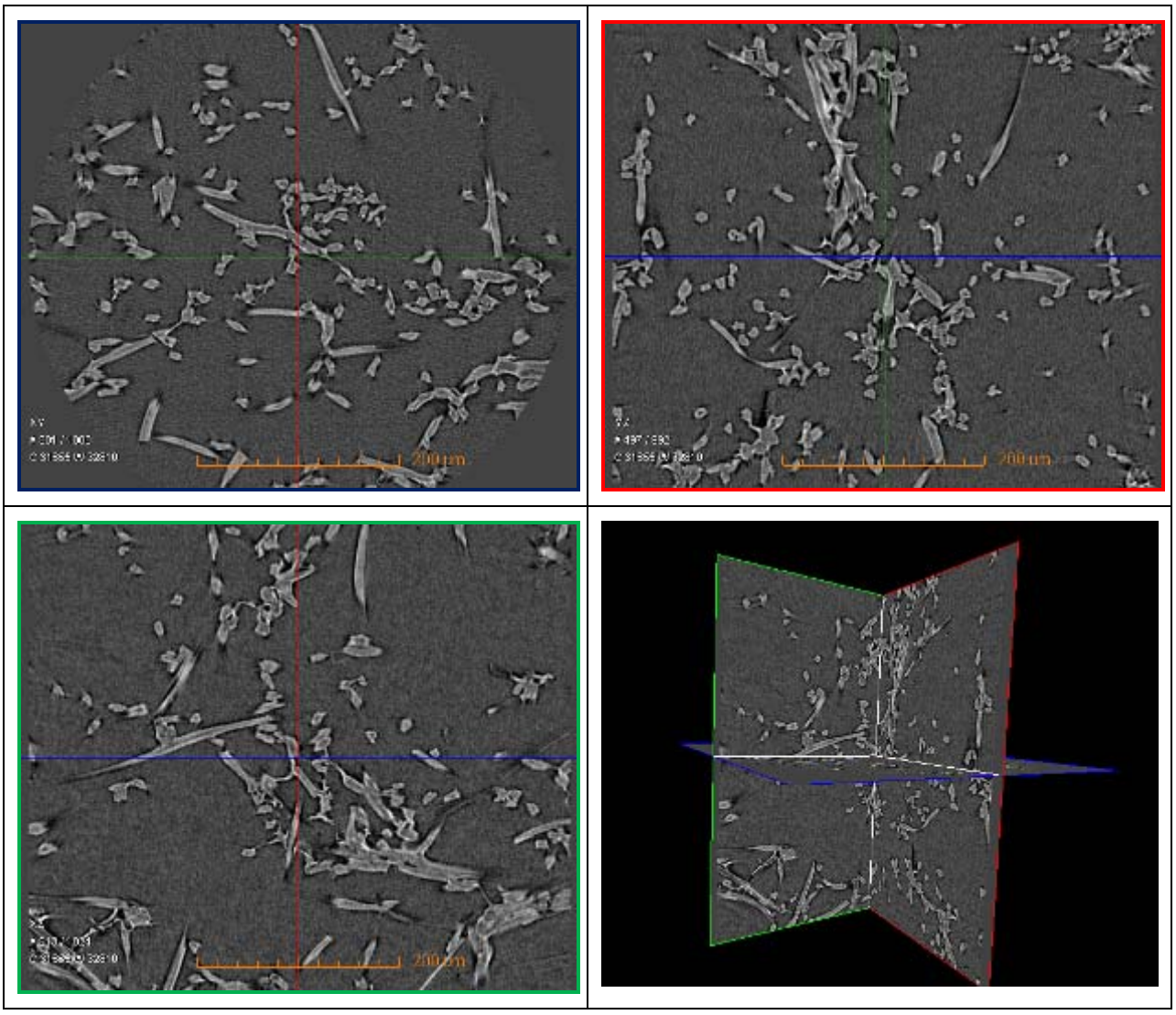


Figure 34: This set of images shows three orthogonal views and their relation to one another. The colored cross hairs in each image correspond to one of the other virtual cross sections. For example, the red and green lines in the upper left frame correspond to the images shown in the upper right and lower left frames, respectively. The lower right frame shows an image that should help explain the relation of the slices to one another.

