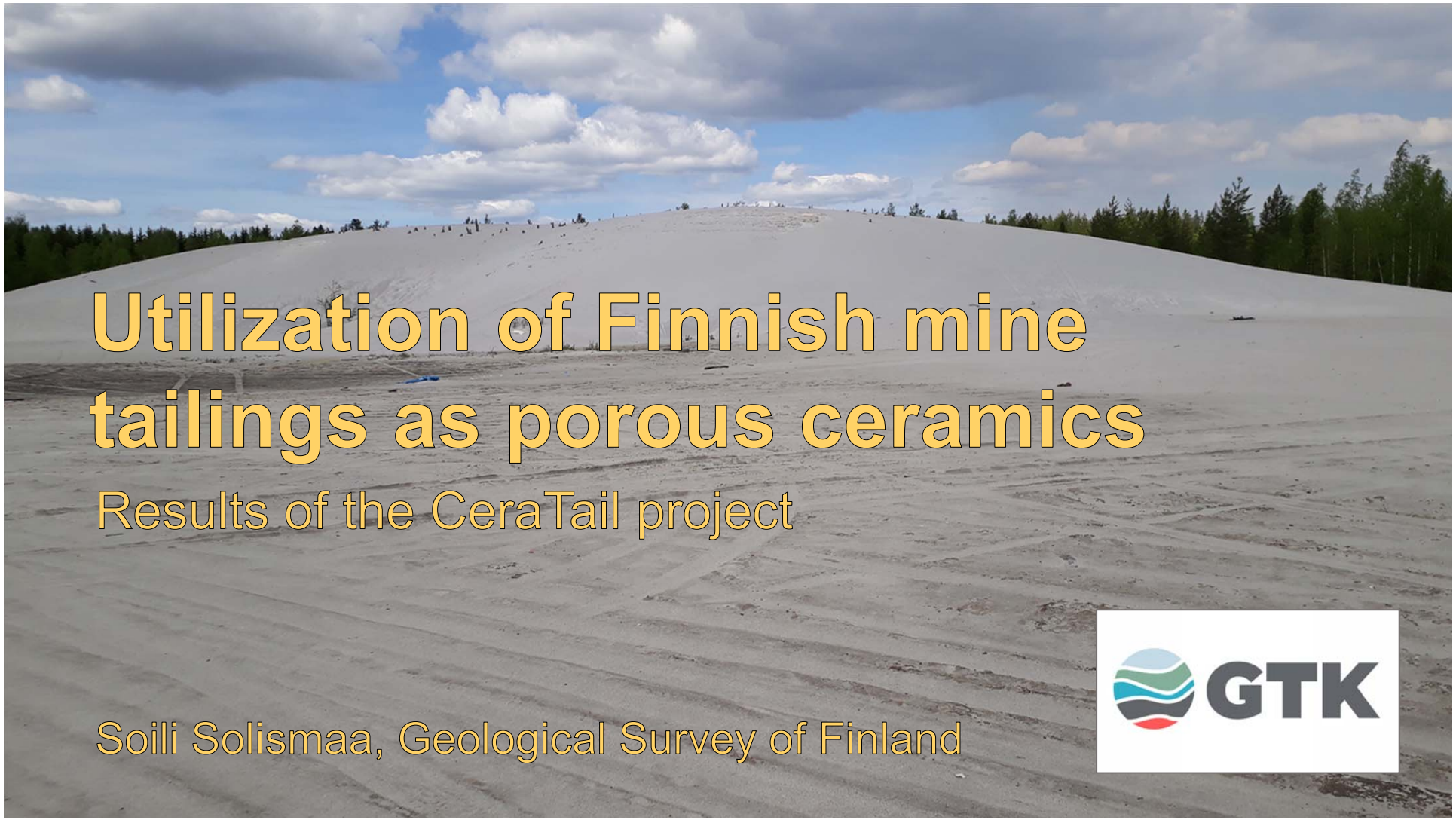


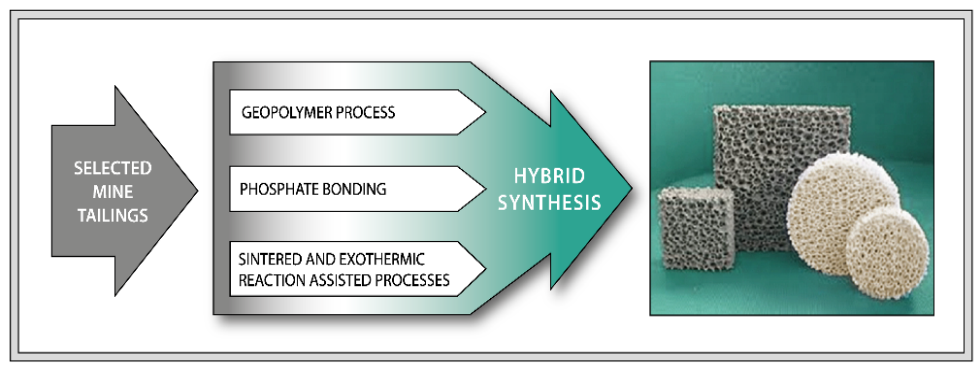
Utilization of Finnish mine tailings as porous ceramics

Results of the CeraTail project

Soili Solismaa, Geological Survey of Finland

CeraTail-project funded by Academy of Finland

- 01.09.2015 - 31.08.2019, coordinated by University of Oulu
- Investigation of the tailings characteristics and their viability for producing porous ceramics
- Porous ceramics are used in industry as filters, catalyst supports, insulators and absorbents



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Mineral Resources and Material Substitution (MISU) Academy Programme

