Controls on the Density and Porosity of Biochar

Catherine Brewer
Rice University
October 14, 2013
USBI North American Biochar Symposium

Acknowledgements

- Co-authors
  - Victoria J. Chuang (Rice University)
  - Caroline A. Masiello (Rice University)
  - Helge Gonnermann (Rice University)
  - Xiaodong Gao (Rice University)
  - Brandon Dugan (Rice University)
  - Kyriacos Zygourakis (Rice University)
  - Laura E. Driver (Cinco Ranch High School)
  - Pietro Panzacchi (University of Bologna; Shell)
  - Christian A. Davies (Shell)

Acknowledgements

RICE UNIVERSITY Shell Center for Sustainability

- Funding
  - Shell Center for Sustainability
  - European Community's 7th Framework Programme (FP7/2007-2013) Grant 251492
  - National Science Foundation EAR 0911685
  - Depart. of Energy SUN Grant DE-FG36-08GO88073
- Assistance
  - Mark Talarico (Micromeritics Analytical Services)
  - Tom Jones (Rice University Statistics)

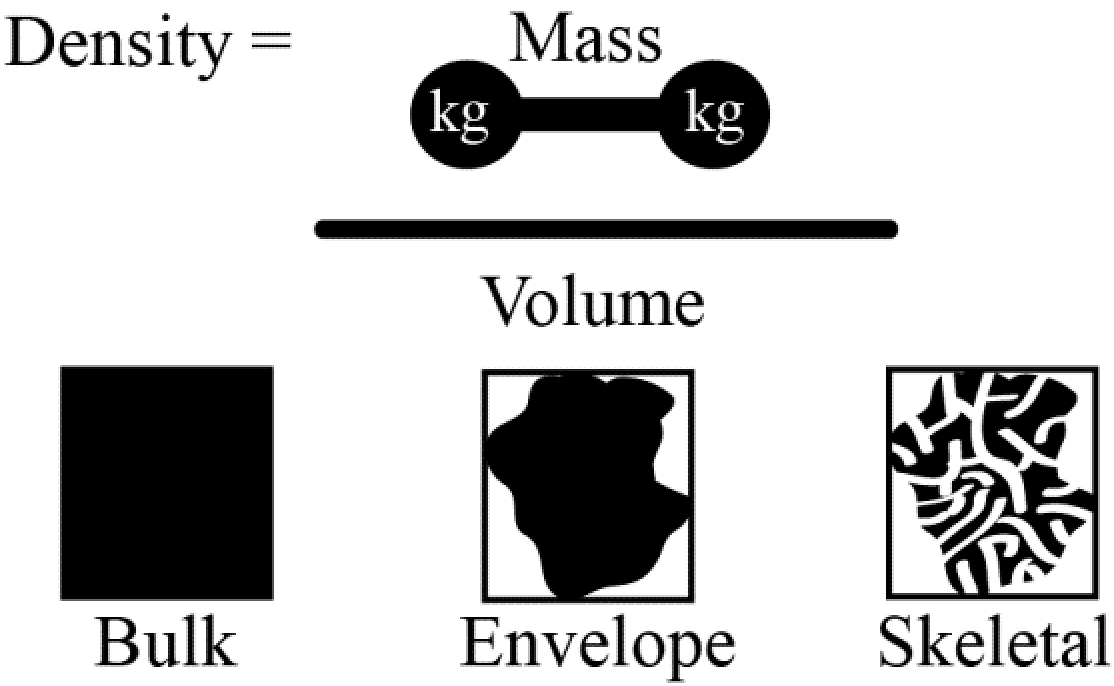
Publication Information

Brewer, C. E.; Chuang, V. J.; Masiello, C. A.; Gonnermann, H.; Gao, X.; Dugan, B.; Driver, L. E.; Panzacchi, P.; Zygourakis, K.; Davies, C. A., New approaches to measuring biochar density and porosity, *under review*.

Outline

- Types of density and why it matters
- Pore size and why it matters
- Our biochars
- Developing envelope density for biochar
- Our results
- Conclusions and implications

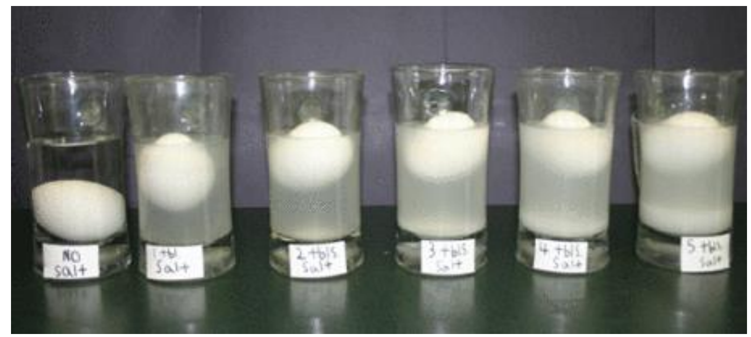
The type of density depends on how volume is defined.

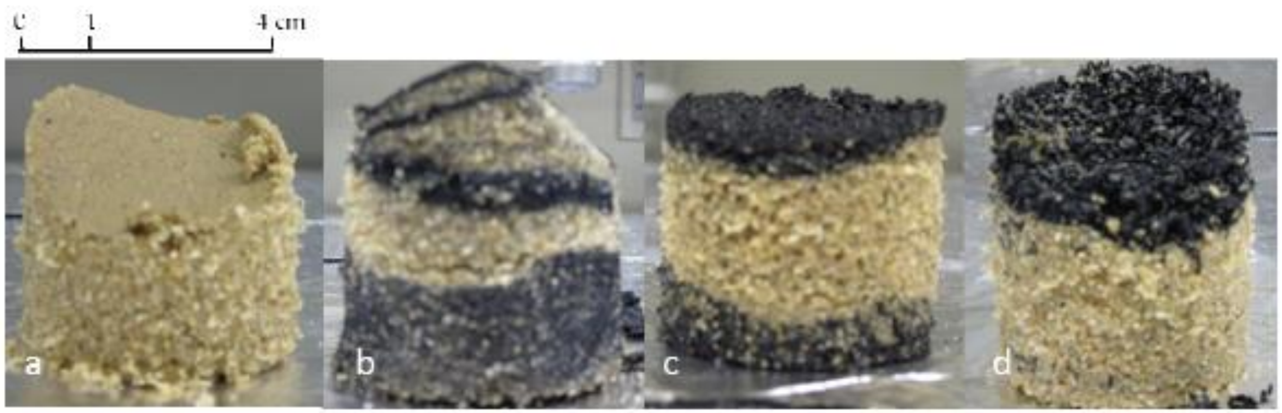


Density affects an object's tendency to float and to be transported.

