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FACULTY OF SCIENCES

3-5 October 2018, Congress Graz, Austria

INTERACTIONS BETWEEN SOIL AND GEOTHERMAL HELICAL HEAT EXCHANGERS: AN OVERVIEW OF ITER PROJECT OUTCOMES

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ITER Project 2015-2017

European Union's Framework Program for Research and Innovation Horizon 2020 (2014-2020) under the Marie Skłodowska-Curie Grant Agreement No.[661396-ITER]

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Outline

- ✓ ITER Project
- ✓ Very shallow geothermal energy: introduction
- ✓ Material and methods
- ✓ Results and discussion
- ✓ Conclusion

ITER Project

Improving **T**hermal **E**fficiency of hoRizontal ground heat exchangers

AIM

to improve heat transfer efficiency of very shallow geothermal (vSG) systems, as horizontal collector systems or special forms, interesting the **first 2 m of depth** from ground level

why?

the performance of a vSG system:

- ✓ *is strongly correlated to the kind of sediment at disposal (mineralogical composition, grain size distribution, bulk density, moisture content)*
- ✓ *suddenly decreases in case of dry-unsaturated conditions in the surrounding soil*

What is vSG?

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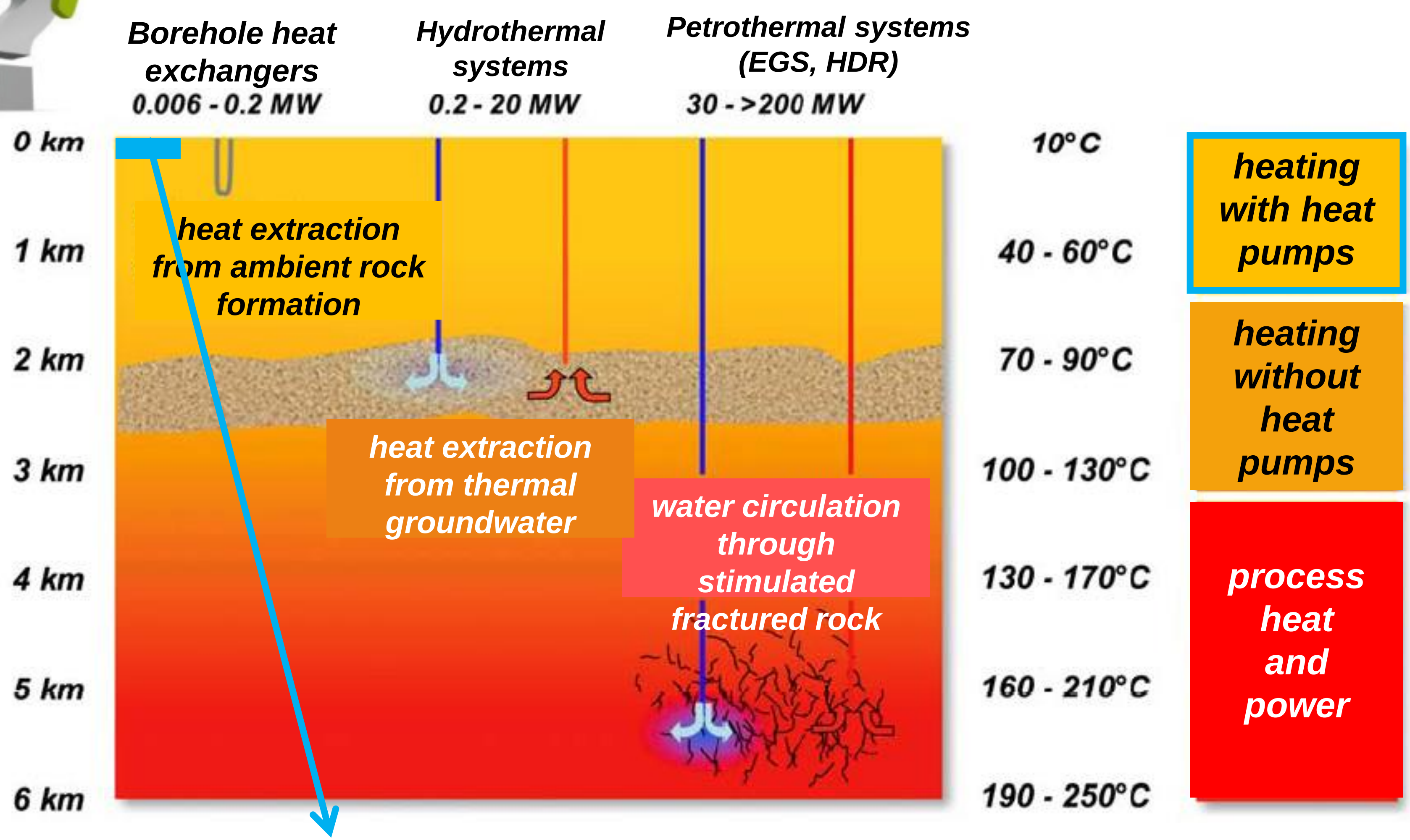
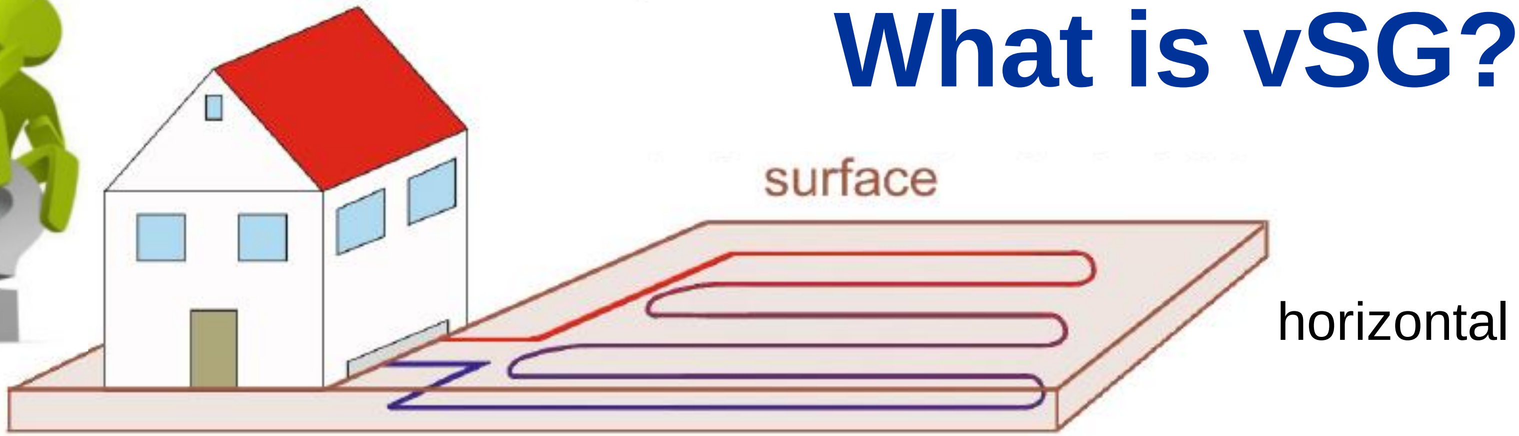
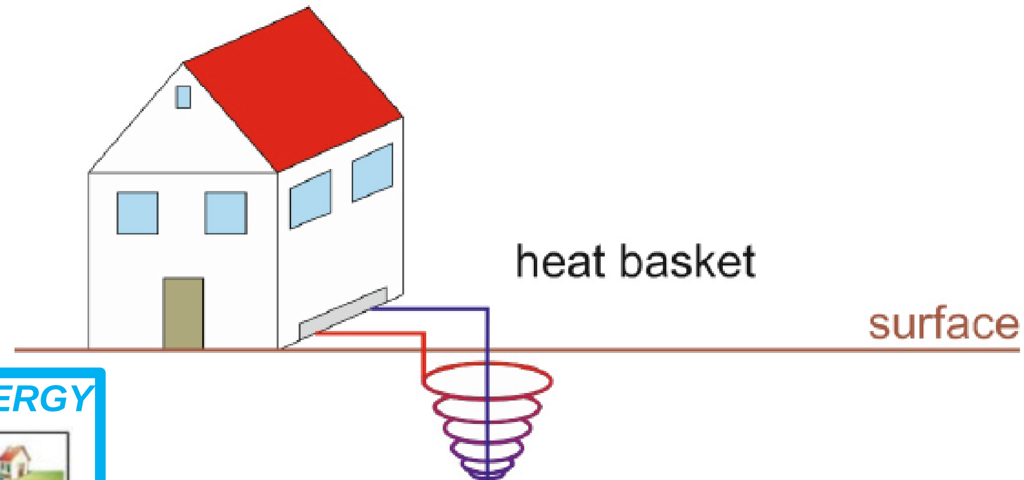


