Exploring Segmentation Techniques for Material Identification in Howardite and Chondrite Meteorites

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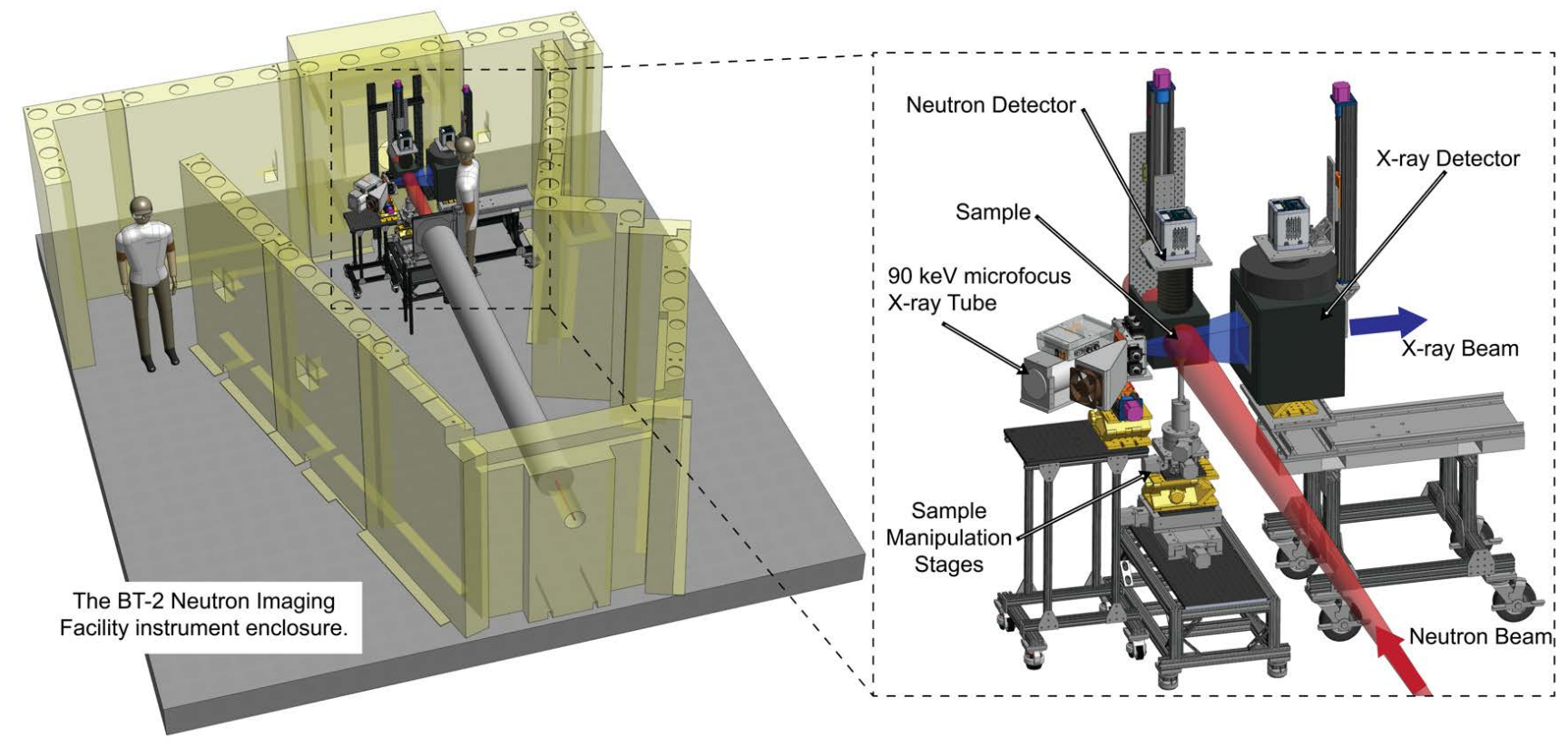
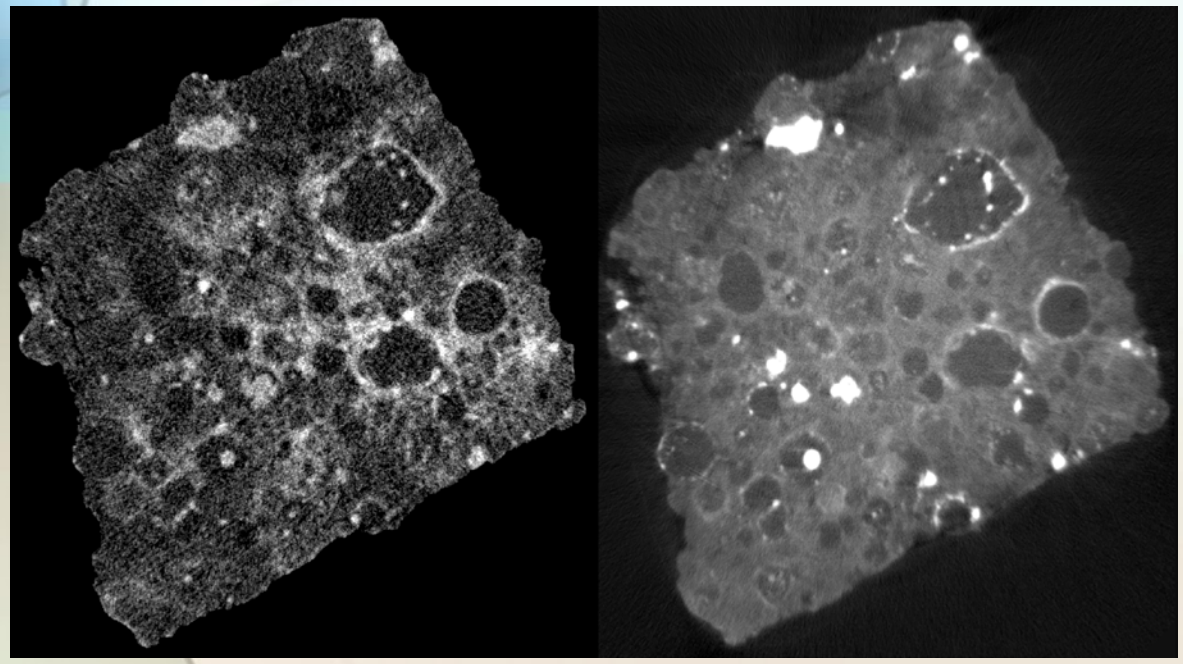
NeXT Dual Tomography System

