

# Focused on the Future



**Natural Resources  
Research Institute**

UNIVERSITY OF MINNESOTA DULUTH

**Driven to Discover™**

# Utilizing Complete Pore Size Distributions For Assessing Process-Surface Morphology Relationships of Balsam Fir Biochar

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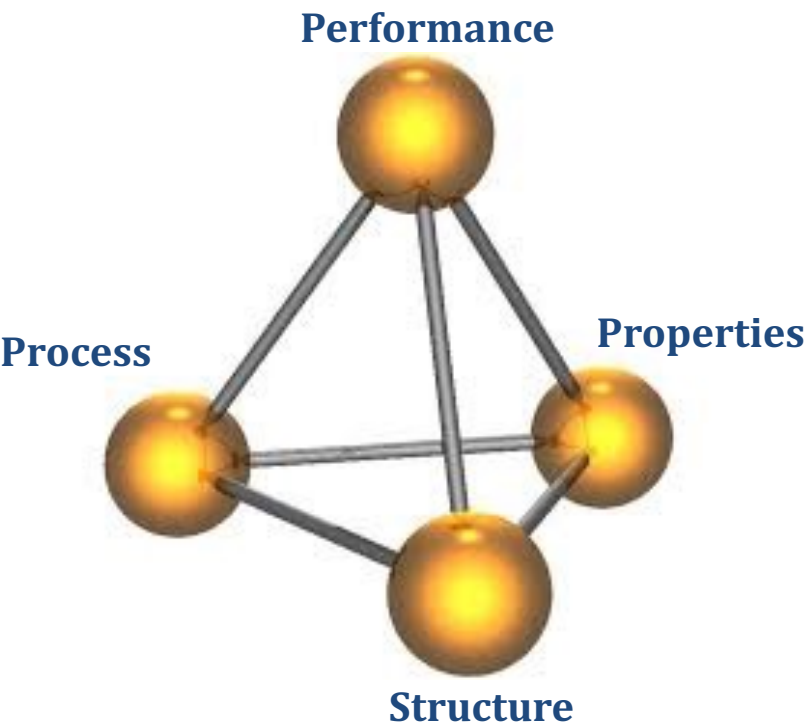
North American Biochar & Bioenergy Conference

August 9<sup>th</sup>, 2022

# Presentation Overview

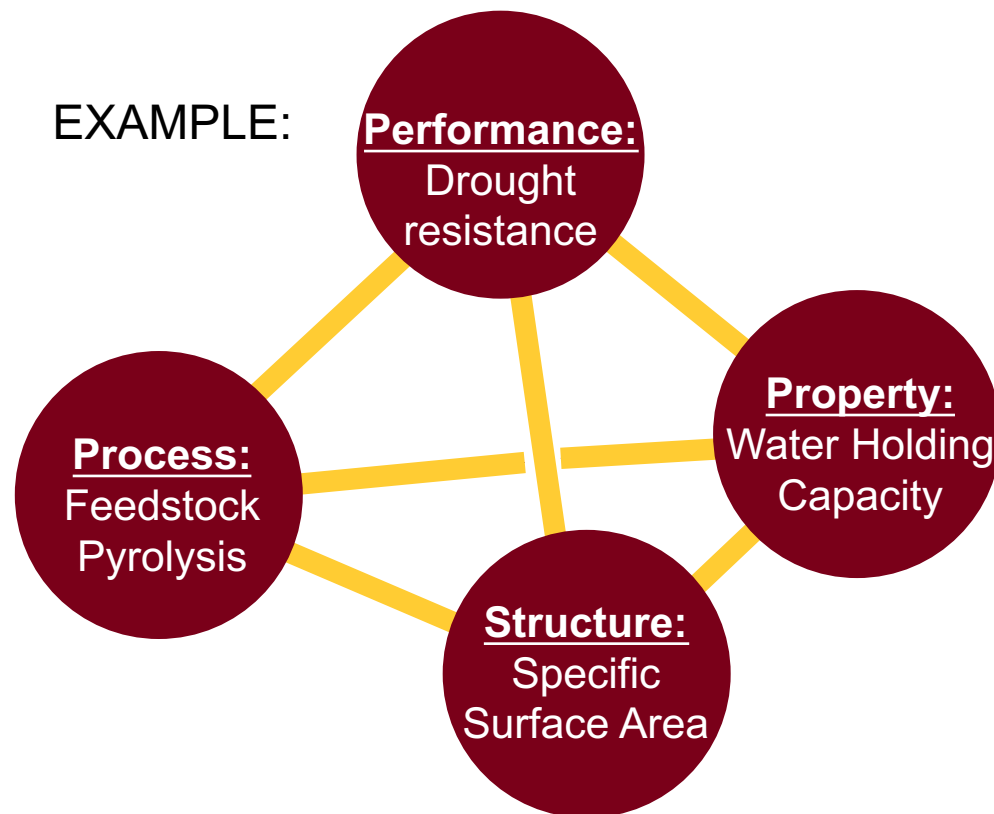
- Why investigate surface morphology?
- Common representations of surface morphology measurements
- NRRI approach to collecting complete pore size distributions (PSDs)
- Analysis of balsam fir PSDs produced under varying pyrolysis conditions
- Opportunities for alternative, regime-specific quantification of pore volumes

