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Thermal storage in packed beds of rock

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Fakulteit Ingenieurswese
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Faculty of Engineering

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P Gauché

Overview of presentation

Feasibility of packed beds of rock for thermal storage:

Packed bed pressure drop characteristics

- Prediction ?
- Particle shape, roughness, alignment ?

Packed bed thermal characteristics

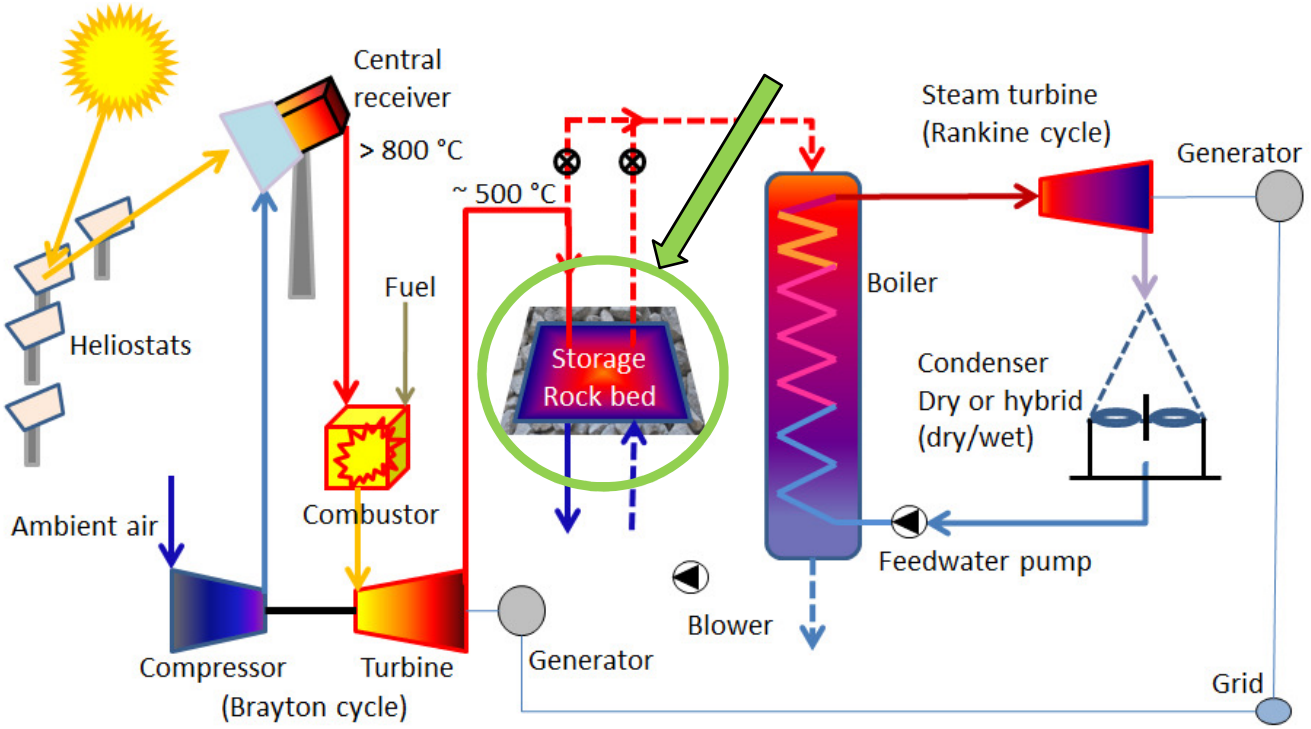
- Heat transfer coefficient (thermocline)
- Particle shape, roughness, alignment ?

Suitable rock – thermal limitation

- Rock properties & availability ?