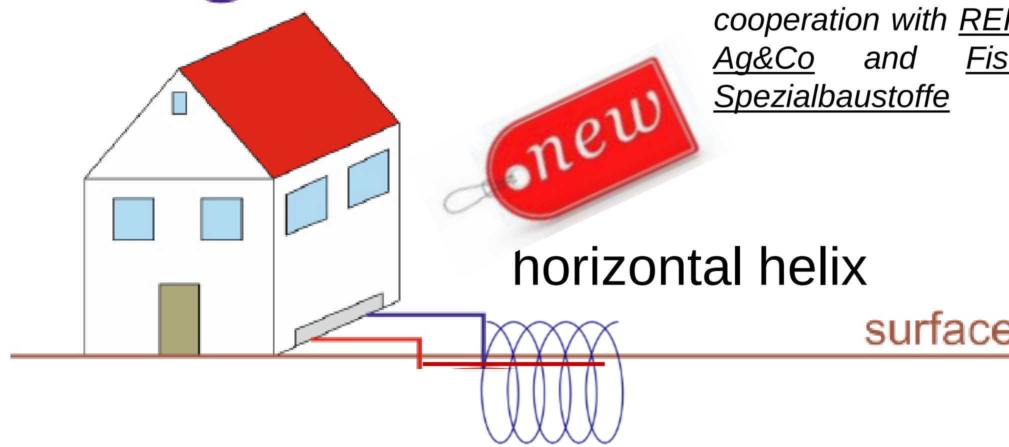
SHALLOW GEOTHERMAL ENERGY
(max depth ≈ 450 m)

What is vSG?

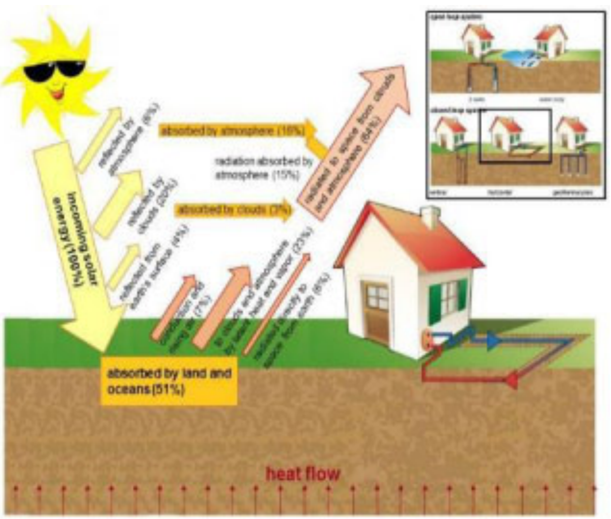




cooperation with <u>REHAU Ag&Co</u> and <u>Fischer Spezialbaustoffe</u>



SHALLOW GEOTHERMAL ENERGY



source NASA, 2017

Project phases

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1. LABORATORY

- ✓ physical-thermal properties of more than 15 soil mixtures *[(i) natural soil, (ii) pure sand and (iii) mixtures of pure sand and clay additives]* tested under different water content percentages and different consolidation degree

2. FIELD TEST MONITORING

- ✓ monthly measurement of thermal conductivity and moisture content on surface
- ✓ continuous recording of (i) T_{ground}, (ii) T_{in}, T_{out}, and (iii) flow rate of the heat carrier fluid belonging to each Helix
- ✓ continuous climatological data acquisition
- ✓ continuous volumetric water content data acquisition

3. NUMERICAL SIMULATION

- ✓ assessment of efficiency and environmental impact of SGHE using TEBM by running numerical simulation (FEFLOW code)

MARIE CURIE ACTIONS

Laboratory

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✓tested different soil mixtures based on sand and fine sand material with incremental water contents and pressure steps