# Why is Surface Morphology Worth Investigating?

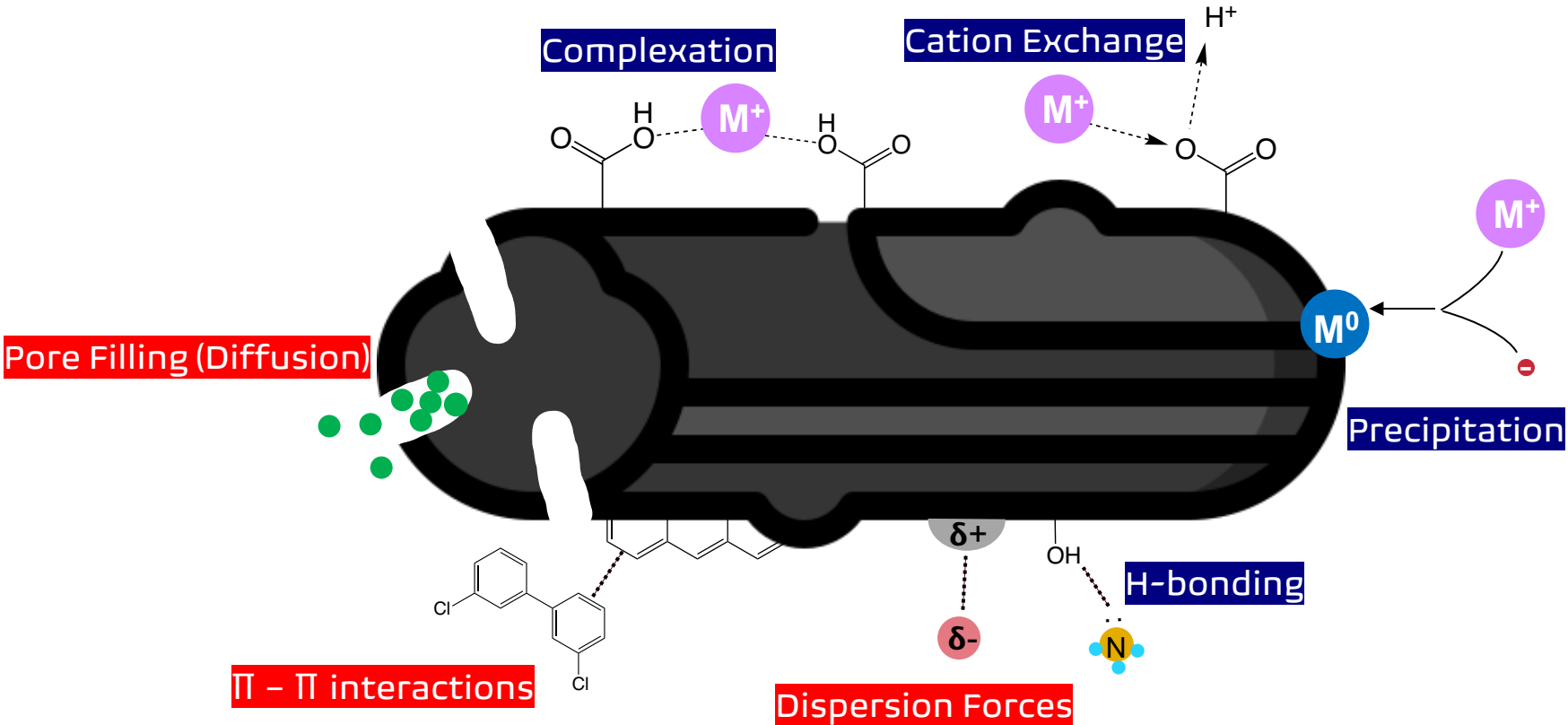


Process ↔ Structure

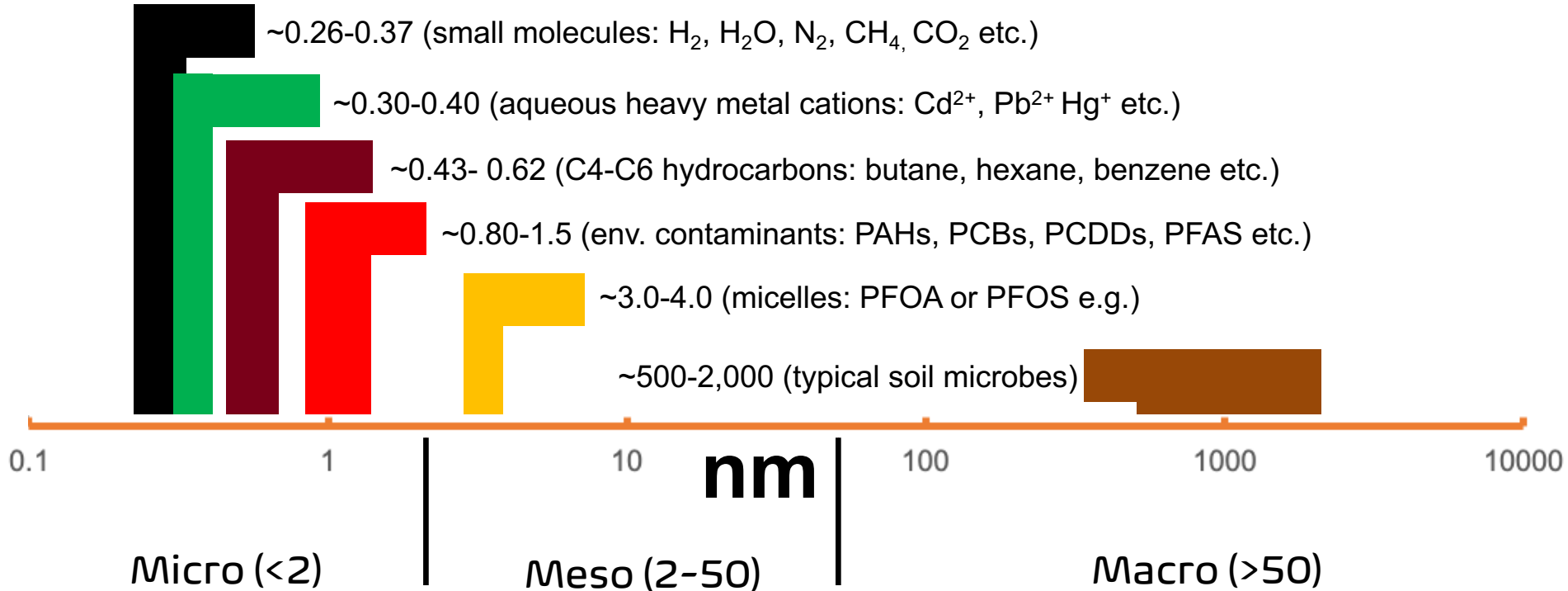
EXAMPLE:



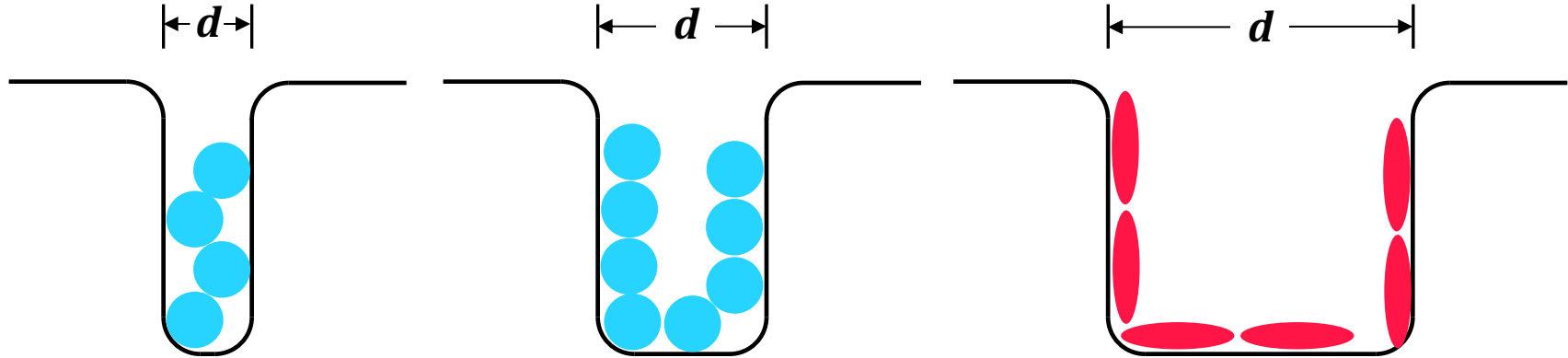
# Surface-Driven Removal



# Adsorbate Sizes (nm)



# Adsorption Capacity vs. Pore Size ( $d$ )???



- **Biochar** adsorption capacities often correlate directly to surface morphology
- Even if surface morphology is not primary factor, still plays important role
- Improved ability to control biochar pore diameter will allow for better studies
- Defining pore size of interest more precisely (better than mesopore volume e.g.)