Context example – SUNSPOT

- Store thermal energy from gas turbine exhaust
- Stored heat used for steam power cycle
- Storage temperature: ≈ 500 - 600 °C



SUNSPOT combined cycle schematic

Packed bed pressure drop and heat transfer

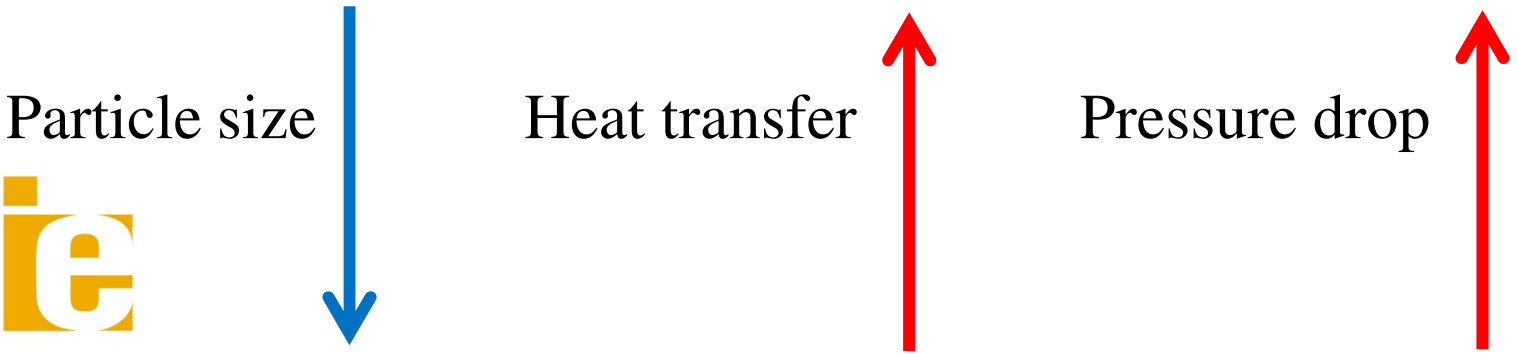
Prediction of pressure drop and heat transfer?

- Influence of particle shape, roughness, alignment?

- Existing pressure drop equations: Inadequate
  - Rock: under-predicts; up to 5 times [Shitzer and Levy, 1983]
- Heat transfer characteristics of rock beds:
  - Very little data at high temperature (≥ 500 °C)

Tension: heat transfer and pressure drop

- Optimum bed length ? Particle size ? Mass flux ?



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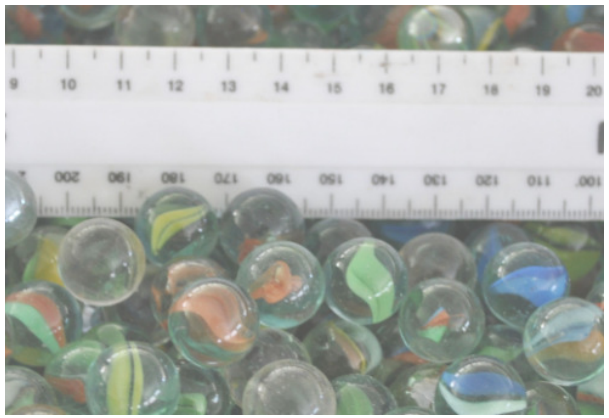
Samples of some particle types tested