✓56 dm^3 Vol to avoid marginal influences and to compare the lab results with the field test

- grain size *(DIN 52102 + Sedigraph)*
- mineralogical content (*X-Ray Diffracton XRD*)
- bulk density *(DIN 52102)*
- water content *(DIN 18121)*

At 75, +1 000, +3 000, +5 000 kg *(incremental steps)*

- thermal conductivity *(transient line source method- ASTM D5334-08)*
- moisture content and bulk electrical conductivity *(time domain reflectometry TDR)*

Laboratory

fine sand mixtures (two additives)

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	pure material	ITER mixtures	sample code
1	fine sand 0-1 mm	*pure*	fs
2		*with 8% Bentonite*	fs8B
3		*with 8% Clay*	fs8C
4		*with 15% Bentonite*	fs15B
5		*with 15% Clay*	fs15C
6		*with 30% Bentonite*	fs30B
7		*with 30% Clay*	fs30C

- ✓ **cohesive additive added gradually to the pure air dried material up to 8%, 15% and 30% of the total weight available (about 60 kg)**
- ✓ **each cycle of measurement consists of 2 thermal conductivity, 4 moisture content and bulk electrical resistivity acquisition**
- ✓ **the entire cycle is repeated four times (1 series of measurements) for each dry mixture varying the pressure exerted on the material with a workshop press**

Laboratory

fine sand 0-1 mm mixtures

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fs

- ✓ **fresh water is added gradually** in incremental steps equals to 2.5% by weight of the dry mixture, until the field capacity is overcome


fs8B


fs15B

fs30B


fs8C


fs15C

fs30C

Thermal conductivity

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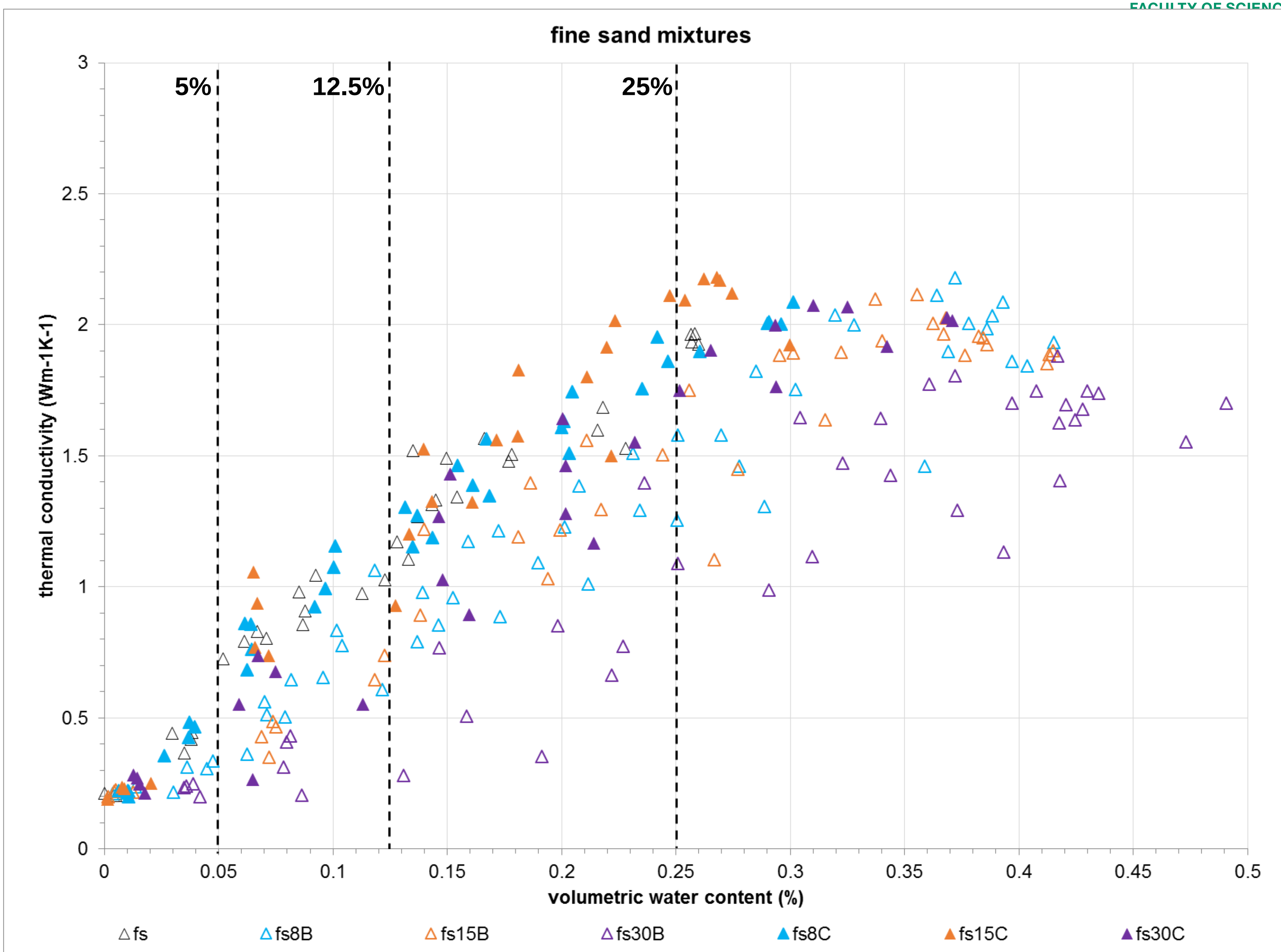

