Reconstruction Rectification and Gas Volume Segmentation for Tomographic Datasets of Laboratory Simulated Degassing-Induced Volcanic Eruptions

GSECARS
GeoSoilEnviroCARS

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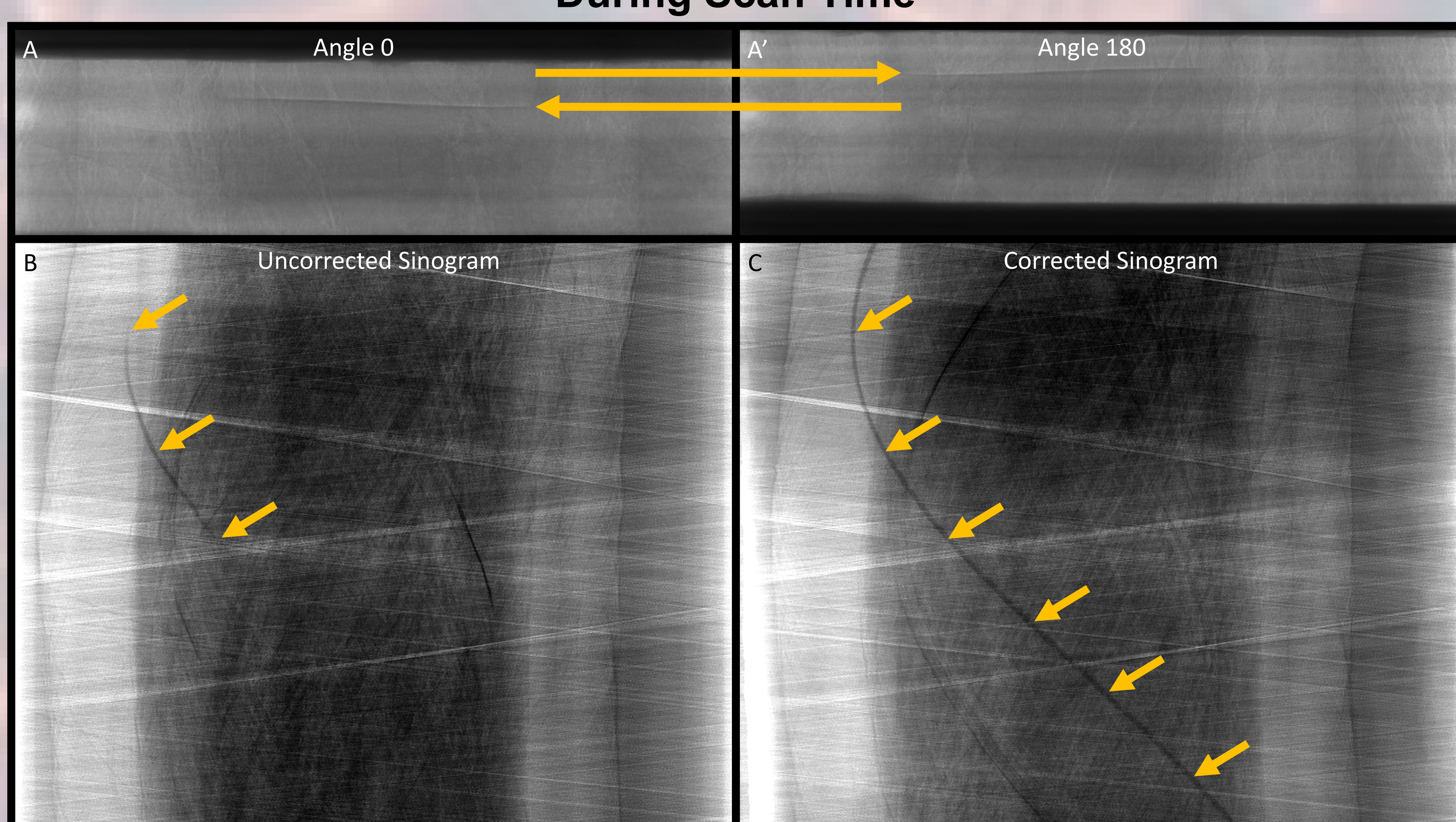
- **Magma eruptions in volcanic activities are driven by the gas phase separation.**
- The carbonate ledge (as deep as 80 km), demarcates the point above which ascending mantle carbonate melts become unstable and produce gas phases.
- The volume expansion during gas separation (degassing) may be the cause of catastrophic carbonatitic magma eruptions.
- GSECARS has developed techniques to simulate and study the process by using synchrotron x-ray tomographic imaging with a Paris-Edinburgh press.
- **However, replicating these high pressure and temperature conditions hinders straightforward image segmentation and analysis due to artifacts in the final reconstructed images caused by low signal and uncontrolled motion.**
- Even after correction, differences in contrast levels, textures, and intensities across and within individual scans prevent the use of classic segmentation approaches such as intensity thresholding or watershed expansion.
- With increasing scan sizes at various conditions, manual image segmentation also becomes less feasible.
- **We present an image processing pipeline that first improves the quality of the raw acquired images and then enables semantic segmentation of different phases.**
- Image correction uses a combination of vertical and horizontal motion adjustment for nonlinear offset, flatfield contrast alteration for improved gain correction, and sinogram center of gravity sinewave fitting for rotational stage errors.
- Our segmentation approach is based on random forest classifier machine learning algorithms with cross validation to manually generated sets, which can save resources and standardize segmentation and analysis across multiple scans.