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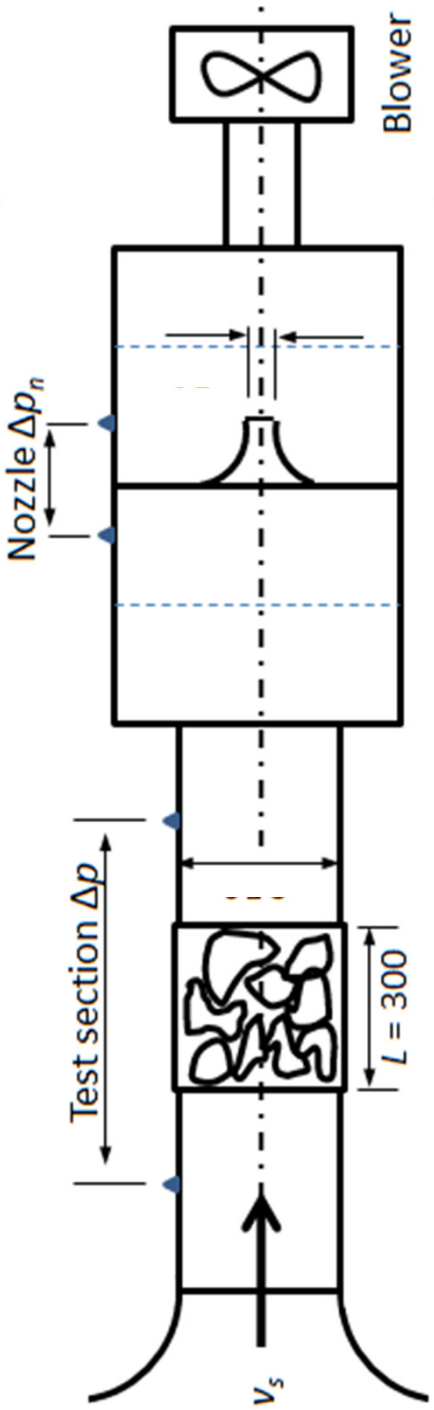

Wind tunnel test facility

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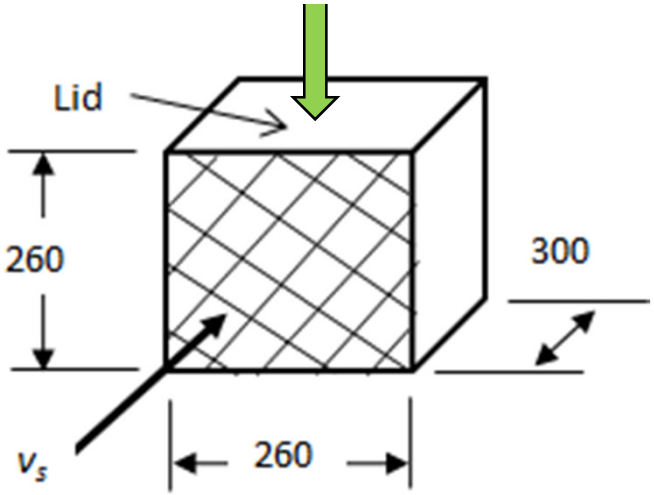
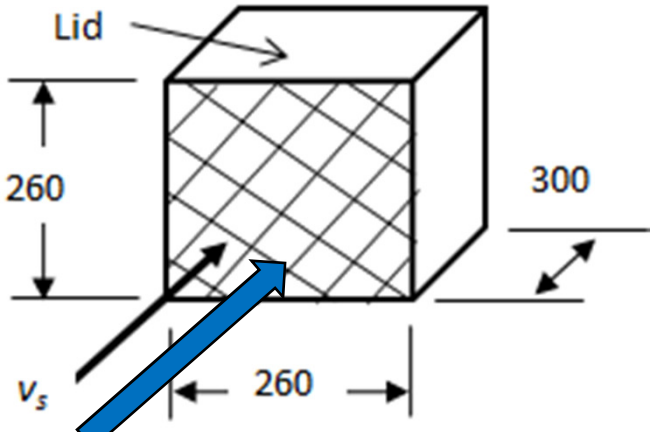
Test section size and packing method

Cross-current packing direction





Co-current packing direction (or counter-current)