Image:http://en.wikipedia.org/wiki/Galileo_Thermometer

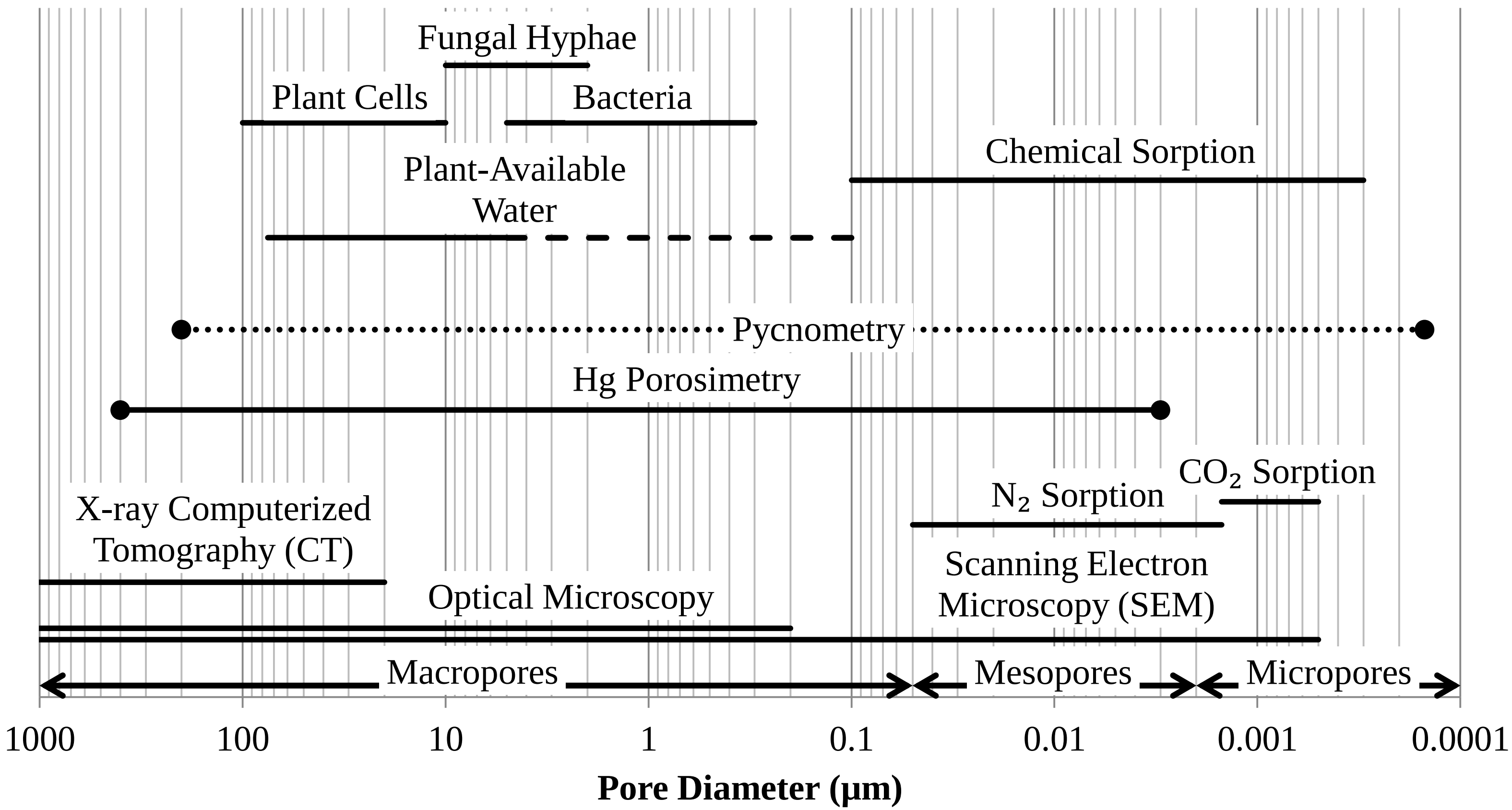
Image:http://hezronkyle.wordpress.com/2012/08/26/lab-experiments/



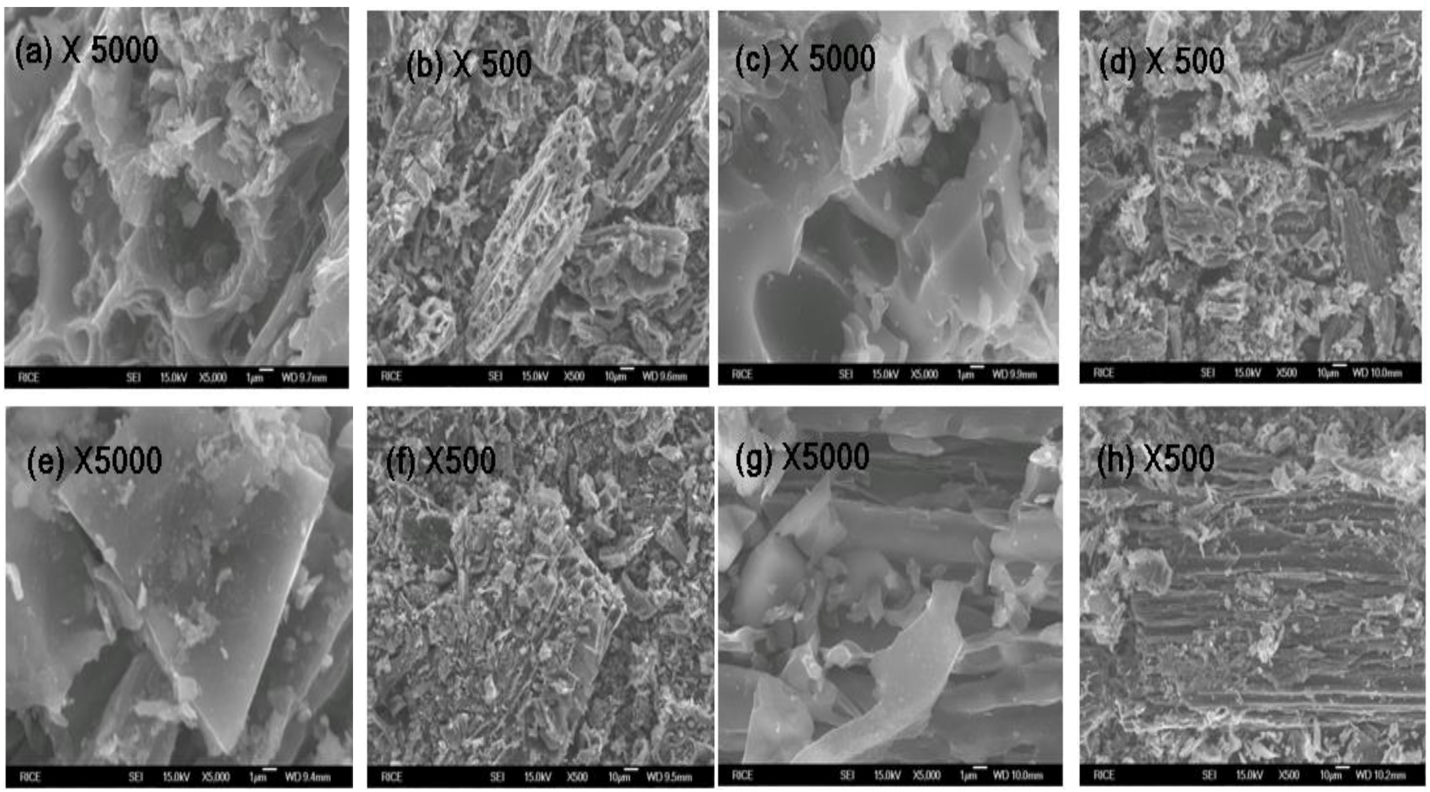


Chuang, et al. Black carbon: does it sink or float? 2012 AGU Ocean Sciences Meeting, 21 February, 2012, Salt Lake City, UT.