# Room For Improvement

- Many biochars contain ultramicropores (<0.7 nm)
  - Specific surface area, total micropore volume
- Typical reported pore volume regimes (mesopores e.g.) are often not informative for predicting performance



# CHARACTERIZATION DATABASE

SELECT X-AXIS Y-AXIS

Plot Selection

- Temperature (°C) Ash content (%)
- Temperature (°C) C/N ratio
- Temperature (°C) O/C ratio
- Temperature (°C) Surface area (m<sup>2</sup>/g)
- Temperature (°C) Cation exchange capacity (cmol/kg)
- Temperature (°C) pH
- H/C ratio O/C ratio

Peer Review

- Peer Reviewed
- Not Peer Reviewed
- All

Feedstock

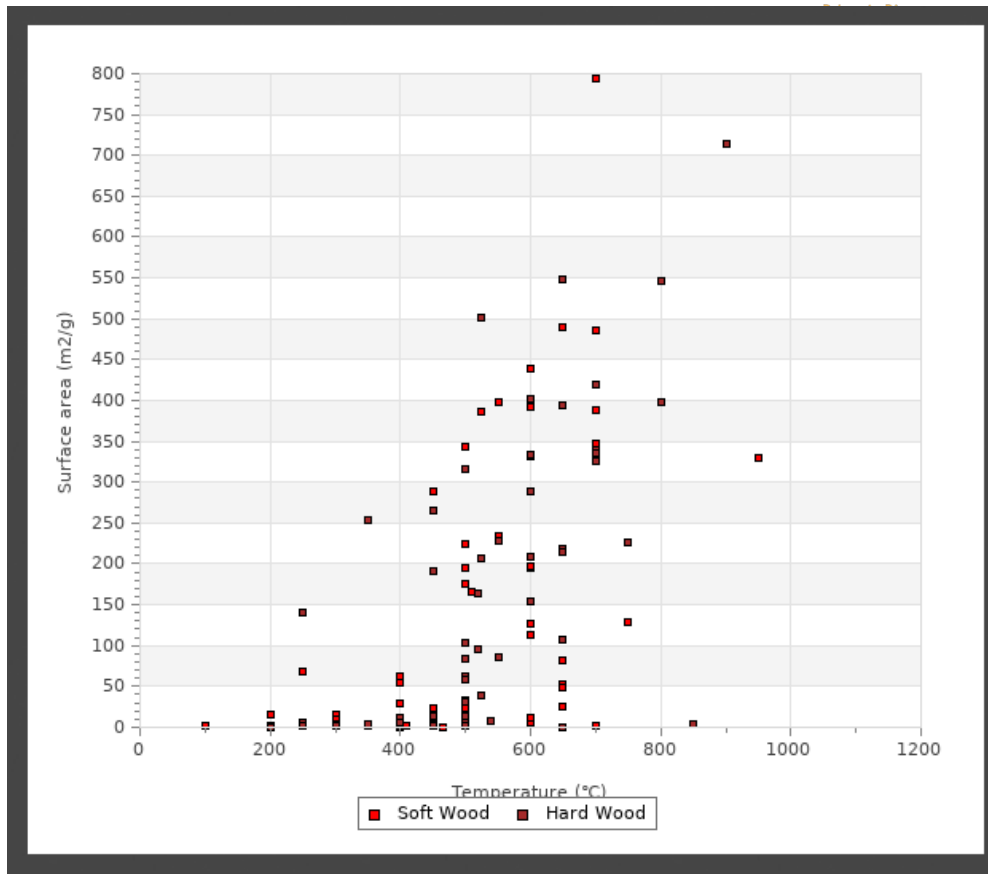
- Algae
- Corn stover
- Grass
- Hull
- Manure
- Nutshell
- Pomace
- Sludge
- Wood
- Soft Wood
- Hard Wood
- ALL

Submit



After submitting your request the database will generate a corresponding plot. Your plot may take a moment to appear. If you receive an error ("Your plot selection returned an empty data set") this results from a lack of data corresponding to one of your specific choices. If this happens please adjust your plot criteria and resubmit.

biochar.ucdavis.edu






# PSD Approach

CO <sub>2</sub> Adsorption 273 K	0.36 – 1.00 nm	} Simultaneous fit 0.36 to 50 nm 2D-NLDFT (heterogenous surface)
N <sub>2</sub> Adsorption 77 K	0.7 to 50 nm	
Hg Intrusion	5 to 500,000 nm	

CARBON 91 (2015) 330–337

Available at [www.sciencedirect.com](http://www.sciencedirect.com)  
**ScienceDirect**  
journal homepage: [www.elsevier.com/locate/carbon](http://www.elsevier.com/locate/carbon)



**Dual gas analysis of microporous carbons using 2D-NLDFT heterogeneous surface model and combined adsorption data of N<sub>2</sub> and CO<sub>2</sub>**

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<sup>b</sup> Instituto Nacional del Carbón, CSIC, Apartado 73, 33080 Orense, Spain

Jacek Jagiello et. al.,  
Carbon 91 (2015) 330–  
337

# Instrumentation



# Superior National Forest Balsam Fir



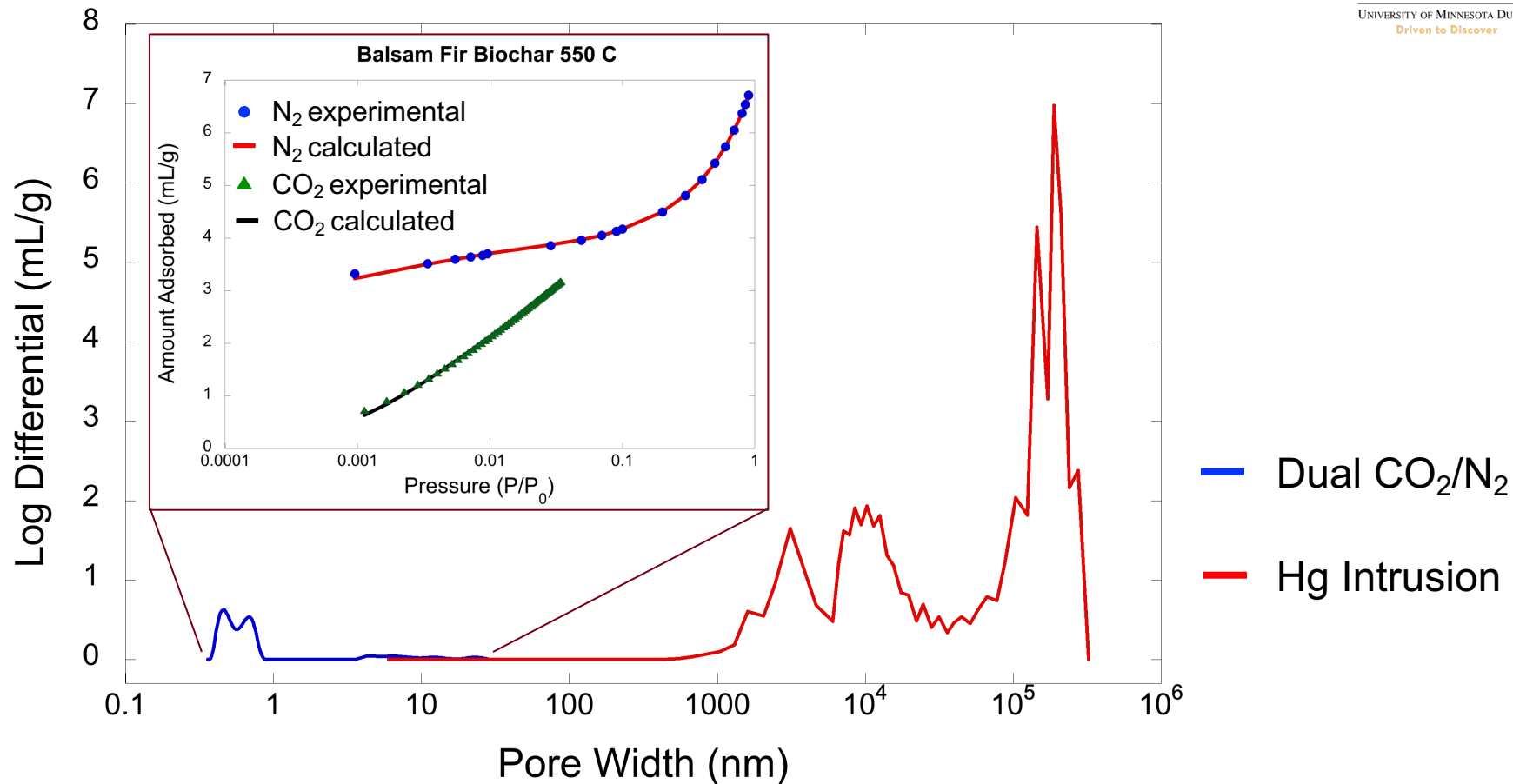
<https://www.fs.usda.gov/main/superior/maps-pubs>