Thermal conductivity

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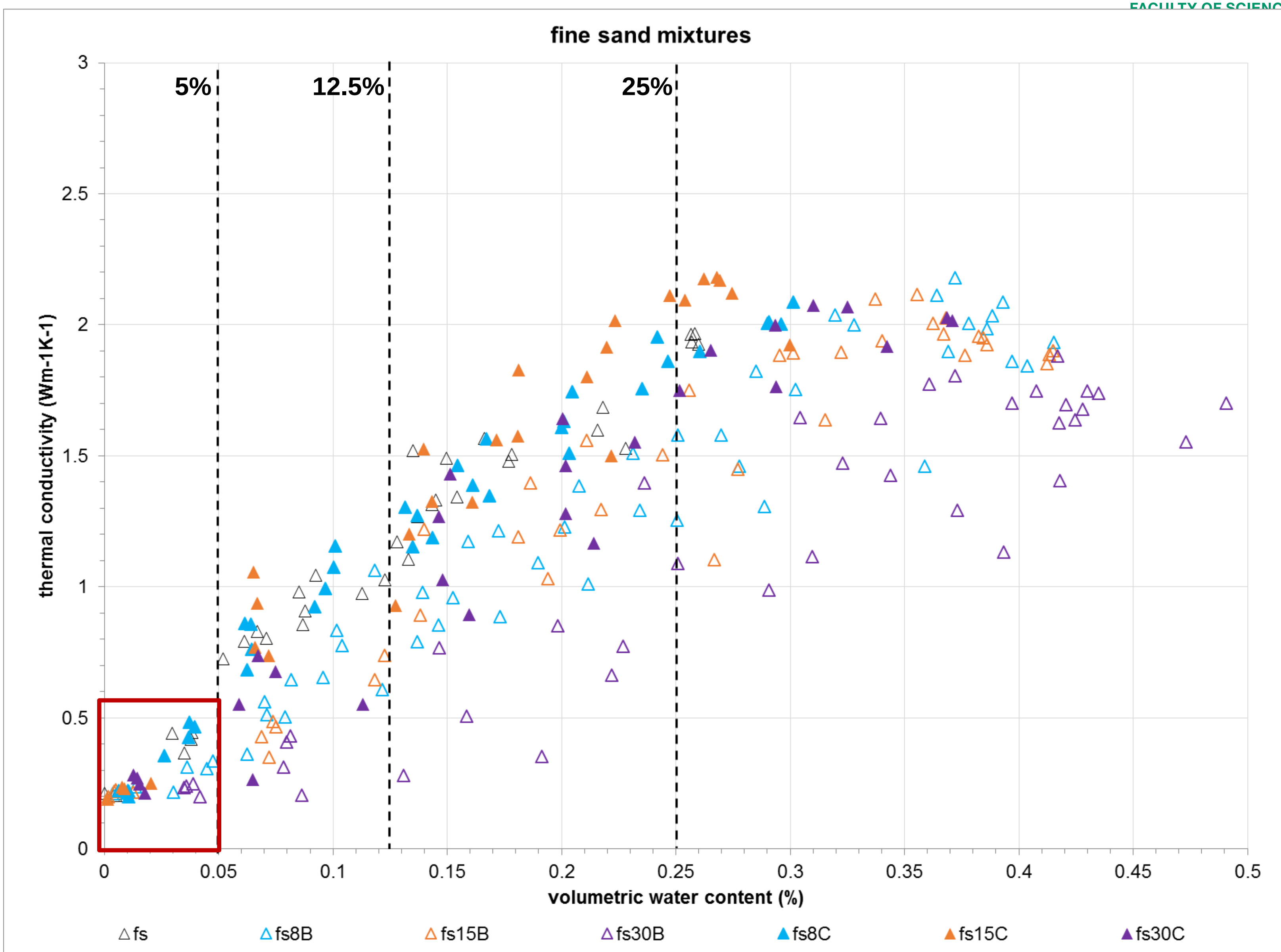
