

Correlating glassy phase composition and spatial distribution in fly ash with reactivity in geopolymer cements

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What?

Fly ash phase characterization for efficient proportioning of geopolymers cements.

fly ash



Why?

Geopolymers are difficult to proportion.

The reactivity of fly ash has historically been correlated to the chemistry of bulk amorphous content, not individual glassy – phases.



caustic activating solution



Now:



analysis
crystalline phases
coupled with
analysis
assay phases

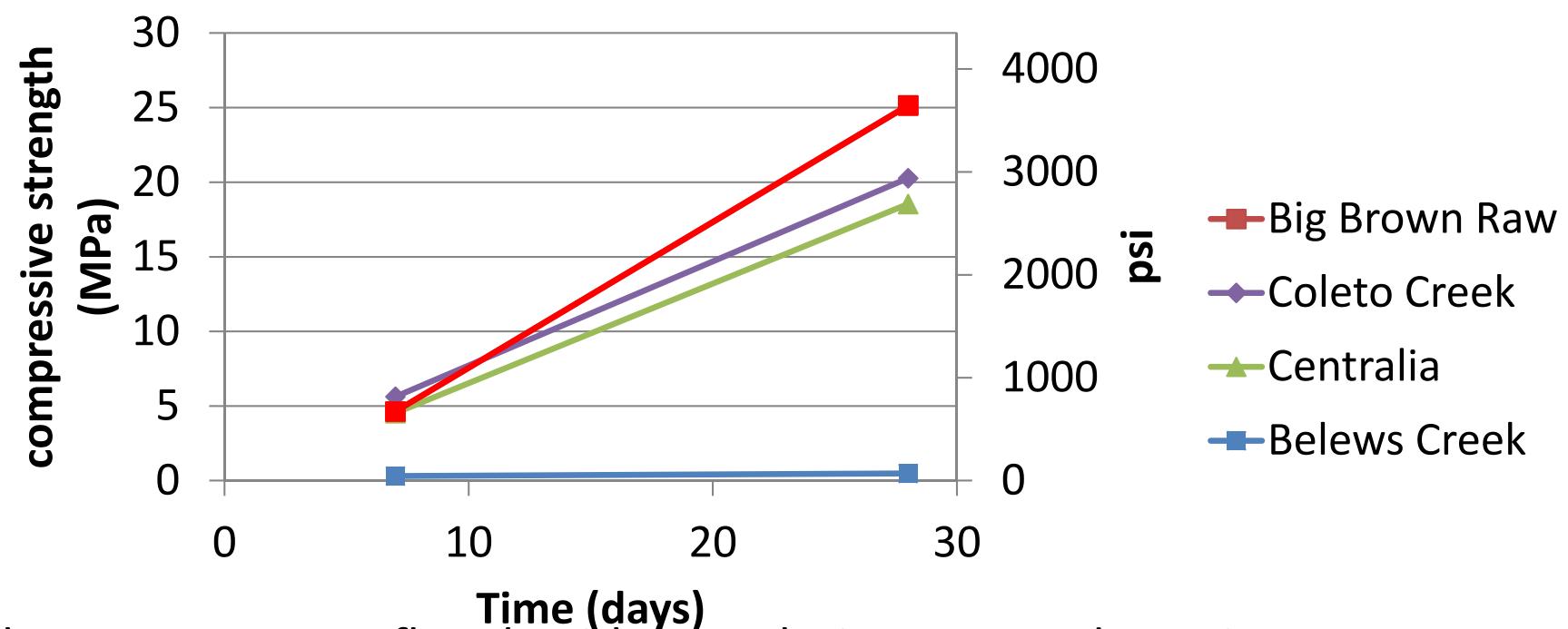
Geopolymer Proportioning

	Literature	Big Brown Raw	Coleto Creek	Centralia	Belews Creek
M ₂ O/SiO ₂	0.2-0.48	0.51	0.57	0.51	0.48
SiO ₂ /Al ₂ O ₃	3.3-4.5	4.59	3.96	5.61	3.09
H ₂ O/M ₂ O	10-25	6.35	6.21	6.07	6.21
M ₂ O/Al ₂ O ₃	0.8-1.6	1.42	1.37	1.70	0.89

(where M is an alkali cation)