## Greenwood Lake Fire 2021 (~27,000 acres)

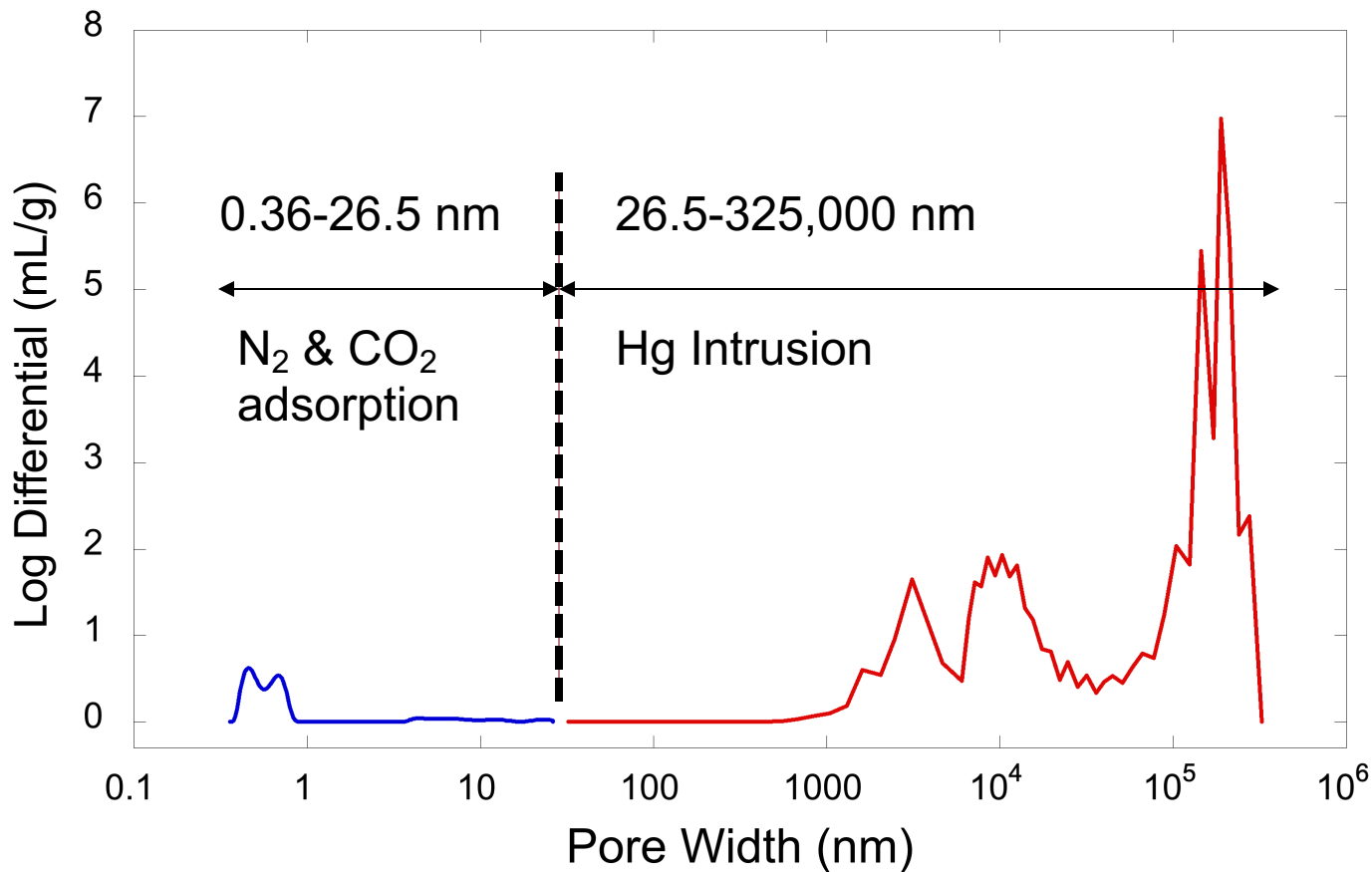


<http://www.timberjay.com/stories/lightning-ruled-the-cause-of-greenwood-lake-fire,18041>

