Hydrothermal alteration of ultrapotassic syenite as affordable option to potash supplies in the tropics

syenite

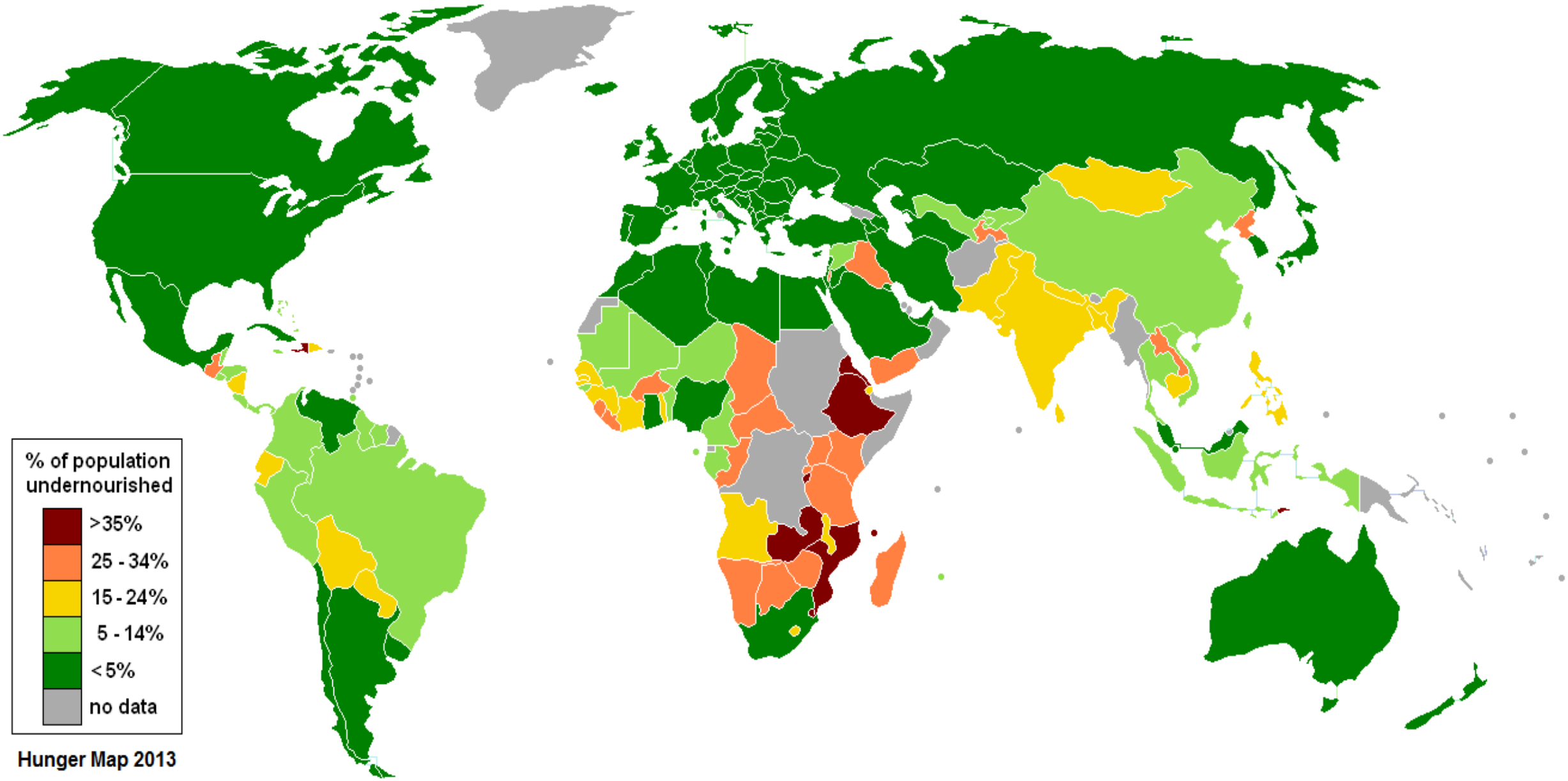
altered syenite

fertilizer effect

Davide Ciceri, Marcelo de Oliveira, Antoine Allanore

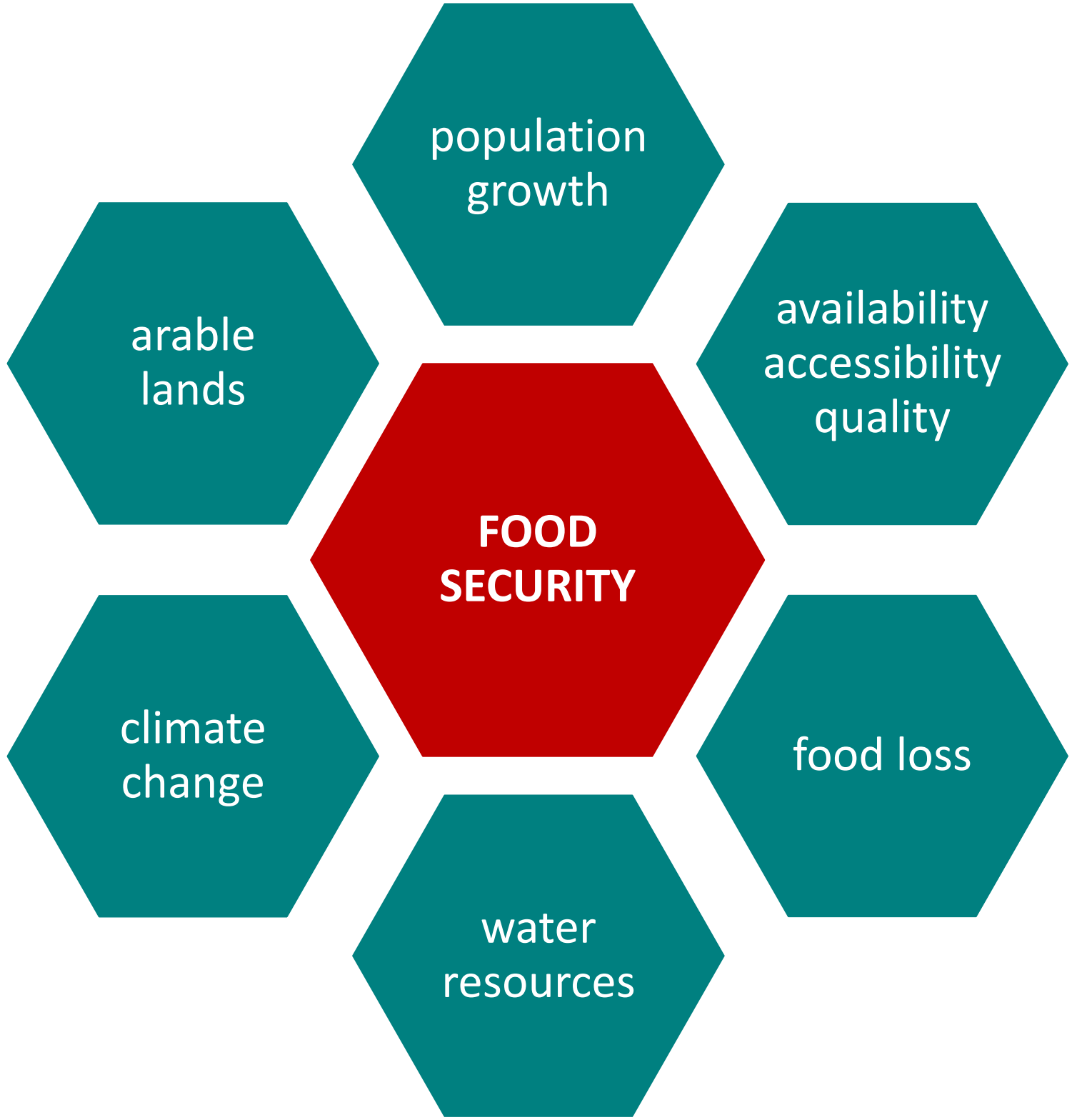
2nd International Workshop on Alternative Potash – 15th June 2017, London

FOOD SECURITY



795 million people are undernourished

FOOD SECURITY



Premanandh 2011

FOOD SECURITY

YIELDS
COST
NUTRITION

FERTILIZERS

N-FERTILIZERS

30-40 GJ t^{-1}_{NH3}

Steel: 15 GJ

P-FERTILIZERS

1-4 GJ t^{-1}_{P2O5}

Glass: 35 GJ

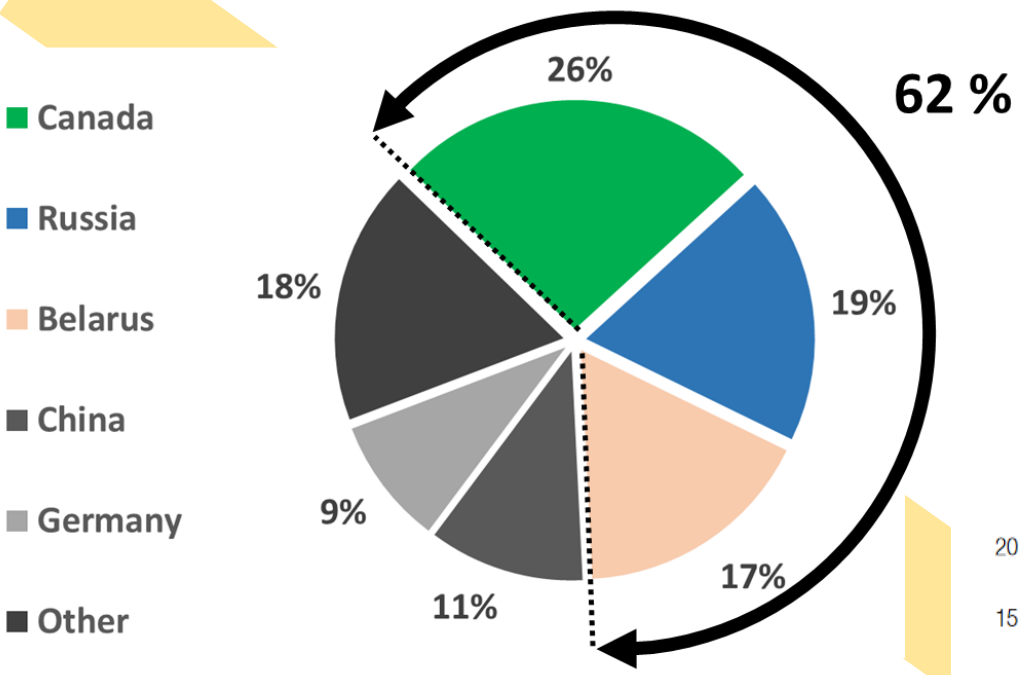
K-FERTILIZERS

1-4 GJ t^{-1}_{K2O}

Wood: 7 GJ

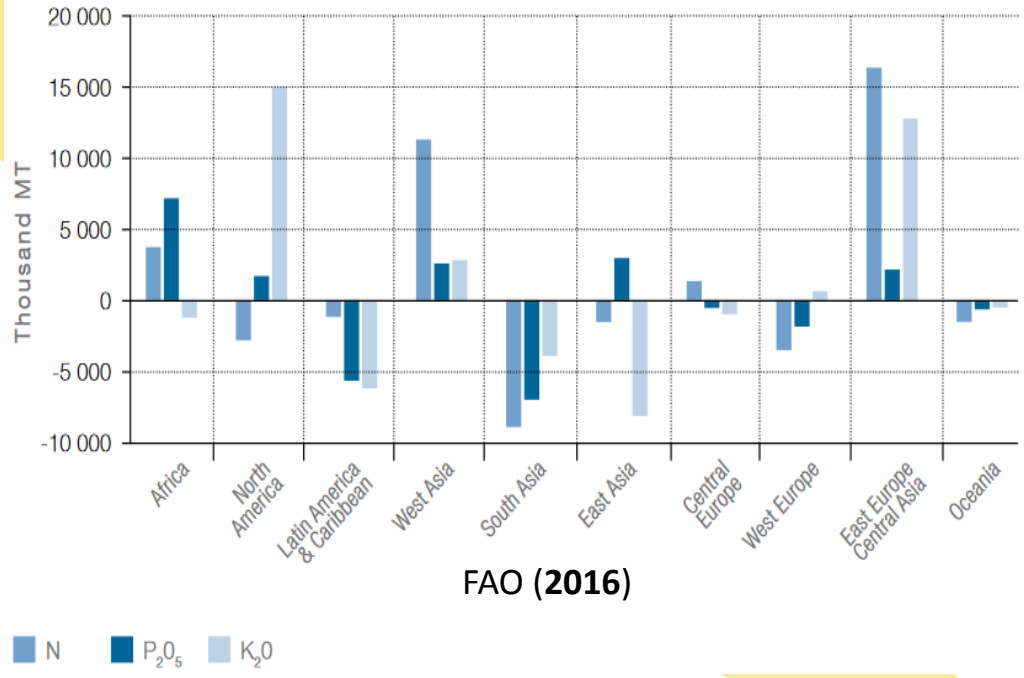
POTASH

PRODUCTION



Skorina and Allanore (**2015**)