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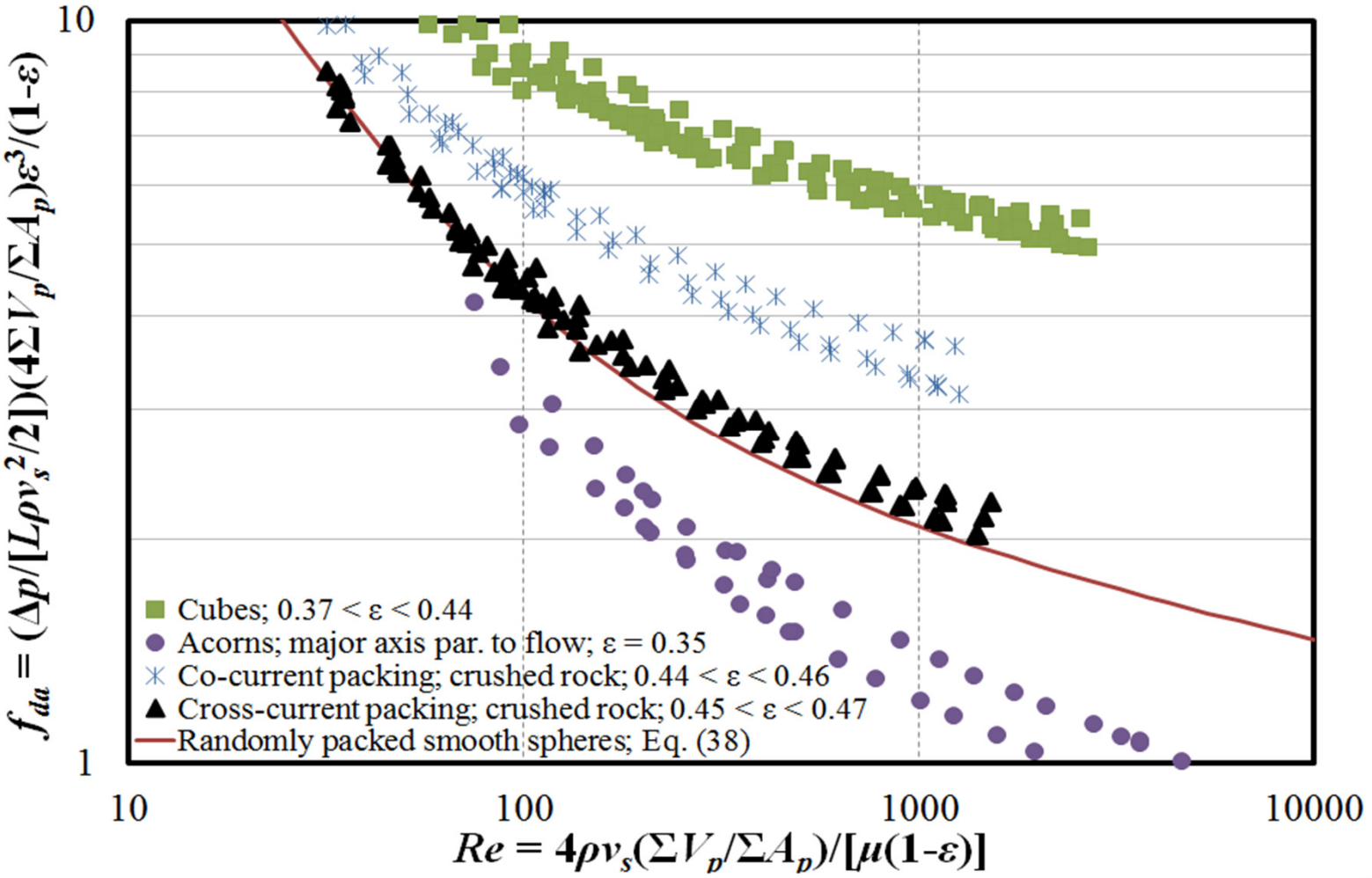
Variation of apparent friction factor