Predicting Geopolymer Strength

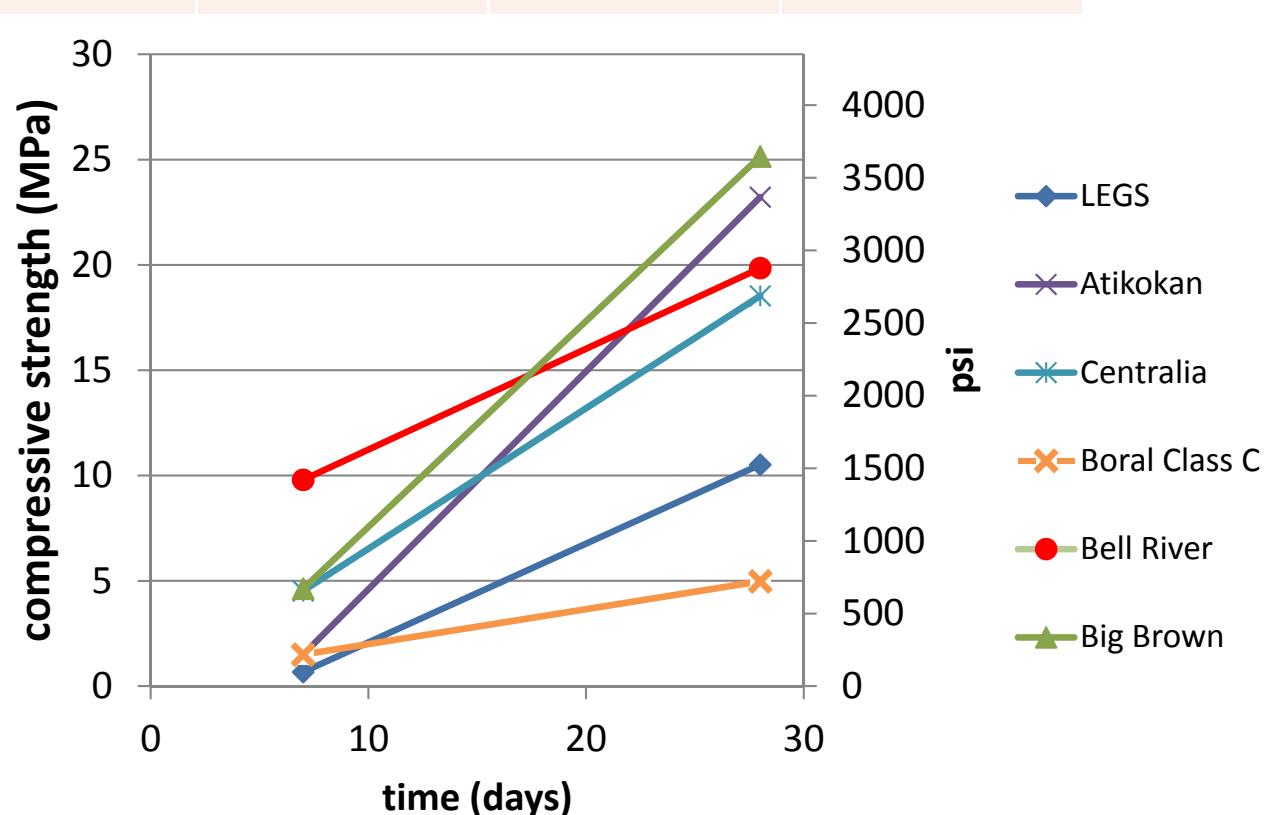
	Big Brown Raw	Coleto Creek	Centralia	Belews Creek
Al_2O_3	18.43	20.98	16.36	30.50
SiO_2	48.36	48.15	54.06	55.81
CaO	14.14	12.77	11.16	1.19
K_2O	1.14	1.20	1.86	2.26
Na_2O	0.64	1.53	1.18	0.28
MgO	2.16	3.42	4.14	0.72



Mortar Cubes: 8 M NaOH + fly ash with 0.4 solution-to-powder ratio

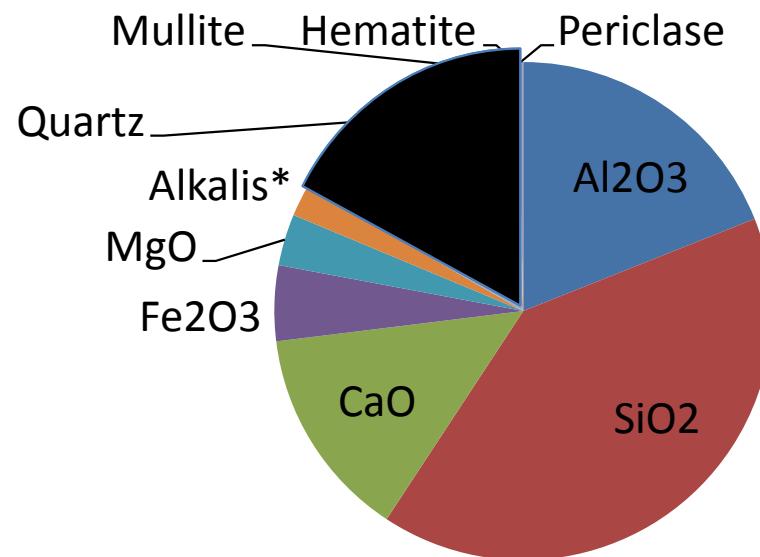
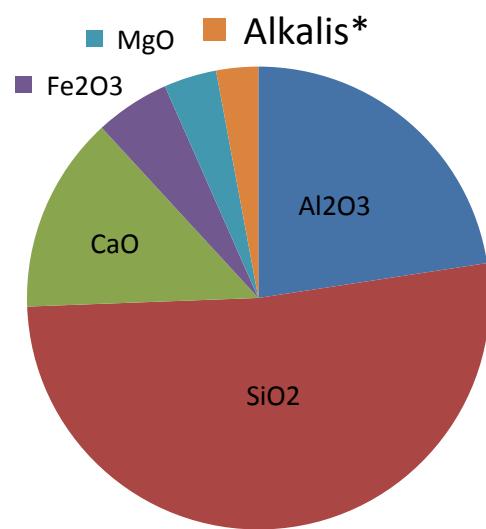
Predicting Geopolymer Strength

	Bell River	Big Brown Raw	Atikokan	Centralia	Limestone (LEGS)
Al ₂ O ₃	17.04	18.43	21.58	16.36	17.80
SiO ₂	33.16	48.36	47.66	54.06	54.14
CaO	27.06	14.14	12.30	11.16	10.70
Fe ₂ O ₃	4.91				
K ₂ O	0.78				
MgO	5.06				
Na ₂ O	4.20				
SO ₃	2.87				
TiO ₂	1.11				



Characterizing ashes

- Oxide analysis



- Subtract crystalline phases
- HF acid method to measure reactive silica[†]

* Alkalies are $\text{Na}_2\text{O} + \text{K}_2\text{O}$

† Fernández-Jiménez, A., and Palomo, A. (2003), "Characterisation of fly ashes: potential reactivity as alkaline cements." *Fuel*, 82, 2259-2265.