CONSUMPTION



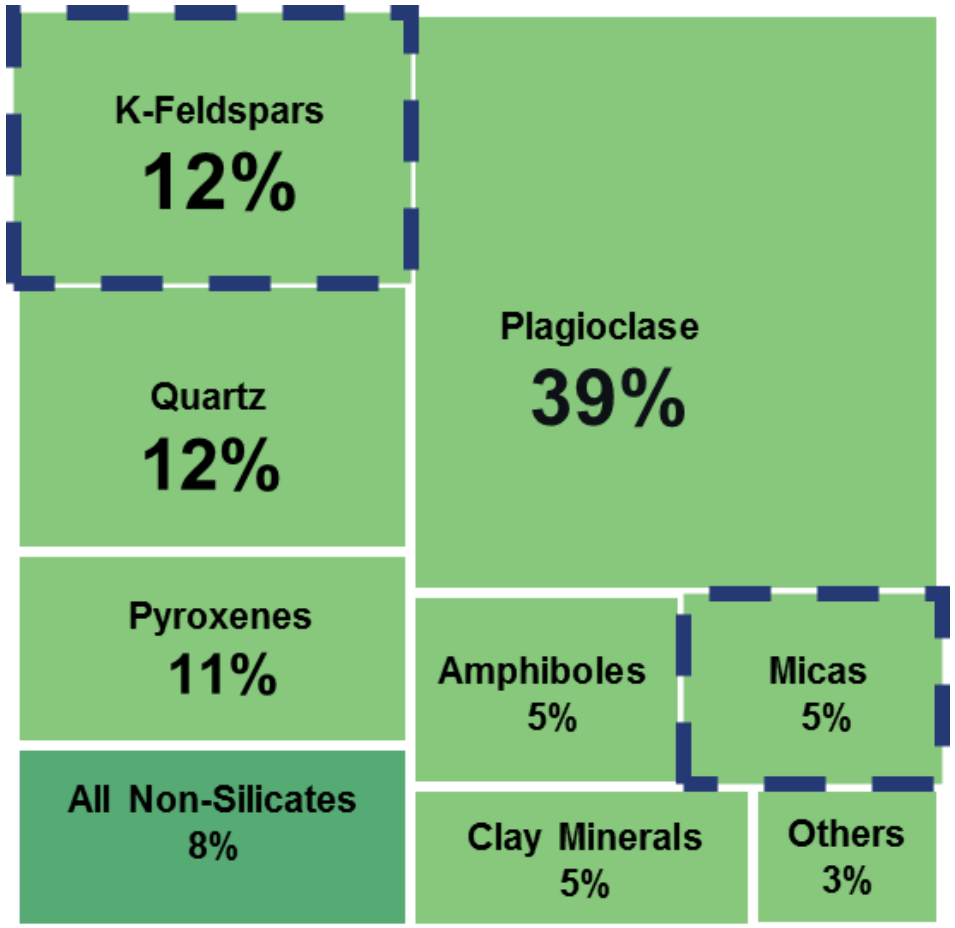
FAO (**2016**)

ALTERNATIVE FORMS OF POTASH?

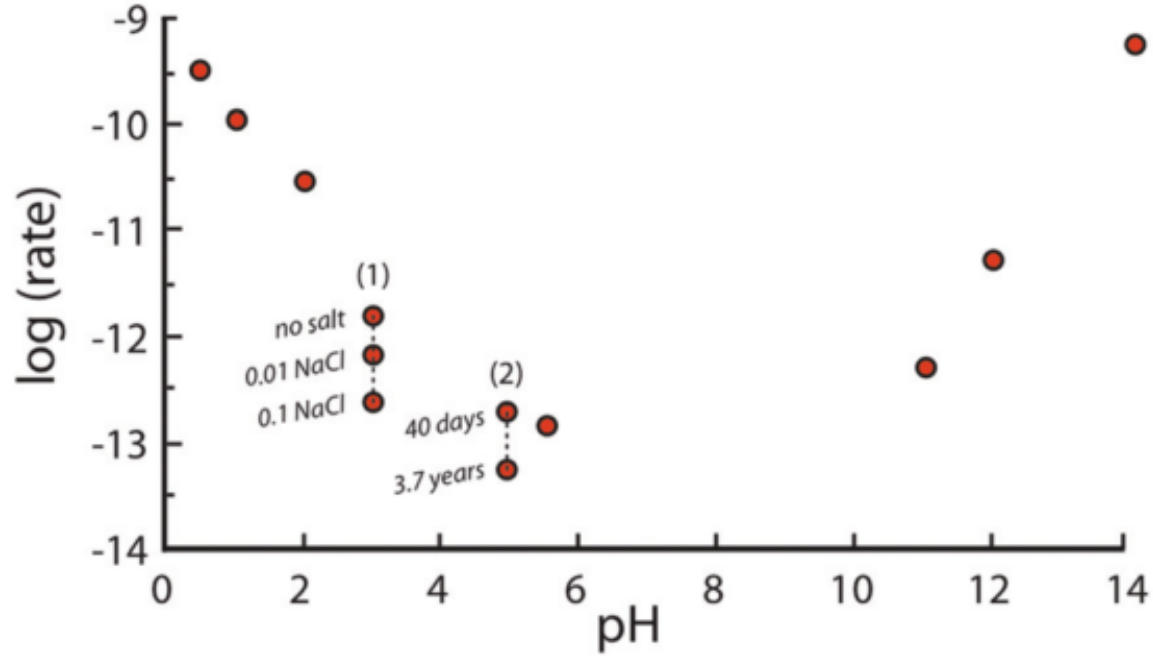
SOIL

Brazilian oxysoil

ALTERNATIVE POTASH SOURCES



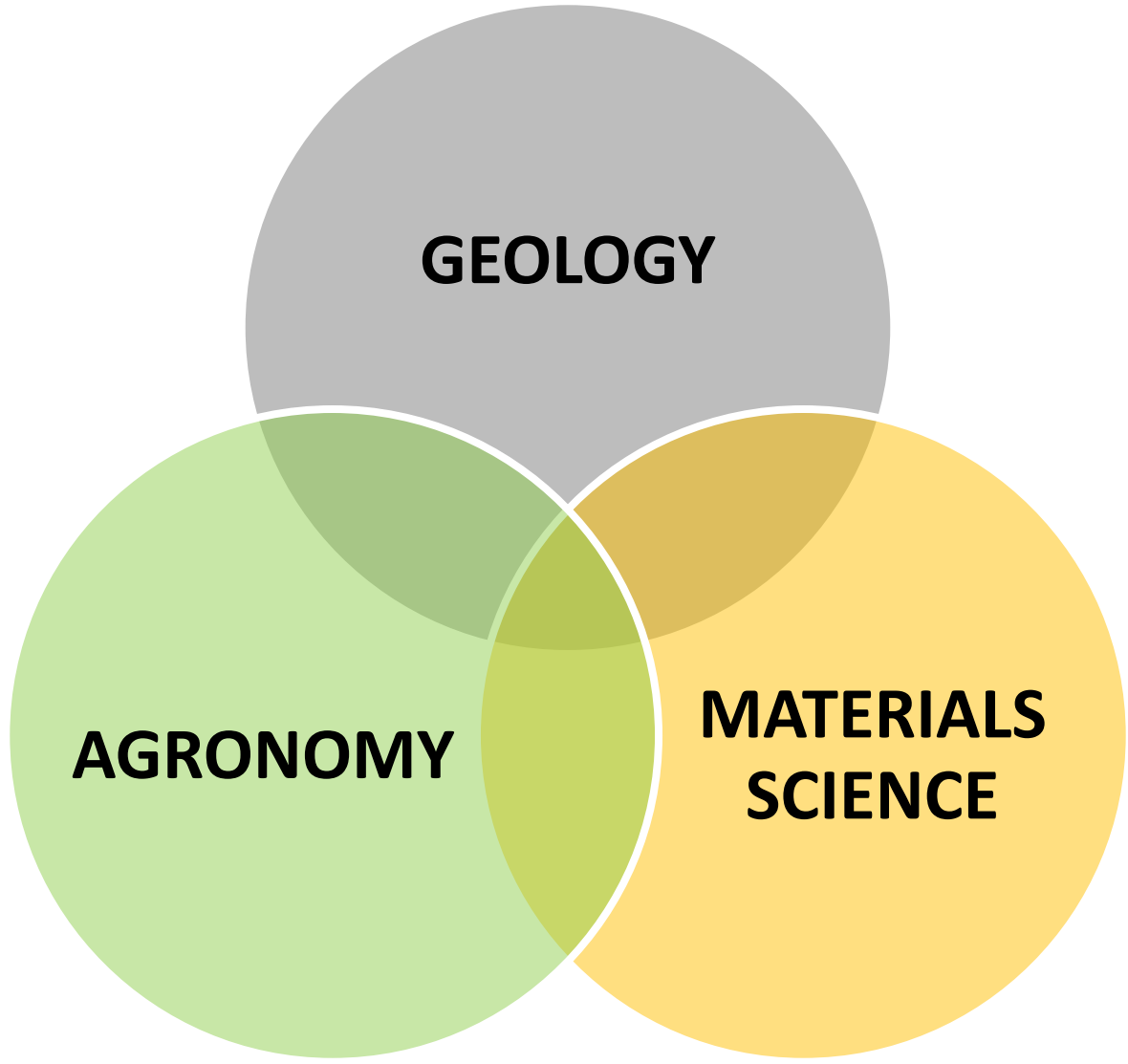
Mason & Moore, Yaroslavsky, Poddervaart



- <u>Abundant</u>
- <u>Available</u> (world-wide distribution; quarry)
- <u>Relatively high grade</u> (~15 wt % K_2O)

In low-temperature, non-aggressive aqueous solutions, 1 mm crystal of K-feldspar dissolves in 520,000 years.