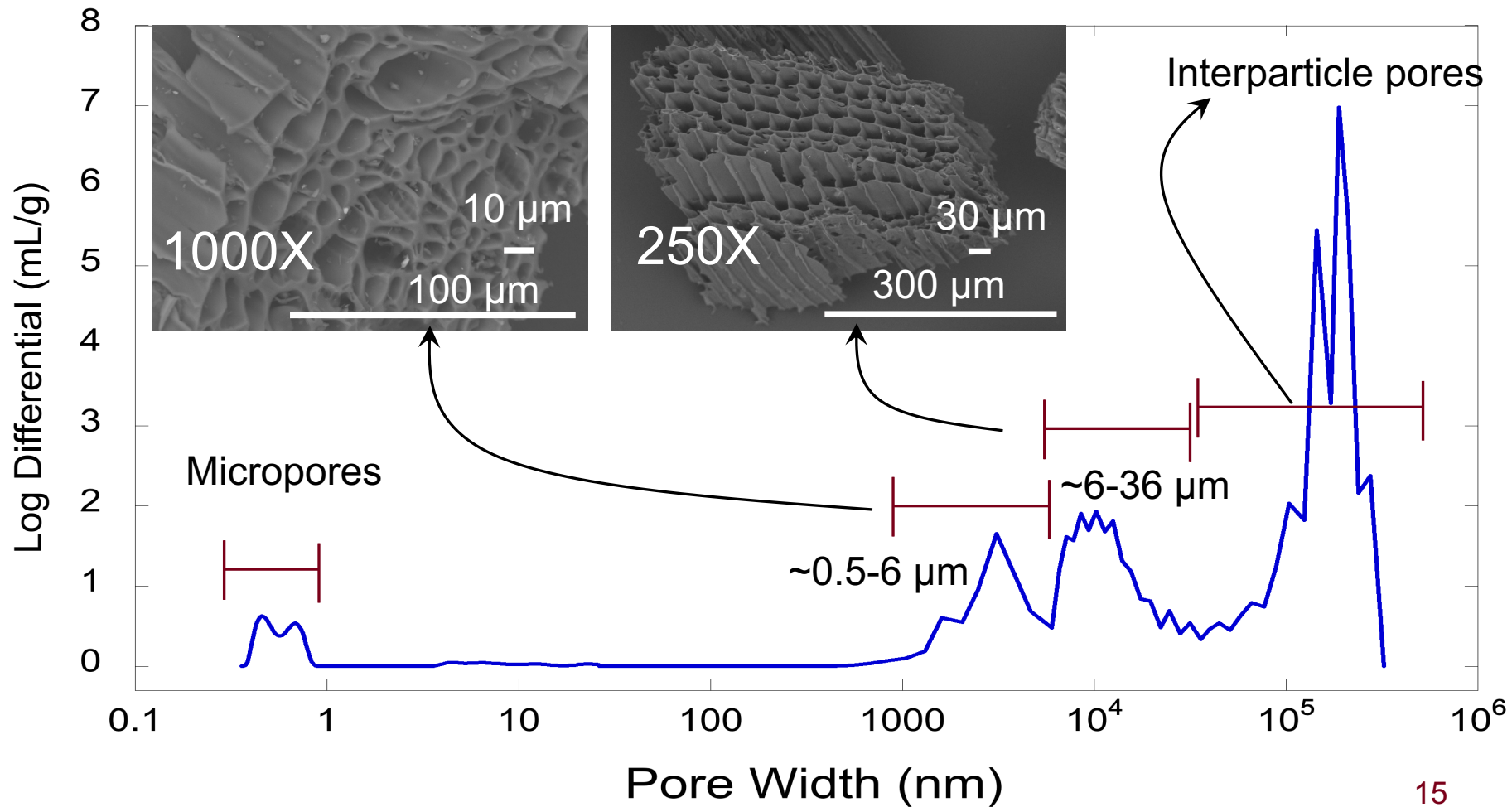
# Balsam Fir Biochar 550°C



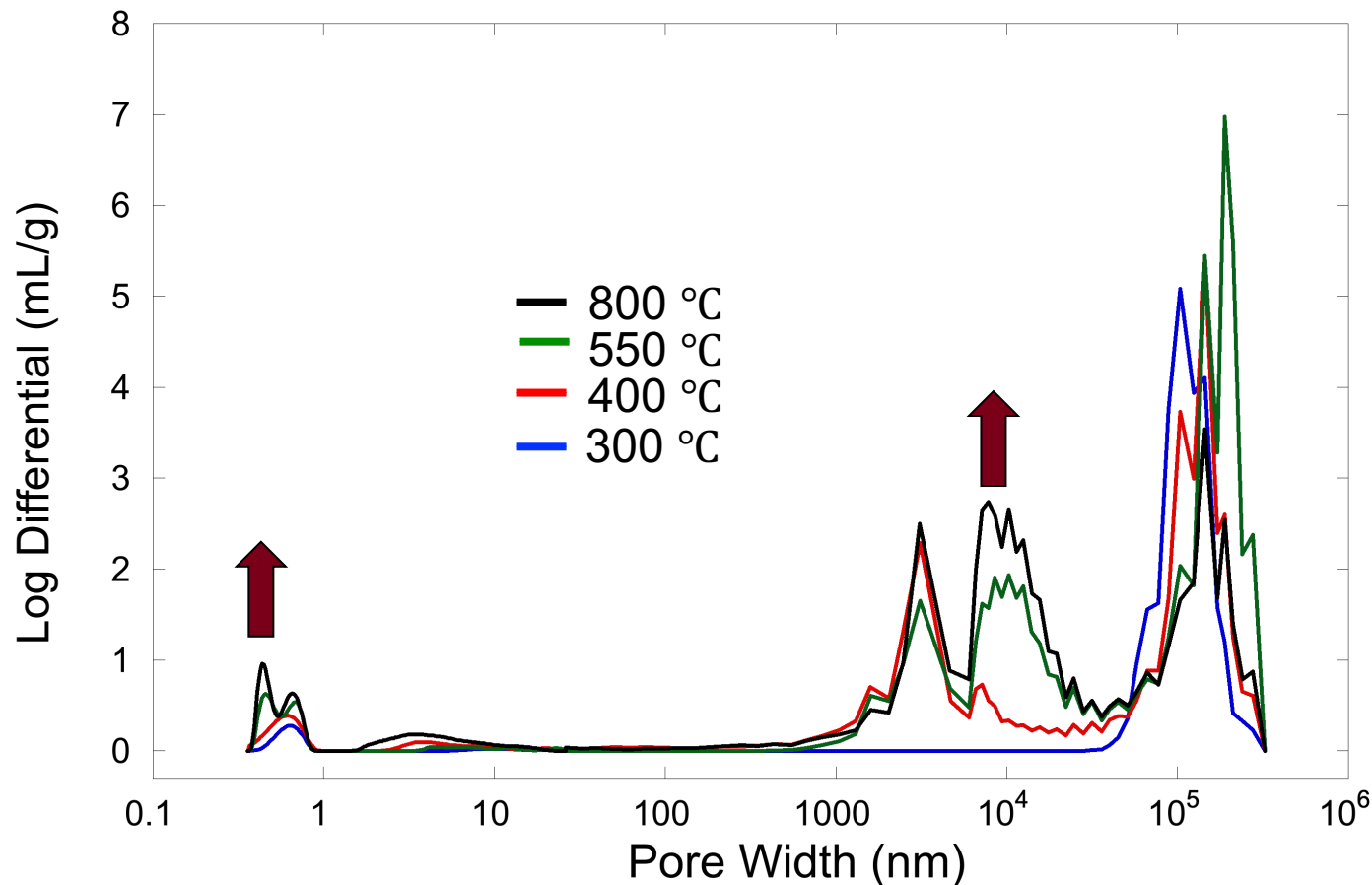
## Balsam Fir Biochar 550°C



# Balsam Fir Biochar 550°C

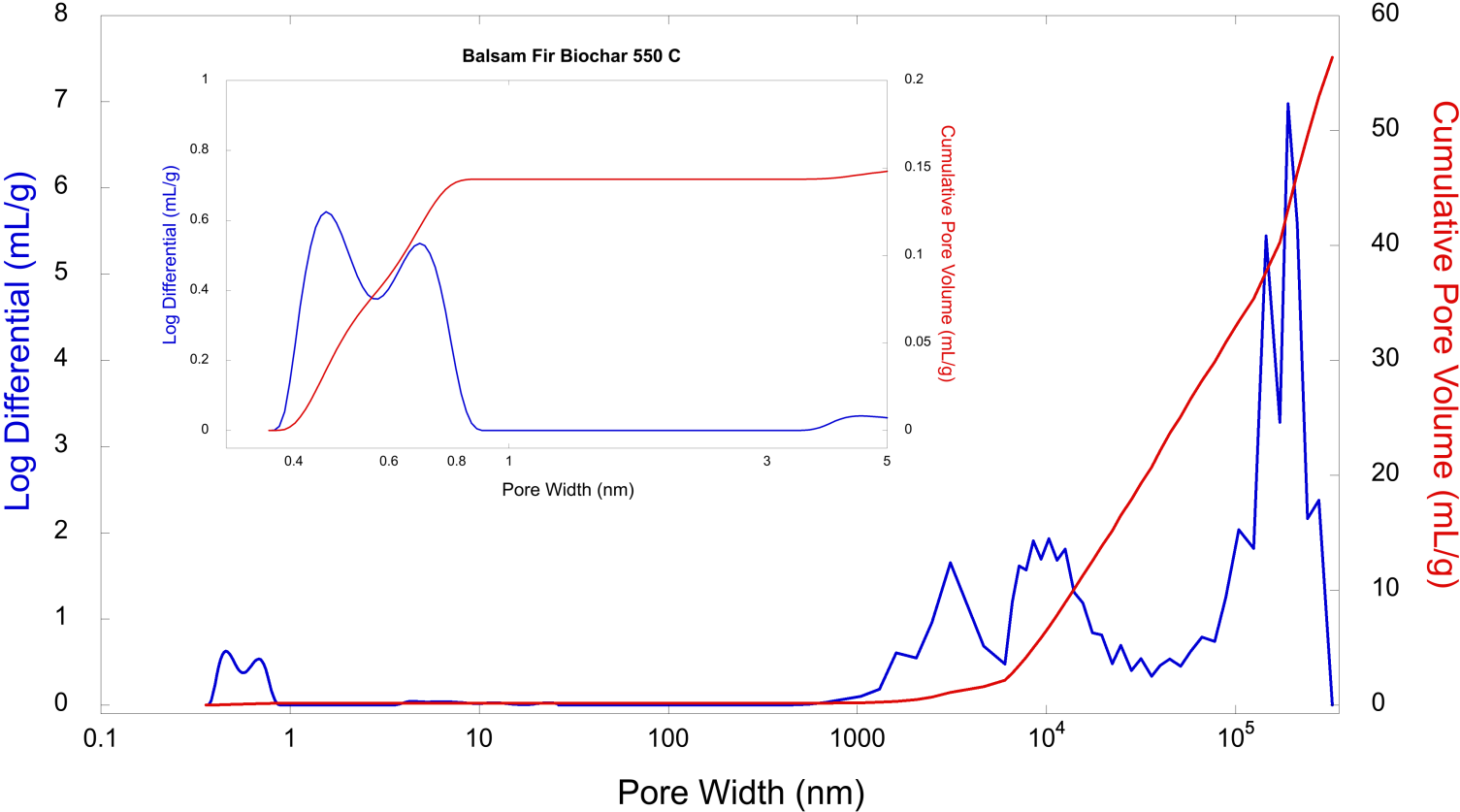