- Tomography refers to the imaging of a sample by cross sections through the use of a penetrating wave
- The NeXT dual tomography system allows for simultaneous capture of Neutron Computed Tomography (NCT) and X-ray Computed Tomography (XCT) images



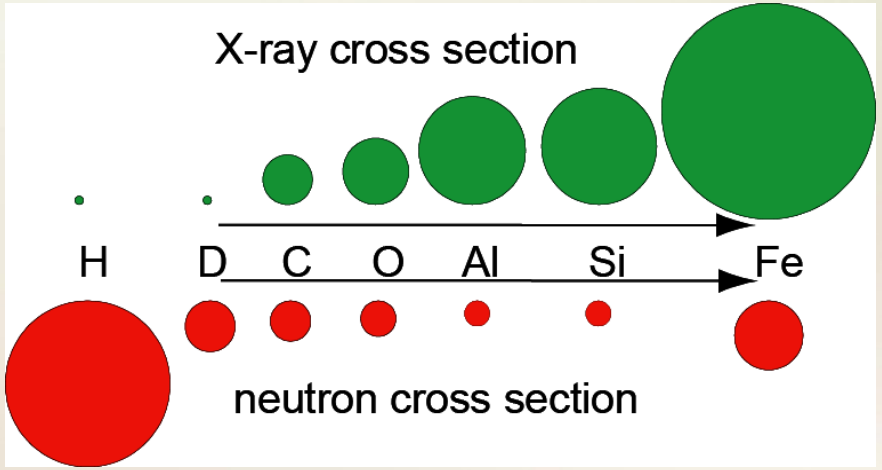
Introduction

- Because of the difference in the attenuation coefficients of thermal neutrons and X-Rays, NCT and XCT images each show different features of the sample



Side by side comparison of NCT cross-section image (left) and XCT cross-section image (right)

- Meteorites are valuable to use as samples because they provide an easy way to study the solar system



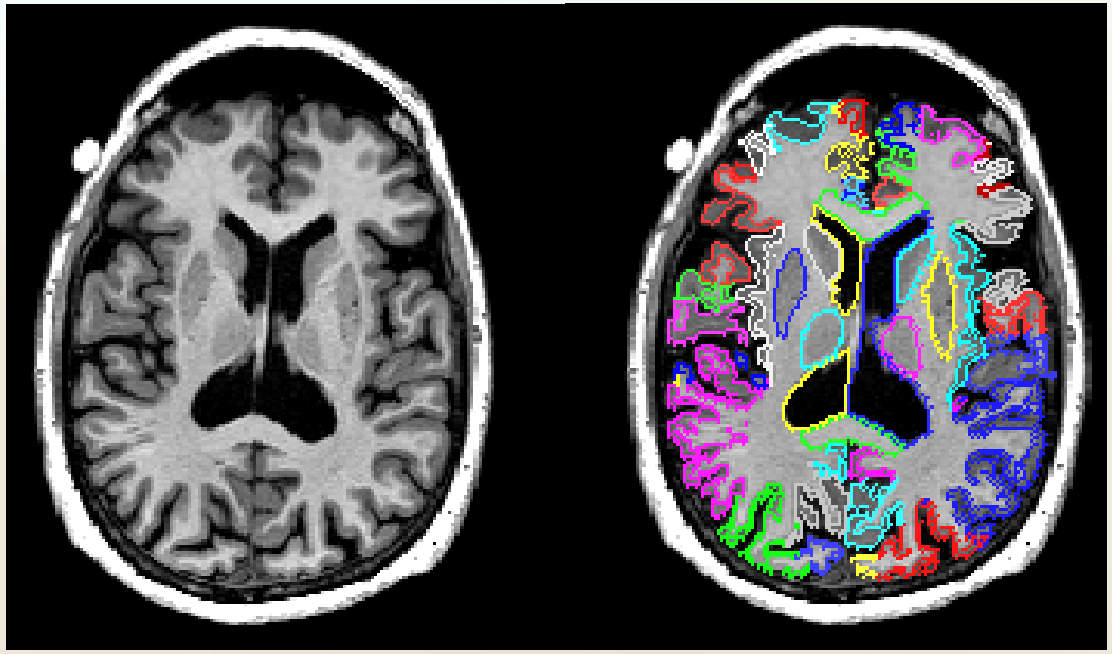
The Meteorites

- Sample EET87503: an achondrite howardite meteorite from the howardite (surface), eucrite (outer crust), diogenite (lower crust) meteorite clan, which all formed from the Vesta asteroid
- Sample GRA06100: a carbonaceous chondrite of the class CR2, which are differentiated by the presence of chondrules, and Iron-Nickel