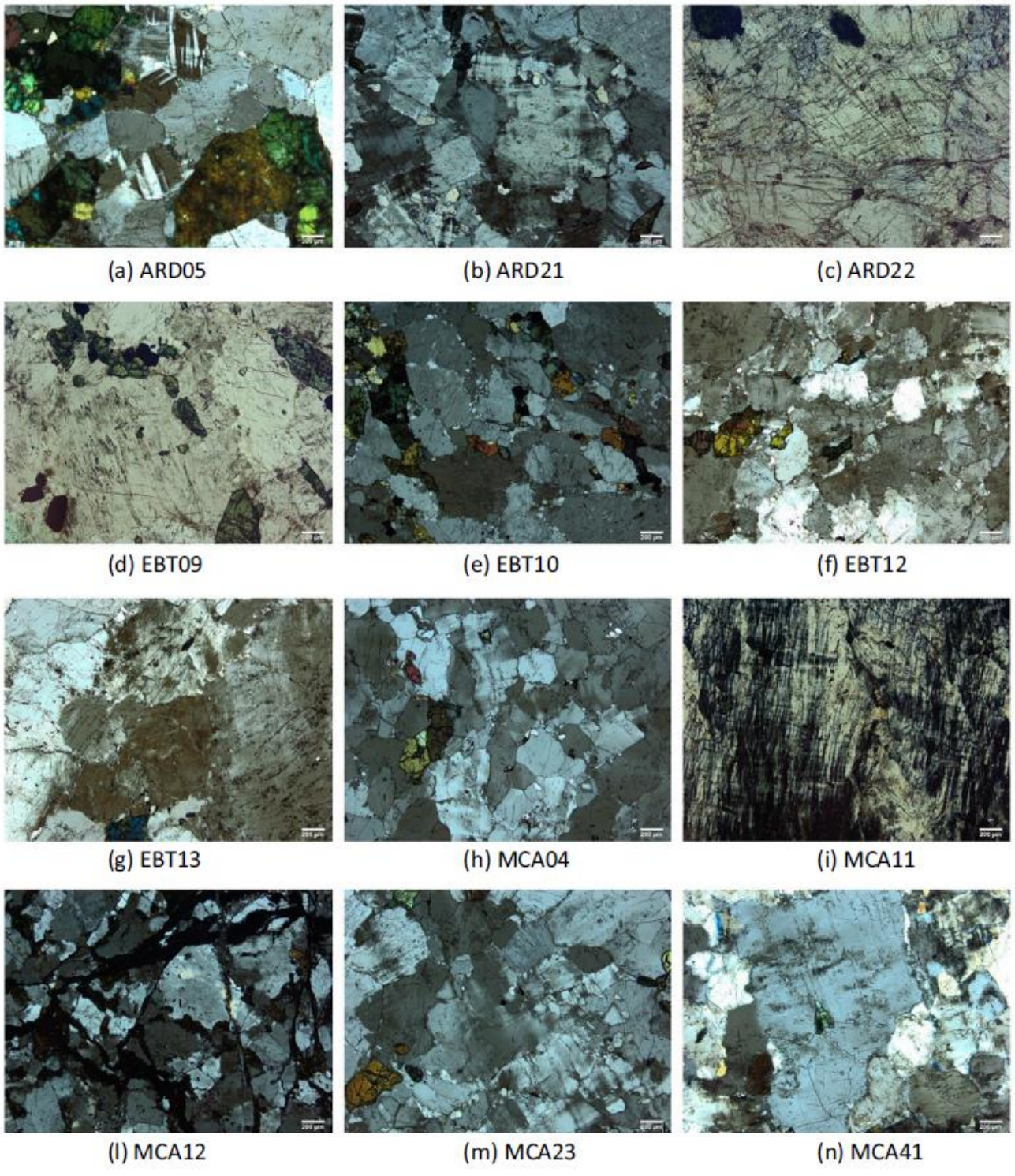
AdvancedPotashTechnologies



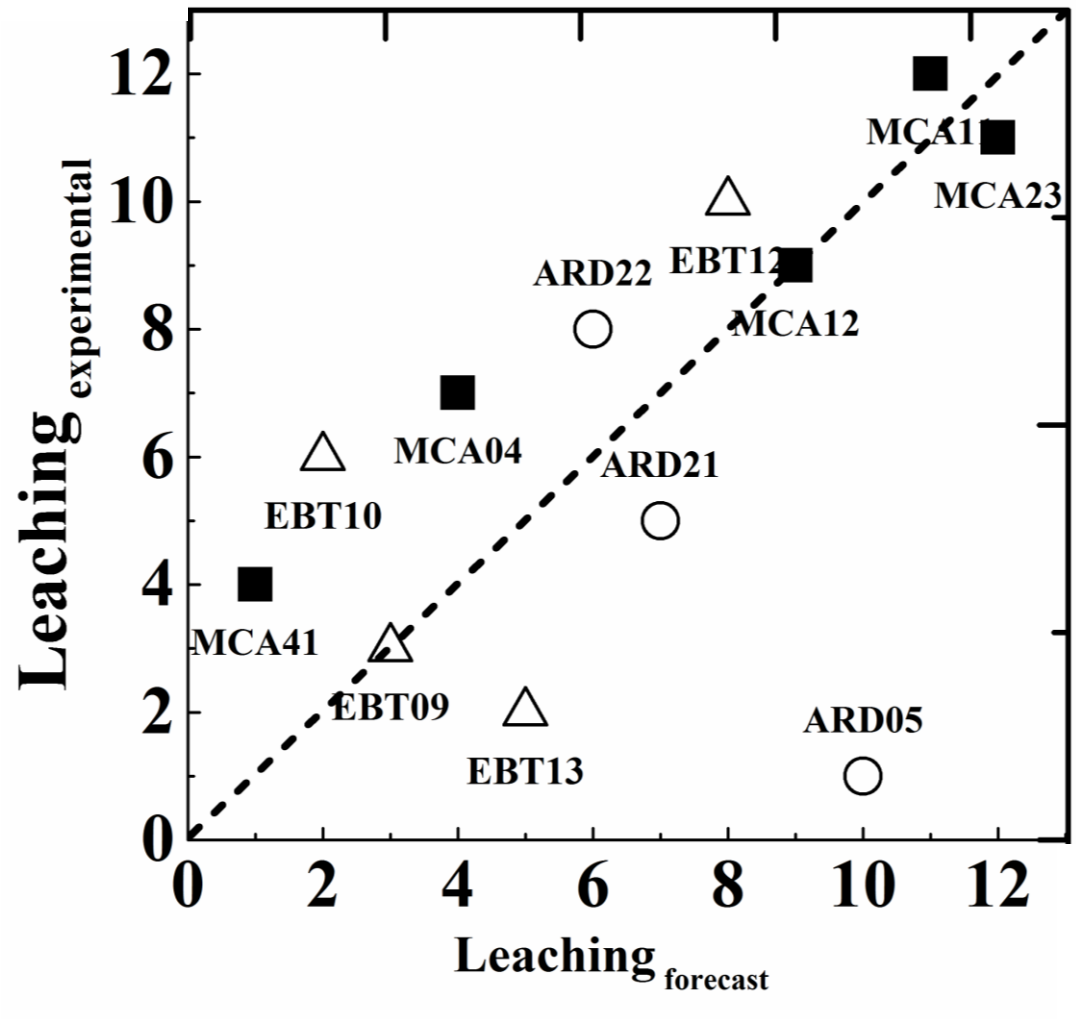
Embrapa

MIT

FELDSPAR CHARACTERIZATION

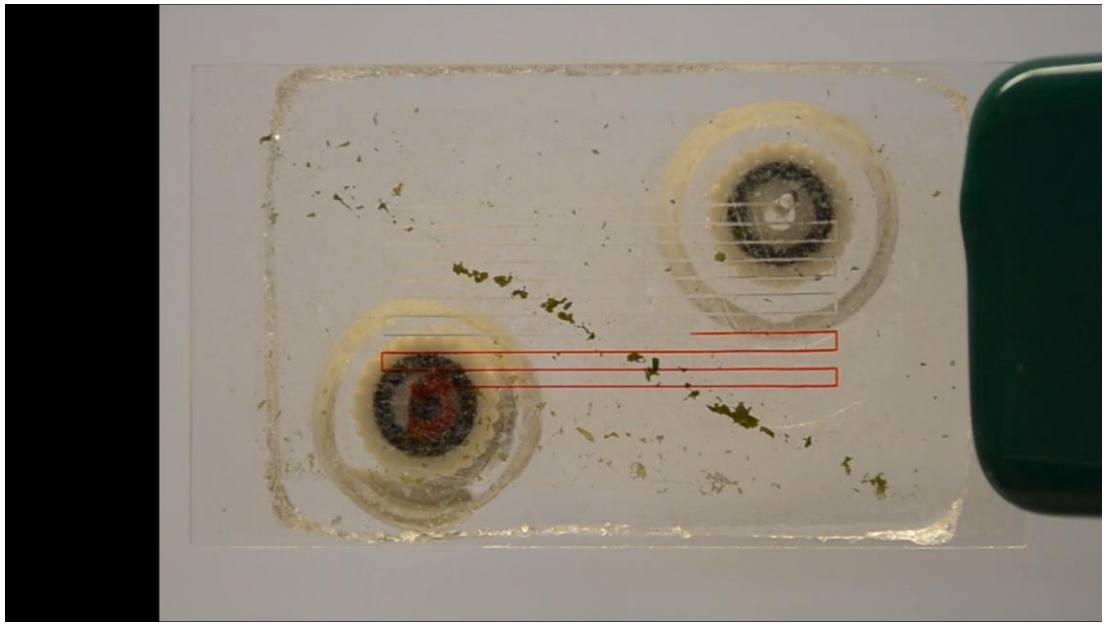


- XRD (mineralogy)
- XRF (elemental content)
- Surface Area
- Particle Size Distribution
- Leaching



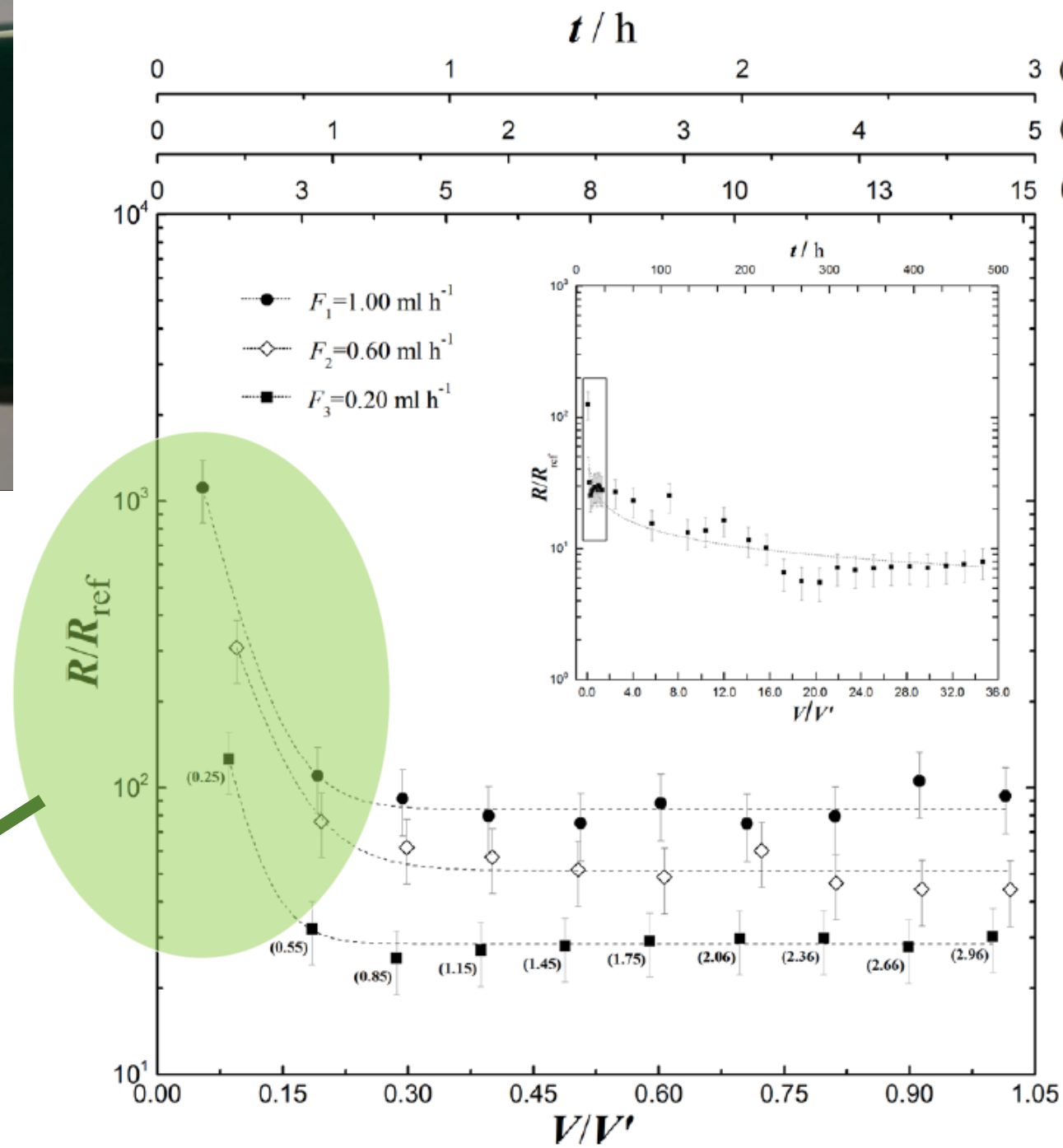
Ciceri *et al.* (**2017**)

FELDSPAR CHARACTERIZATION



Ciceri *et al.* (**2015**)

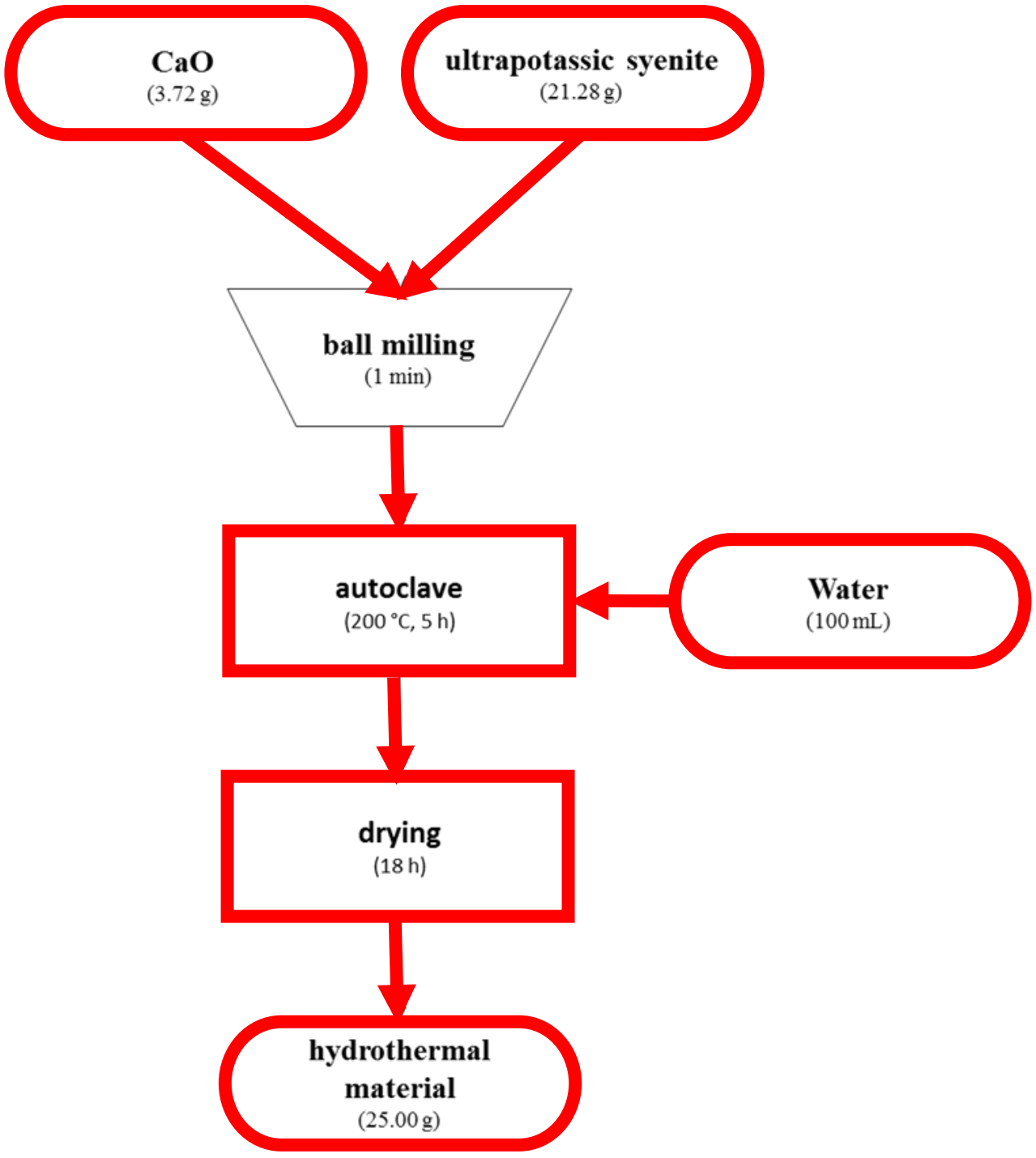
Rate of K-feldspar dissolution is up to 1000 times faster than in a standard flow through system