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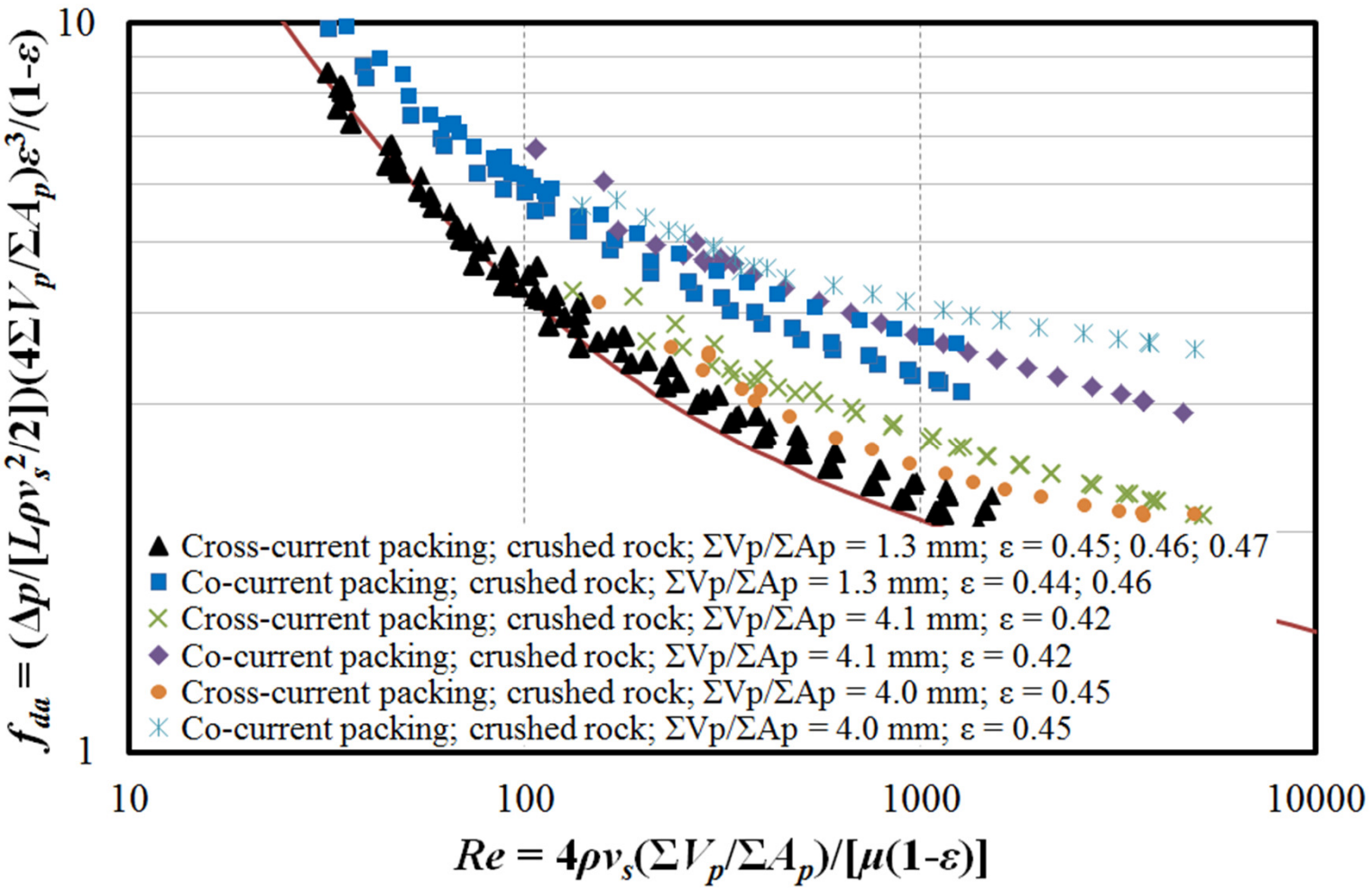
Apparent friction factors – crushed rock