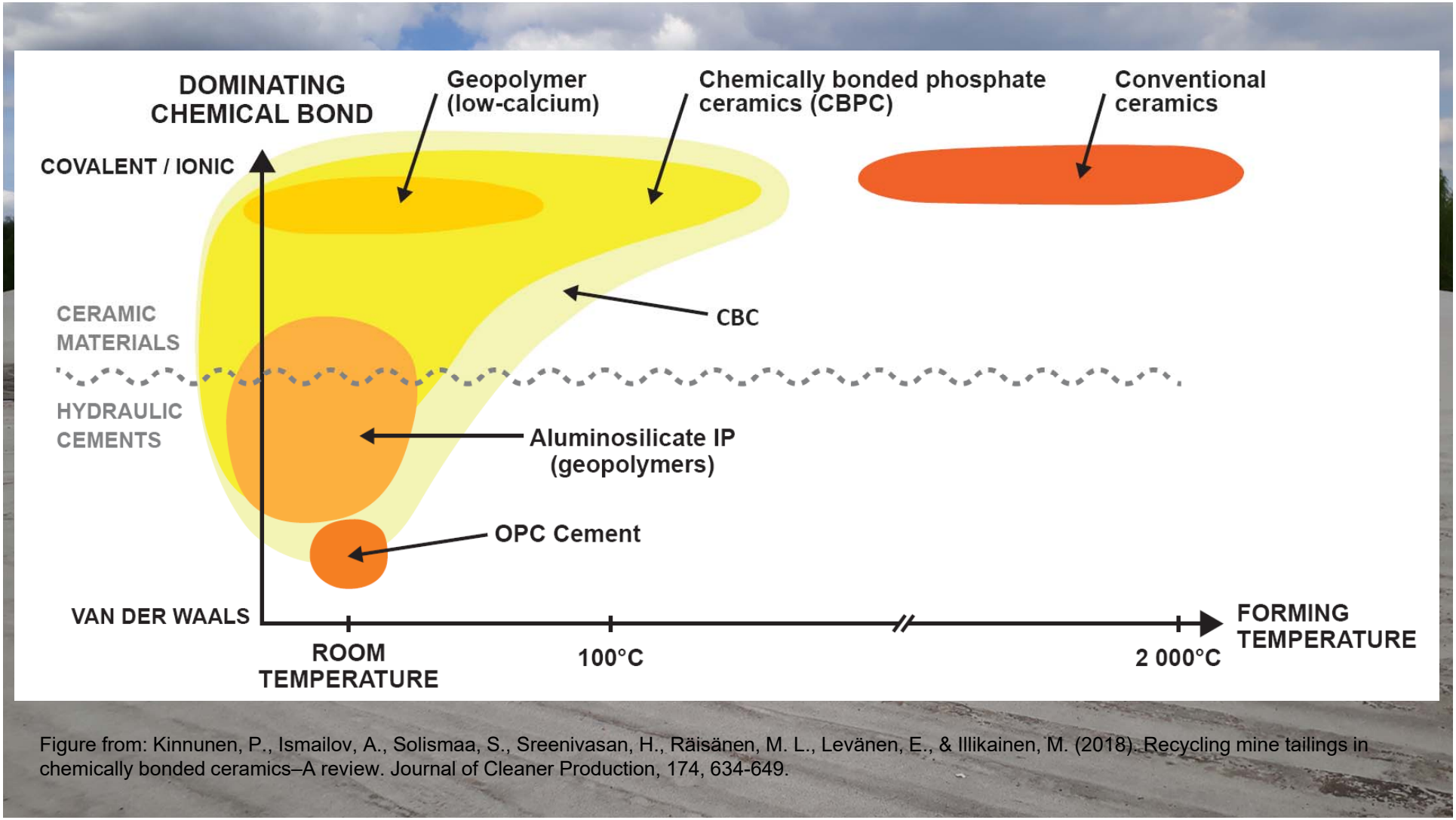
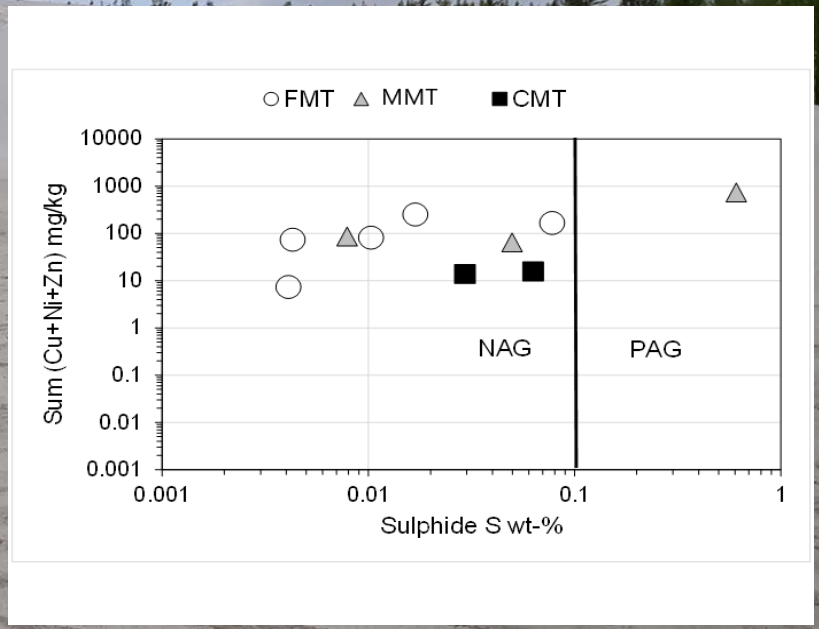


Figure from: Kinnunen, P., Ismailov, A., Solismaa, S., Sreenivasan, H., Räisänen, M. L., Levänen, E., & Illikainen, M. (2018). Recycling mine tailings in chemically bonded ceramics–A review. Journal of Cleaner Production, 174, 634-649.

GTK research topics

- Find, characterize and classify the tailings viable for the ceramic technologies
  - ✓ Identify mineral transformations
- Selected tailings are mostly inert (S≤0.1wt%) with low content of chalcophile elements



FMT = Felsic Mine tailings, MMT = Mafic mine tailings,

CMT = Tailings rich in carbonates

Selected study materials

5 industrial mineral mine tailings, 5 metal ore mine tailings and 2 side products