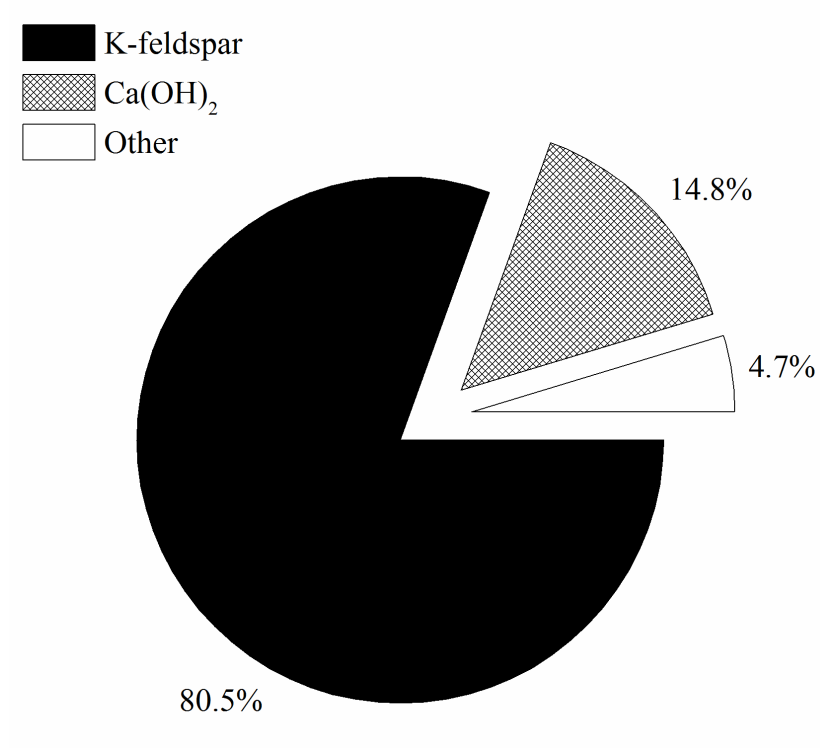


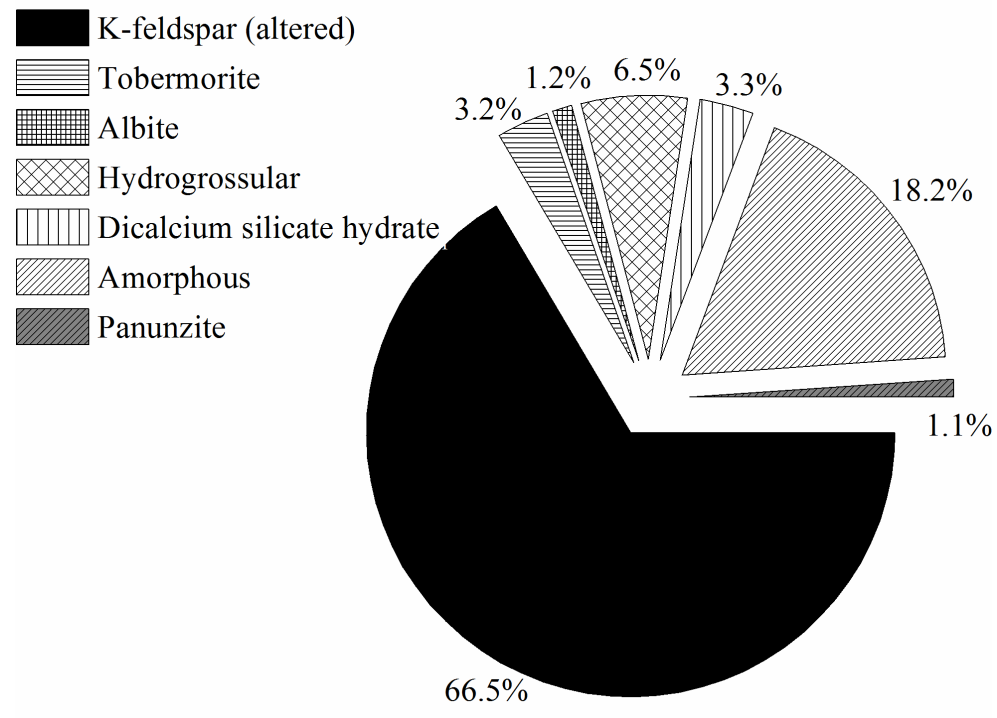
MATERIALS SCIENCE

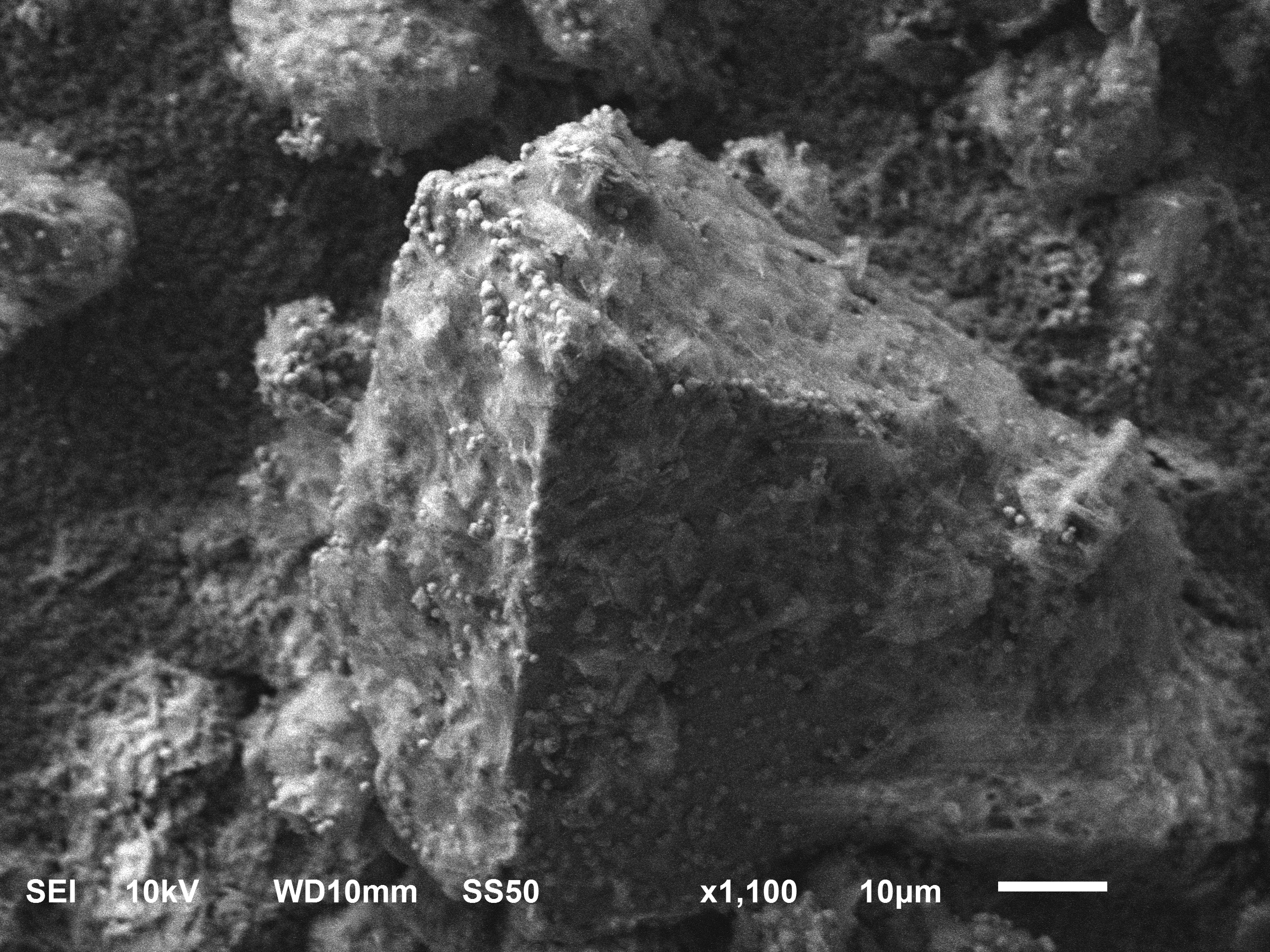
Processing technology	Pros/Cons
comminution and/or mechano-activation of K-feldspar and microorganism-mediated dissolution (bioweathering)	• No K_2O dilution; cheap; no waste • Limited experimental evidence; need of strict experimental protocols.
calcination in presence of fluxes/additives	• K_2O concentration • *T*; waste; type of flux?; limited experimental data
alkaline hydrothermal alteration	• Mild processing conditions; no waste • K_2O dilution; water
• other resources (manure, seawater, algae, ashes, sugar beets liquors, etc.) • K_2O content; abundance; limited know-how; scale up	