Multispectral Image Analysis (MSIA)

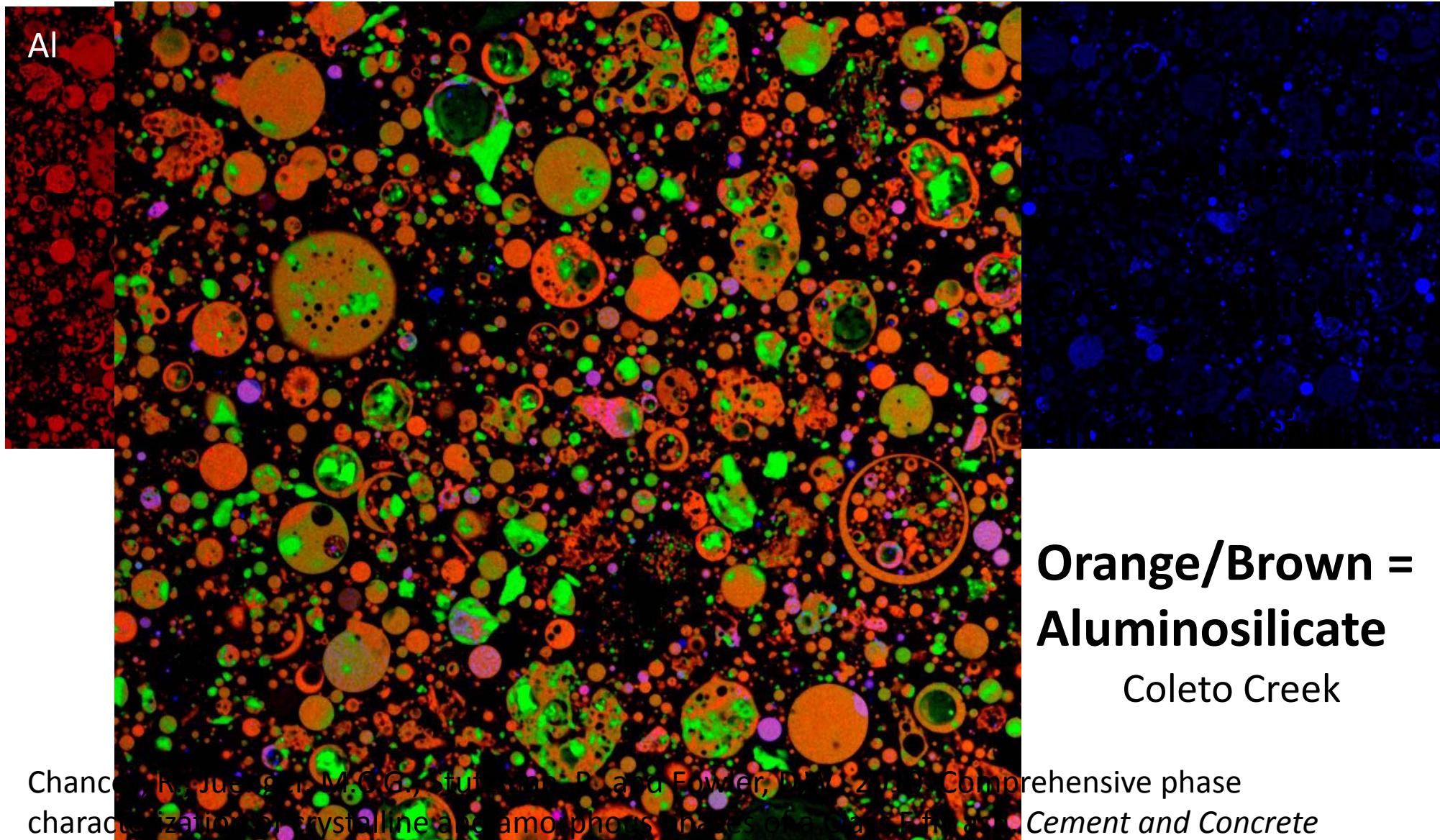
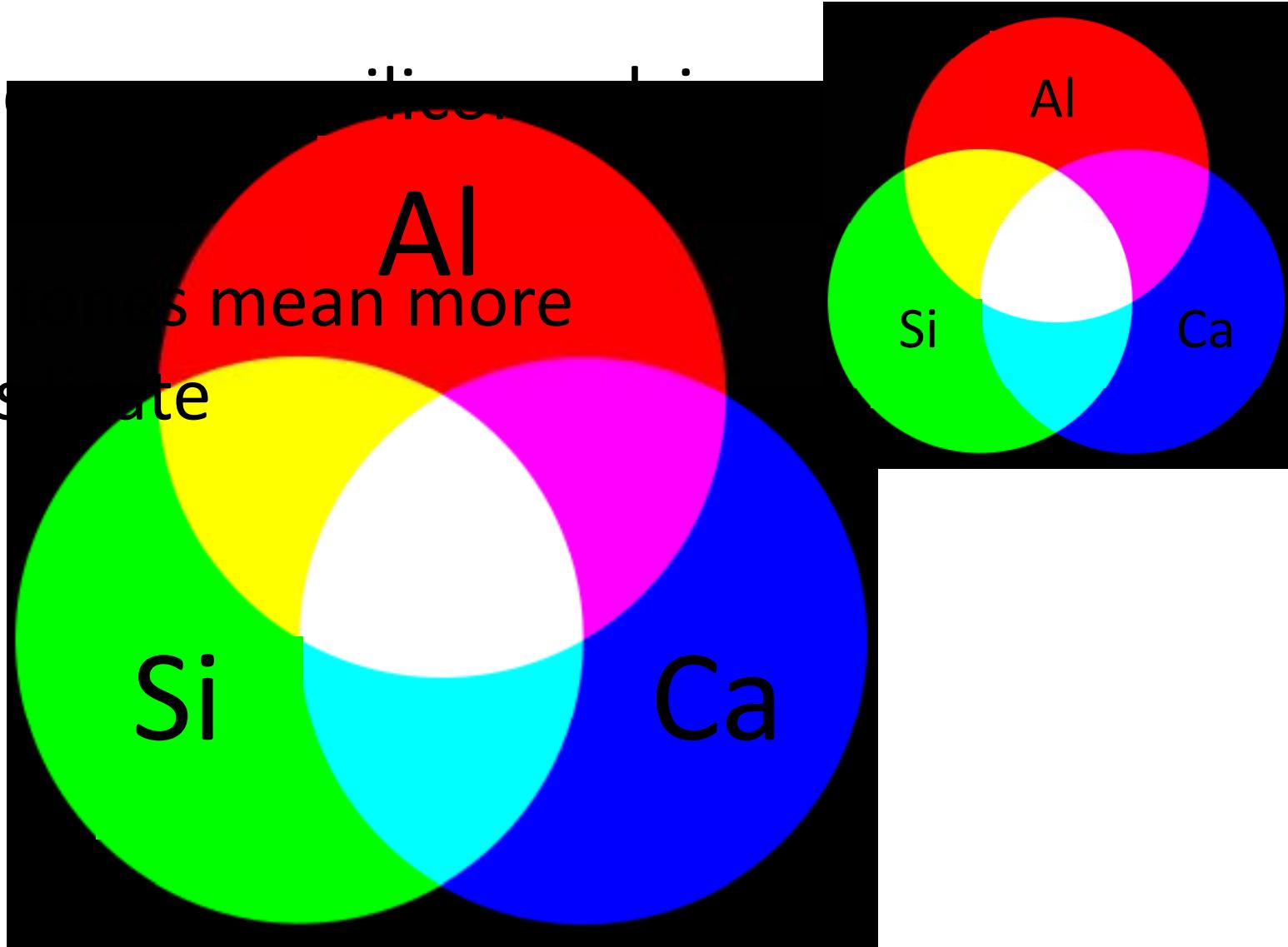