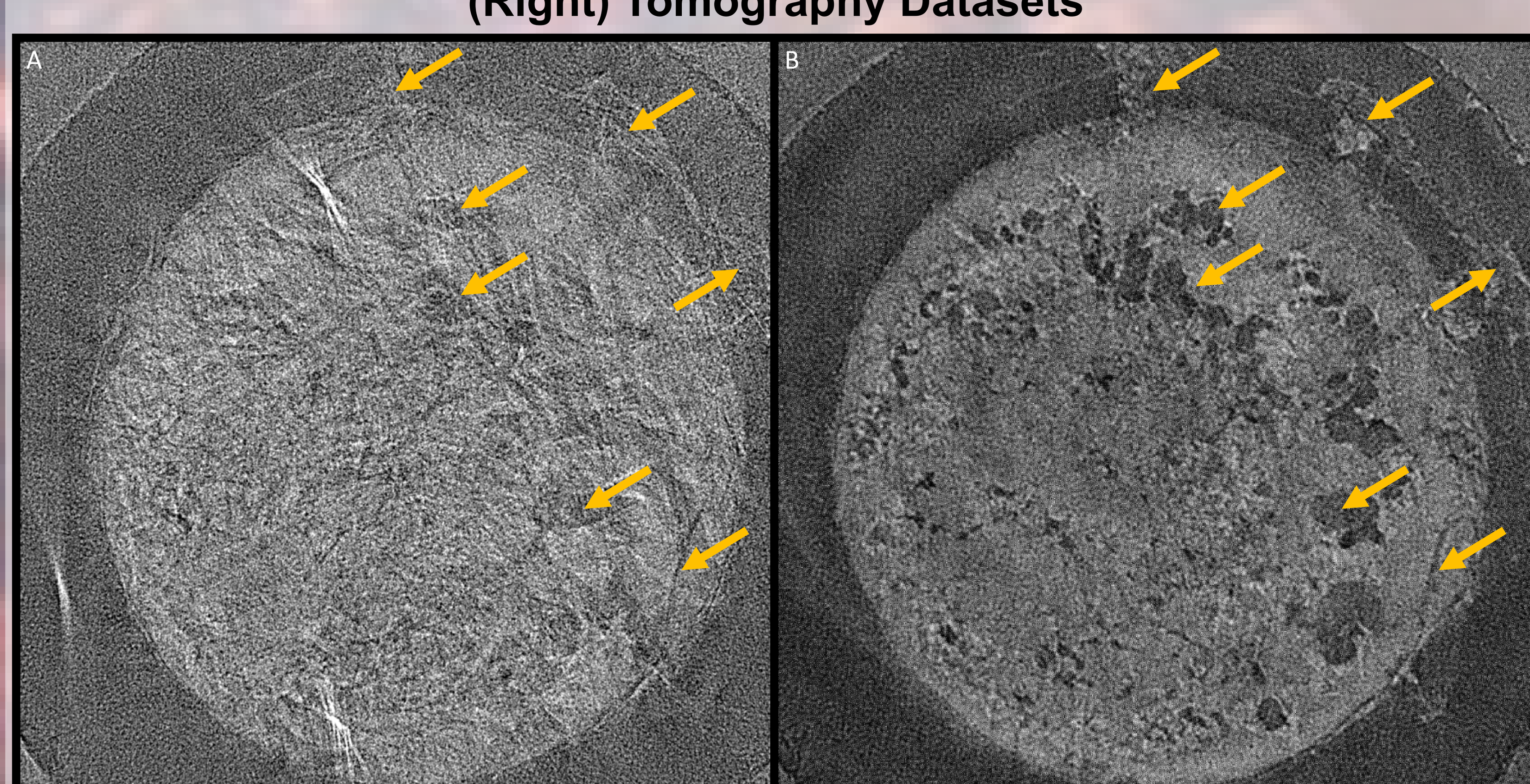
High Pressure/Temperature Tomography Datasets at GSECARS