HYDROTHERMAL PROCESSING

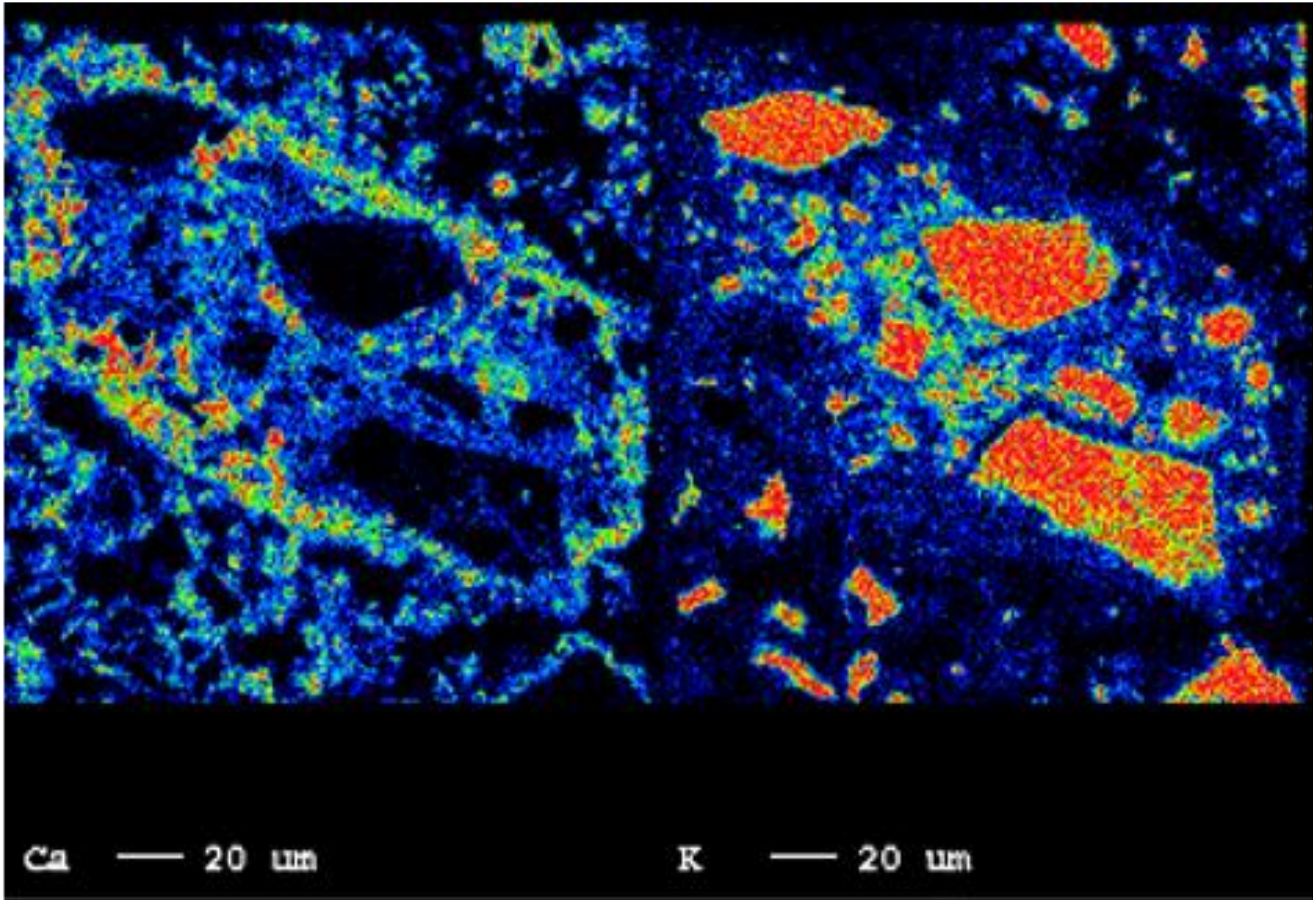




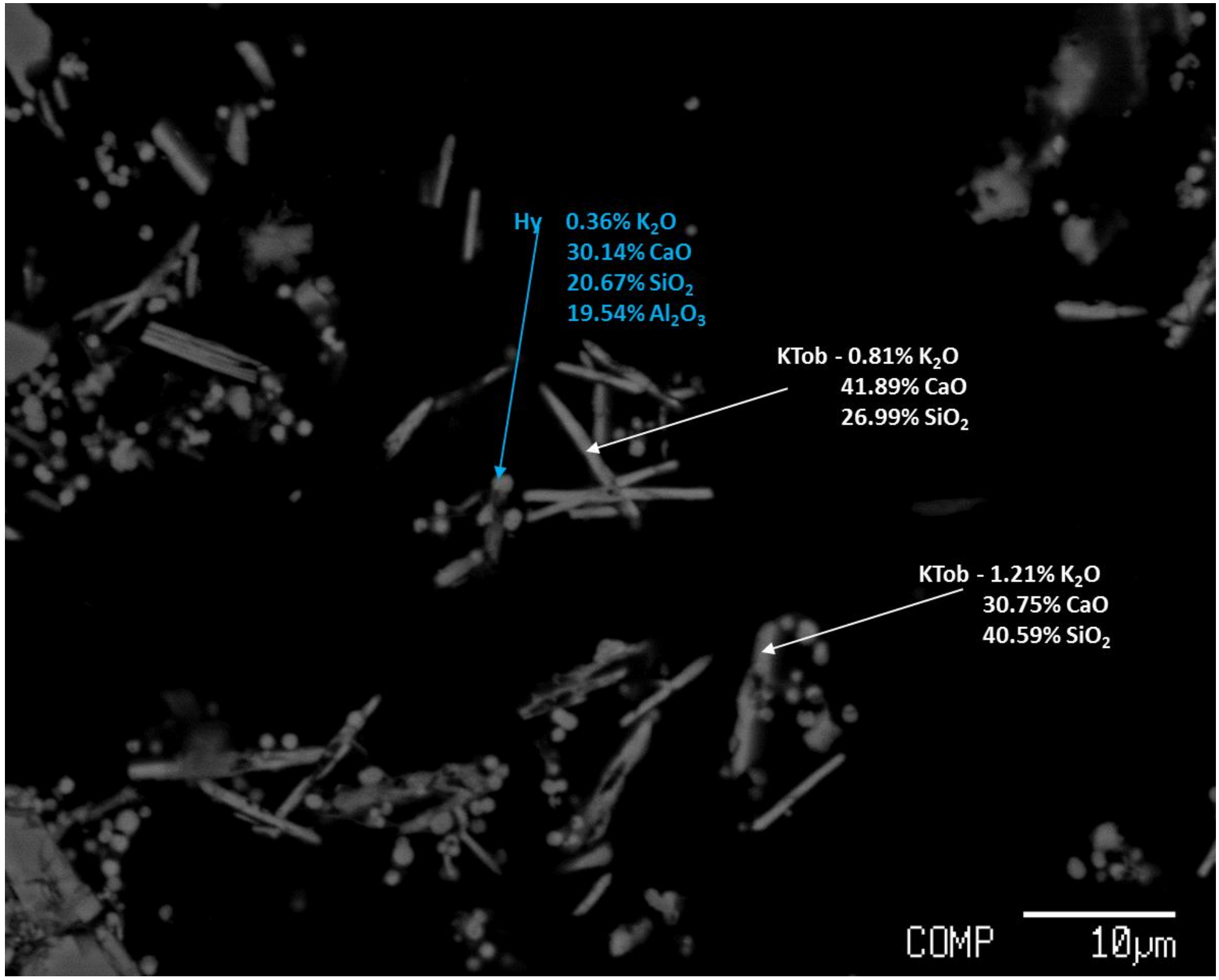



SEI 10kV WD10mm SS50 x1,100 10µm

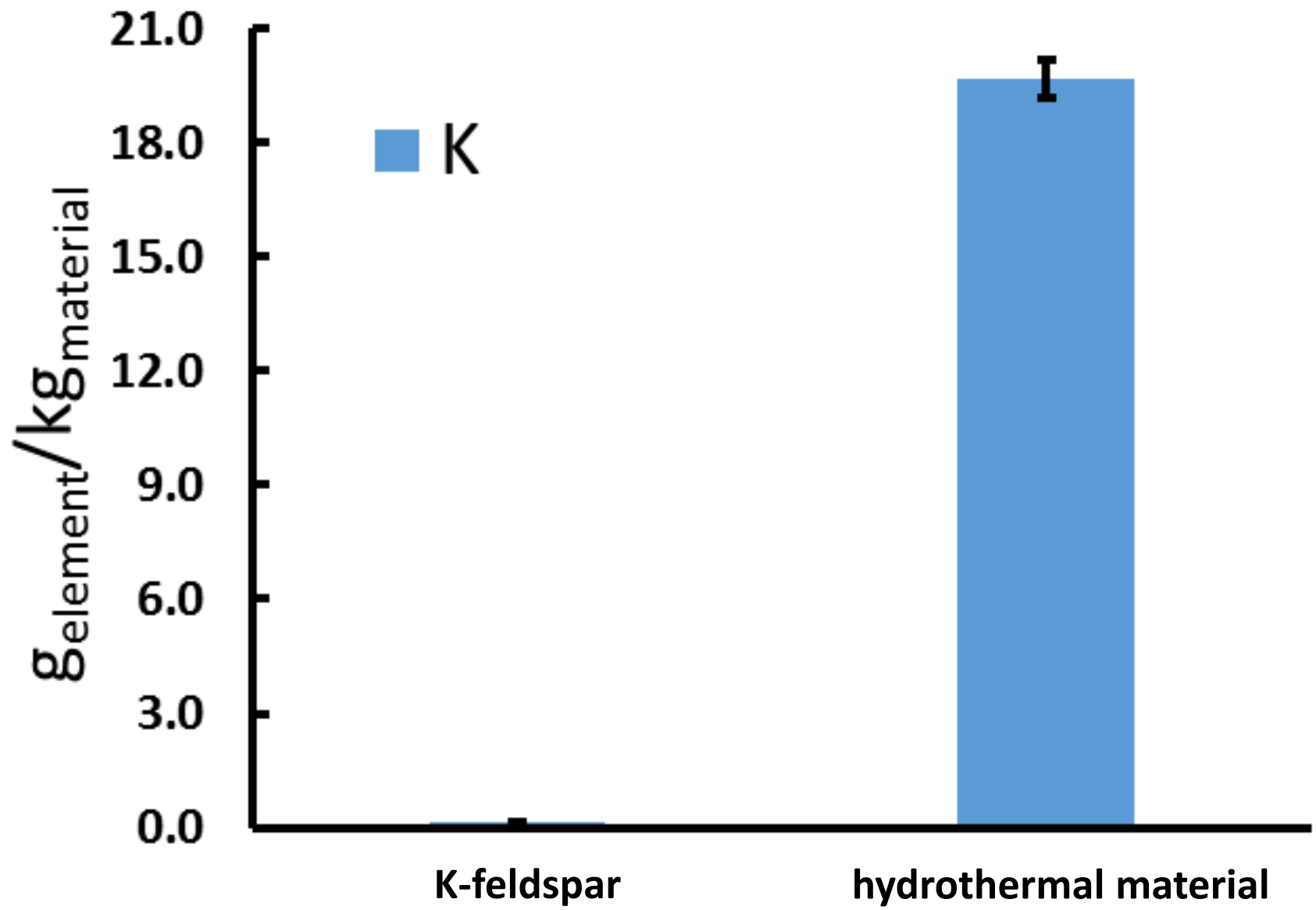
HYDROTHERMAL PROCESSING



MINERALOGICAL COMPOSITION



ELEMENTAL RELEASE



CONCLUSION

- **Importance of fertilizers for global food security (potash)**

- **Long-term research effort, from mine to processed product**
  - ➢ characterization of K-feldspar sources (Ciceri *et al.* 2017)
  - ➢ processing technologies (Ciceri *et al.* 2015)
  - ➢ characterization of processed material (Ciceri *et al. in prep.*)

- **Hydrothermally altered K-feldspar as a promising alternative source of potash: mineralogy and potassium release ≈ 20 g_K/kg_{HS} at pH=5 (24h)**

- **Preliminary economic considerations**

- **Example of succesful partnership between industry and academia**

ACKNOWLEDGEMENTS

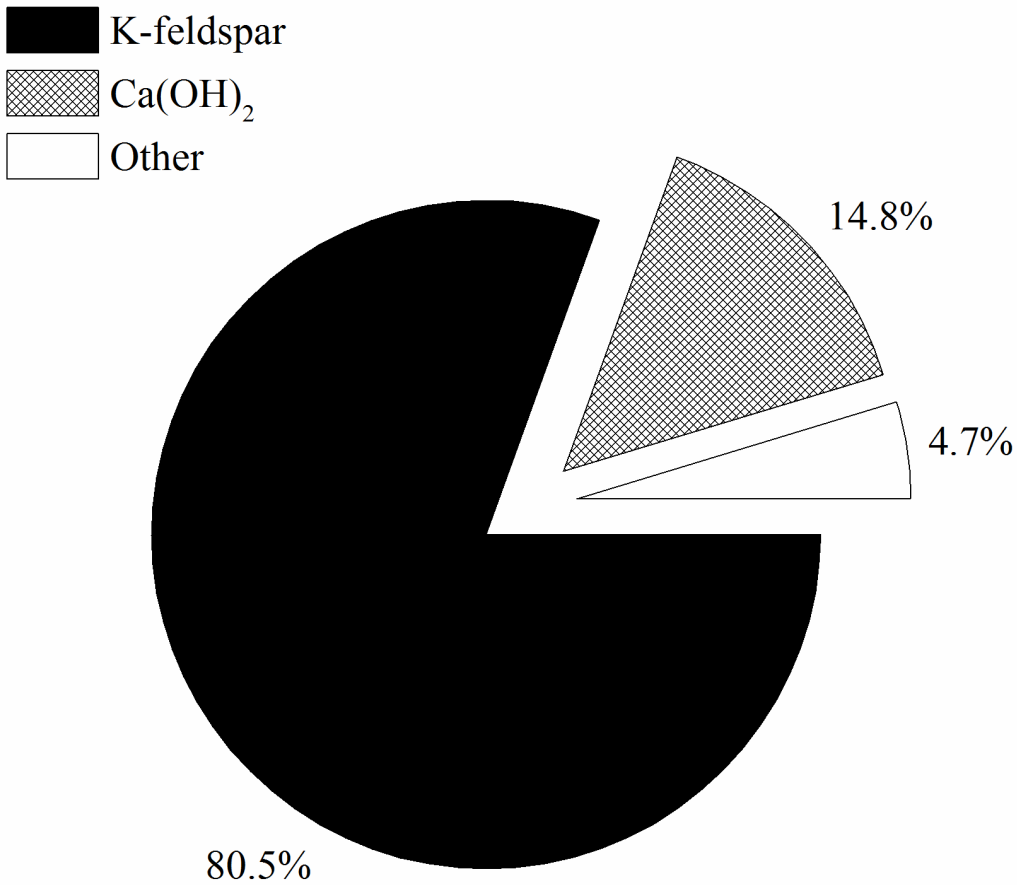
MIT team: Prof. Allanore, Dr. de Oliveira, Dr. Gadois, Dr. Skorina, Dr. Stokes, Dr. Sabatini, Ms. Berger, Mr. Grimonprez, Ms. Dolittle, Ms. McDunn, Mr. Sumitro, Mr. Blanchard, Mr. Martin, Ms. Kestin, Ms. Gutierrez, Mr. Sankararaman, Mr. Williams, Ms. Postak, Ms. Sypnievski, Mr. Kitcher., Mr. Martins, Mr. Buscemi, Mr. Zaharil