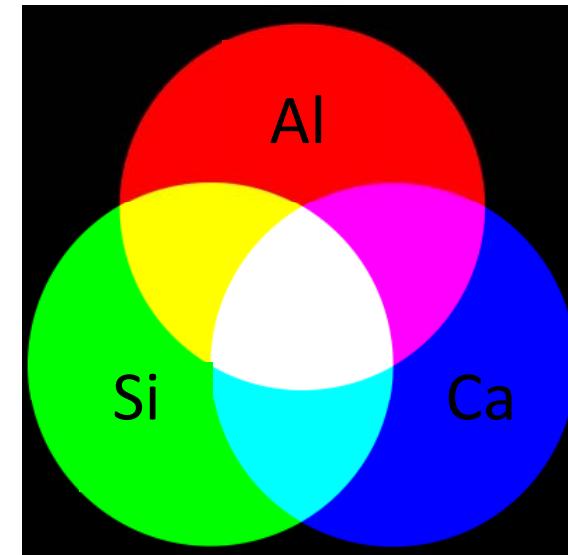
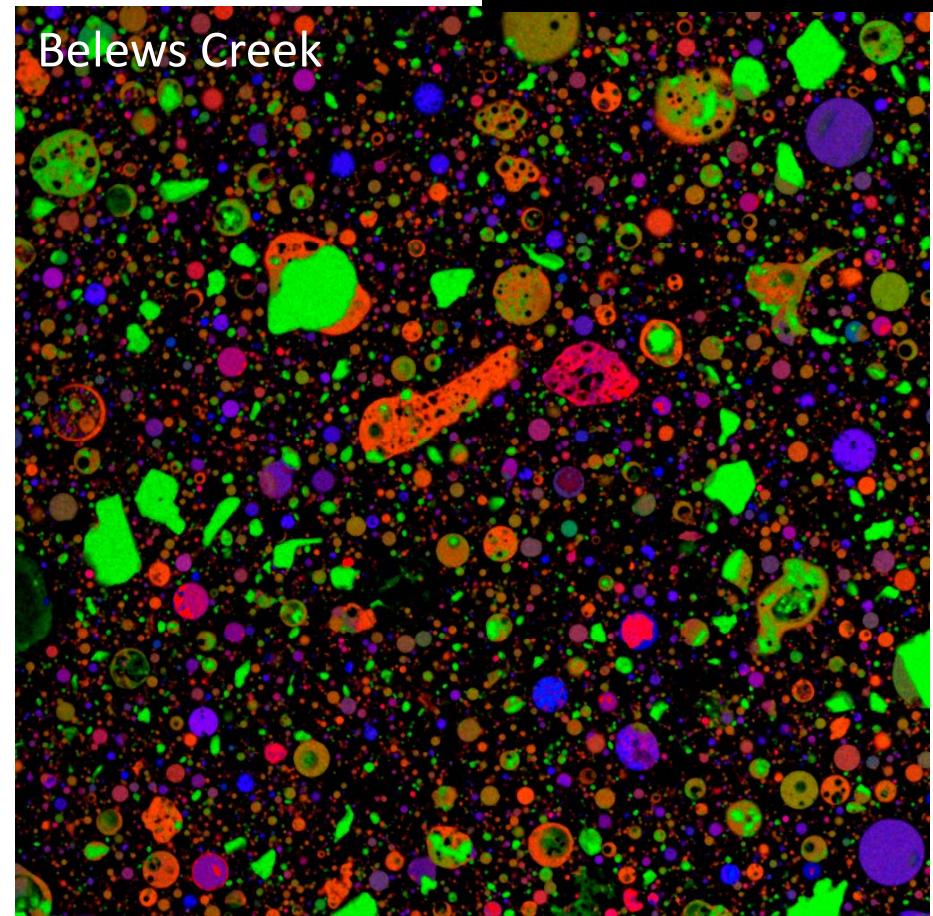
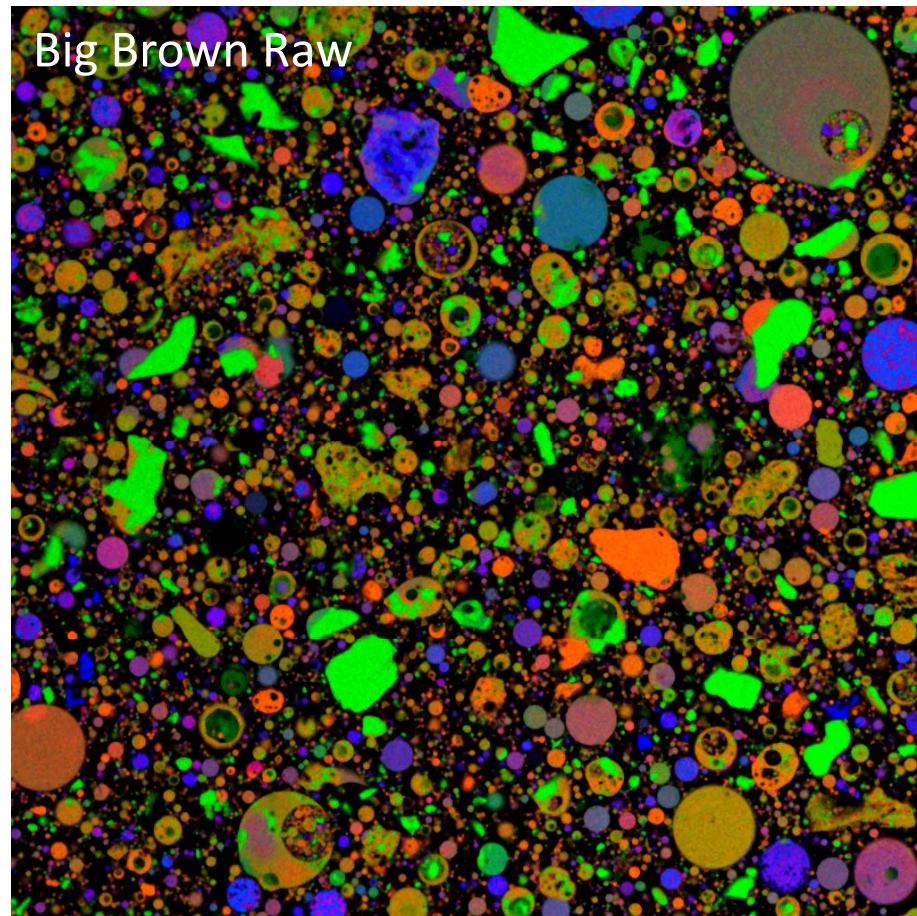