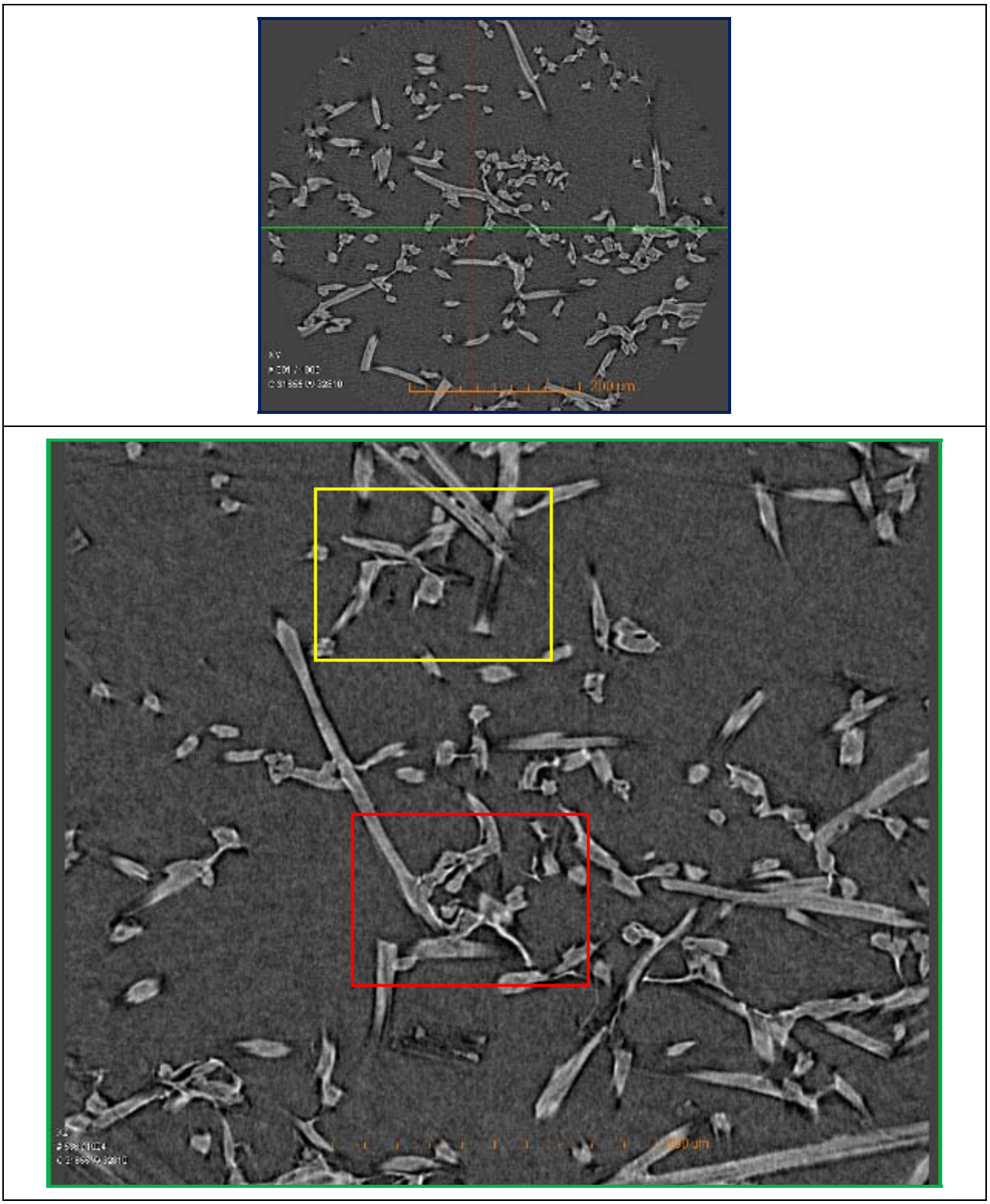


Figure 35: The green line in the upper image indicates the location of the virtual cross section shown in the lower image. The yellow and red boxed areas are shown in greater detail in the next figure.

