A Modern Correlative Workflow Environment to Master the Multi-scale Challenge

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In most fields of study, it is imperative to understand the behavior of a system across several length scales in three dimensions in order to properly address the structural parameters that govern its performance. In order to characterize a system, be it the brain, a structural metal alloy, or a porous rock reservoir, multiple microscopic methods have evolved to specialize in capturing a relatively well defined window of scales, modalities or dimensions of information. Examples of this include medical-CT, confocal light microscopy, X-ray tomography, FIB-SEM tomography, serial block face SEM, TEM tomography, atom probe tomography, and more. As these techniques have progressed individually, a clear challenge that has emerged has been how to intelligently navigate to and acquire 3D volumes of interest (from centimeter to nanometer), and, subsequently, to fuse multi-scale and multi-modality datasets in such a way that leaves the microscopist in control as recently published in the context of a corrosion study [1].

In this forum, we will discuss the emergence of two major technologies that address this challenge. The first is the increased utilization of laboratory X-ray microscopy (XRM), a powerful technique to perform nondestructive 3D imaging on samples over a range of length scales and material types [2]. XRM has shown the ability to provide valuable context, time-lapse, and navigational information in the correlative microscopy environment, complementing information from light and electron microscopy instruments [3].

The second major development enabling correlation, is the recent development of a modern microscopy workflow environment (ZEISS Atlas 5), which acts as the glue between experiments obtained on multiple platforms (SEM, LM, FIB-SEM, XRM, etc.). Atlas 5 automates several advanced SEM and FIB-SEM acquisition tasks, but also provides a visualization environment to co-locate and register multiple datasets from multiple instruments in one place. Going further, this environment extends beyond the conventional 2D correlation approach, by incorporating 3D datasets such as those obtained by XRM or FIB-SEM tomography.

We will review both developments in the context of three examples, from Materials Research, Life Science and Geoscience. In Materials Science, XRM tomograms collected on an Al 7075 aluminum alloy (Figure 1) are used to locate inclusions and pores within the interior of the microstructure, which are then selected and examined at higher resolution by targeted FIB-SEM serial sectioning at defined regions of interest [4]. In Life Sciences, XRM presents a unique opportunity to bridge the length scales between light and electron microscopy (Figure 2), easing the 'needle in a haystack' navigation problem for locating the same region of interest using multiple microscopes [5]. In Geosciences, we demonstrate the great 2D and 3D multi-scale challenge, and how Atlas 5 has been successfully used to enable the efficient study of such porous media systems.

References:

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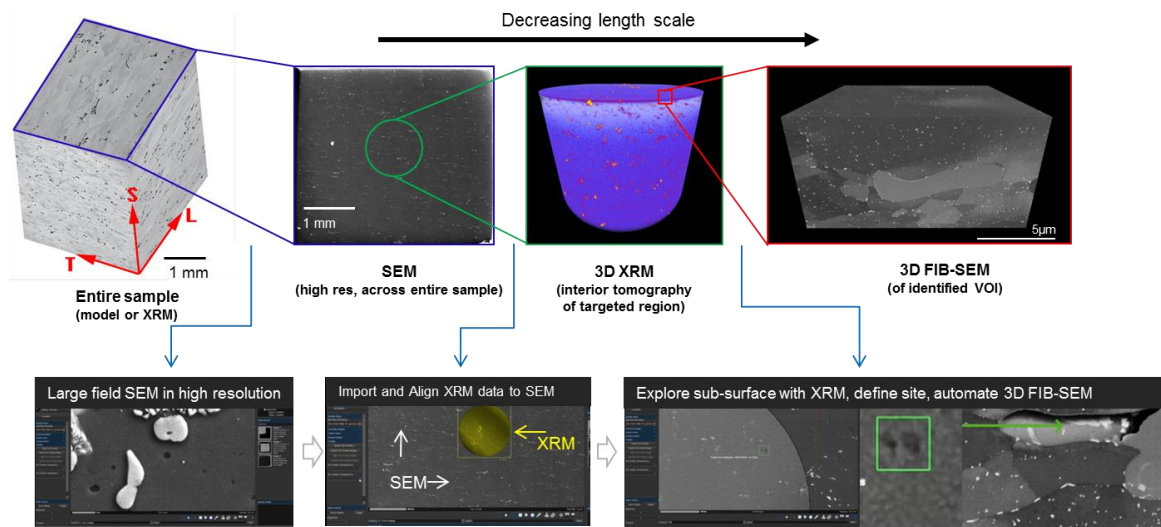
Figure 1: A 3D automated correlative workflow demonstrated on an Aluminum 7075 alloy to access information about inclusions, voids, precipitates and the Al matrix grain structure. In collaboration with N. Chawla and S. Singh of Arizona State University.
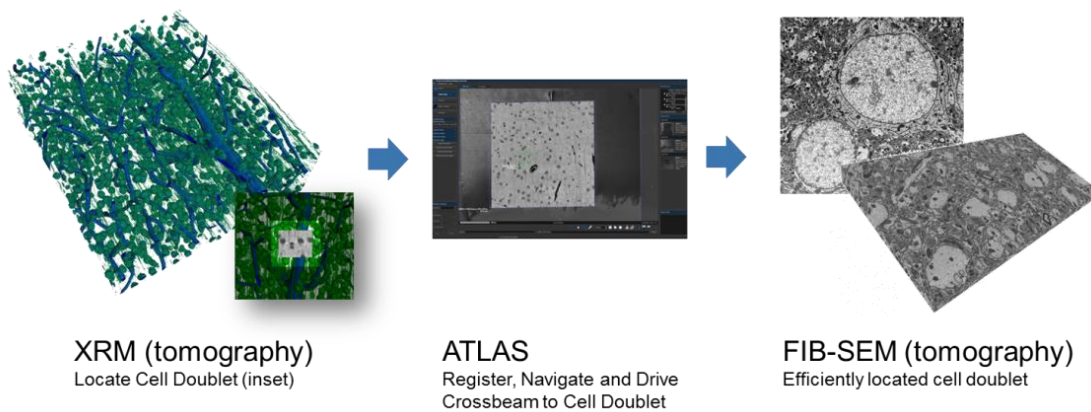
Figure 2: XRM dataset of stained (for EM) mammalian brain tissue, used to navigate to specific subsurface volumes of interest quickly, thereby multiplying the efficiency of 3D EM techniques. In collaboration with NCMIR at the University of California San Diego.