MUNICIPALITY	DEPOSIT NAME	COMPANY	MINED PRODUCT
Industrial mines			
SIILINJÄRVI	SIILINJÄRVI	YARA	P
NILSIÄ	KINAHMI	SIBELCO	QUARTZITE
KEMIÖ	KEMIÖ	SIBELCO	FELDSPAR
LAPPEENRANTA	IHALAINEN	NORDKALK	Ca, W
SOTKAMO	LAHNASLAMPI	MONDO MINERALS	TALC
Metal mines			
ULLAVA	LÄNTTÄ	KELIBER	Li
KEMIJÄRVI	KÄRVÄSVAARA	CLOSED MINE	Fe
KEMIJÄRVI	RAAJÄRVI	CLOSED MINE	Fe
LIEKSA	MÄTÄSVAARA	CLOSED MINE	Mo
PAMPALO	HATTUVAARA	ENDOMINES	Au
Side products			
JUUKA	NUNNALAHTI	TULIKIVI	SOAP STONE
SIILINJÄRVI	LKAB	LKAB	PHLOGOPITE

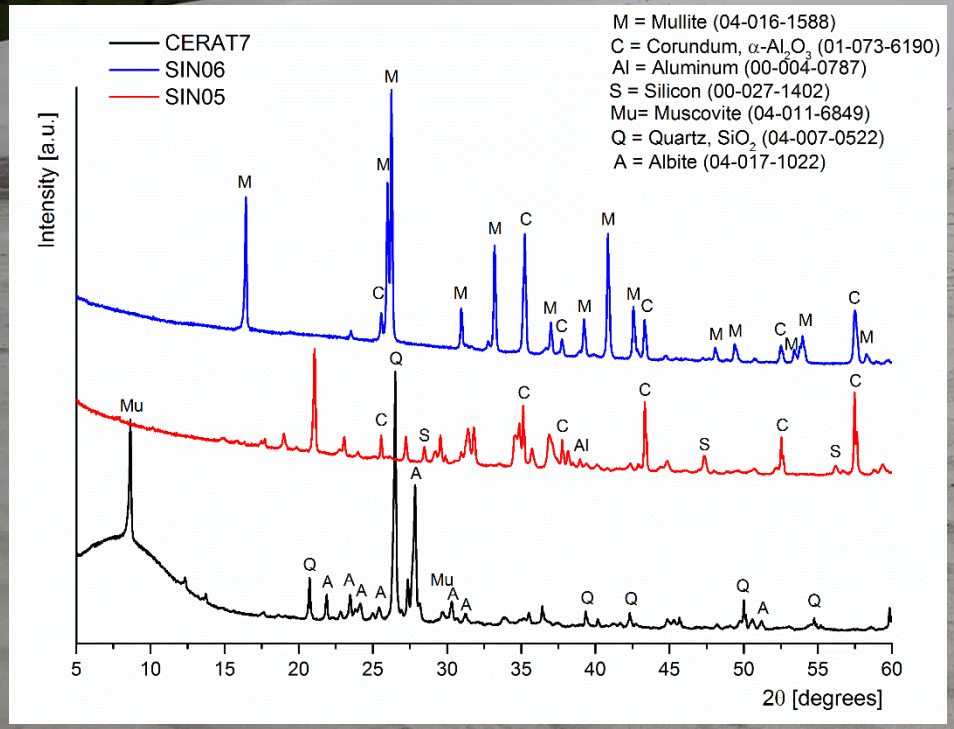
SS3

Results achieved with mullite based reaction sintering

Samples (gold-, quartzite- and molybdenum mine tailings) were grinded to grain size below 10 µm and mixed with aluminum additive. The mixture was heated to 1300°C

Sample code	Mine tailing	(g)	Al powder (g)	AlO(OH) powder (g)
SIN01	Gold	162.5	87.5	-
SIN02	Gold	101	-	149
SIN03	Quartz	101	149	-
SIN04	Quartz	72	-	178
SIN05	Mo	132.5	117.5	-
SIN06	Mo	84	-	166

- During the heat treatment felspars and micas converted to liquid form which promoted the dissolution of silica into the liquid which enabled the reaction with added alumina source->mullite crytallization