# Full Pore Size Distributions of Balsam Fir Biochar at Various HTT

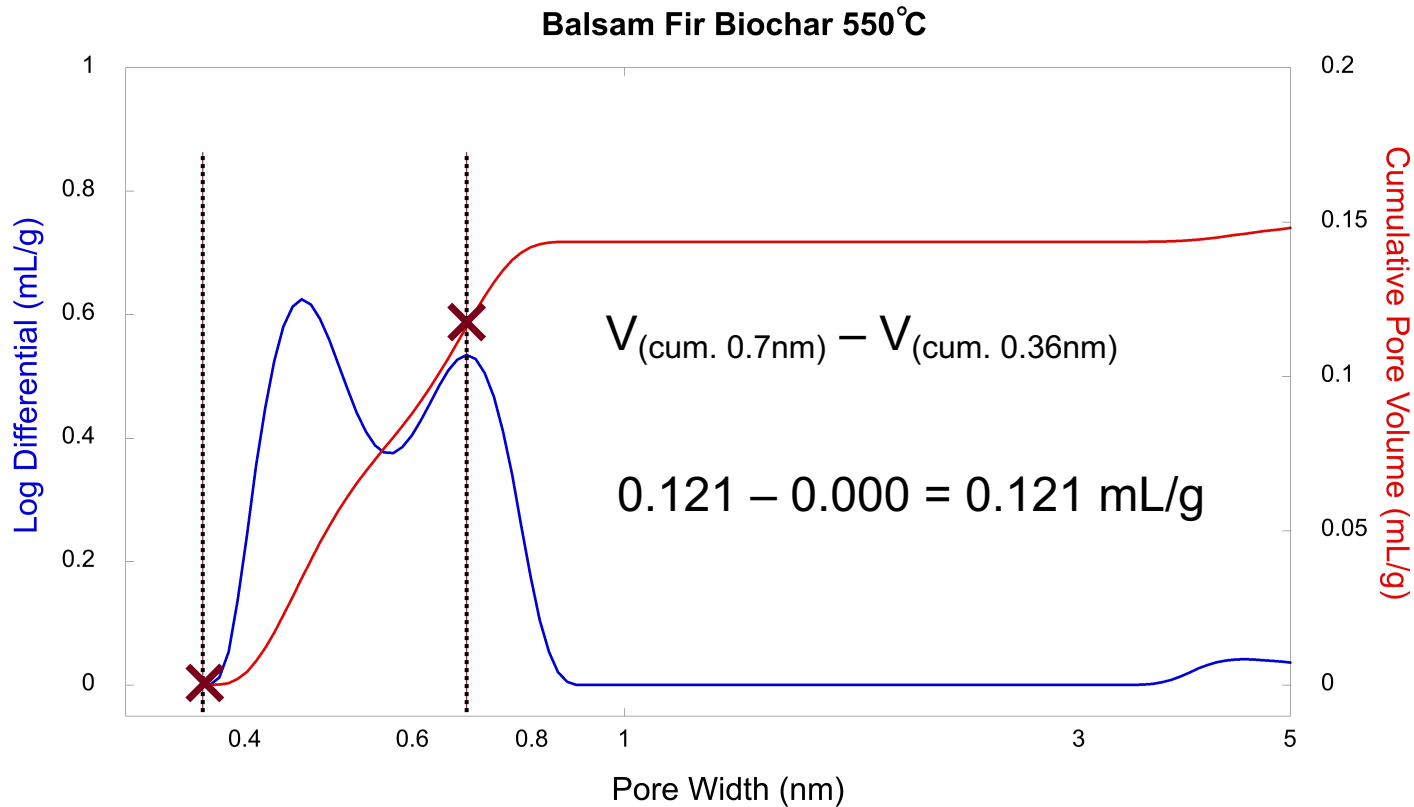




# Balsam Fir Biochar 550°C

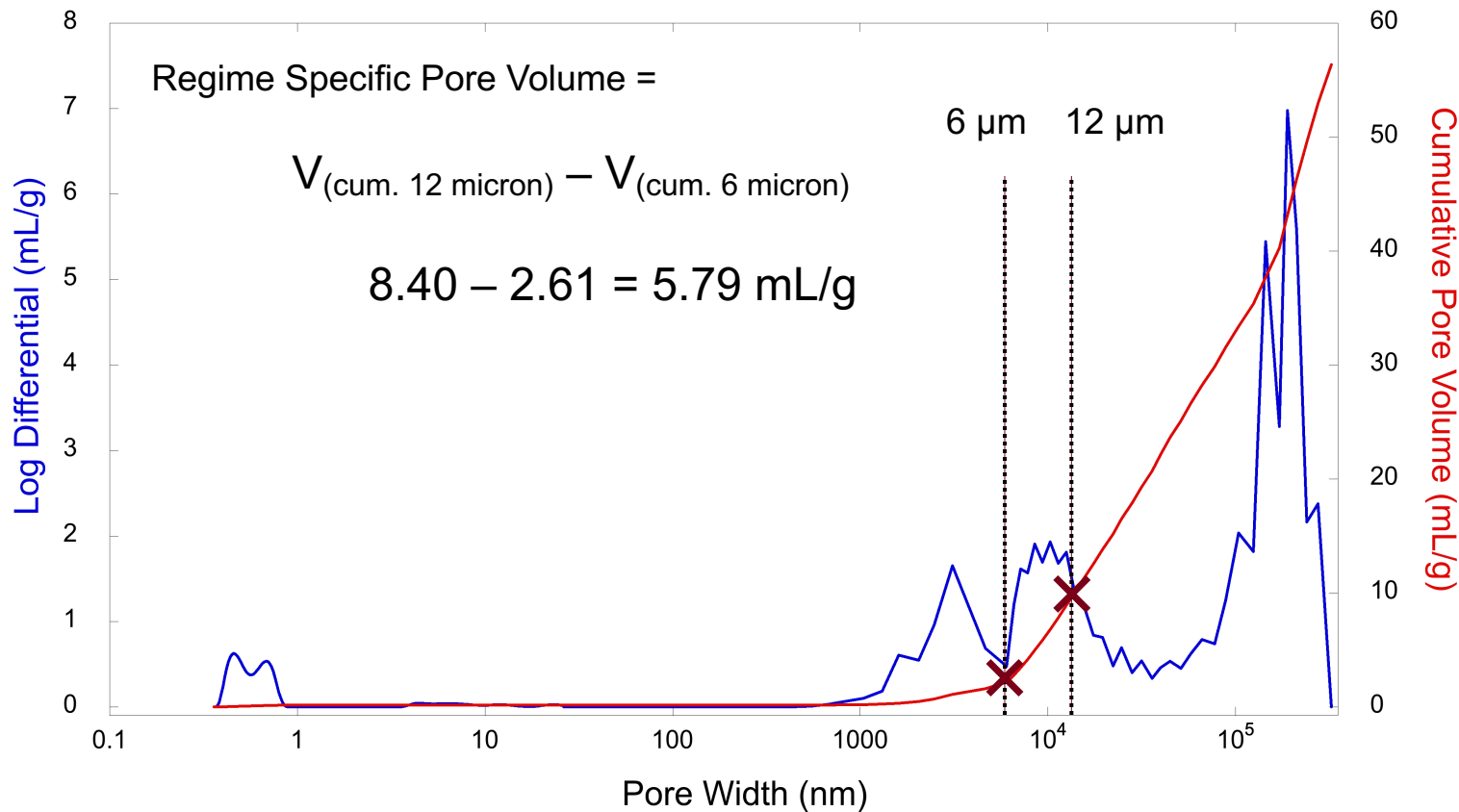


# Pore Volume 0.36-0.70 nm

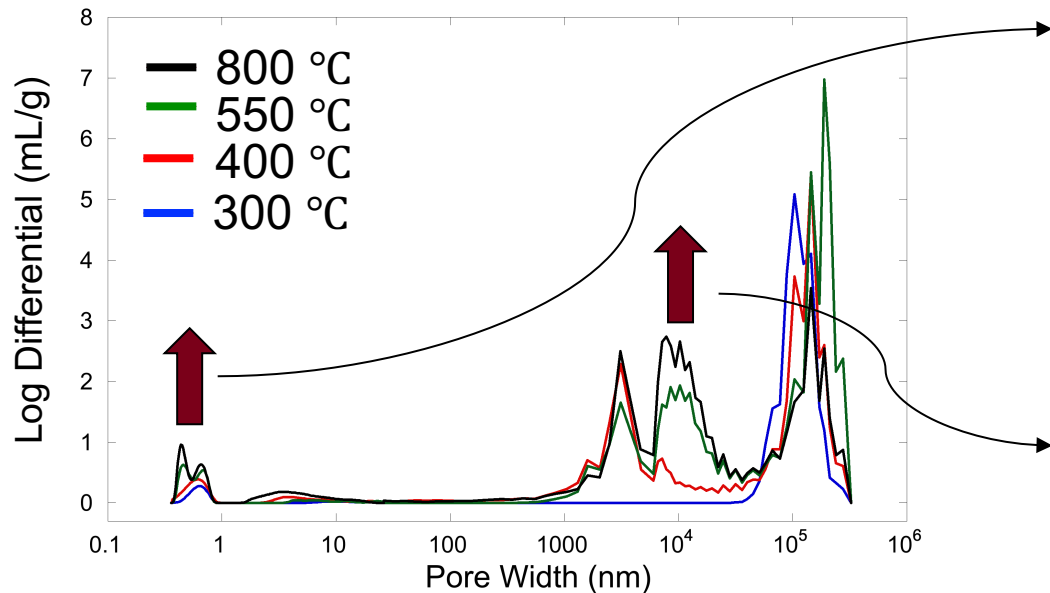