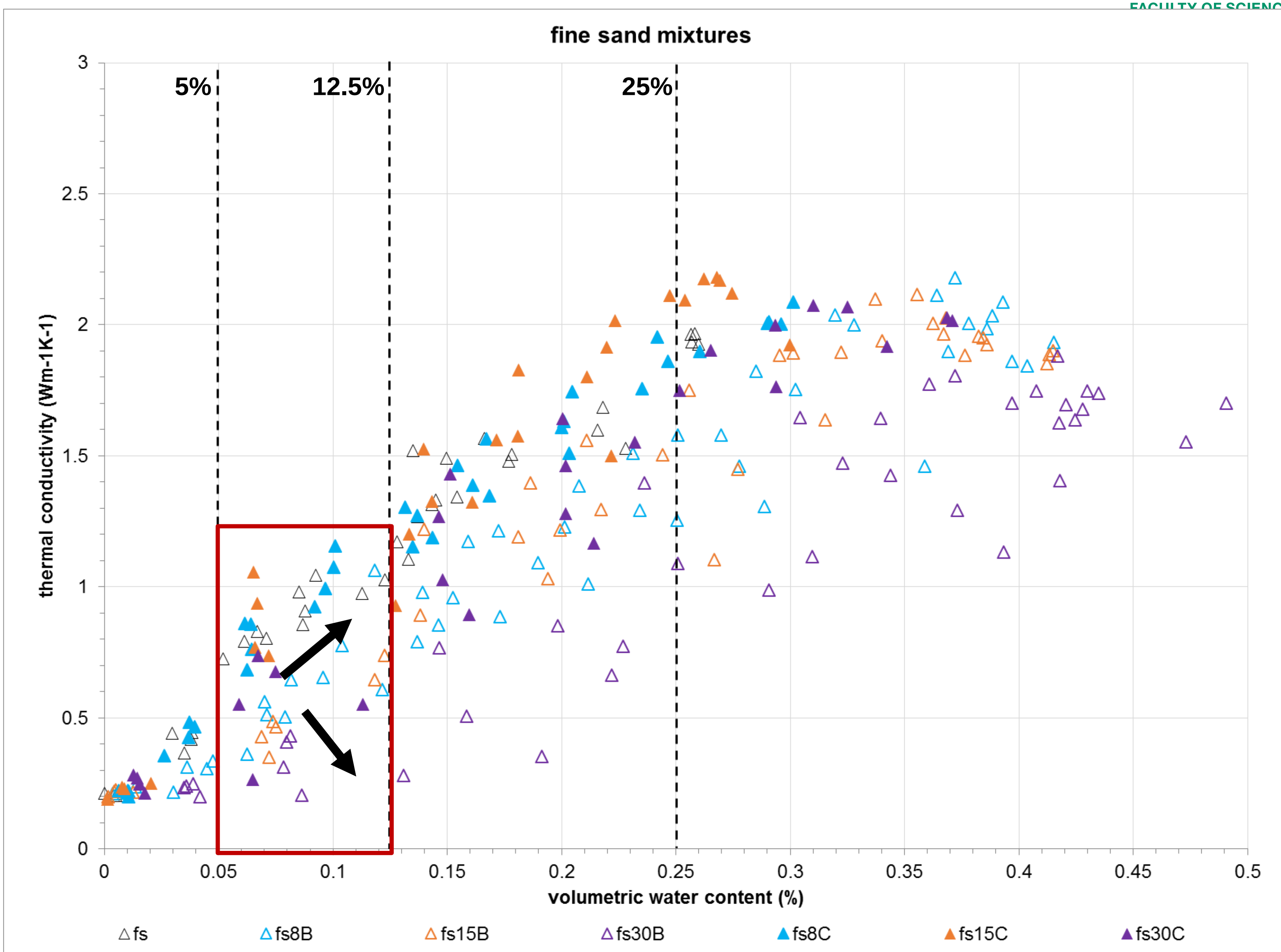
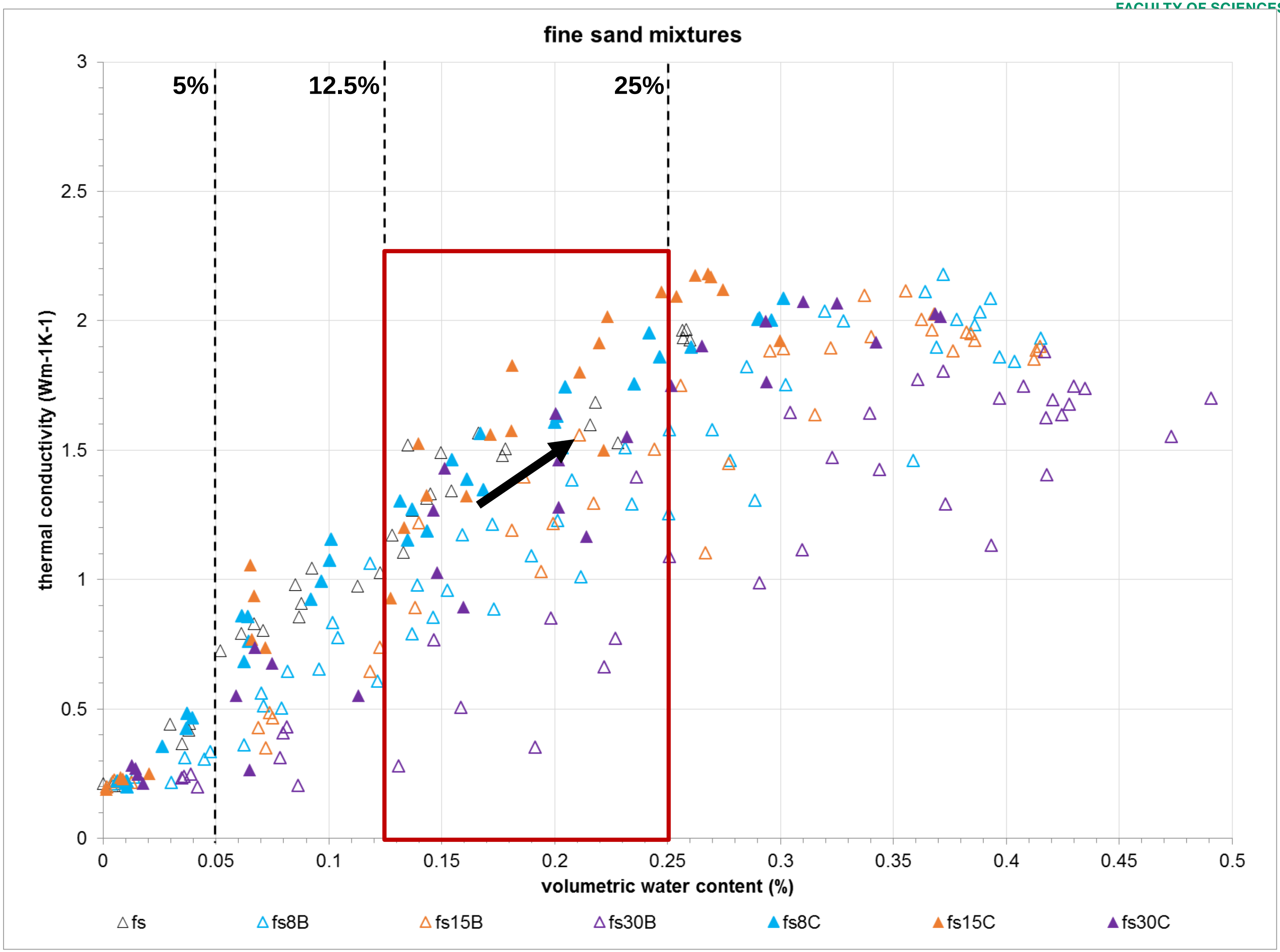