AlO(OH) powder

Al powder

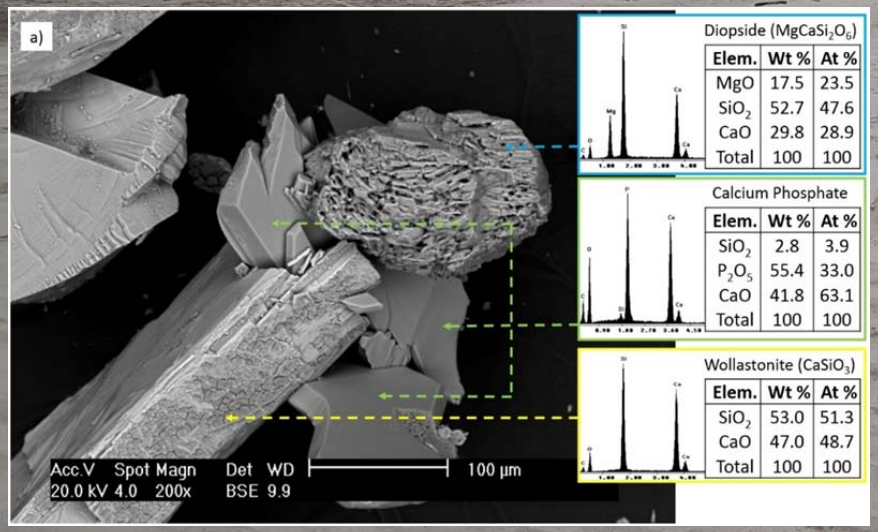
Original FMT material

Changes in mineralogy → Mullite and corundum formation at 1300 °C

Compressive strength similar as for the reference (~60 Mpa)

Results achieved with phosphate bonding

- Limestone minetailings were exposed to 2.5% orthophosphoric acid for 24 hours -> Reaction with calcite resulted new calcium phosphate phase, diopside and wollastonite showed surface degradation



Diopside ($MgCaSi_2O_6$)

Elem.	Wt %	At %
MgO	17.5	23.5
SiO_2	52.7	47.6
CaO	29.8	28.9
Total	100	100

Calcium Phosphate

Elem.	Wt %	At %
SiO_2	2.8	3.9
P_2O_5	55.4	33.0
CaO	41.8	63.1
Total	100	100

Wollastonite ($CaSiO_3$)

Elem.	Wt %	At %
SiO_2	53.0	51.3
CaO	47.0	48.7
Total	100	100

Calcium phosphate lamellae (green) after acid exposure in a CMT material; Surface degradation in wollastonite (yellow) and diopside (blue)

Results achieved with alkali activation

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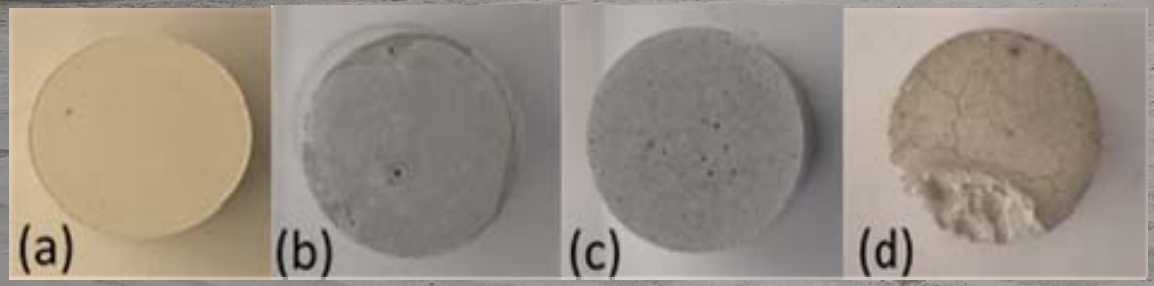
- Mixing thermally treated phlogopite with metakaolin improved the compressive strength of geopolymer
- The highest strength was observed in sample heated at 60°C