Image Analysis- Color

- Cool tones mean more signal
- Warmer tones mean more aluminosilicate



What do we see?



What do we see?

- Ca in small particles

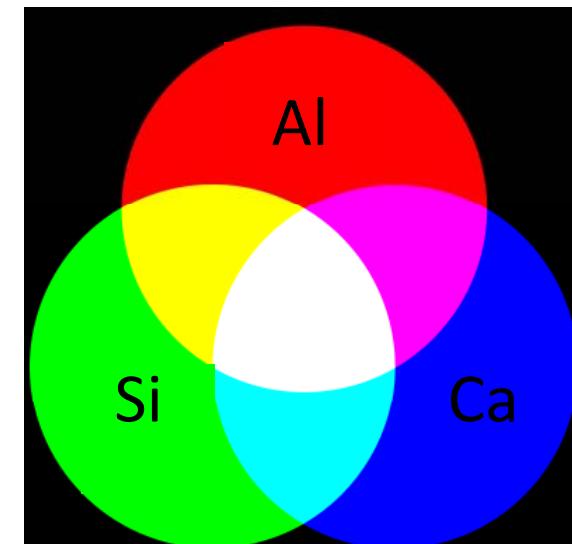
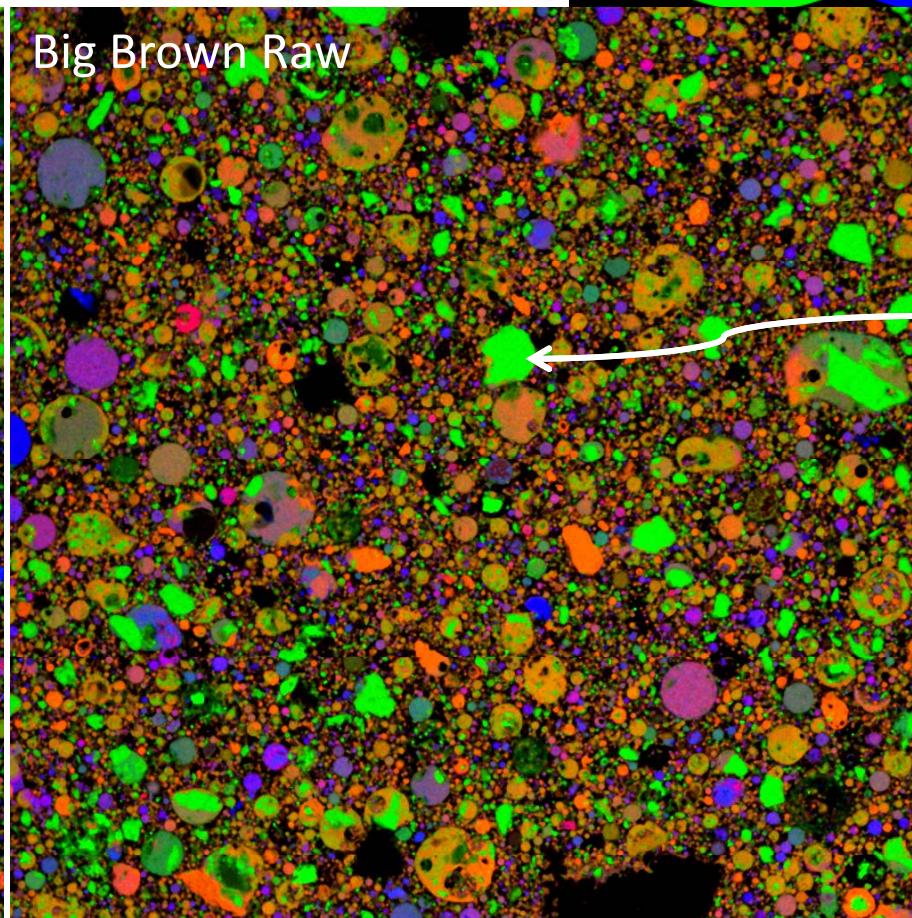
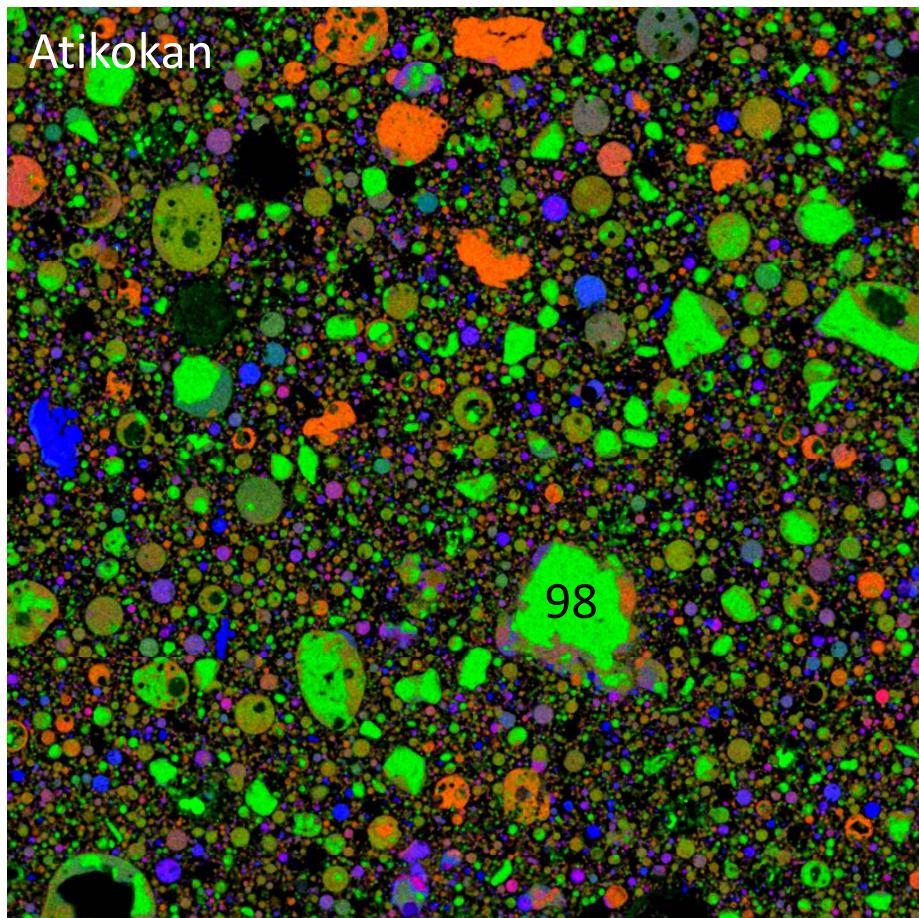
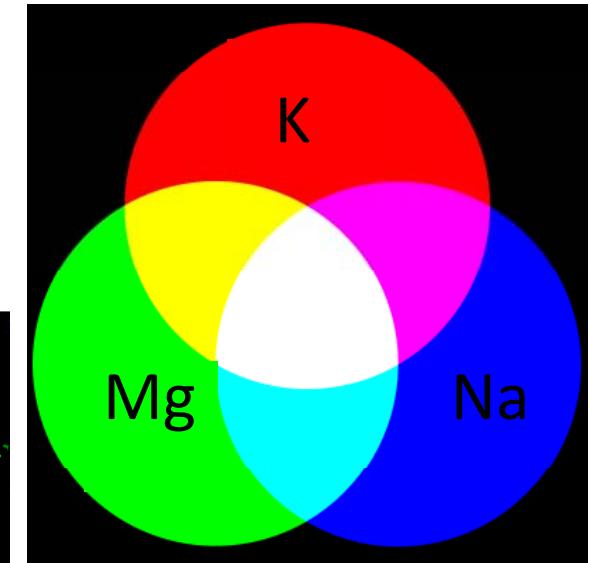
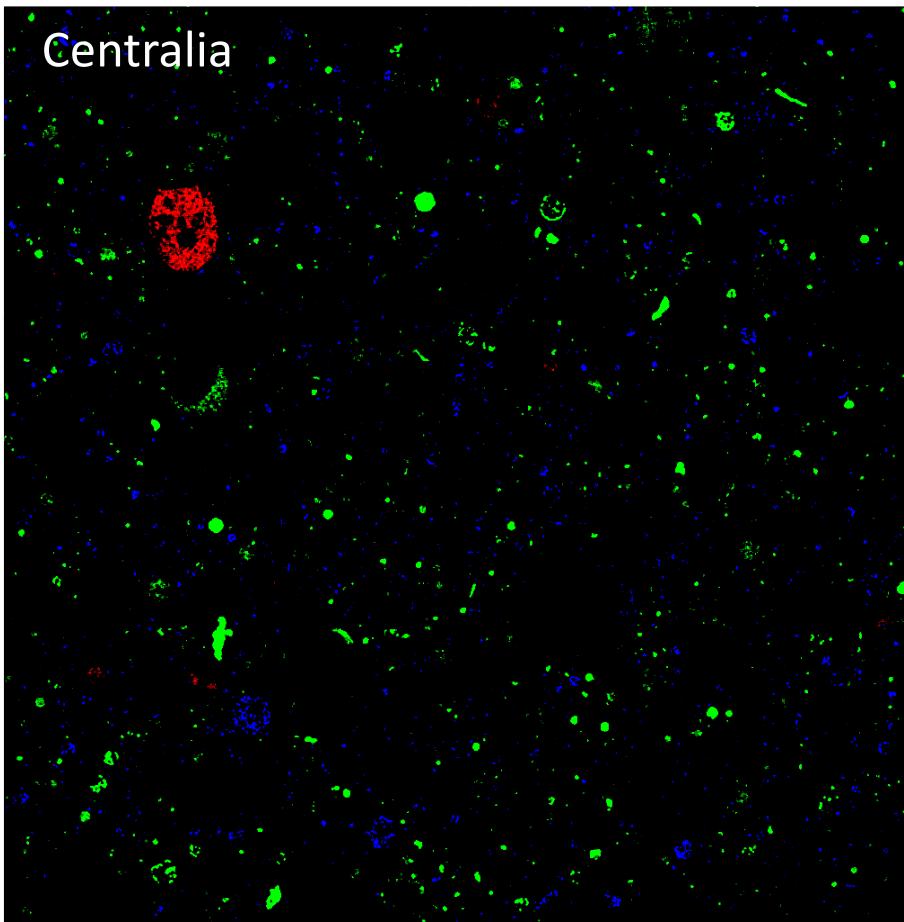
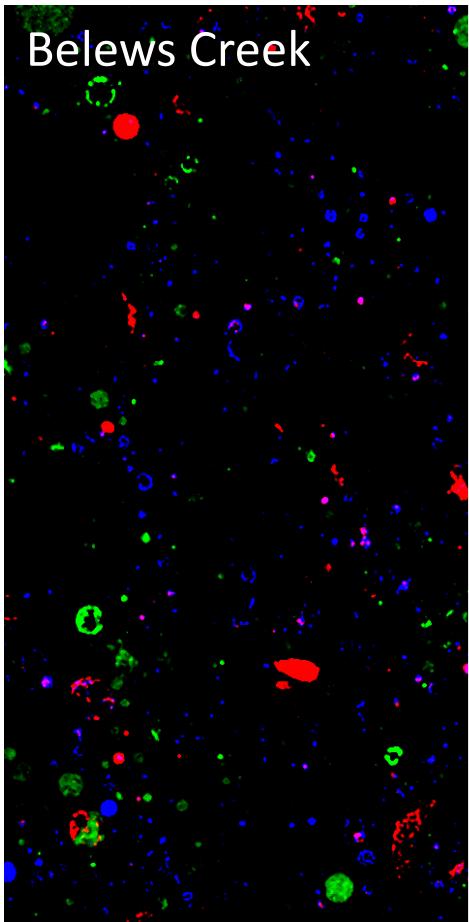