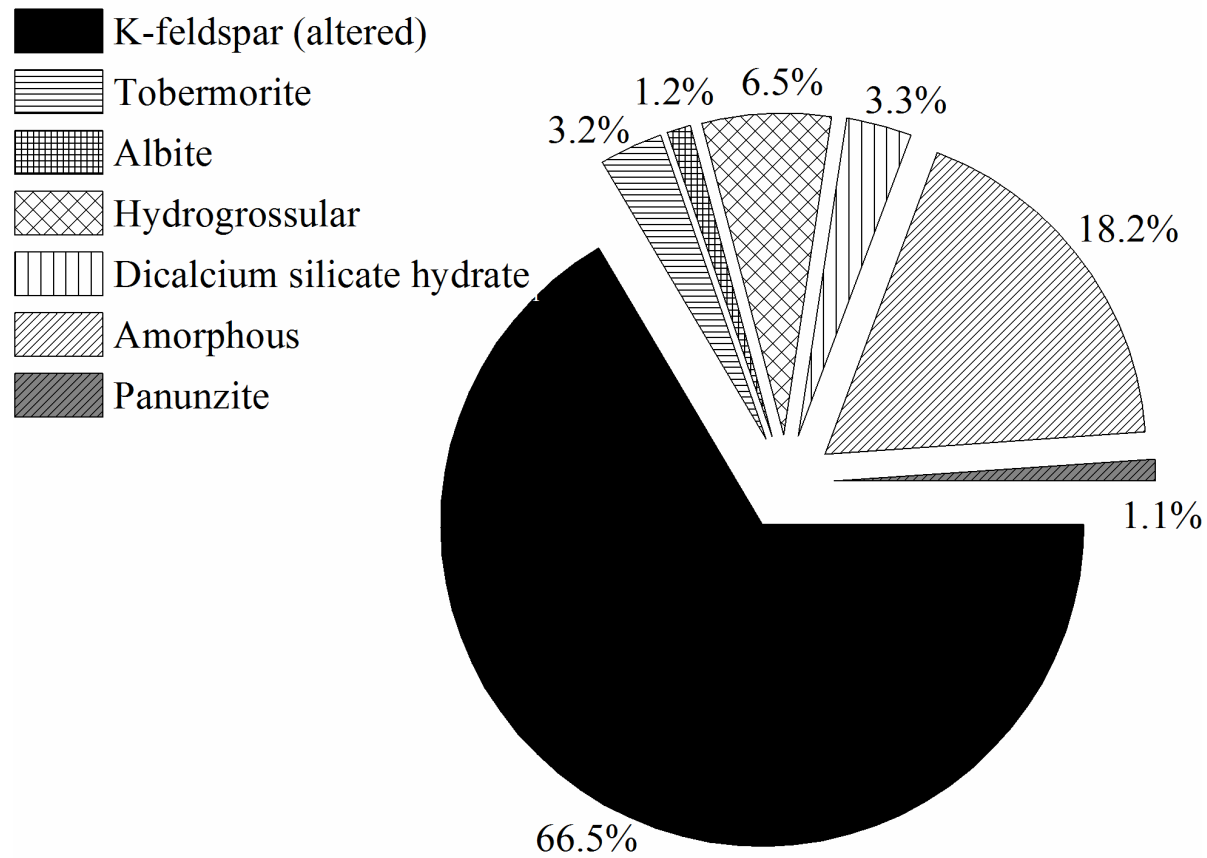
H&M Analytical Services, Inc.: Dr. Steve Miller

AdvancedPotashTechnologies

EXTRA SLIDES

MINERALOGICAL COMPOSITION





K-feldspar:	$KAlSi_3O_8$
Albite:	$NaAlSi_3O_8$
Hydrogrossular:	$Ca_3Al_2(SiO_4)_{3-x}(OH)_{4x}$
Dicalcium silicate hydrate:	$Ca_2(SiO_3OH)(OH)$
Tobermorite:	$Ca_5Si_6O_{16}(OH)_2 \cdot 4H_2O$
Panunzite:	$(K, Na)AlSiO_4$

Conversion of K-feldspar

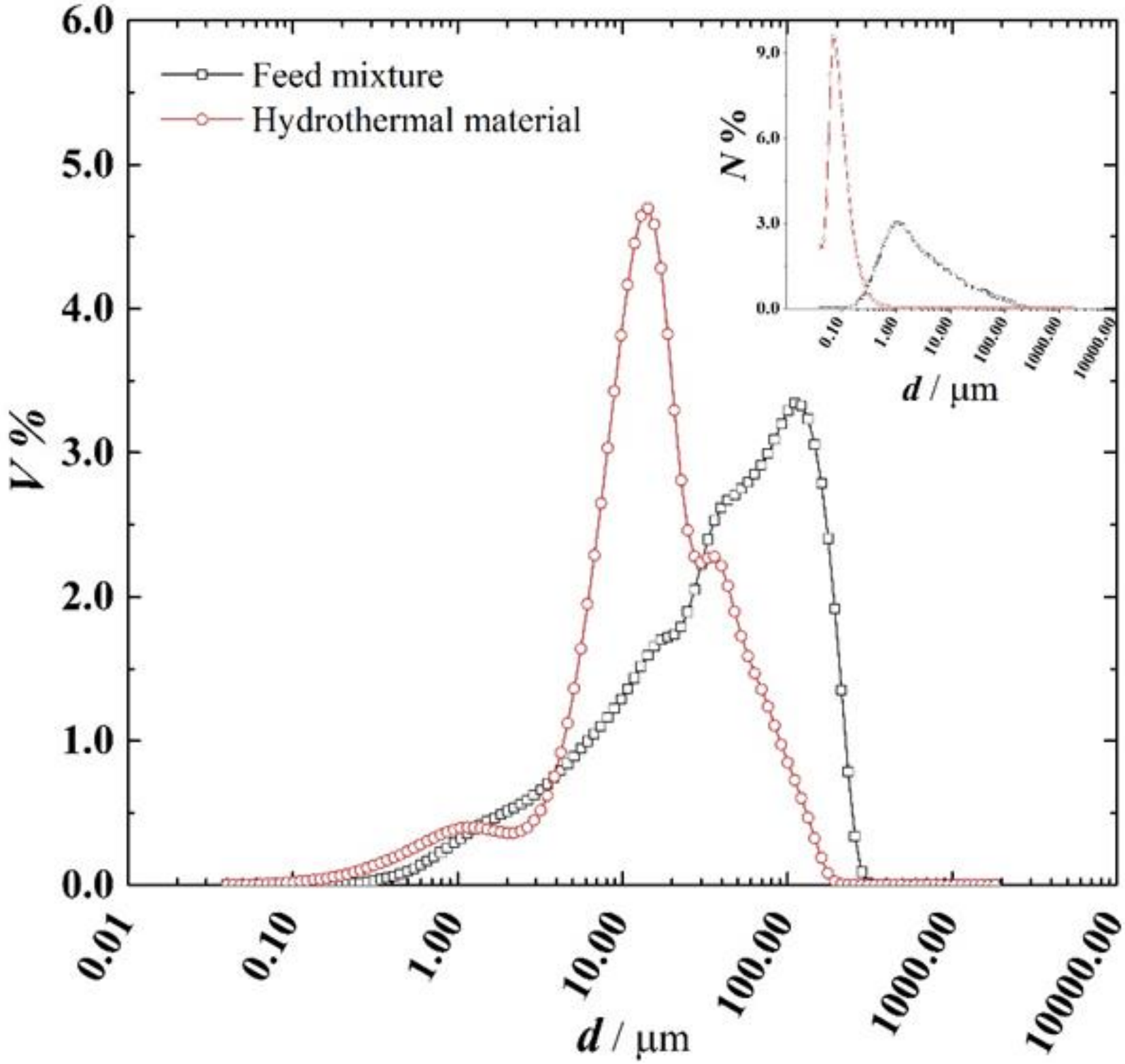
17.4 wt %

- Specific heat water: 4.2 kJ kg^{-1} K^{-1}
- Latent heat of evaporation: 2.3 kJ kg^{-1}

- 1 kg K_2O ←→ 8.6 kg material ←→ 6.5 kg rock

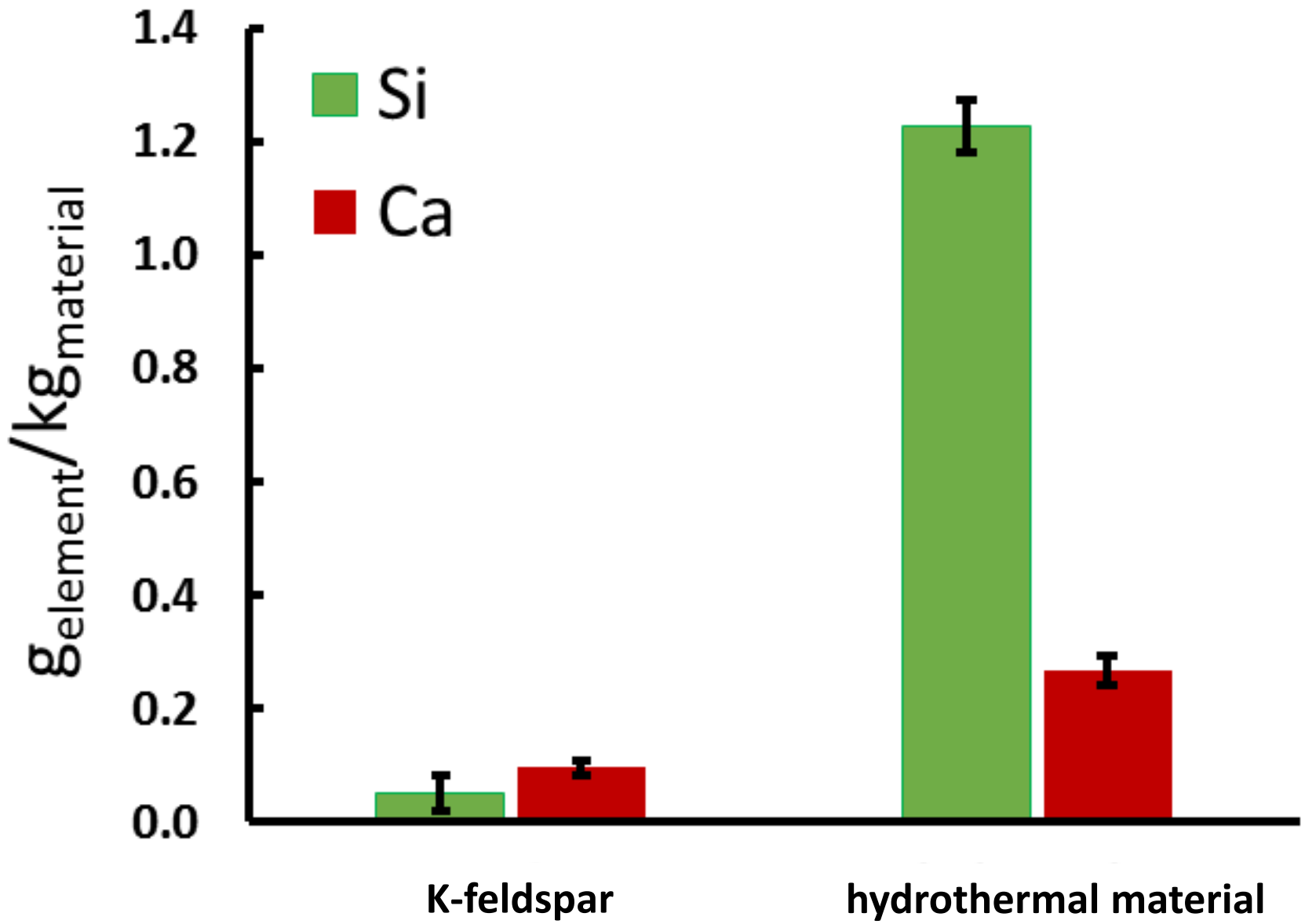
- Latent heat: 77.2 kJ kg^{-1}_{H2O}
- Specific heat: 64.2 kJ kg^{-1}_{H2O}
- Grinding: 258.6 kJ
- Total heat = 0.4 GJ ton_{K2O}