Thermal conductivity



Thermal conductivity



Thermal conductivity

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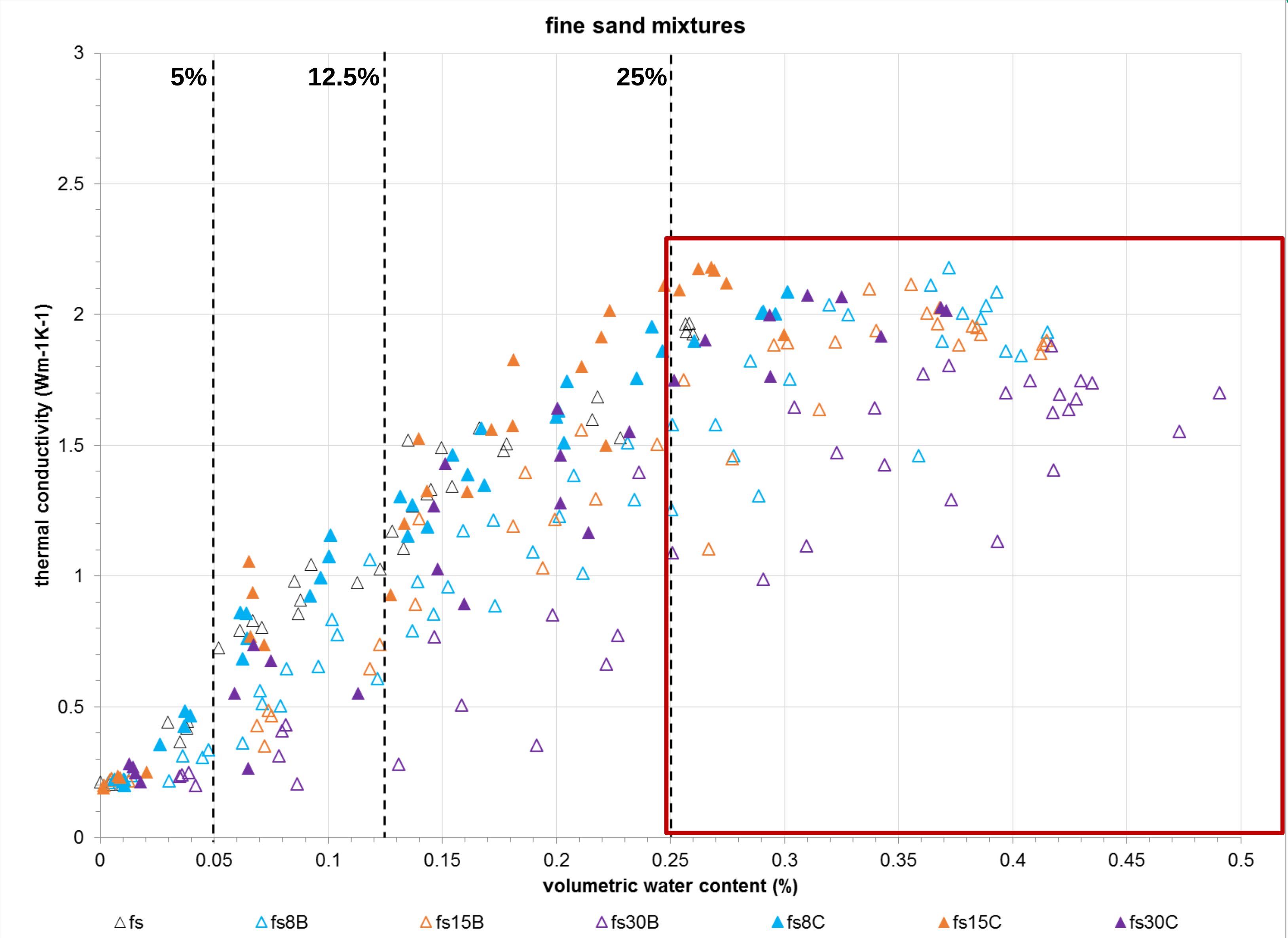
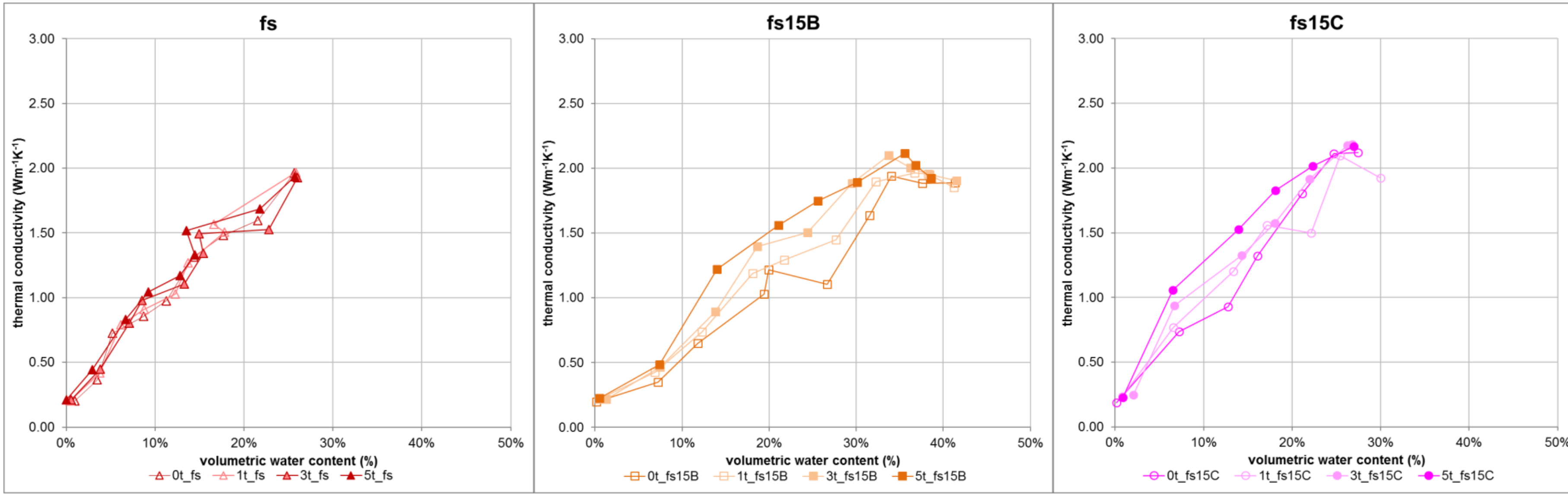


Thermal conductivity



- **adding an additive to a pure material enriched in quartz (fs) reduces its capacity to transfer heat**
- **an increased amount of bentonite** is responsible both for a lowering of the heat transfer values and for a gain in the capacity for retaining moisture
- **in the same moisture condition**, **an increase of the pressure load** determines an improvement of the heat transfer ability