Measurement techniques target specific pore size ranges.



Biochar contains pores that range from < 1 nm to 100s of μm.

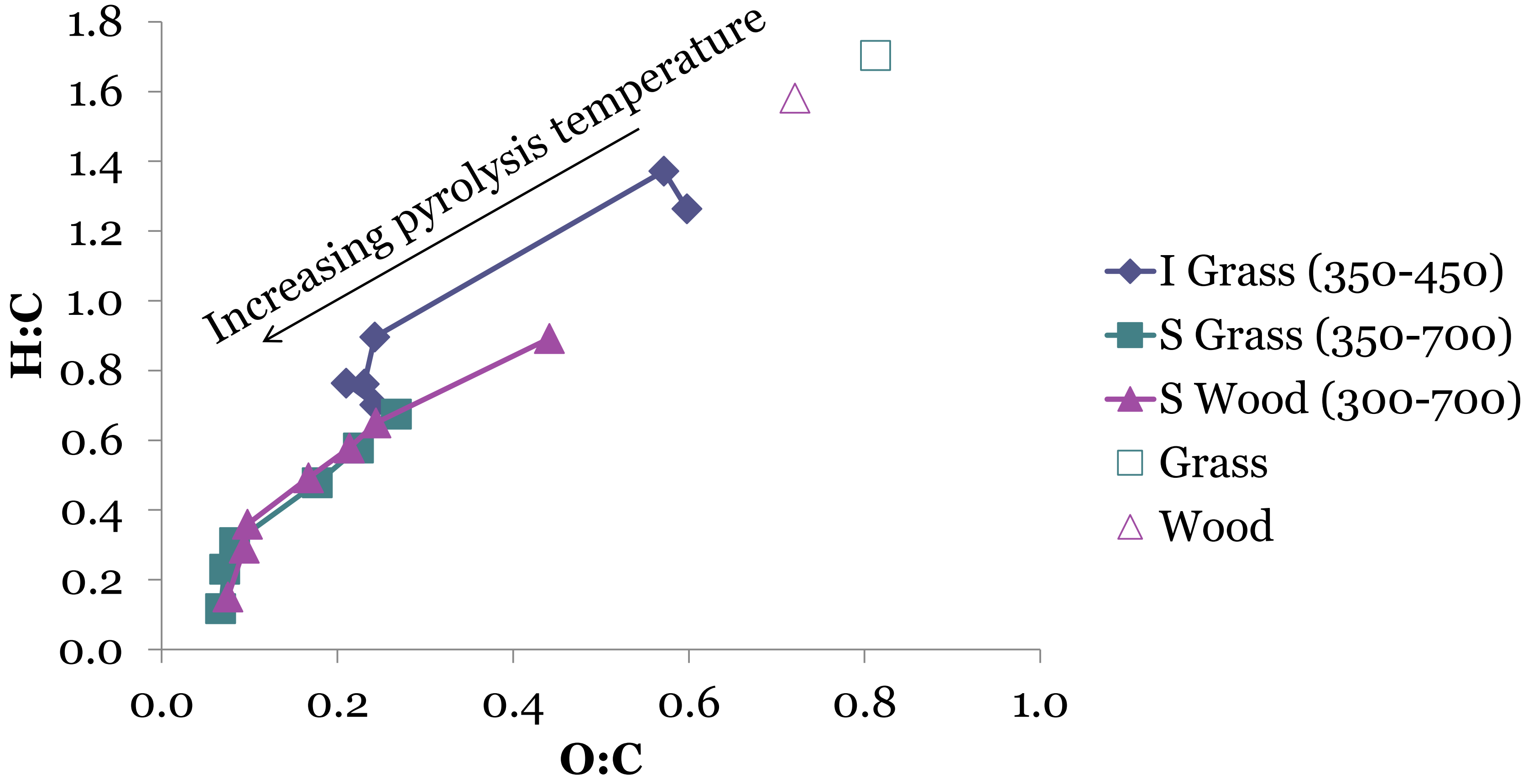


Sun, et al. *Ind. Eng. Chem. Res.* **2013**, *51 (9)*, 3587-3597.

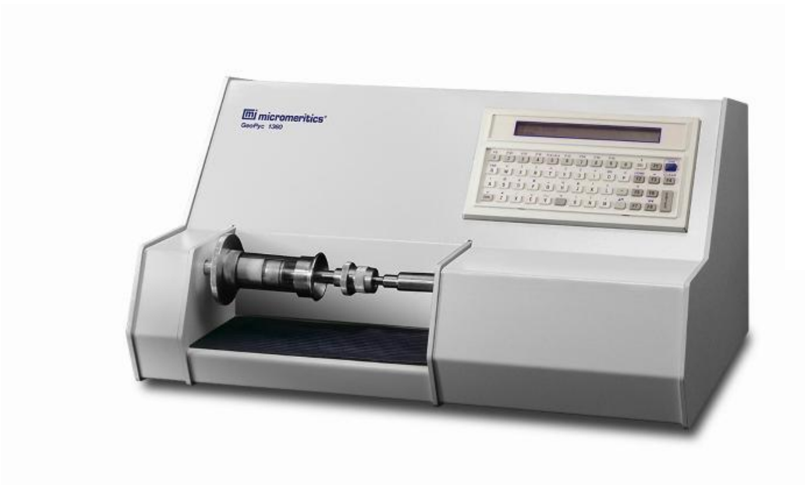
We made 19 biochars to cover a range of conditions and properties.

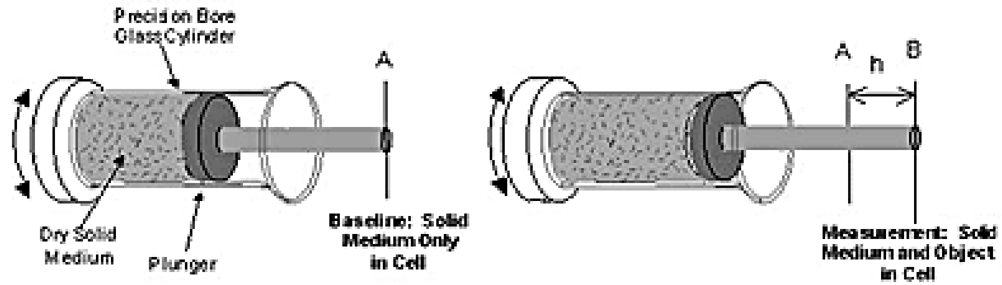
- Miscanthus grass
  - Intermediate pyrolysis (I): 350, 360, 370, 400, 425, and 450°C
  - Slow pyrolysis (S): 350, 400, 450, 550, 600, and 700°C
- Mesquite wood
  - Slow pyrolysis (S): 300, 350, 400, 450, 550, 600, and 700°C

Our intermediate pyrolysis biochars were unusual in composition.



We used a Geopyc® to develop a biochar envelope density procedure.