Meteorites provided by Allan Treiman, Lunar and Planetary Institute

Segmentation

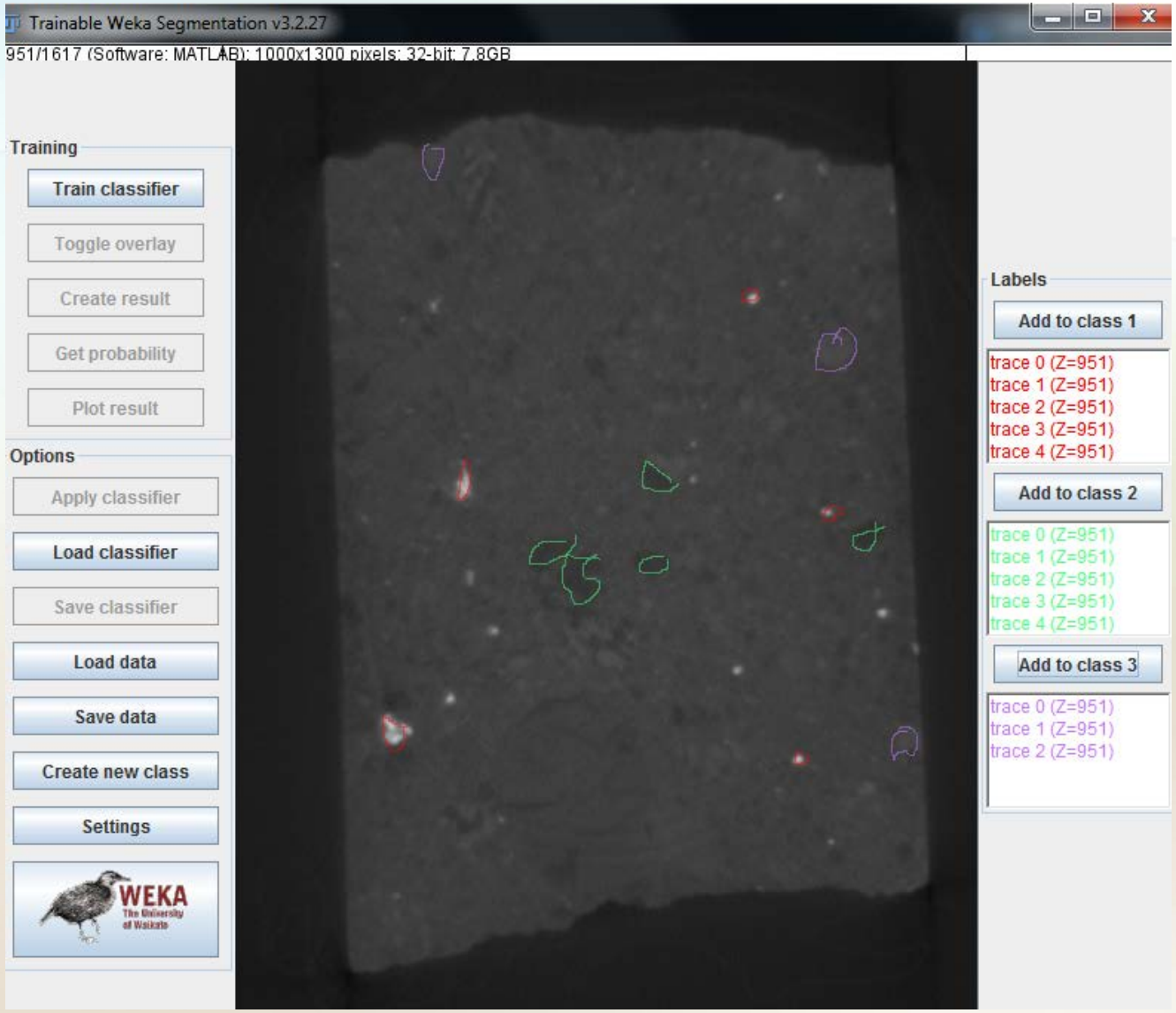
- After image stacks (volumes) are generated from the NeXT system, edited, and registered, the process of **segmentation** begins, where features of interest are isolated from an image and analyzed individually
- Three methods of segmentation were tested on the meteorite stacks and evaluated: a machine learning plugin, a superpixelation method, and a phase segmentation program