PARTICLE SIZE DISTRIBUTION

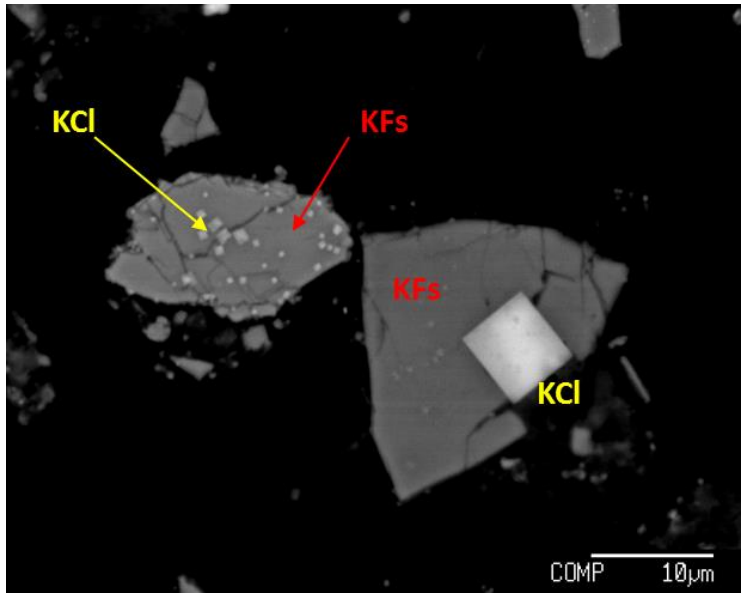


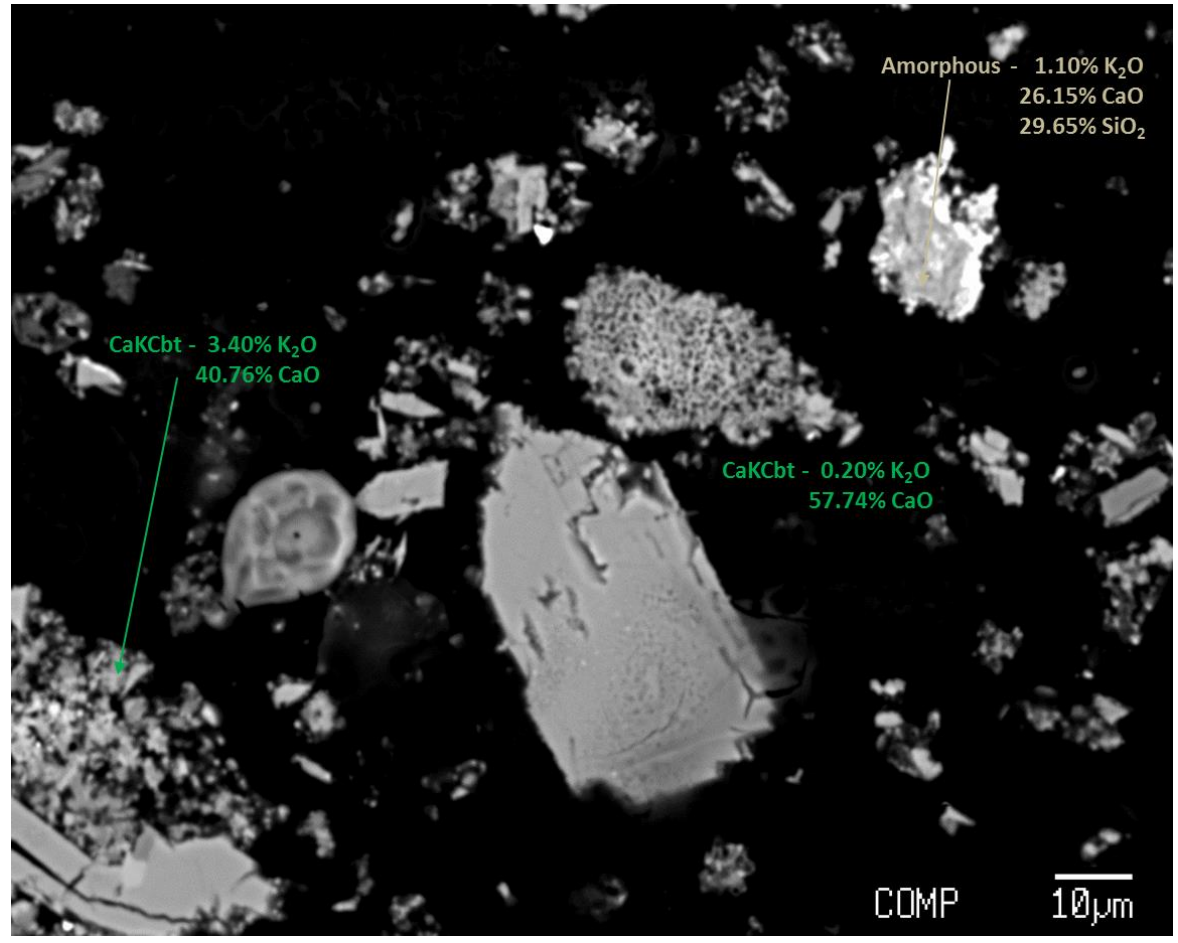
ELEMENTAL RELEASE

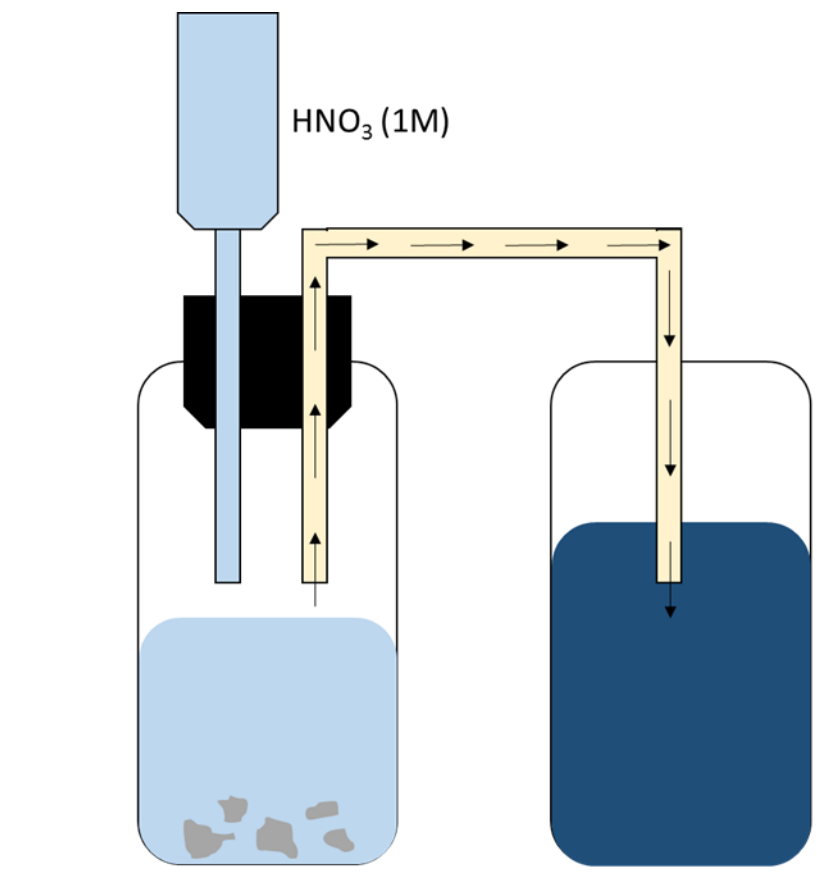
Release of Si and Ca^{2+} from hydrothermal material (24 h, pH=5, agitation)