GSECARS facilitates the acquisition and dissemination of tomography datasets to its userbase, but **unconventional imaging techniques such as high temperature/pressure tomography can create low signal, high artifact images that are difficult to interpret and segment**. We have created a data workflow including horizontal and vertical motion adjustment, along with flat-field contrast normalization prior to conventional flat-field correction. Furthermore, a closer collaboration between GSECARS and user groups that enables deeper dataset interrogation could expand the possibilities of planned experiments and improve study sensitivity. To this end, we are beginning to implement the unifying analytical components of 3D image processing and dissemination at GSECARS, with a focus on generalizable tools for segmentation and visualization.

Sinogram Realignment Compensates for Unpredictable Movement During Scan Time

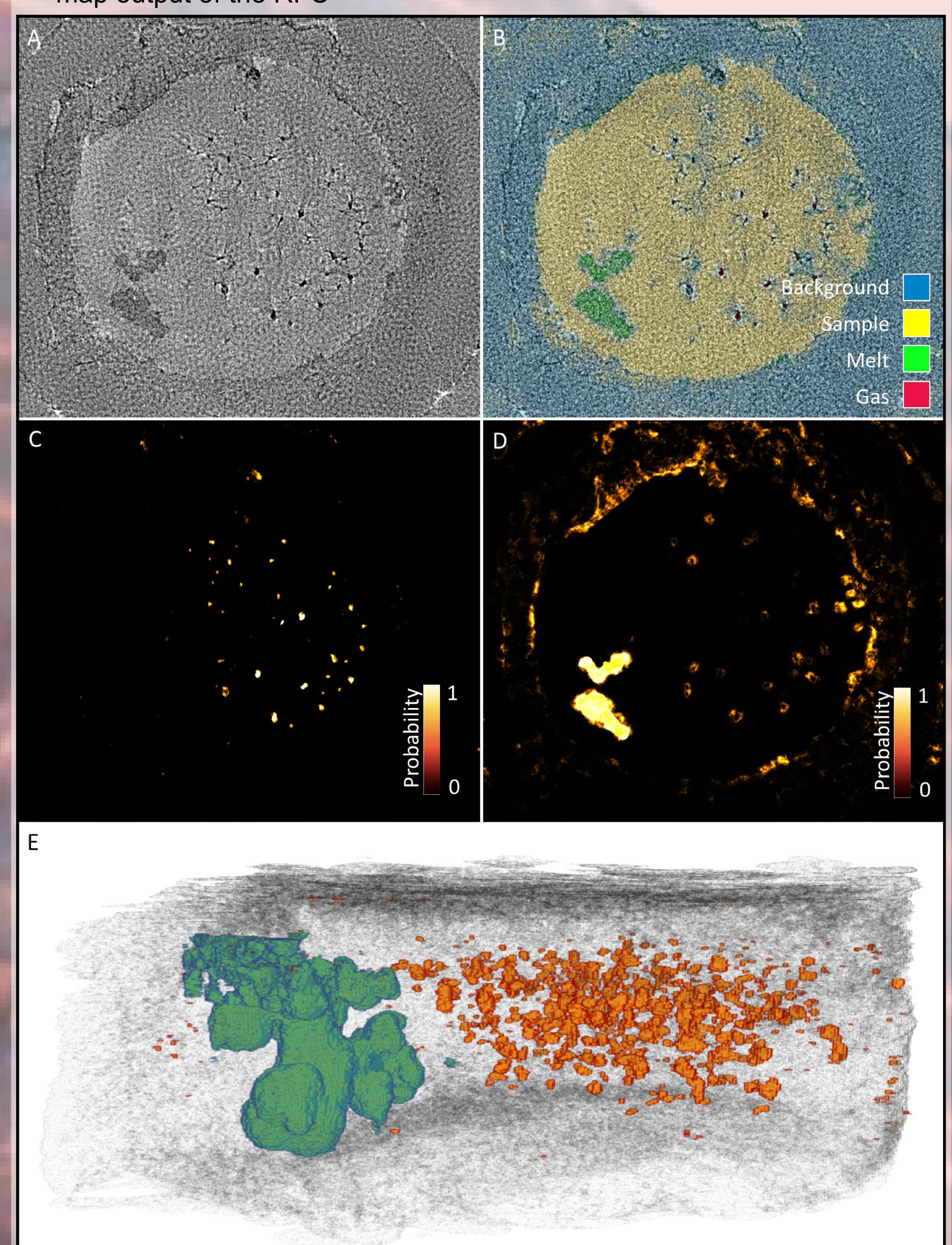


Reconstruction Comparison Between Uncorrected (Left) and Corrected (Right) Tomography Datasets