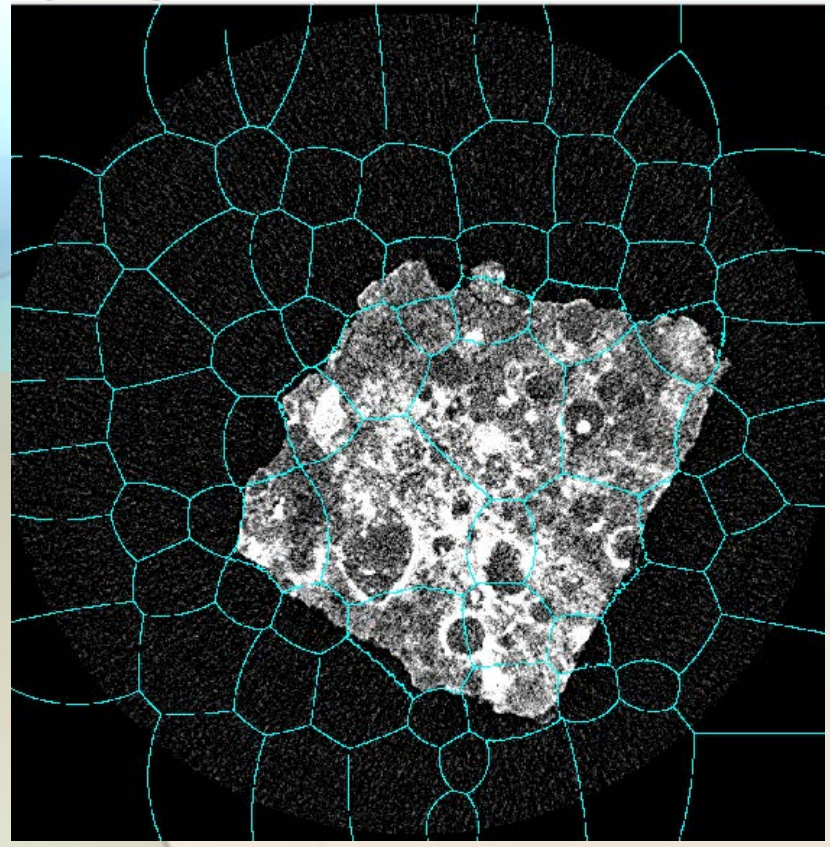
Courtesy of Ralph Heckemann

Segmentation: Trainable Weka Plugin

- Regions from cross-section images are traced and added to different groups (classes), and a classifier is trained based on this training data and applied to the whole stack
- Exceeded certain time and memory limits which made it impractical to use