MINERALOGICAL COMPOSITION

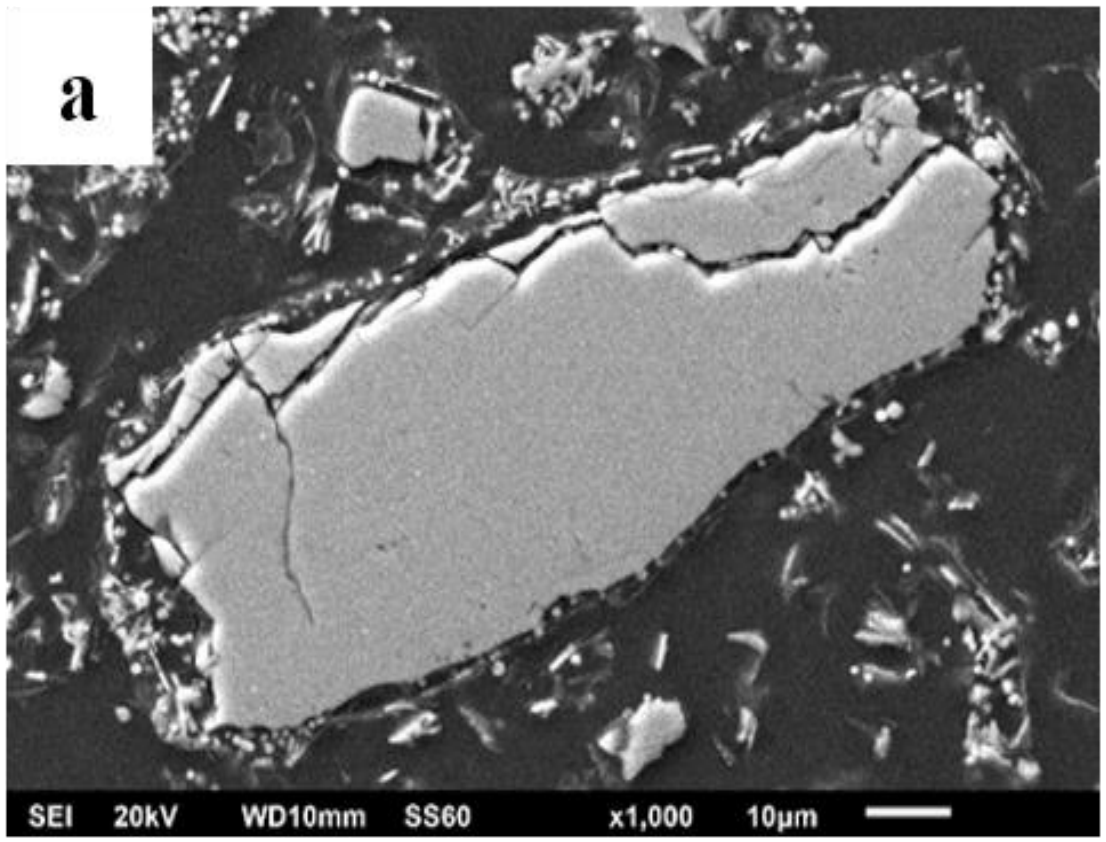


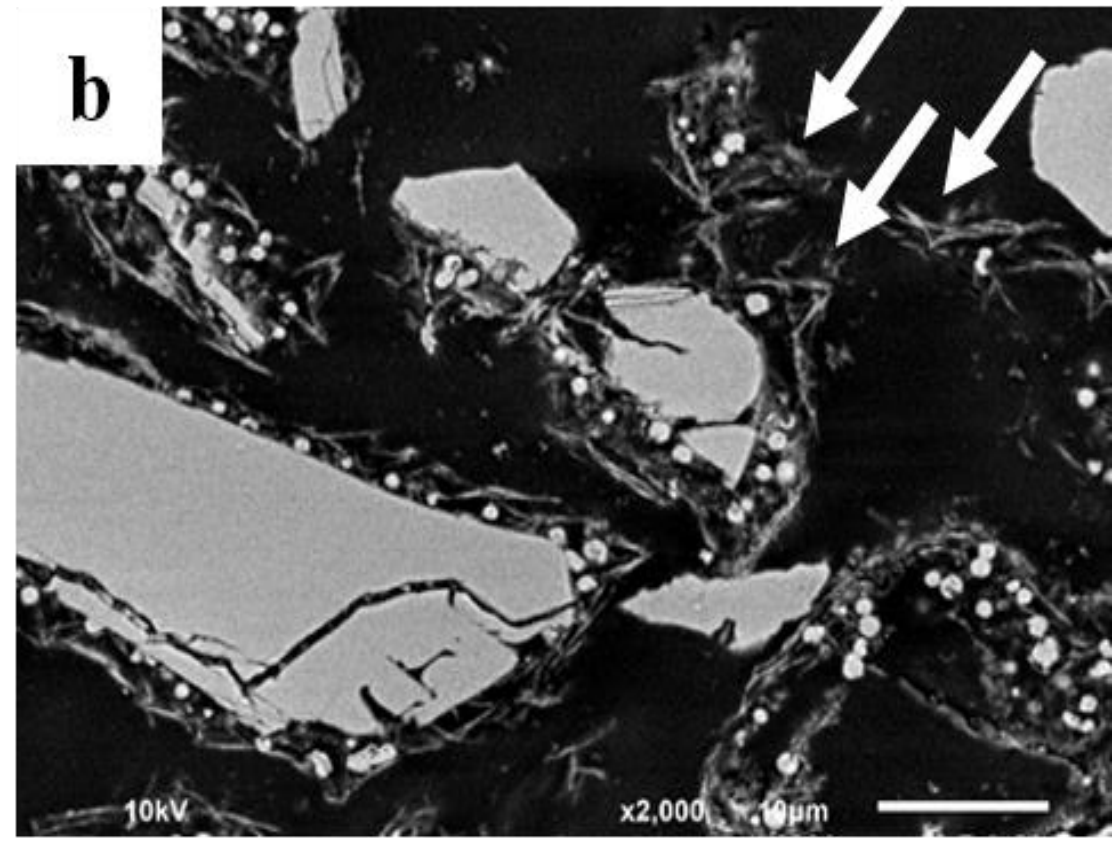


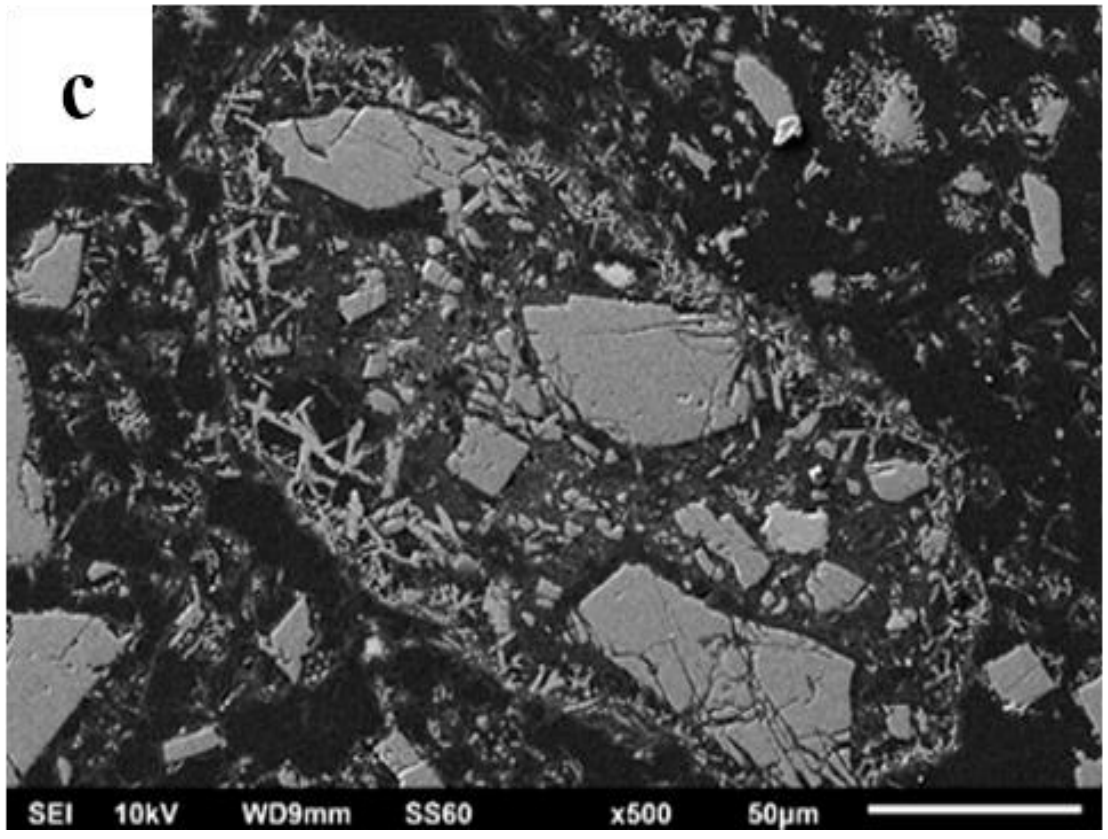


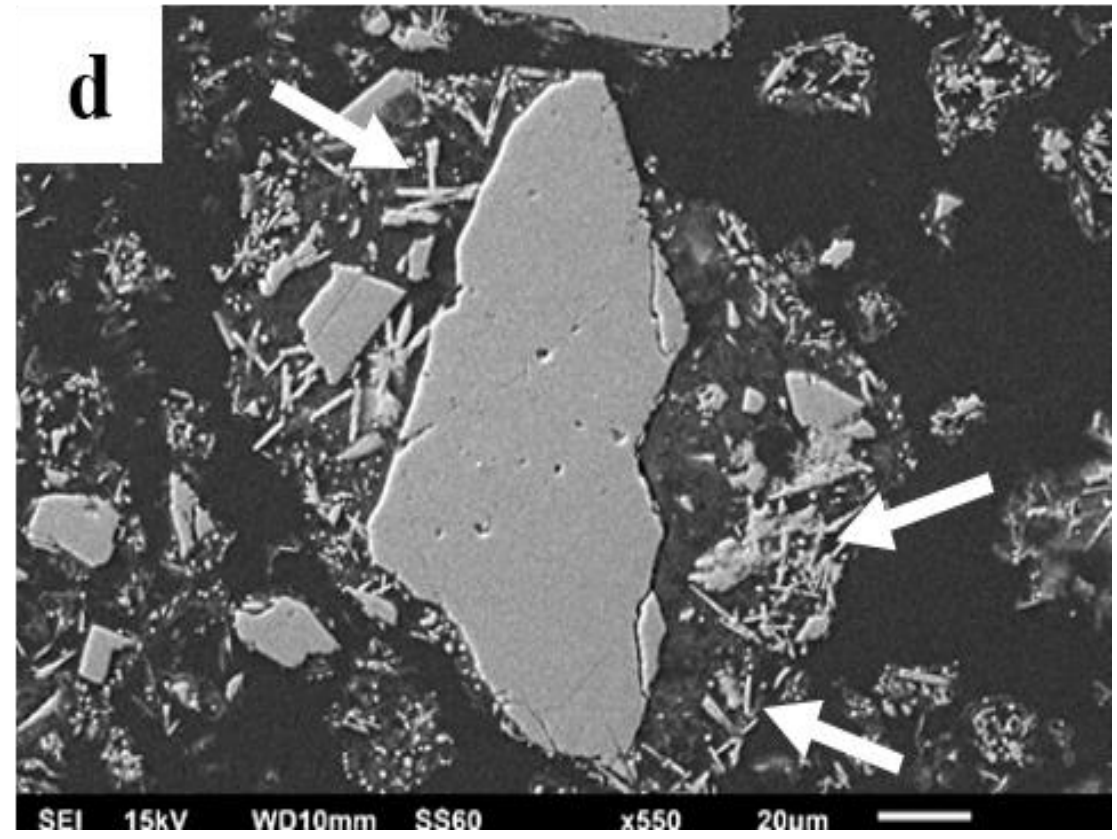
$CO_3^{2-}{}_{(aq)} + 2H_3O^+{}_{(aq)} \rightarrow CO_{2\,(g)} + 3H_2O_{\,(aq)}$

$CO_{2\,(g)} + Ba(OH)_{2(aq)} \rightarrow BaCO_{3(s)} + H_2O_{(aq)}$


a
SEI 20kV WD10mm SS60 x1,000 10µm

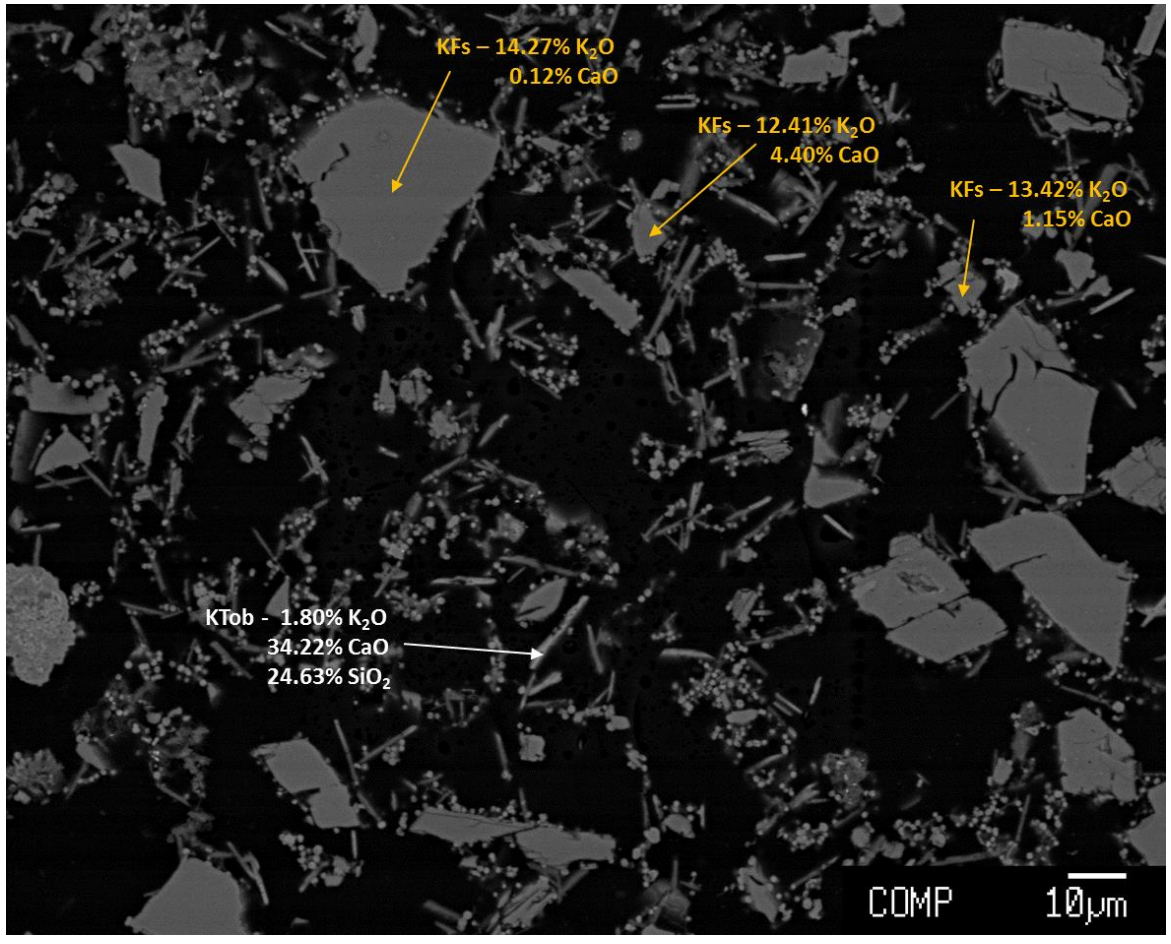

b
10kV x2,000

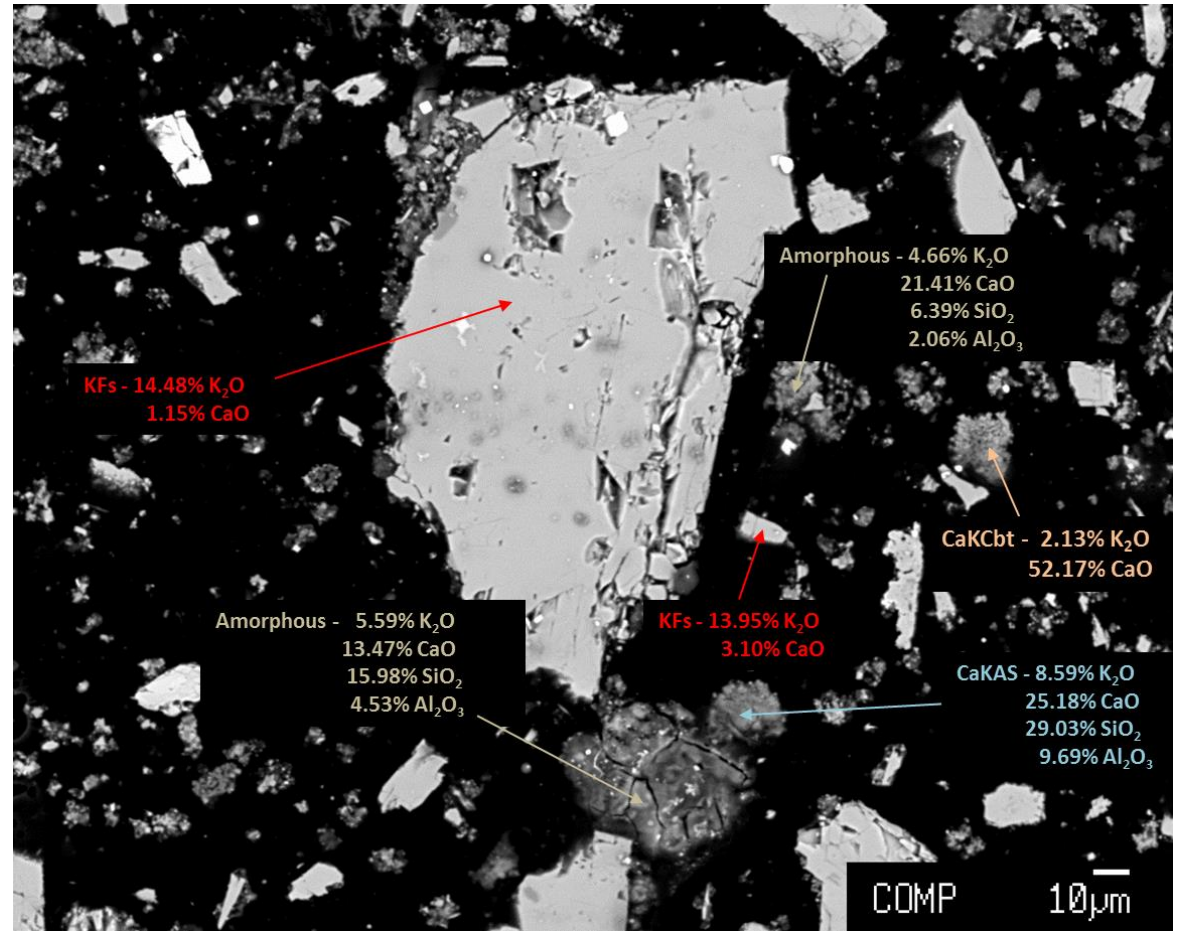

c
SEI 10kV WD9mm SS60 x500 50µm


d
SEI 15kV WD10mm SS60 x550 20µm

MINERALOGICAL COMPOSITION

Electron microprobe





HYDROTHERMAL PROCESSING