SS2

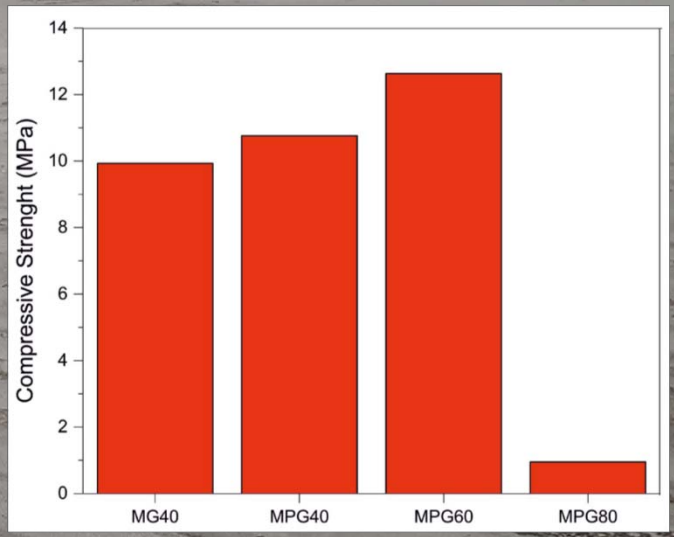


Metakaolin 40˚C

Metakaolin+ phlogopite, 40˚C

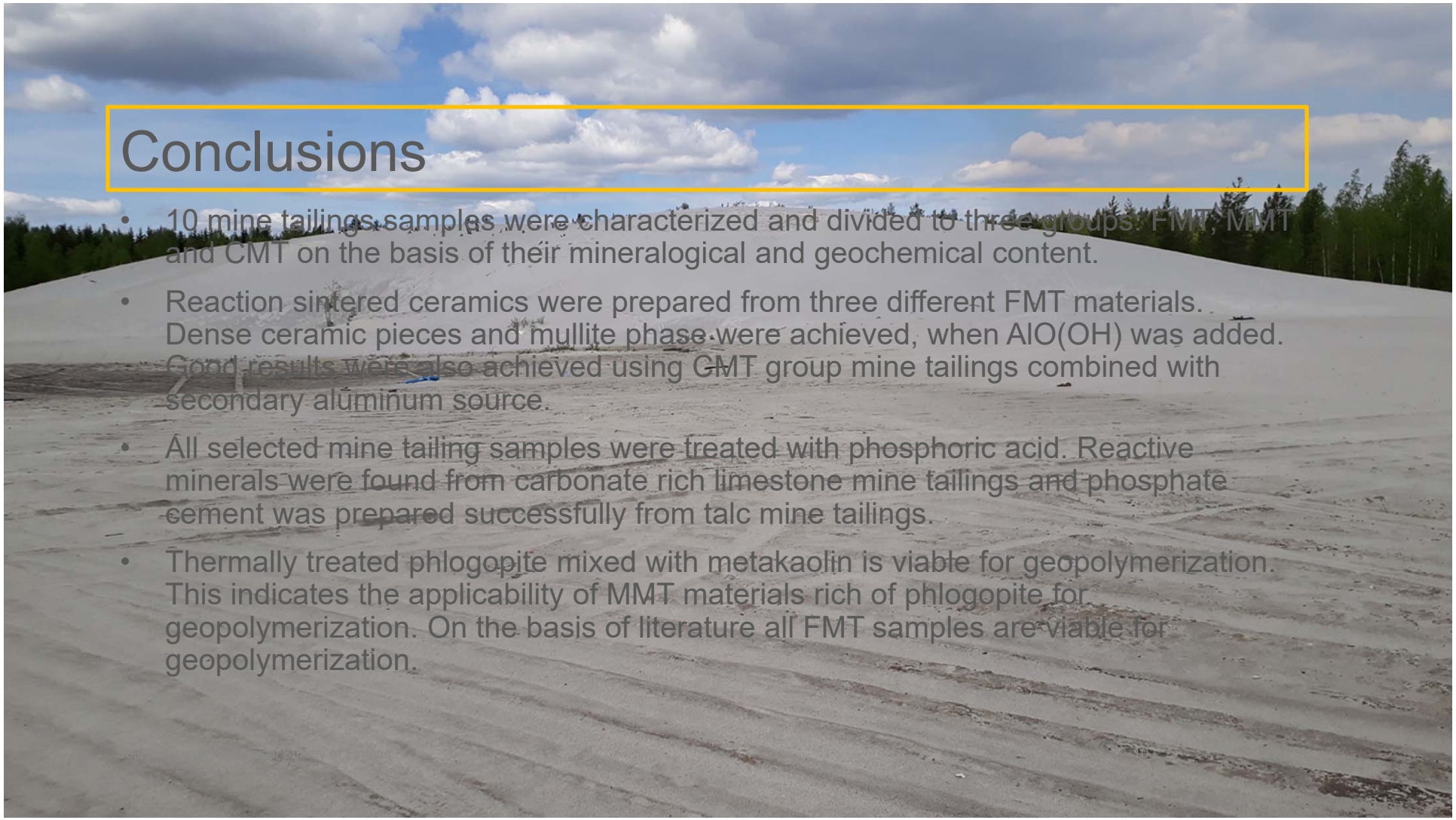
Metakaolin+ phlogopite, 60˚C