Segmentation: Superpixel Segmentation

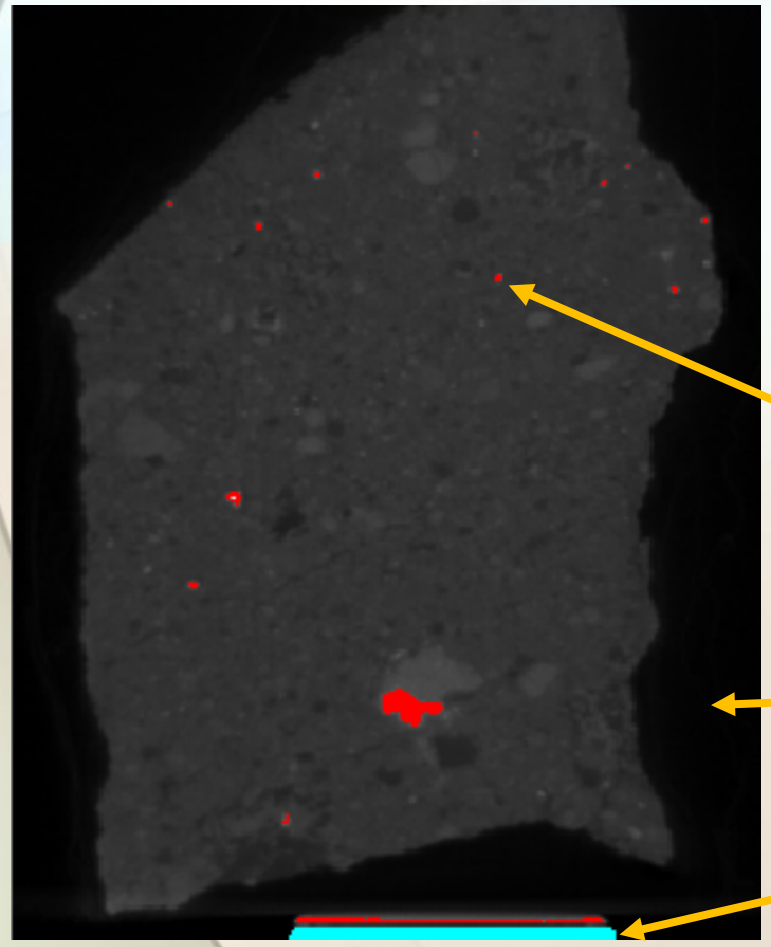


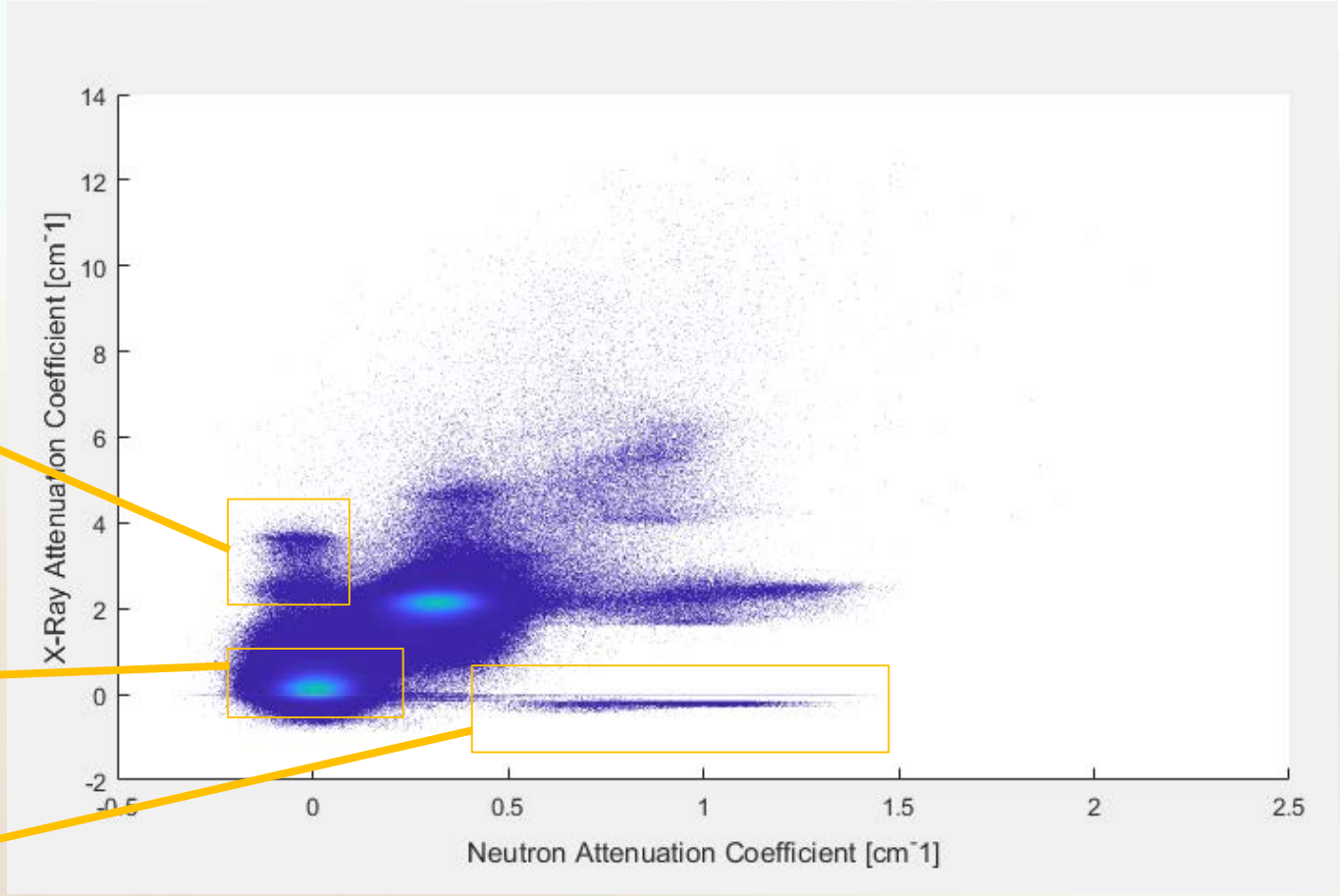
Superpixels over an XCT cross-section image

- A feature of MATLAB allows superpixels of different sizes can be generated, drawn over an image, and manipulated
- An optimal amount of superpixels for each cross-section could not be calculated easily
- Provided no easy way to combine features of interest found in XCT and NCT image stacks