# Pore Volume 6-12 microns

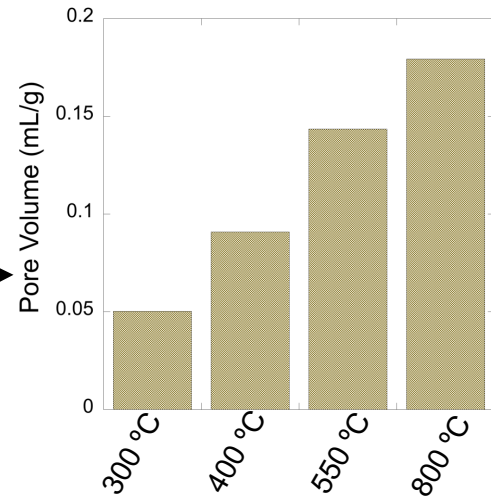
Balsam Fir Biochar 550°C



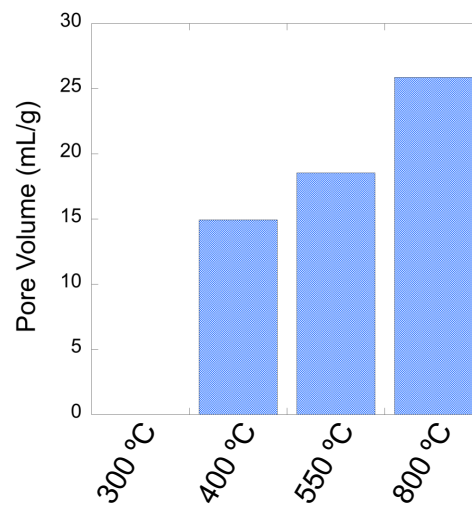
Full Pore Size Distributions of Balsam Fir Biochar at Various HTT