Metakaolin+ phlogopite, 80˚C



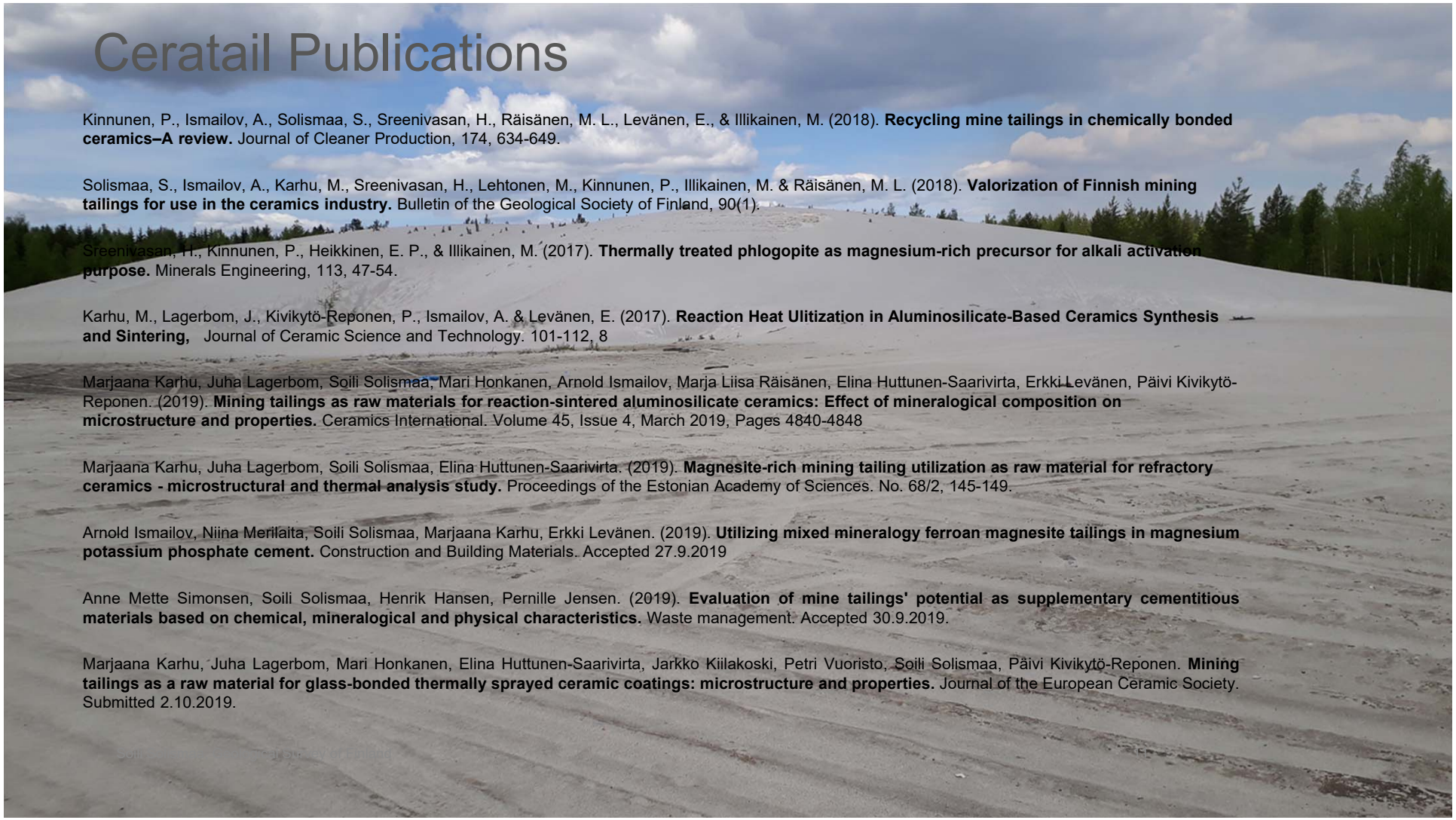
SS2 Phlogopite was heated (1600) and mixed with metakaolin and Sodium silicate solution ->curing for one day