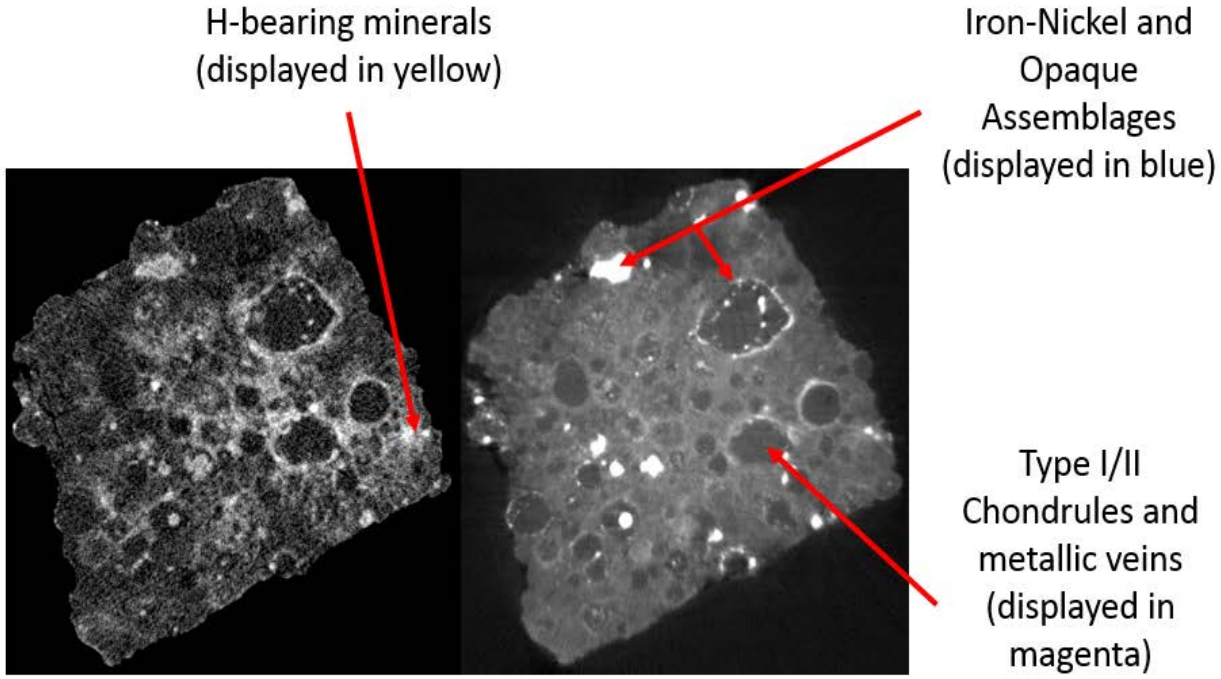
Segmentation: Phase Segmentation

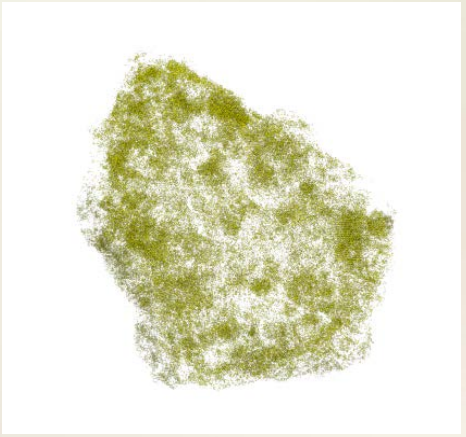
- Best method: a program written in MATLAB designed specifically to create regions of interest considering the Neutron and X-Ray volumes by using a bivariate histogram