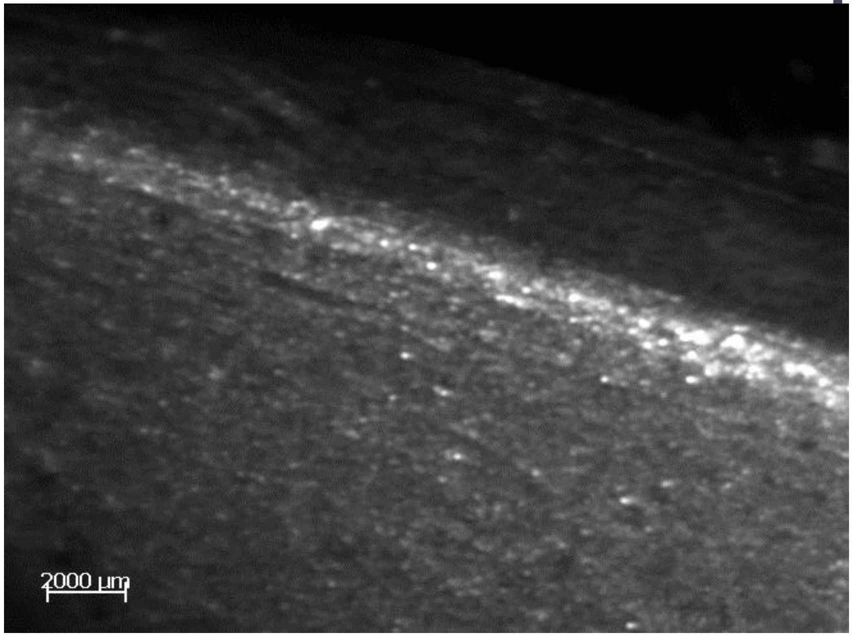


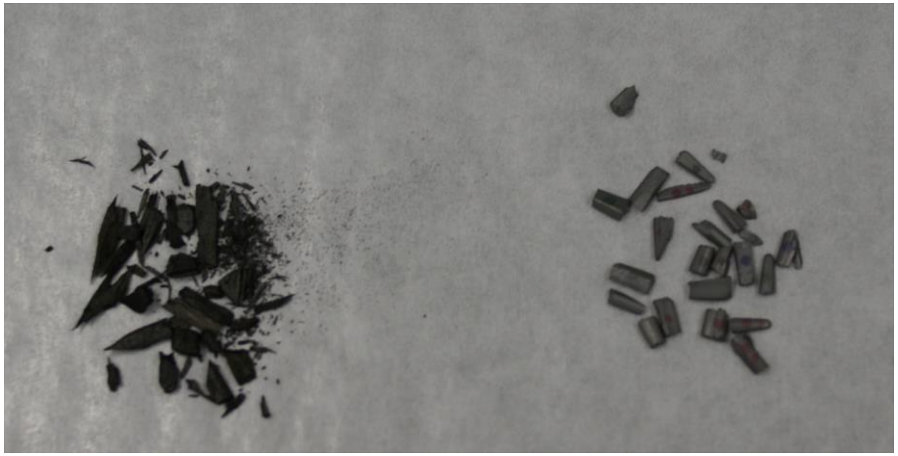


Images: http://www.micromeritics.com/Product-Showcase/GeoPyc-1360-Envelope-Density-Analyzer.aspx

		Consolidation Force (N)		
		19	**22**	**29**
Sample Volume ($cm^3\ cm^{-3}$)	**0.15**	4 runs		4 runs
	0.20		4 runs	
	0.25	4 runs	4 runs	4 runs

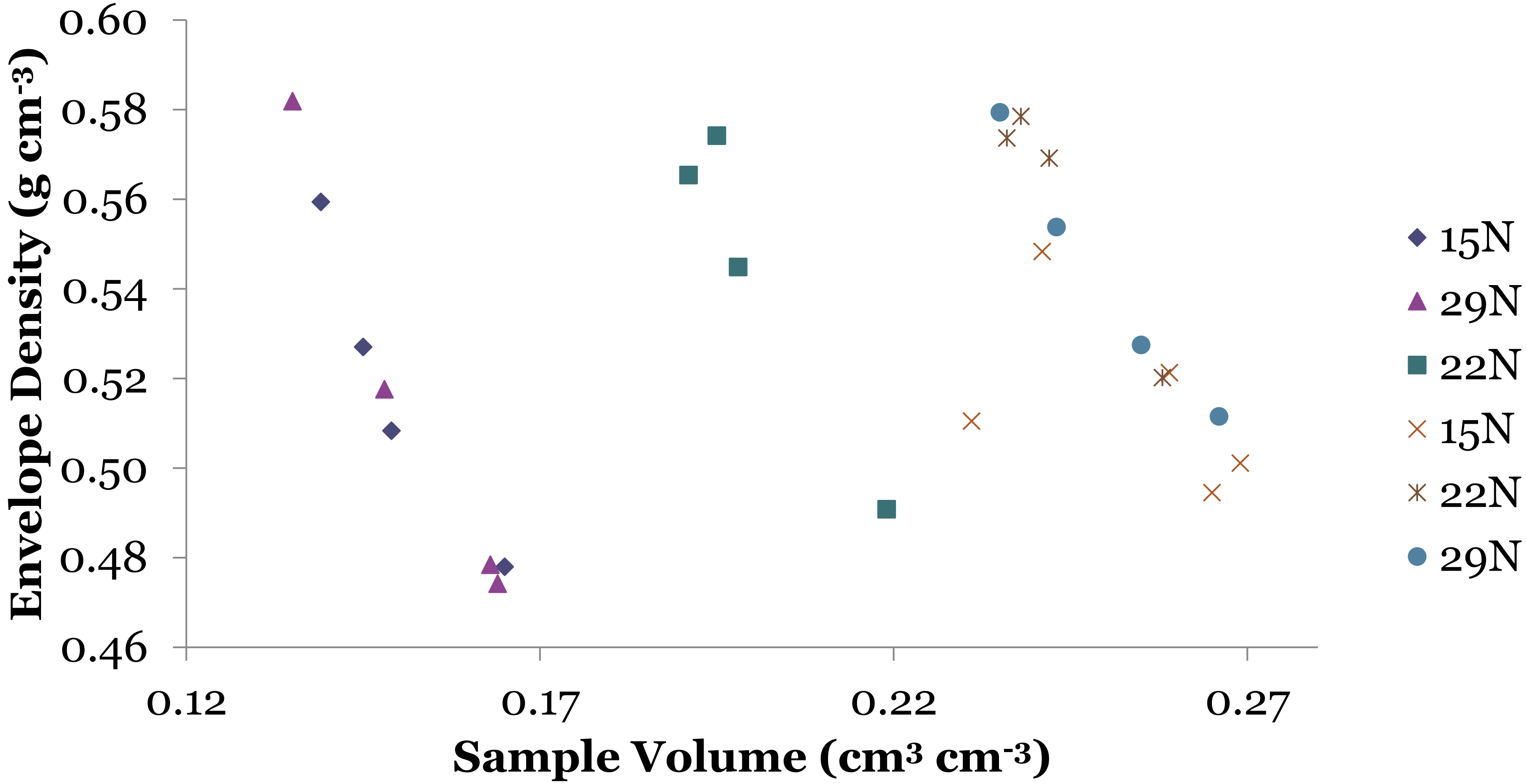
Calibrating the Geopyc® required selection of a non-porous proxy.