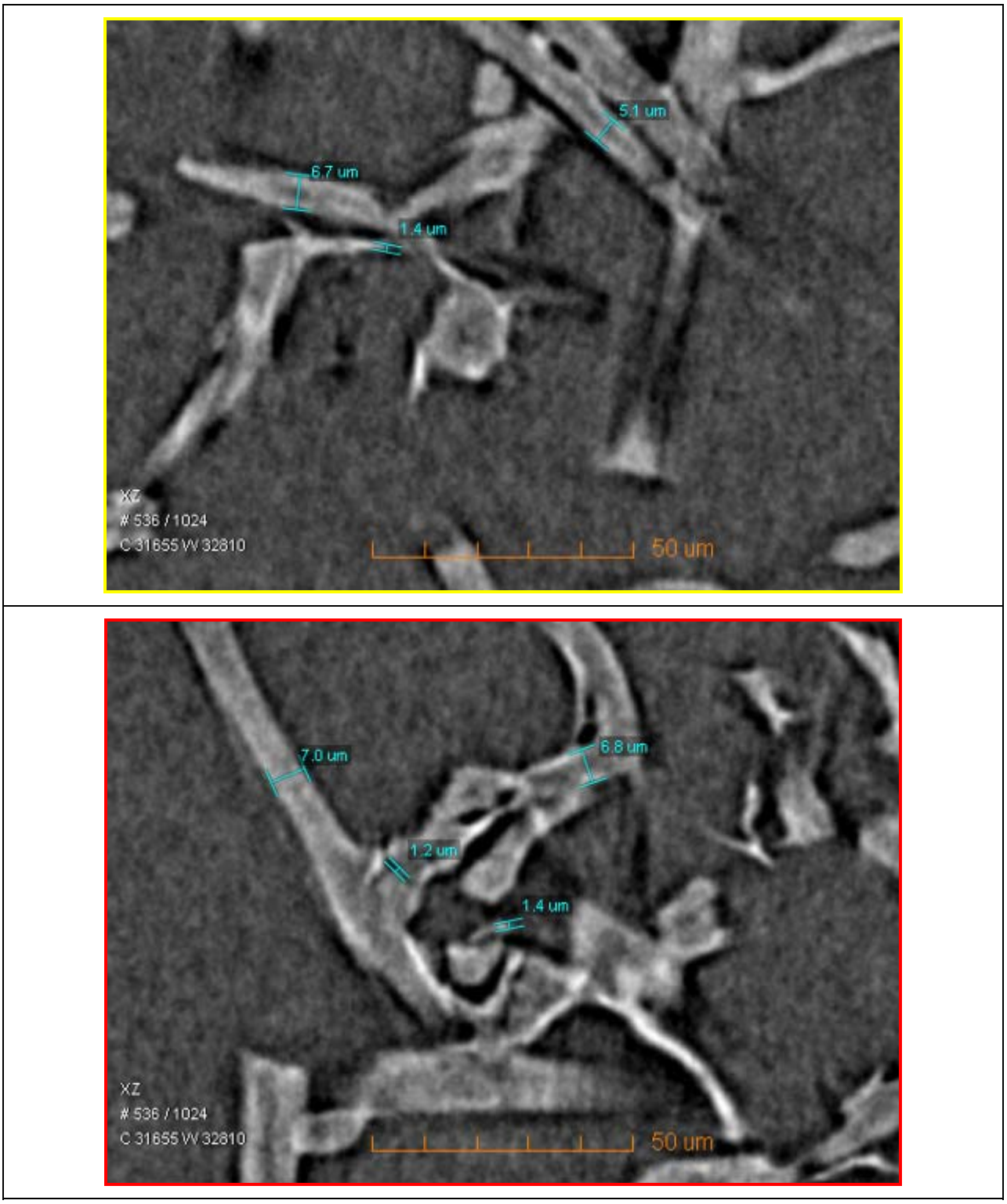


Figure 36: Detailed views of the areas in the yellow and red boxes in the previous figure.