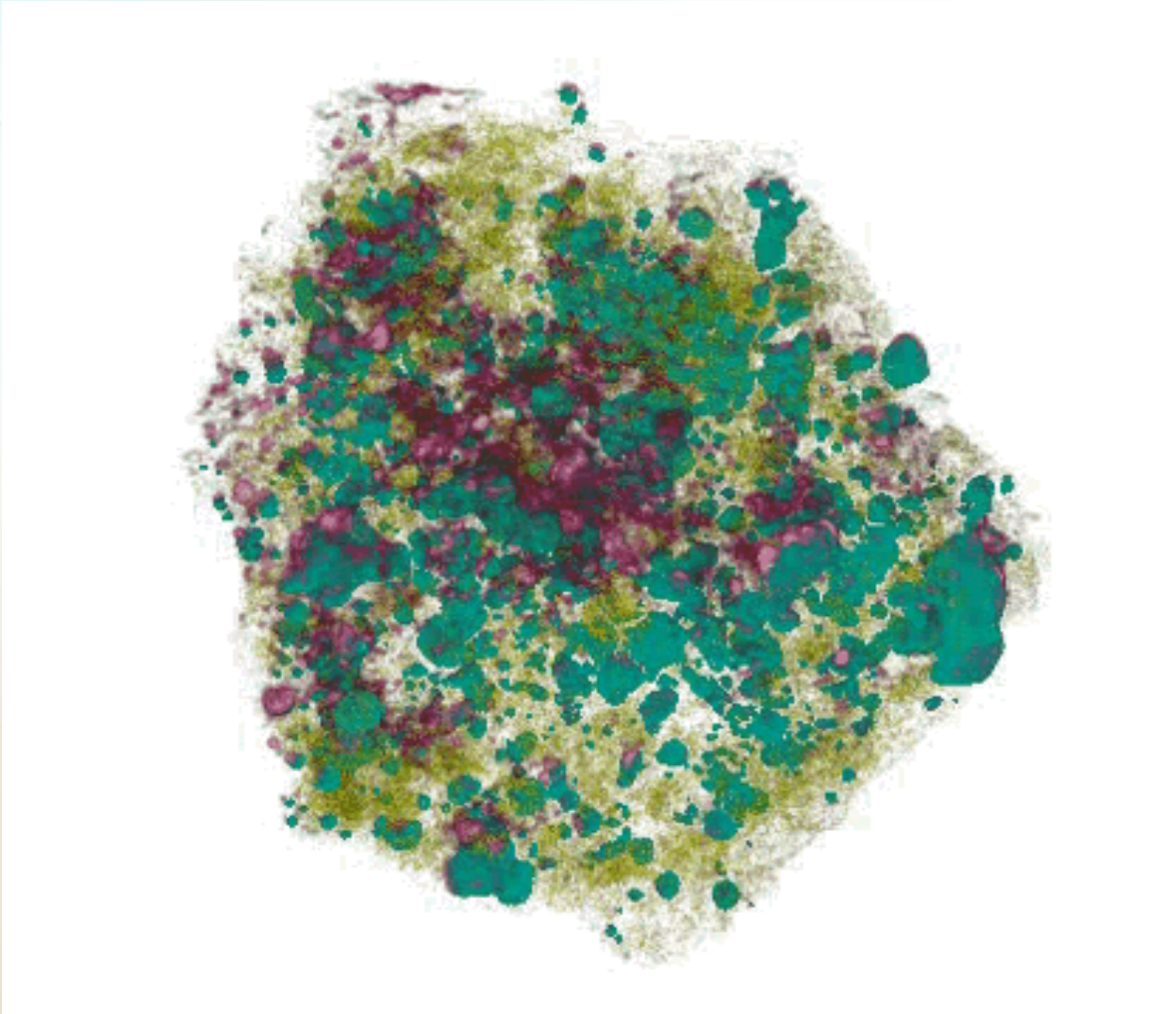
Results: GRA Chondrite



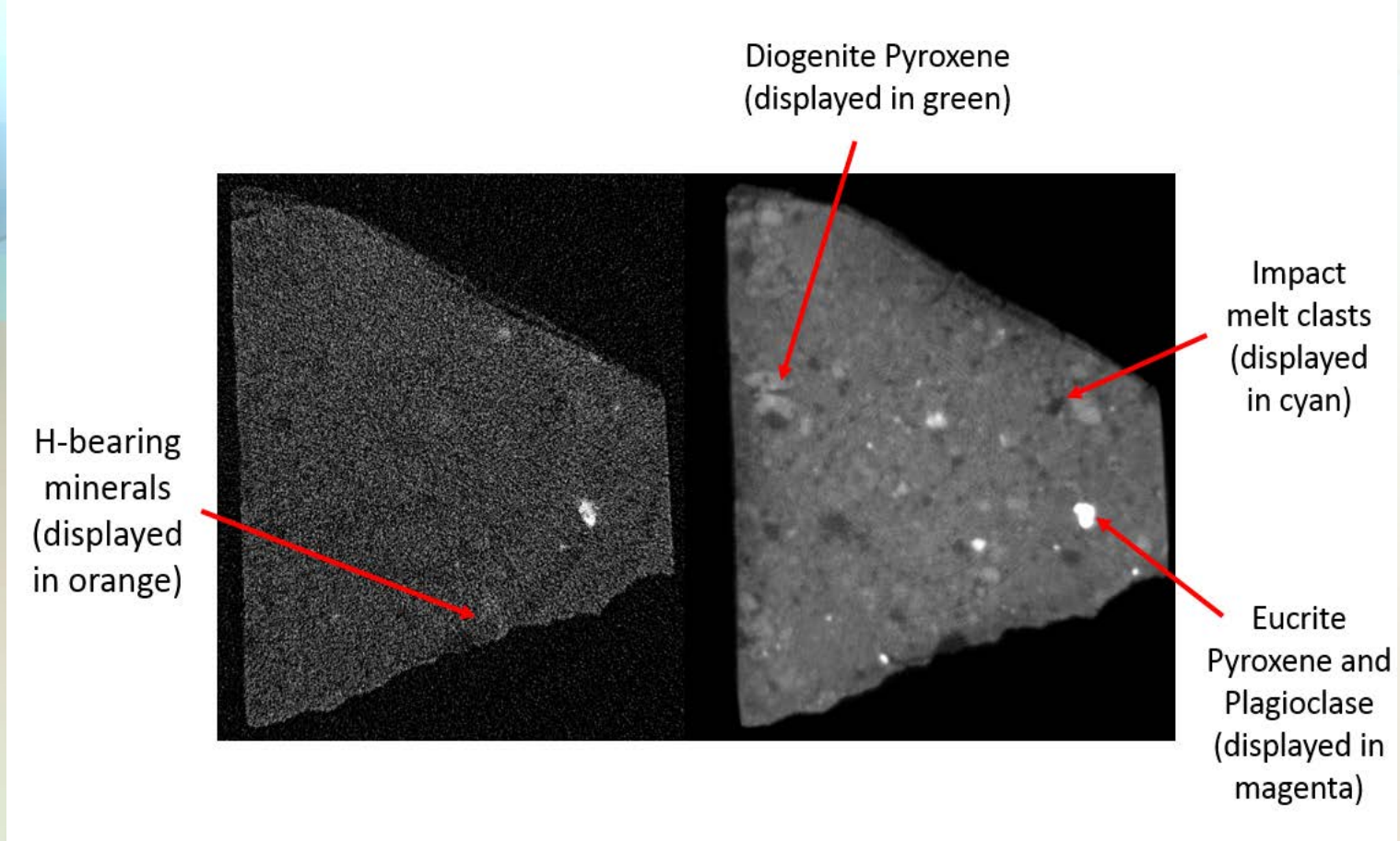


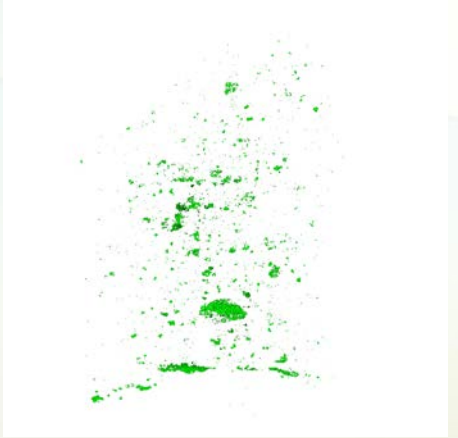
Results: GRA Chondrite

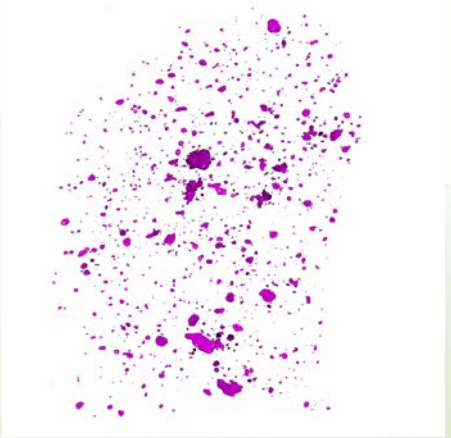
- H-Bearing Minerals
- Iron-Nickel and Opaque Assemblages
- Type I/II Chondrules and Metallic Veins