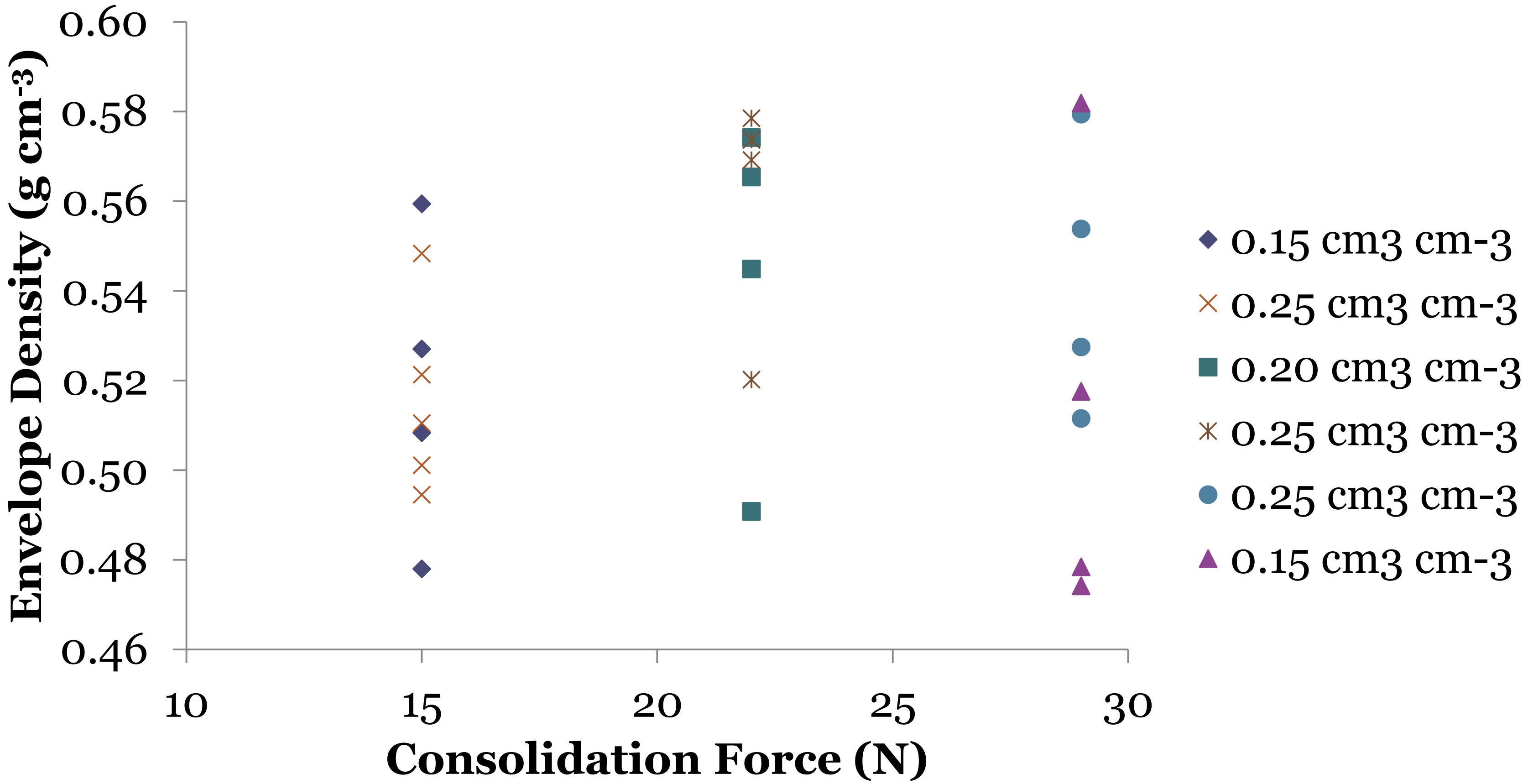


DryFlo® particle •

Envelope density variability is a function of sample volume fraction…



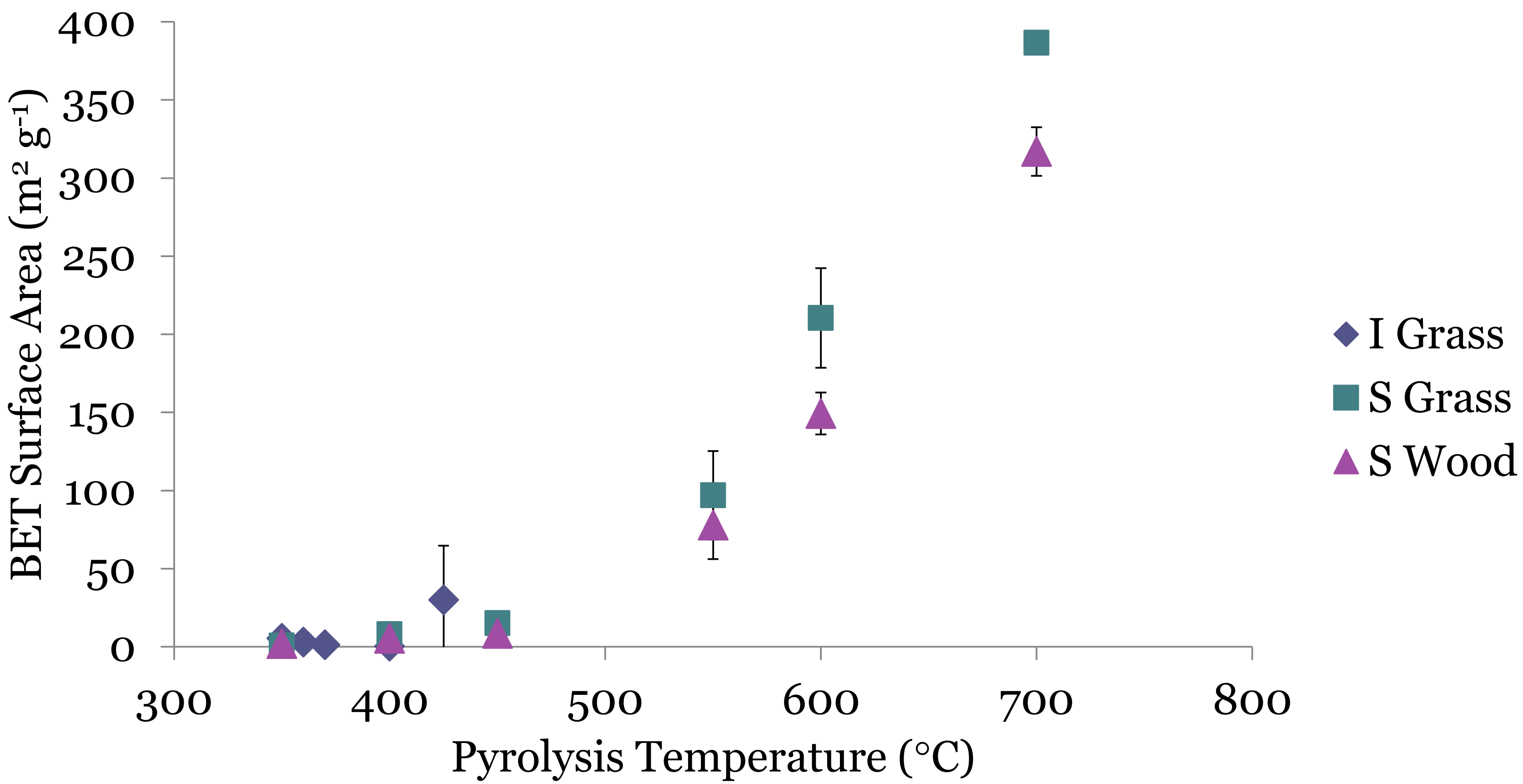
…rather than a function of consolidation force.