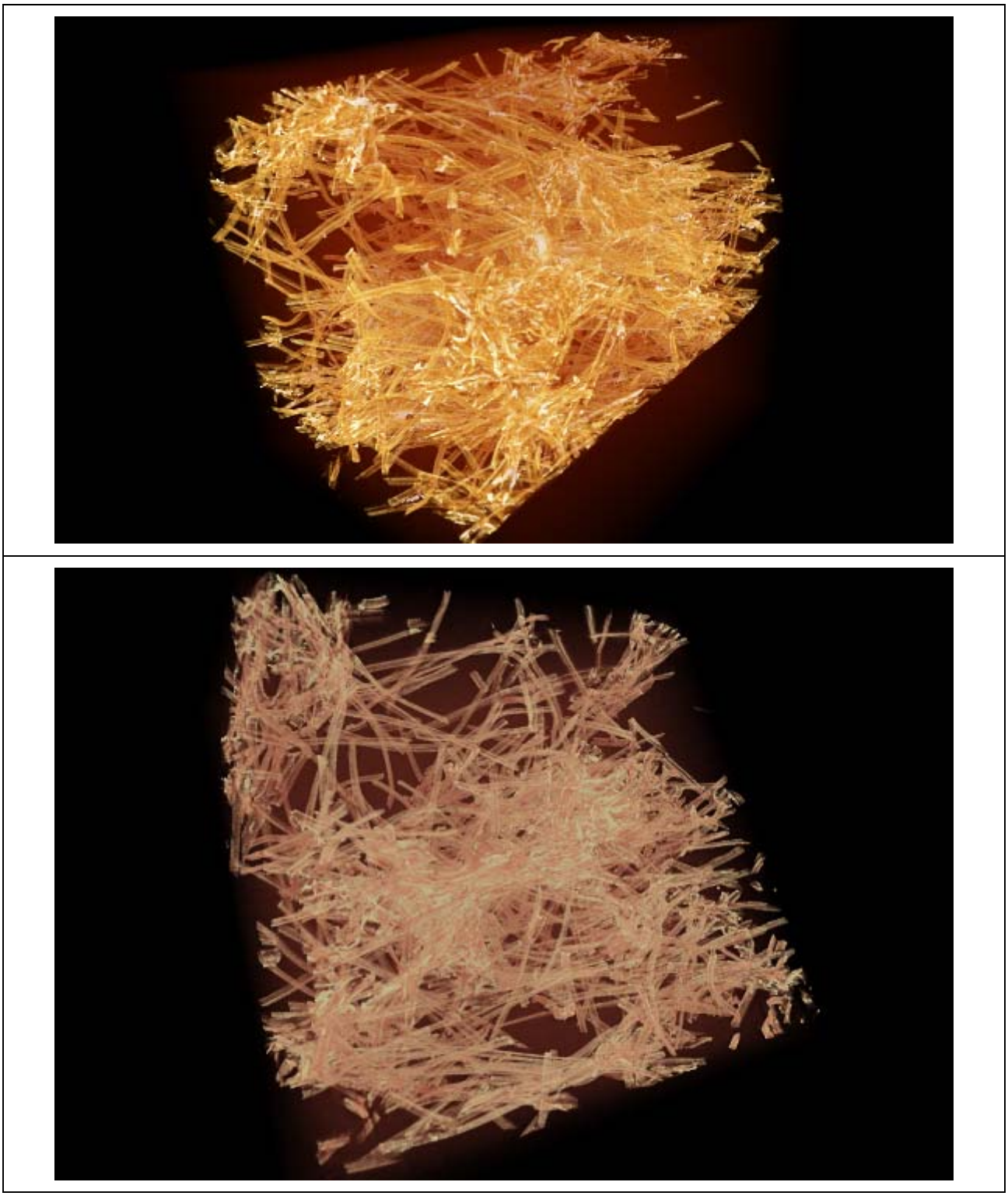


Figure 37: 3D rendered views of the imaged region.

5 Summary

NASA Ames supplied several material samples for the purpose of demonstrating the capabilities of Xradia's MicroXCT. The goal of this demonstration was to evaluate the ability of the MicroXCT to examine the internal structure of various fiber samples in a non-destructive manner. We've successfully provided 2D virtual cross sections of 3 samples showing many features of interest at various levels of resolution and field of view. The resultant image data from such samples can allow a user to analyze the material for distribution of fibers in the transverse and planar directions and to determine contact frequency. We also provided 3D images which are useful in visualizing the overall structure of the imaged regions.

This report highlighted the following characteristics of the MicroXCT:

- The ability to image a variety of materials, especially those with low x-ray absorption
- The ability to provide artifact free images.
- The ability to provide detailed three dimensional data for identifying a variety of different features and morphology
- 2D virtual cross-sectioning
- 3D volume rendering
- 2D delayering movies