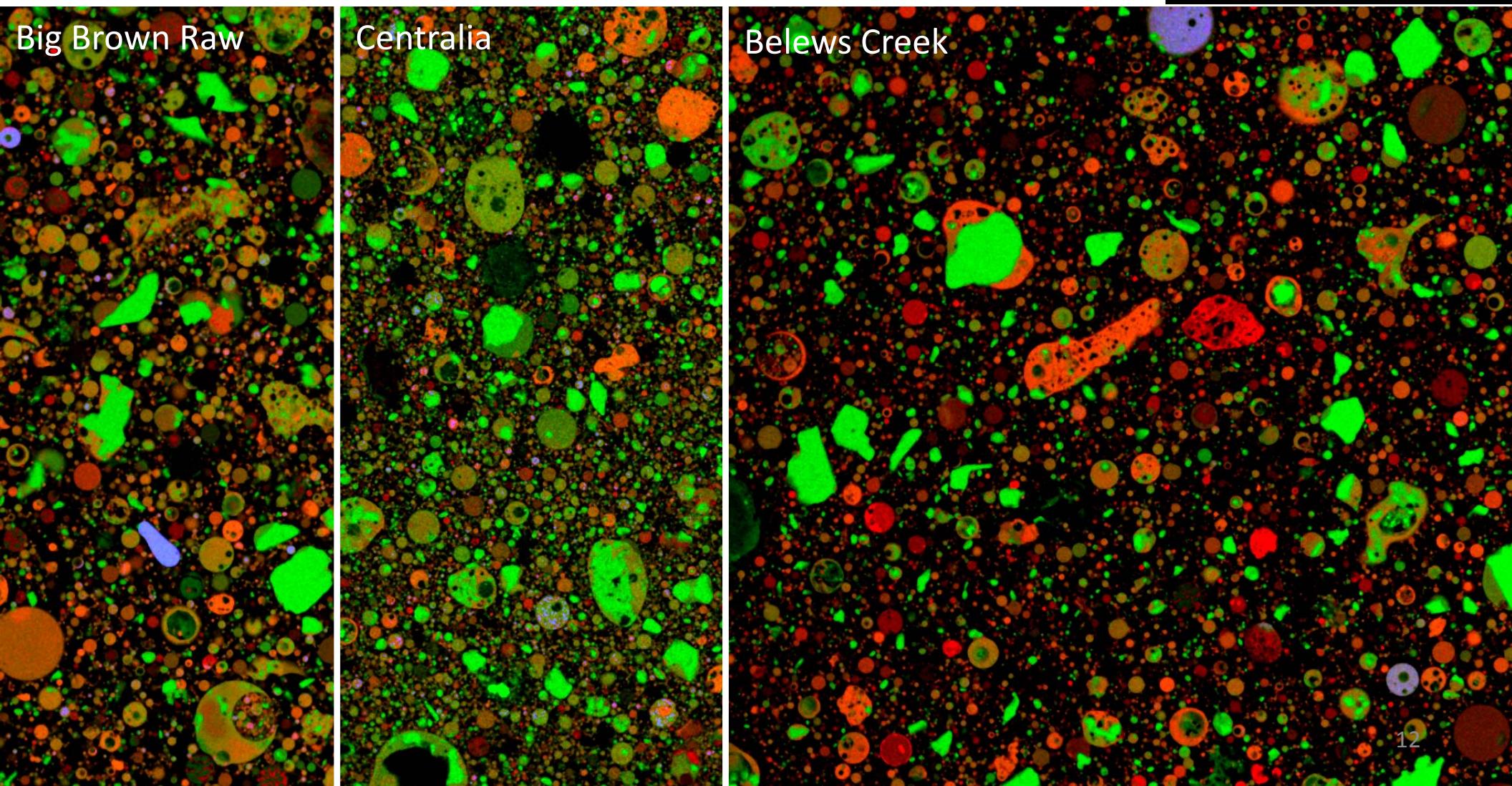
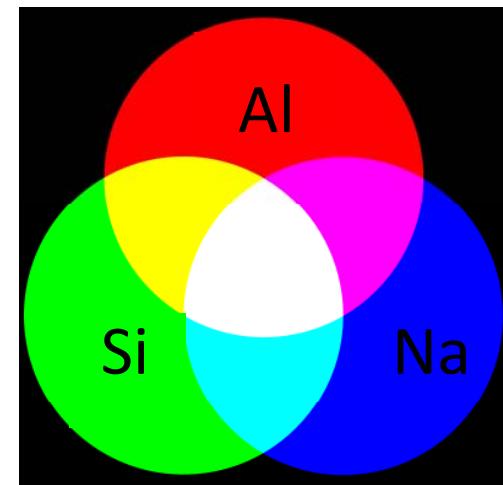
Image analysis- phase dispersion