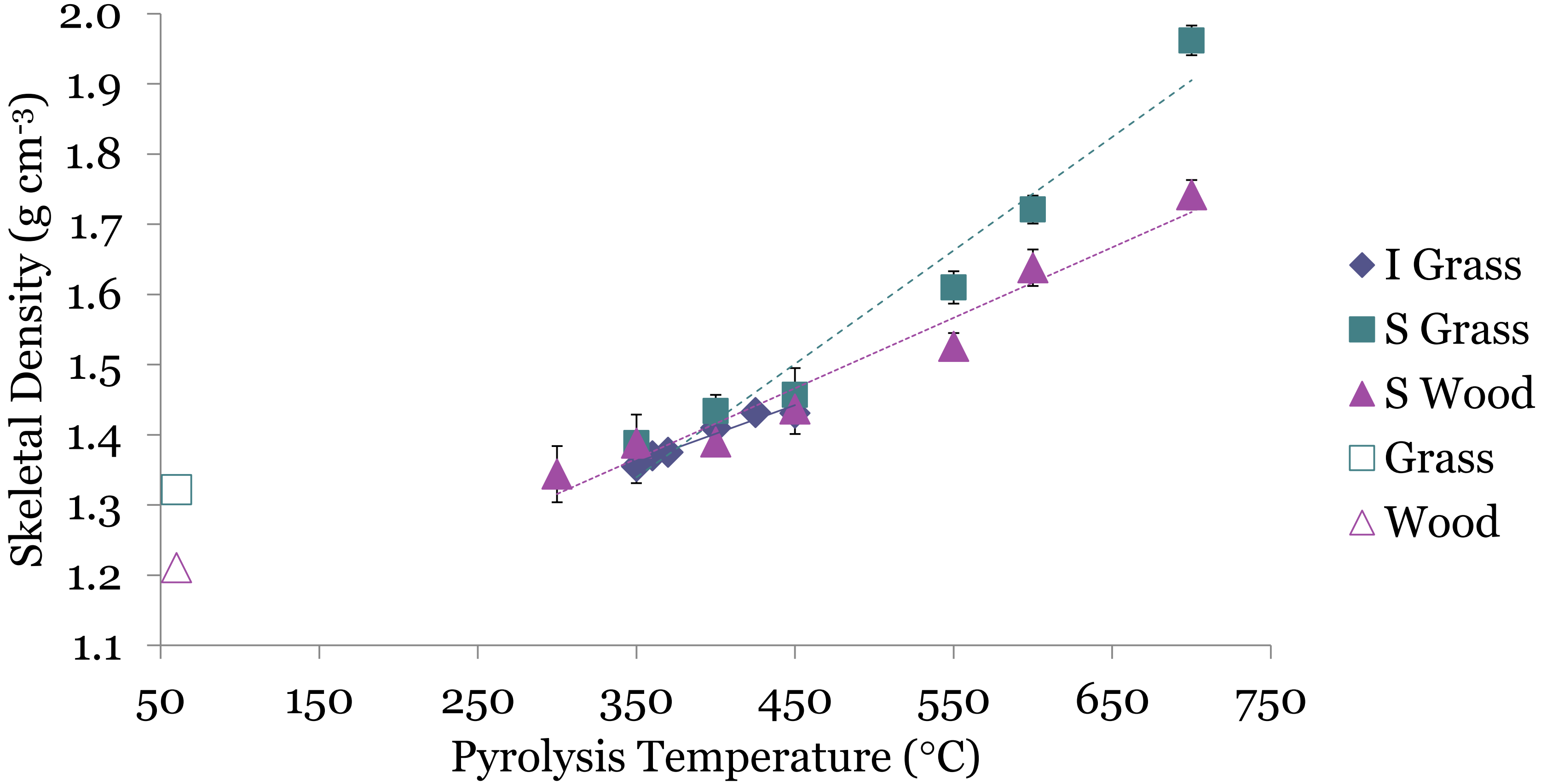
We arrived at the conditions that gave the best reproducibility.

- 25 ± 2% volume sample + 75% volume DryFlo®
- 22 N consolidation force
- 20 preparation + 20 analysis consolidation cycles
- 0.124 $cm^3\ mm^{-1}$ conversion factor based on plastic fork tines
- Fresh biochar and DryFlo® each time.
- 3 replicates for each biochar sample.

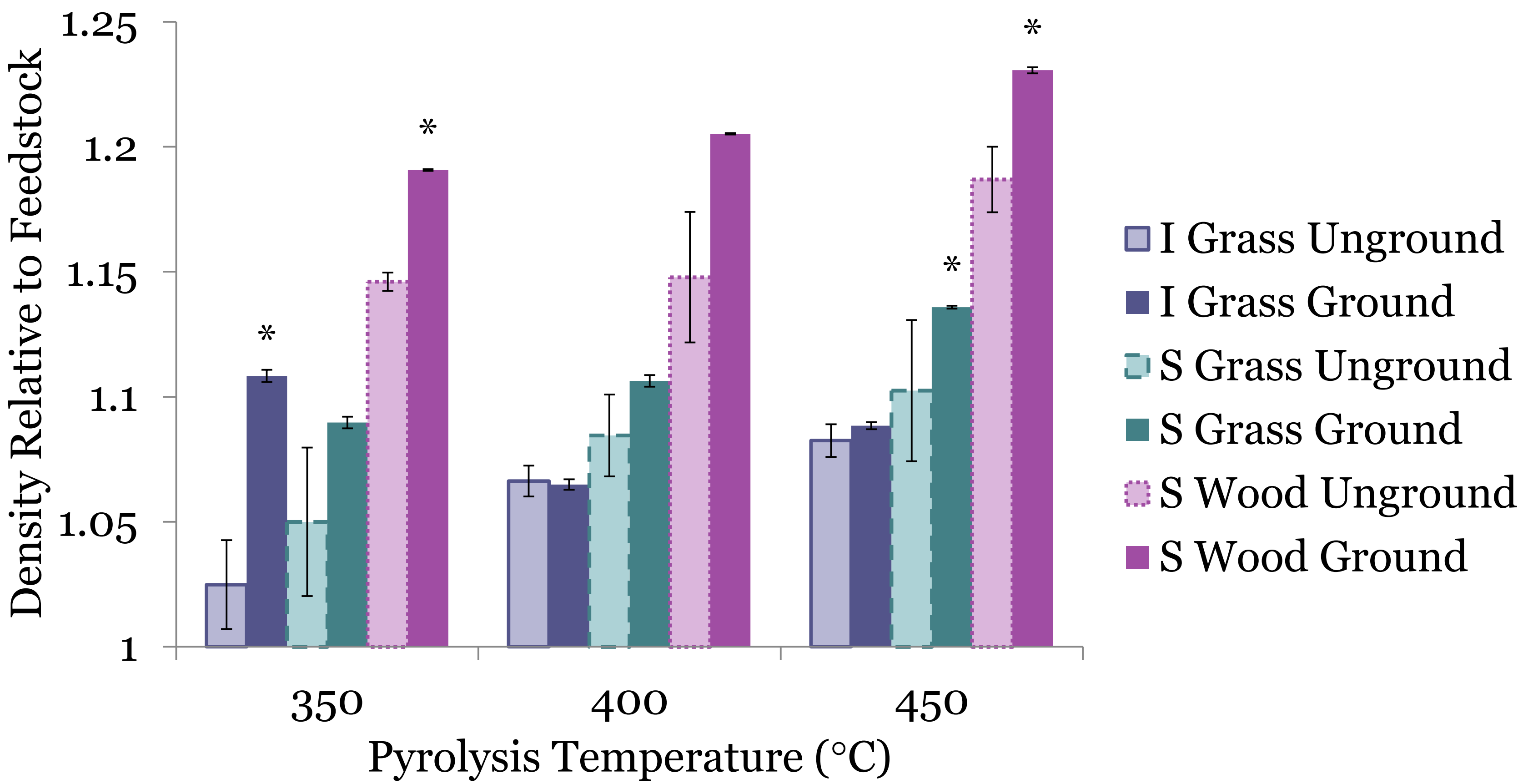
Biochar surface area increased with pyrolysis temperature.