Thermal conductivity

pressure step + 1 000 kg

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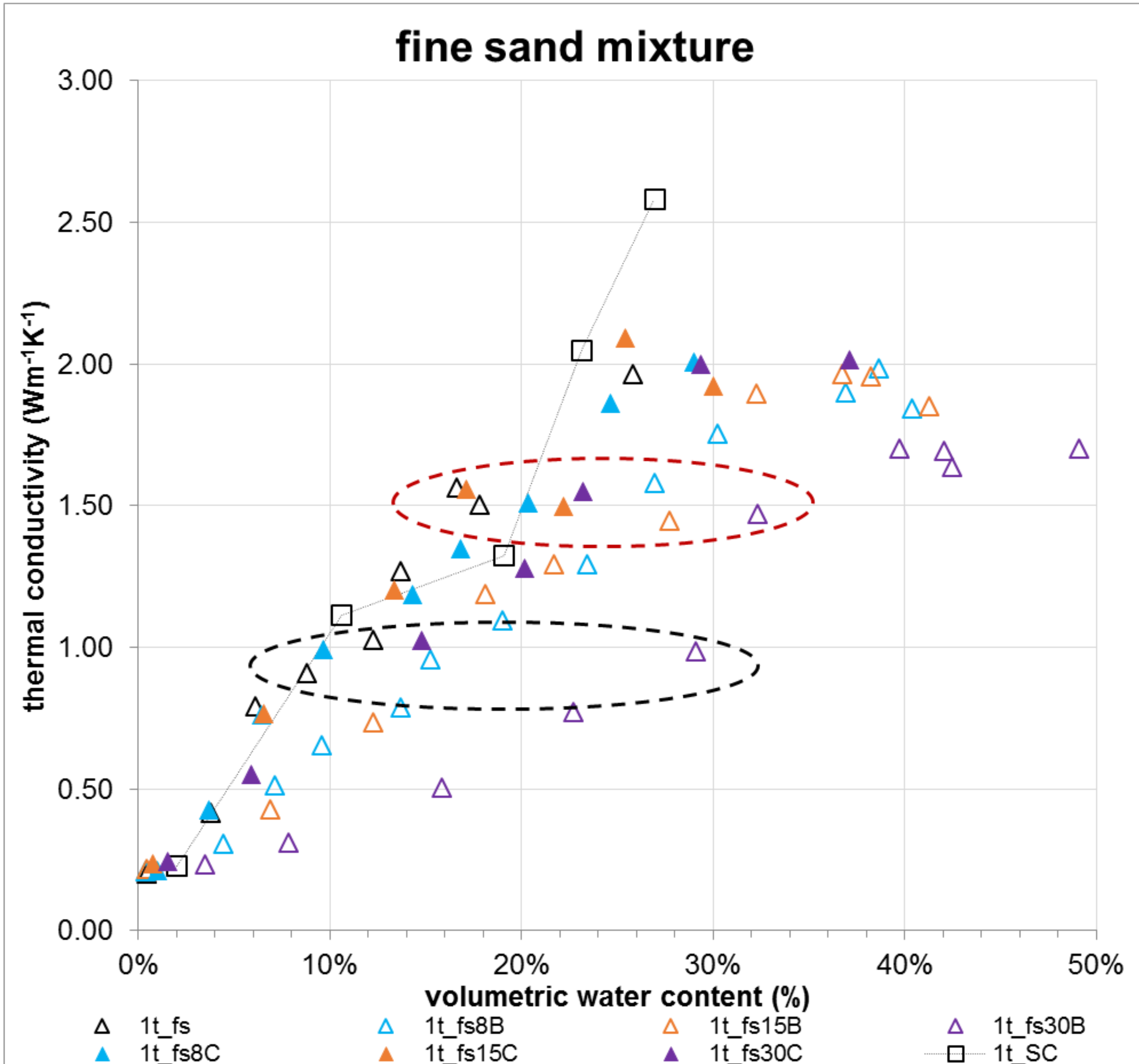

Thermal conductivity

pressure step + 1 000 kg

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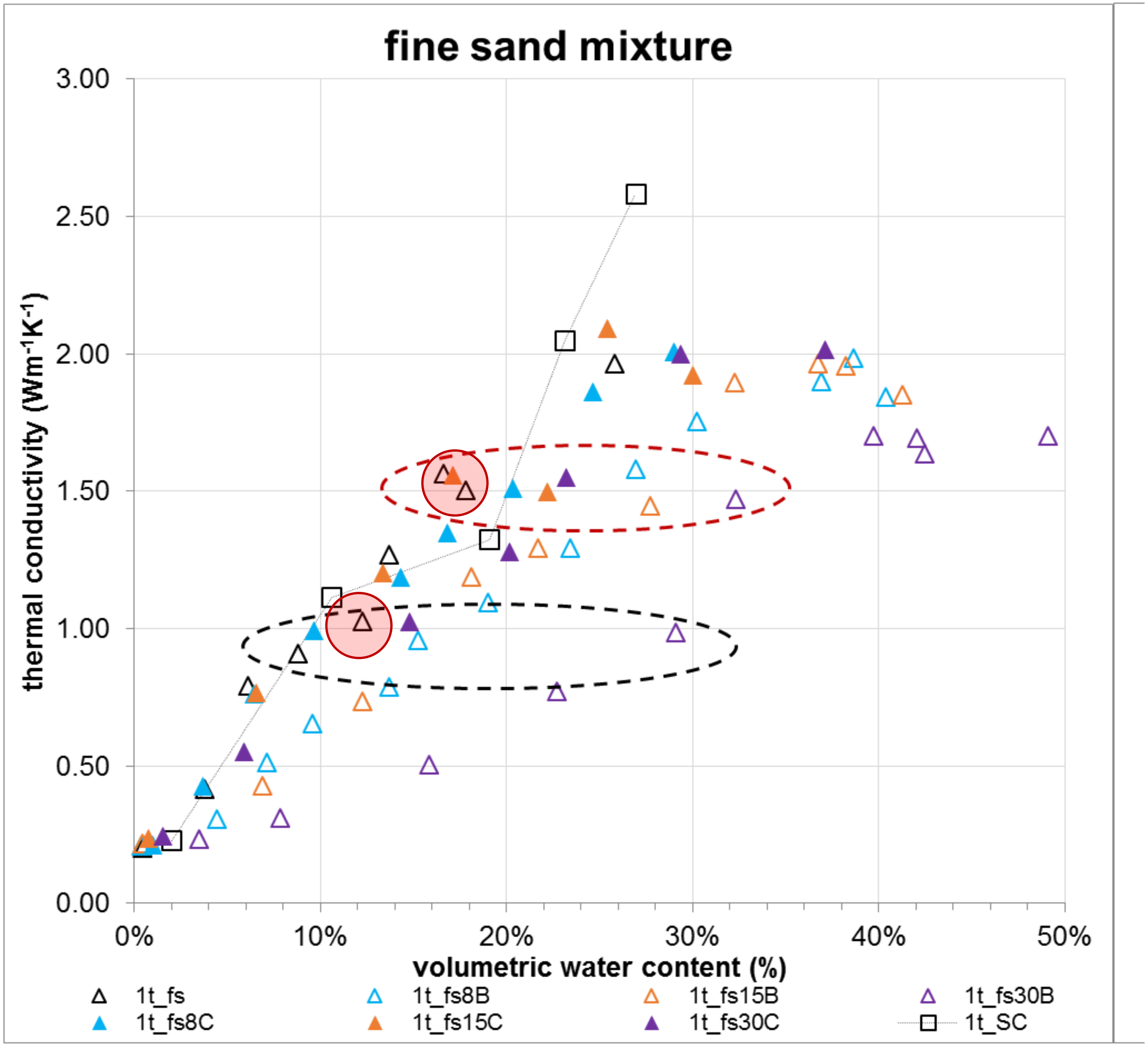