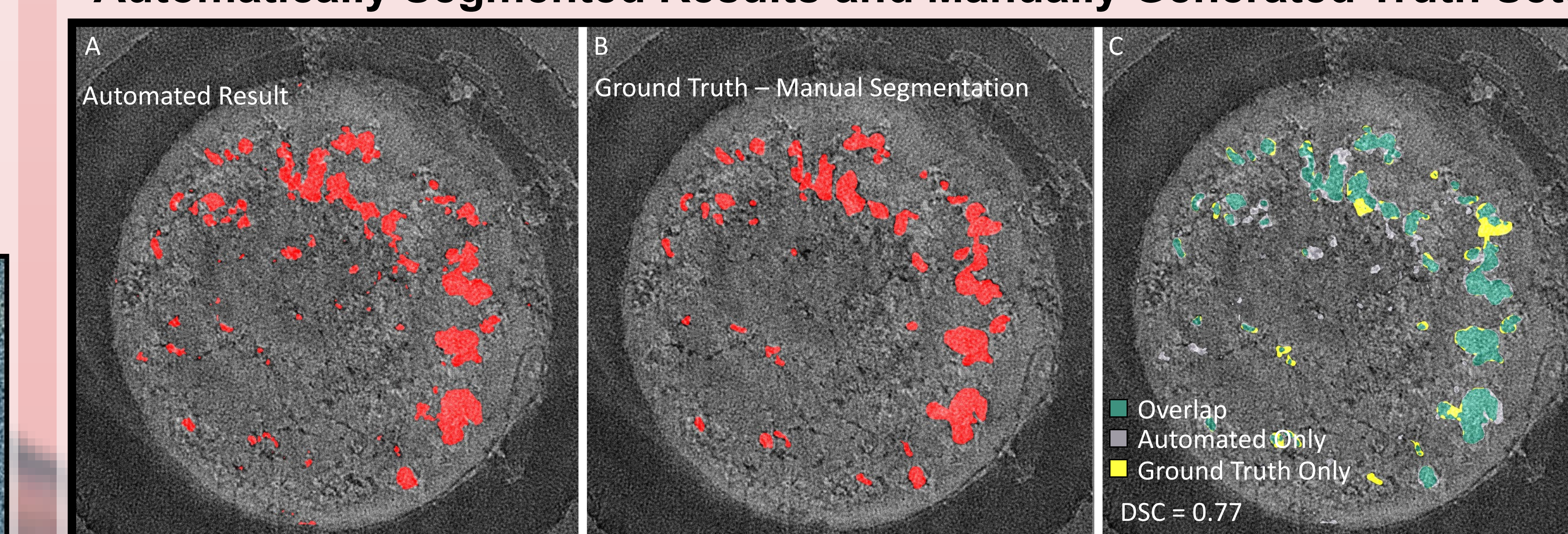


Training in Ilastik Allows Segmentation of Gas and Melt Phases in Low SNR, High Pressure and Temperature Tomography Data

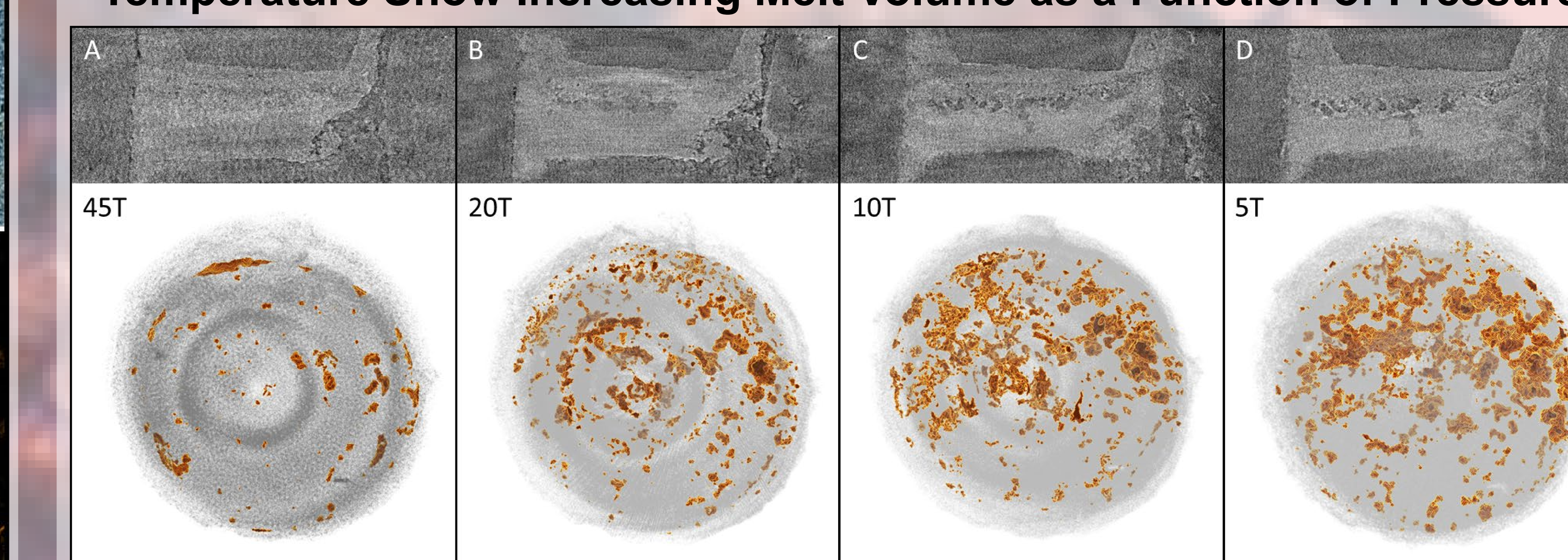
- Ilastik was used to iteratively train a Random Forest Classifier (RFC) for segmentation of raw reconstructed images into separate classes
- Binary mask segmentation was preformed by thresholding the probability map output of the RFC