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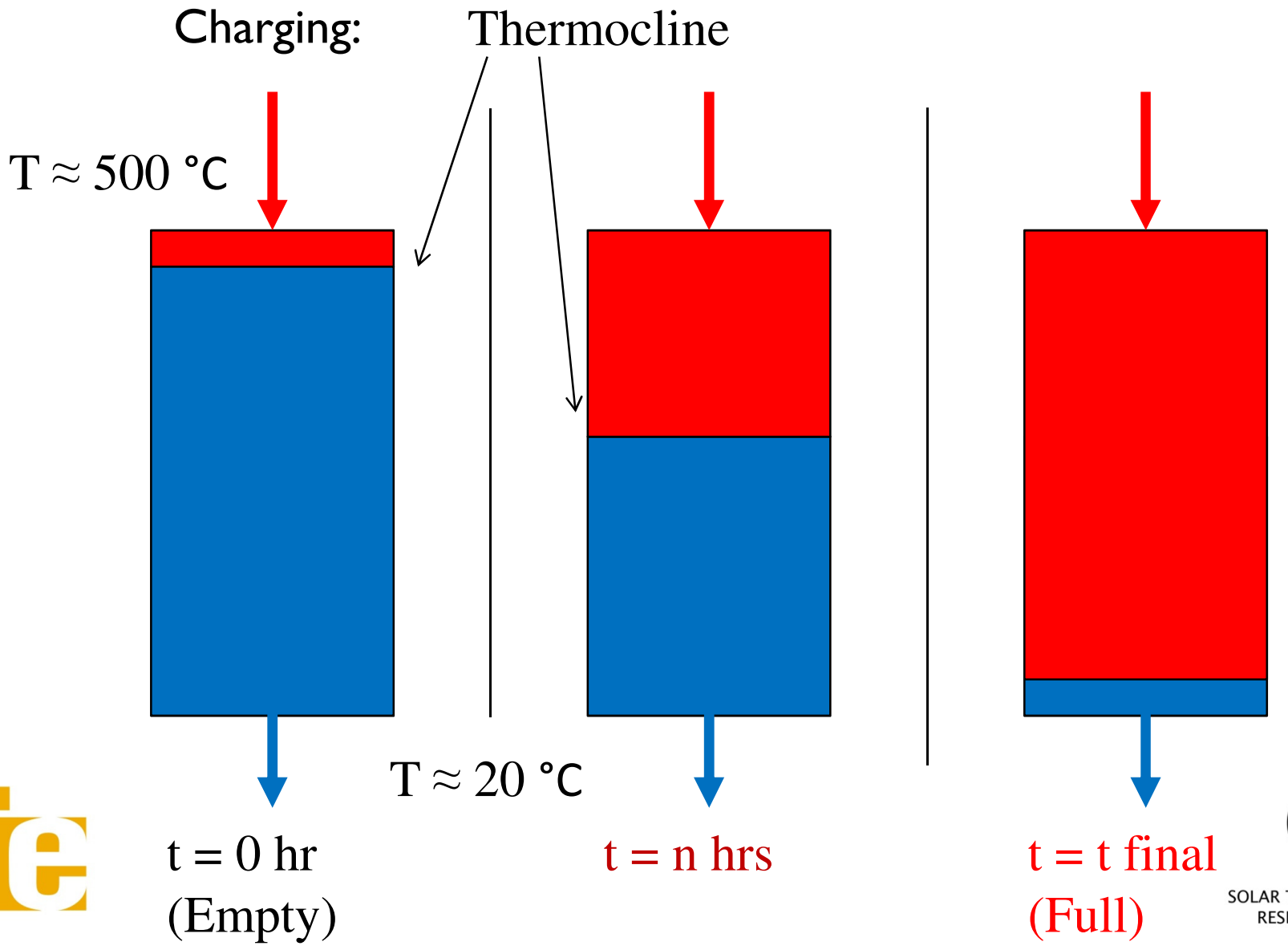
How does an ideal packed bed work?