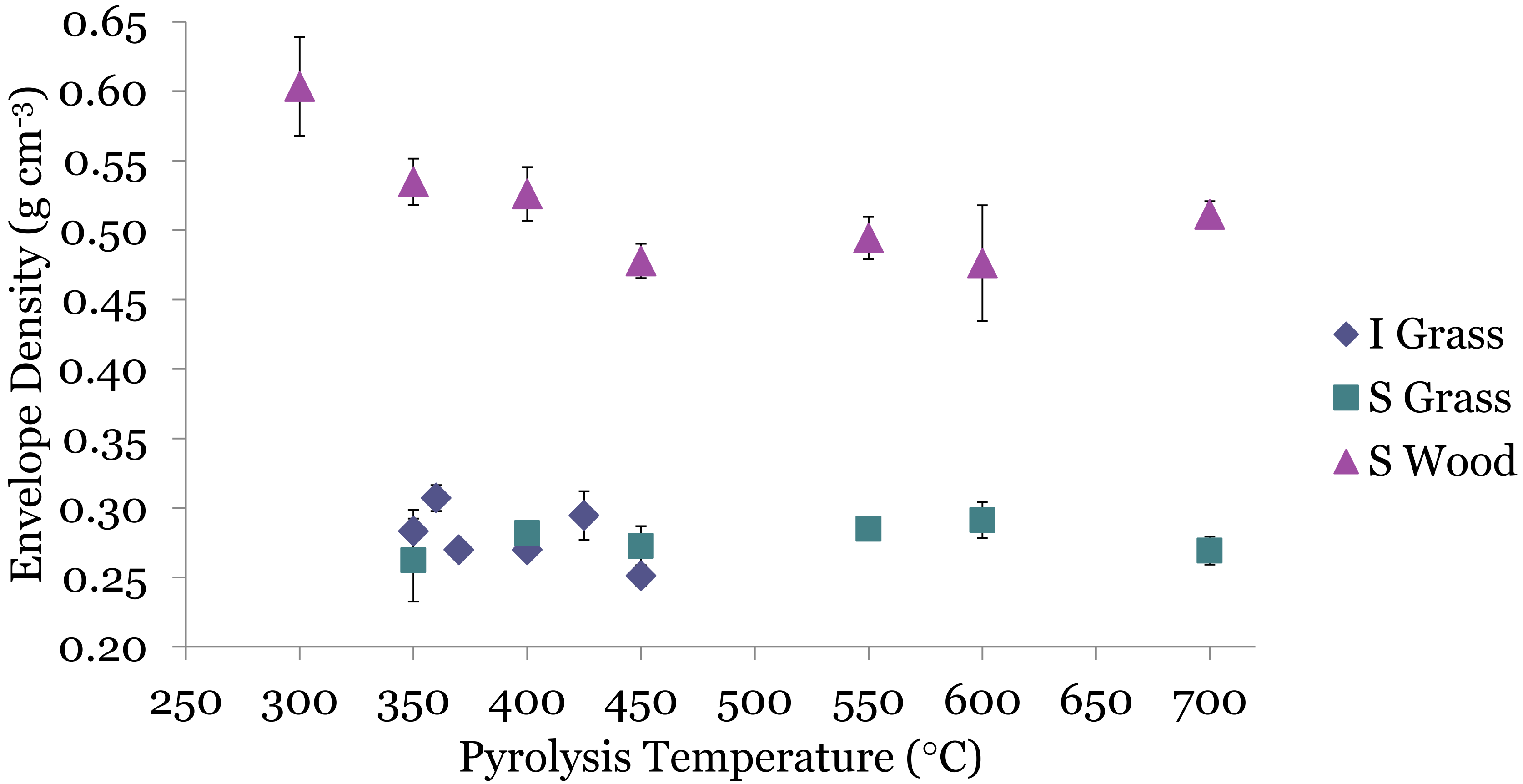
Biochar skeletal density increased with pyrolysis temperature.