- The elements present in small amounts are interesting



What do we see?

- Na widespread in stronger materials



Ongoing work

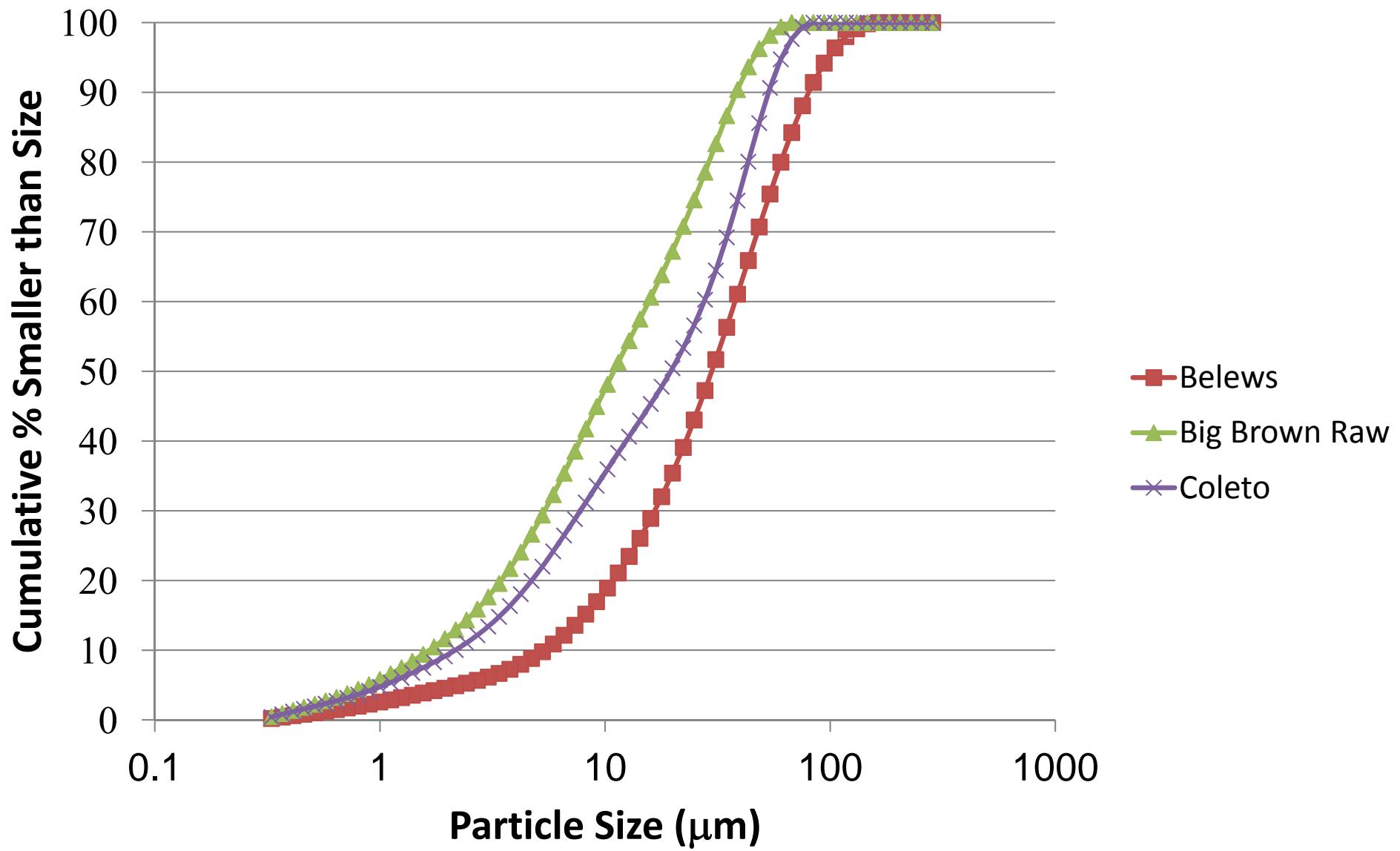
- Quantify the observations
- Dissolution study
 - Expose fly ash to caustic solutions for up to 28 days for re-examination by XRD and SEM-MSIA
- Additional activating solutions
 - NaOH + waterglass
 - KOH
 - NaOH + Ca (lime)

Questions?

Acknowledgements

- NSF grant CMMI 0926627
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- Leslie Hollis and Rachel Cano, undergraduate researchers extraordinaire

Laser PSD



Characterize fly ash: XRD