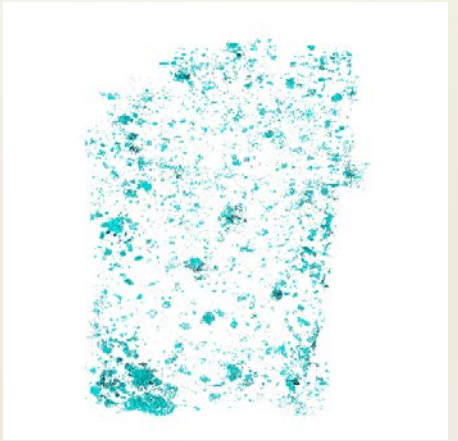


Results: EET Howardite



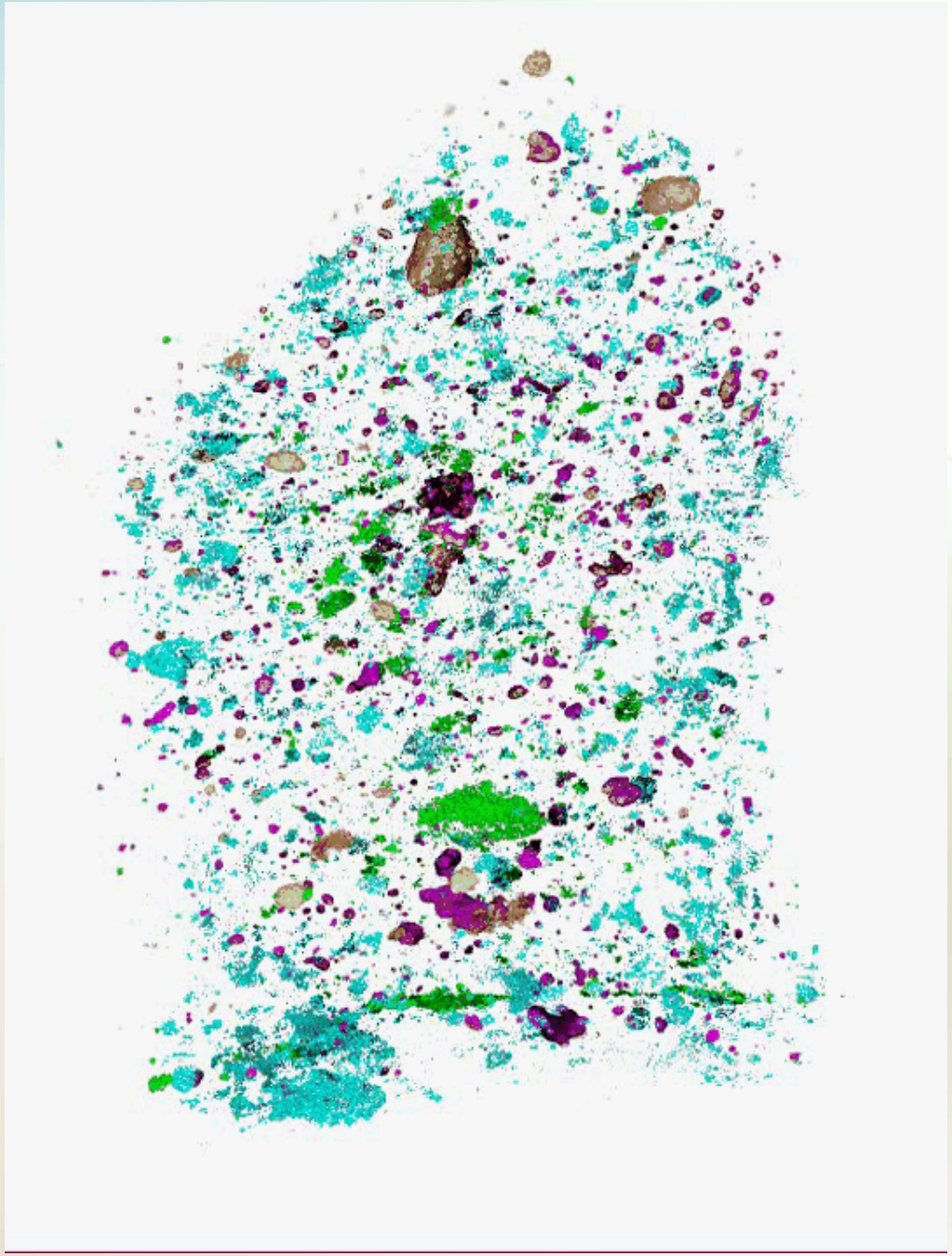






Results: EET Howardite

- H-Bearing Minerals
- Diogenite Pyroxene
- Impact Melt Clasts
- Eucrite Pyroxene and Plagioclase



Conclusions

- Phase segmentation, combined with other minor editing tools, is the most efficient way to properly segment 3D volumes obtained from the NeXT device
- The structure of the GRA Chondrite shows metal lodes and chondrules primarily on one side, which supports the theory it was impacted by shock metamorphism
- The segmentation of the EET Howardite reveals how rock from the different layers of the Vesta asteroid combined to form this complex structure

Acknowledgments

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