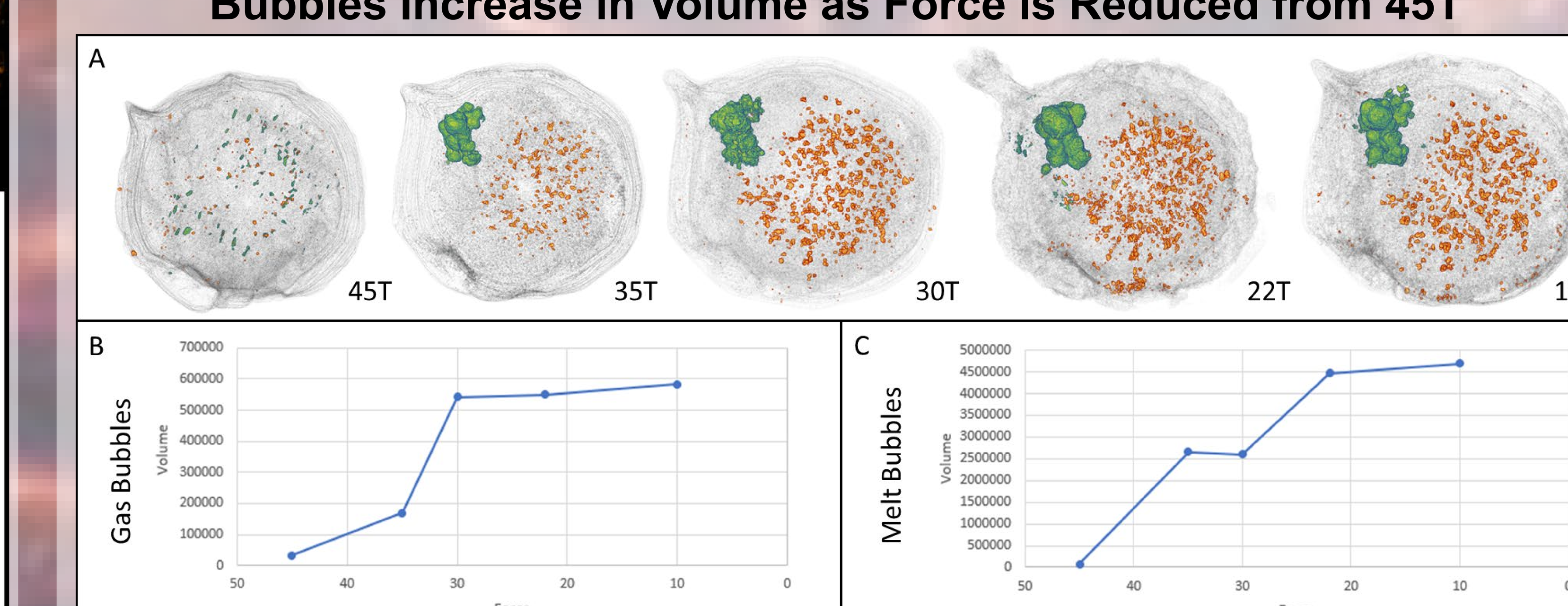
Validation Through Comparing Dice-Sorensen Coefficients Between Automatically Segmented Results and Manually Generated Truth Sets



Segmentation of Melt in a Single Sample Under High Pressure and Temperature Show Increasing Melt Volume as a Function of Pressure



Qualitative and Quantitative Assessment Confirms Gas and Melt Bubbles Increase in Volume as Force is Reduced from 45T



References/Acknowledgements

Yu, T., Wang, Y., Rivers, M. L. & Sutton, S. R. (2019). C. R. Geosci. 351, 269–279.

GeoSoilEnviroCARS is supported by the National Science Foundation – Earth Sciences via SEES: Synchrotron Earth and Environmental Science (EAR –2223273). Tomography capability developments were supported by DOE BES Geosciences (DE-SC0020112). This research used resources of the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357.