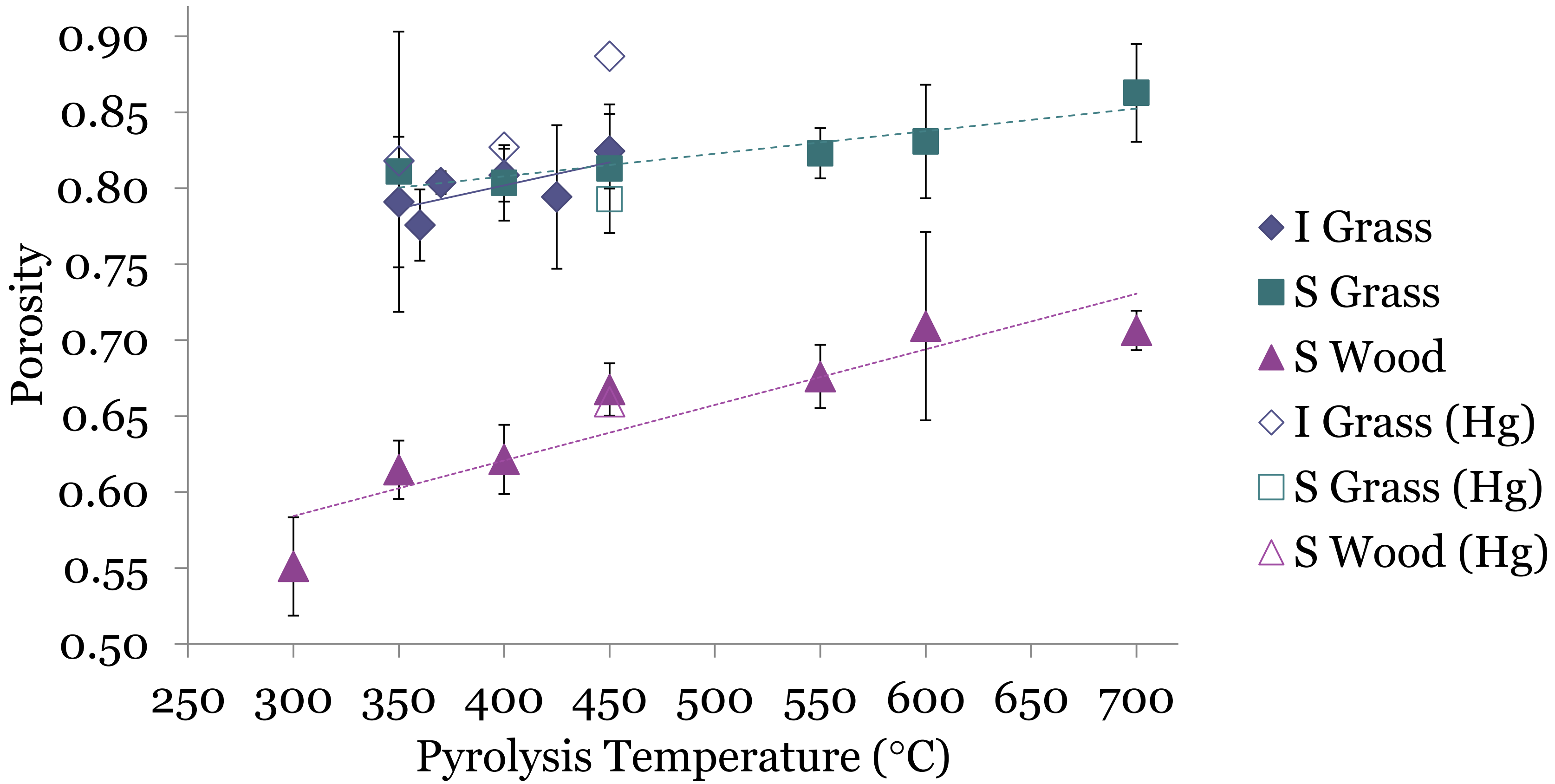
Grinding biochars increased helium access to biochar pores.



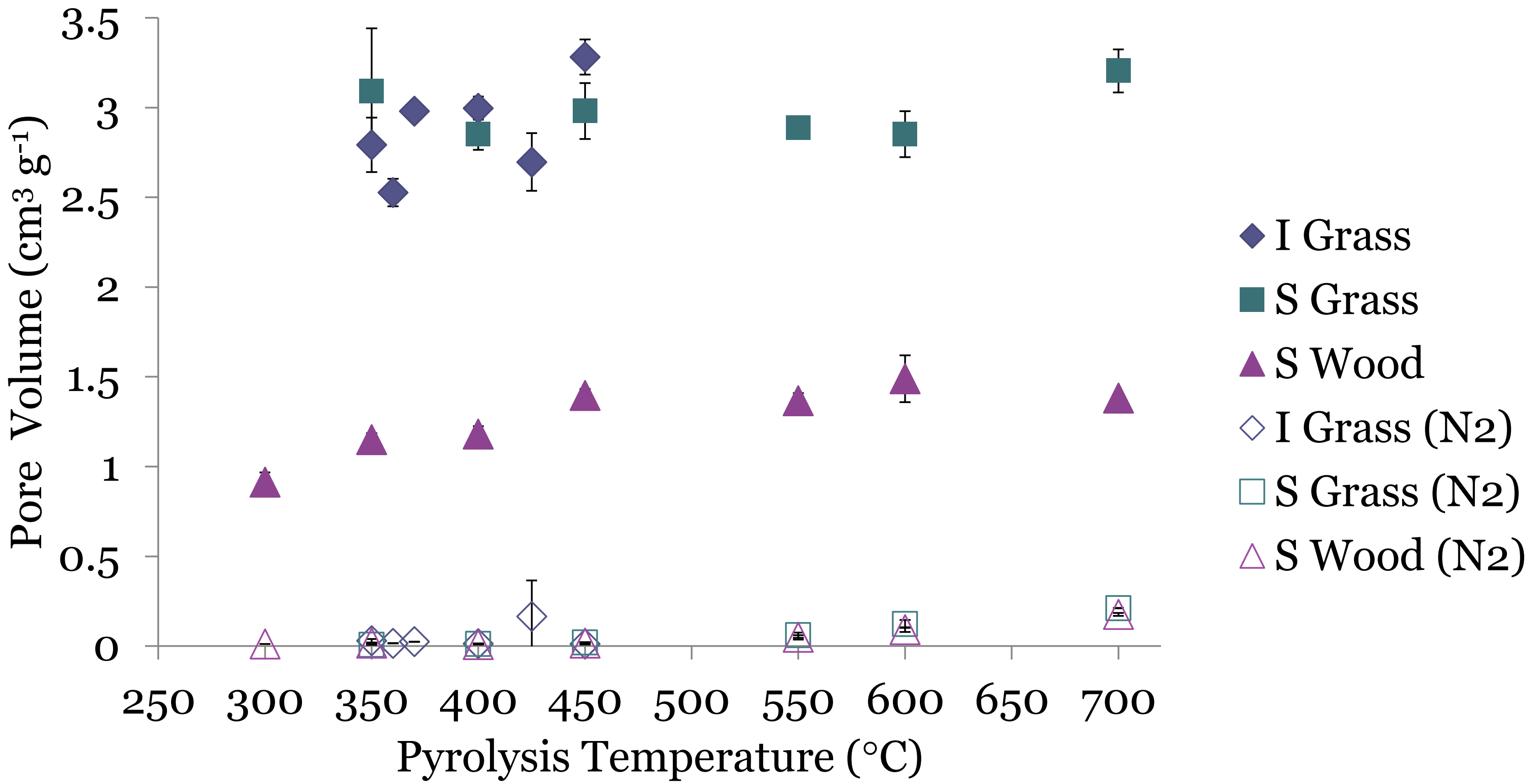
Biochar envelope density varied with biomass feedstock.



Biochar porosity was higher for grass biochars than for wood biochars.



Measuring biochar pore volume by N_2 adsorption misses many pores.



Conclusions & Implications

- Biochar physical properties play a key role in understanding how biomass feedstocks and pyrolysis conditions relate to biochar's environmental impacts.
- One challenge to characterizing the effects of biochar porosity on soil is reliable measurements of pore volume over the entire pore size range.

Conclusions & Implications

- Our combined skeletal- and envelope-density analysis provides a novel and valuable method for quantifying biochar porosity characteristics over the whole pore size range.
- Biochar skeletal density and micropore volume are primarily controlled by pyrolysis temperature (reaction).
- Biochar envelope density, porosity, and macropore volume are predominantly controlled by biomass anatomy (feedstock).

Questions?
Further information:

Dr. Catie Brewer
New Mexico State University
Department of Chemical Engineering
cbrewer@nmsu.edu

Dr. Carrie Masiello
Rice University
Department of Earth Science
masiello@rice.edu