Thermal conductivity

pressure step + 1 000 kg

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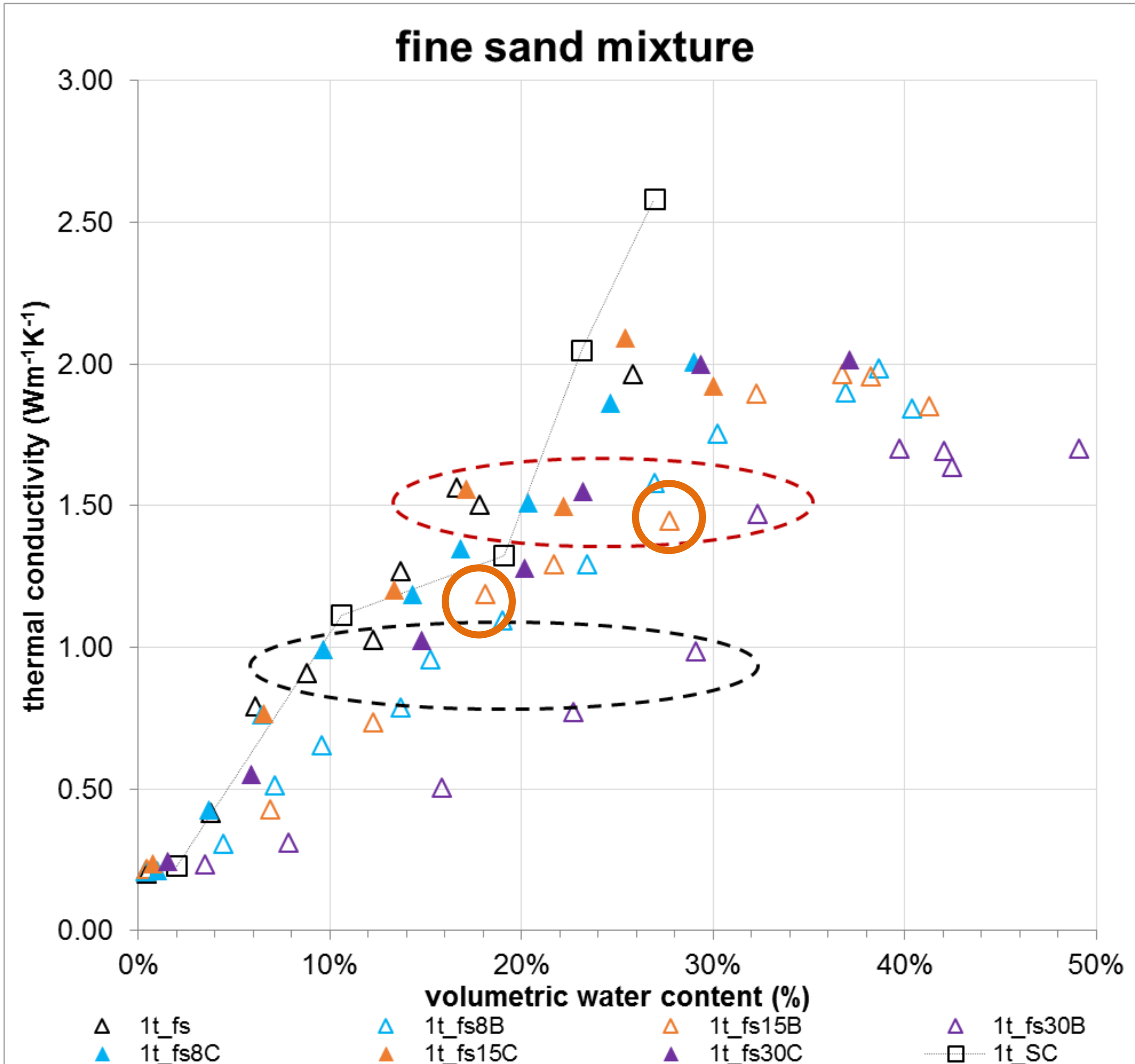

Conclusion

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- **several soil mixtures** characterized by different grain size distribution have been tested under different pressure, water content and mineralogical content allowing **to create a detailed database of physical-thermal properties variations in soil bodies**

- an increase of bulk density and / or moisture content lead to an **increase of the thermal conductivity.** However, the measurements performed on 15 different soil typologies **confirm the dominant influence of water content on the thermal conductivity**

- in the **fine sand mixtures**, the **increase of λ** with an increase of θ and ρ **is gradual** and lead all mixtures **to approaches an equilibrium** at circa 2.0 $Wm^{-1}K^{-1}$;

Conclusion

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- **bentonite and clay powder mixtures reach similar λ, but are characterized by different ρ and θ values** (ρ_{bent} between 1.2-1.6 gcm^{-3}; $\rho_{clay\ powder}$ between 1.4-1.8 gcm^{-3}; θ_{bent} > 40%, $\theta_{clay\ powder}$ < 40%).

- a **gradual (or rapid) increase of λ** with θ in soils implies also **a gradual (or rapid) dissipation of heat** following a water content reduction;

- **bentonite compounds** are **promising for *fs* mixtures**: the ***fs15B*** mixture has been selected, together with the coarse sand (***s***), the coarse sand mixture (***s15B***), the fine sand (***fs***), and loamy sand (***SC***) to be tested in situ.

Further outcomes / developments

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- the ***comparison between laboratory results and monitoring data***
- the ***influence of environmental conditions*** on VSGs
- the ***numerical simulation to evaluate the performance of the helix*** with different mixtures and taking into consideration the variation of environmental condition

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ITER Project

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http://iter-geo.eu/

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