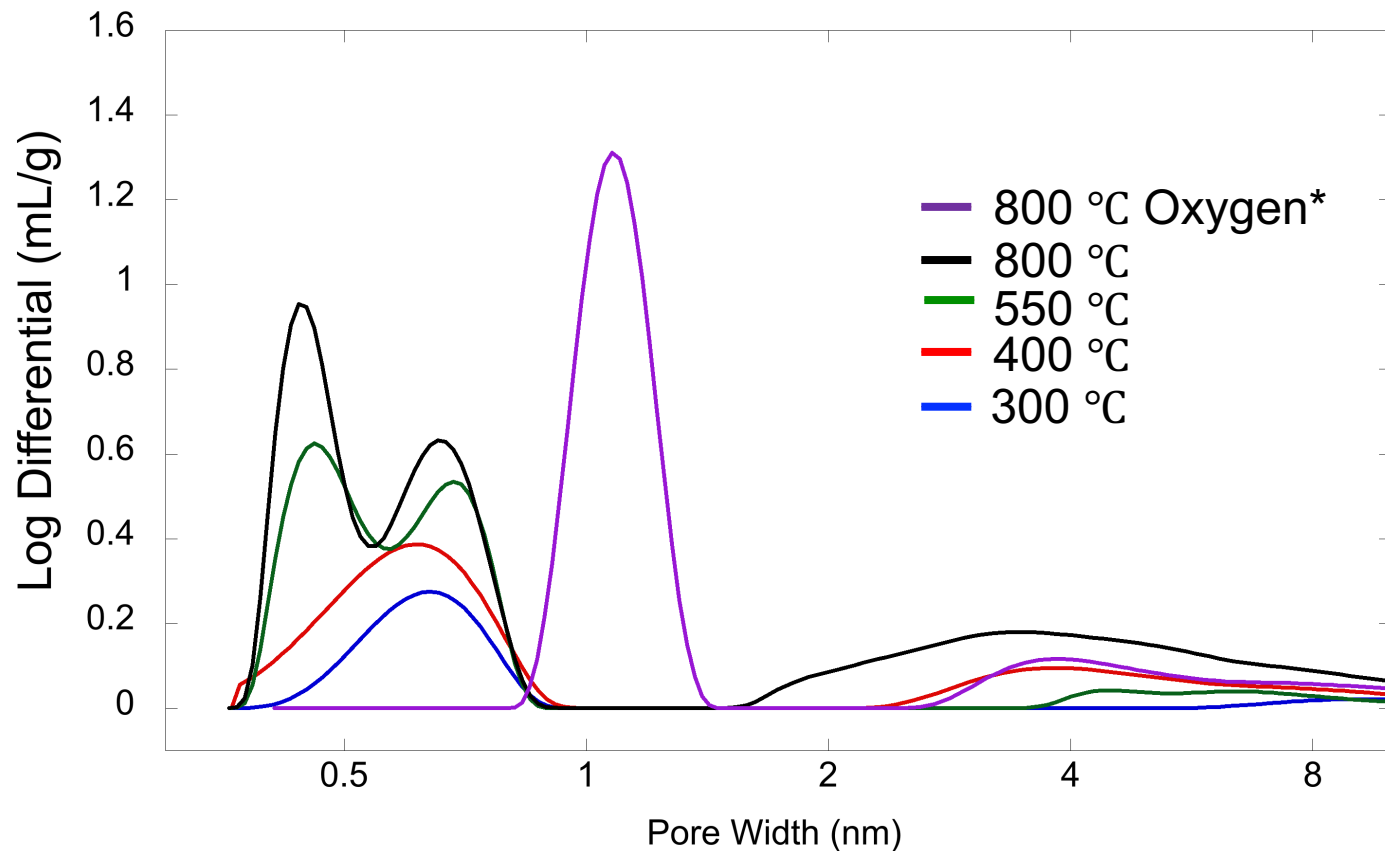
Total Pore Volume 0.36 to 1.00 nm



Total Pore Volume 6 to 36 Microns

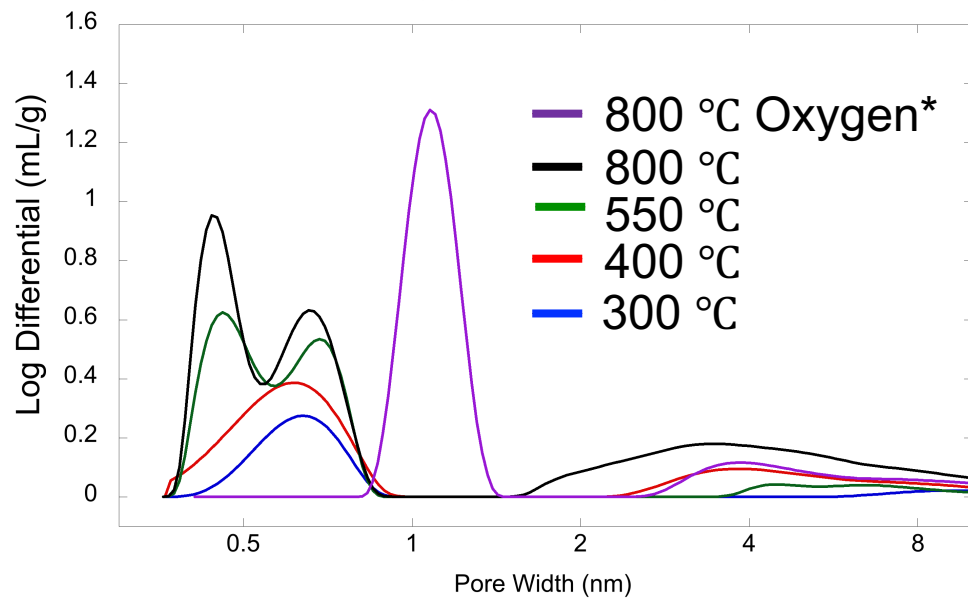


## Balsam Fir Biochar

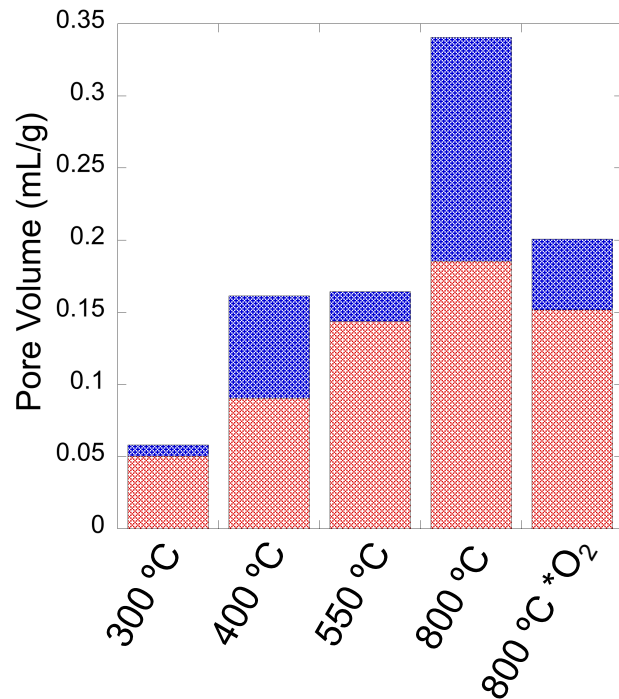


\*Small % O<sub>2</sub> was introduced into the sweep gas for short period of time

### Balsam Fir Biochar



### Micro/Meso Pore Volumes



# Acknowledgements

## NRRI Team:

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# QUESTIONS?

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