Solismaa Soili; 19.8.2019



Conclusions

- 10 mine tailings samples were characterized and divided to three groups: FMT, MMT and CMT on the basis of their mineralogical and geochemical content.
- Reaction sintered ceramics were prepared from three different FMT materials. Dense ceramic pieces and mullite phase were achieved, when AlO(OH) was added. Good results were also achieved using CMT group mine tailings combined with secondary aluminum source.
- All selected mine tailing samples were treated with phosphoric acid. Reactive minerals were found from carbonate rich limestone mine tailings and phosphate cement was prepared successfully from talc mine tailings.
- Thermally treated phlogopite mixed with metakaolin is viable for geopolymerization. This indicates the applicability of MMT materials rich of phlogopite for geopolymerization. On the basis of literature all FMT samples are viable for geopolymerization.



Ceratail Publications

Kinnunen, P., Ismailov, A., Solismaa, S., Sreenivasan, H., Räisänen, M. L., Levänen, E., & Illikainen, M. (2018). **Recycling mine tailings in chemically bonded ceramics–A review.** Journal of Cleaner Production, 174, 634-649.

Solismaa, S., Ismailov, A., Karhu, M., Sreenivasan, H., Lehtonen, M., Kinnunen, P., Illikainen, M. & Räisänen, M. L. (2018). **Valorization of Finnish mining tailings for use in the ceramics industry.** Bulletin of the Geological Society of Finland, 90(1).

Sreenivasan, H., Kinnunen, P., Heikkinen, E. P., & Illikainen, M. (2017). **Thermally treated phlogopite as magnesium-rich precursor for alkali activation purpose.** Minerals Engineering, 113, 47-54.

Karhu, M., Lagerbom, J., Kivikytö-Reponen, P., Ismailov, A. & Levänen, E. (2017). **Reaction Heat Ulitization in Aluminosilicate-Based Ceramics Synthesis and Sintering,** Journal of Ceramic Science and Technology. 101-112, 8

Marjaana Karhu, Juha Lagerbom, Soili Solismaa, Mari Honkanen, Arnold Ismailov, Marja Liisa Räisänen, Elina Huttunen-Saarivirta, Erkki Levänen, Päivi Kivikytö-Reponen. (2019). **Mining tailings as raw materials for reaction-sintered aluminosilicate ceramics: Effect of mineralogical composition on microstructure and properties.** Ceramics International. Volume 45, Issue 4, March 2019, Pages 4840-4848

Marjaana Karhu, Juha Lagerbom, Soili Solismaa, Elina Huttunen-Saarivirta. (2019). **Magnesite-rich mining tailing utilization as raw material for refractory ceramics - microstructural and thermal analysis study.** Proceedings of the Estonian Academy of Sciences. No. 68/2, 145-149.

Arnold Ismailov, Niina Merilaita, Soili Solismaa, Marjaana Karhu, Erkki Levänen. (2019). **Utilizing mixed mineralogy ferroan magnesite tailings in magnesium potassium phosphate cement.** Construction and Building Materials. Accepted 27.9.2019

Anne Mette Simonsen, Soili Solismaa, Henrik Hansen, Pernille Jensen. (2019). **Evaluation of mine tailings' potential as supplementary cementitious materials based on chemical, mineralogical and physical characteristics.** Waste management. Accepted 30.9.2019.

Marjaana Karhu, Juha Lagerbom, Mari Honkanen, Elina Huttunen-Saarivirta, Jarkko Kiilakoski, Petri Vuoristo, Soili Solismaa, Päivi Kivikytö-Reponen. **Mining tailings as a raw material for glass-bonded thermally sprayed ceramic coatings: microstructure and properties.** Journal of the European Ceramic Society. Submitted 2.10.2019.