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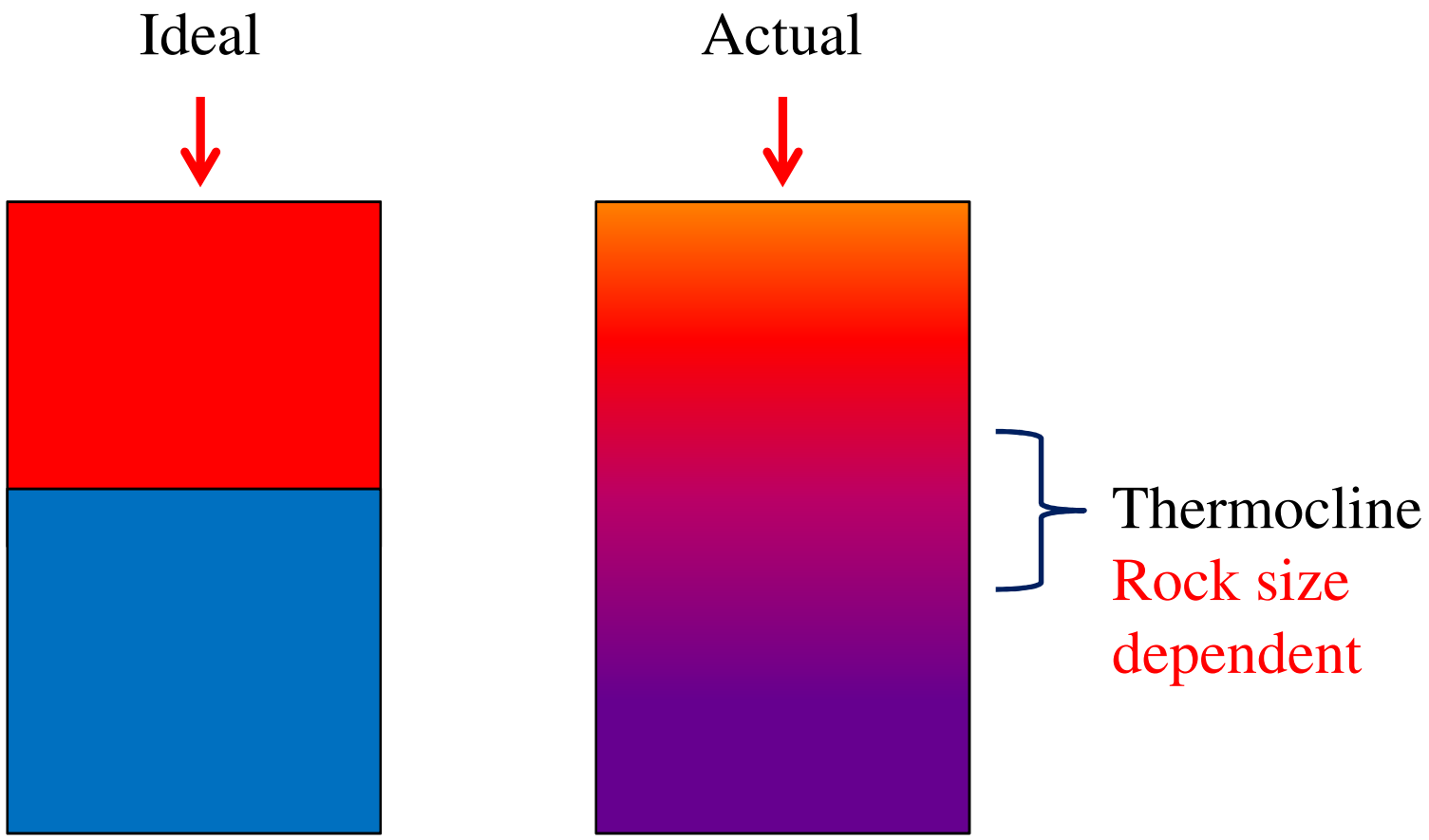
How does a real packed bed work?



Temperature profile?
Heat transfer?

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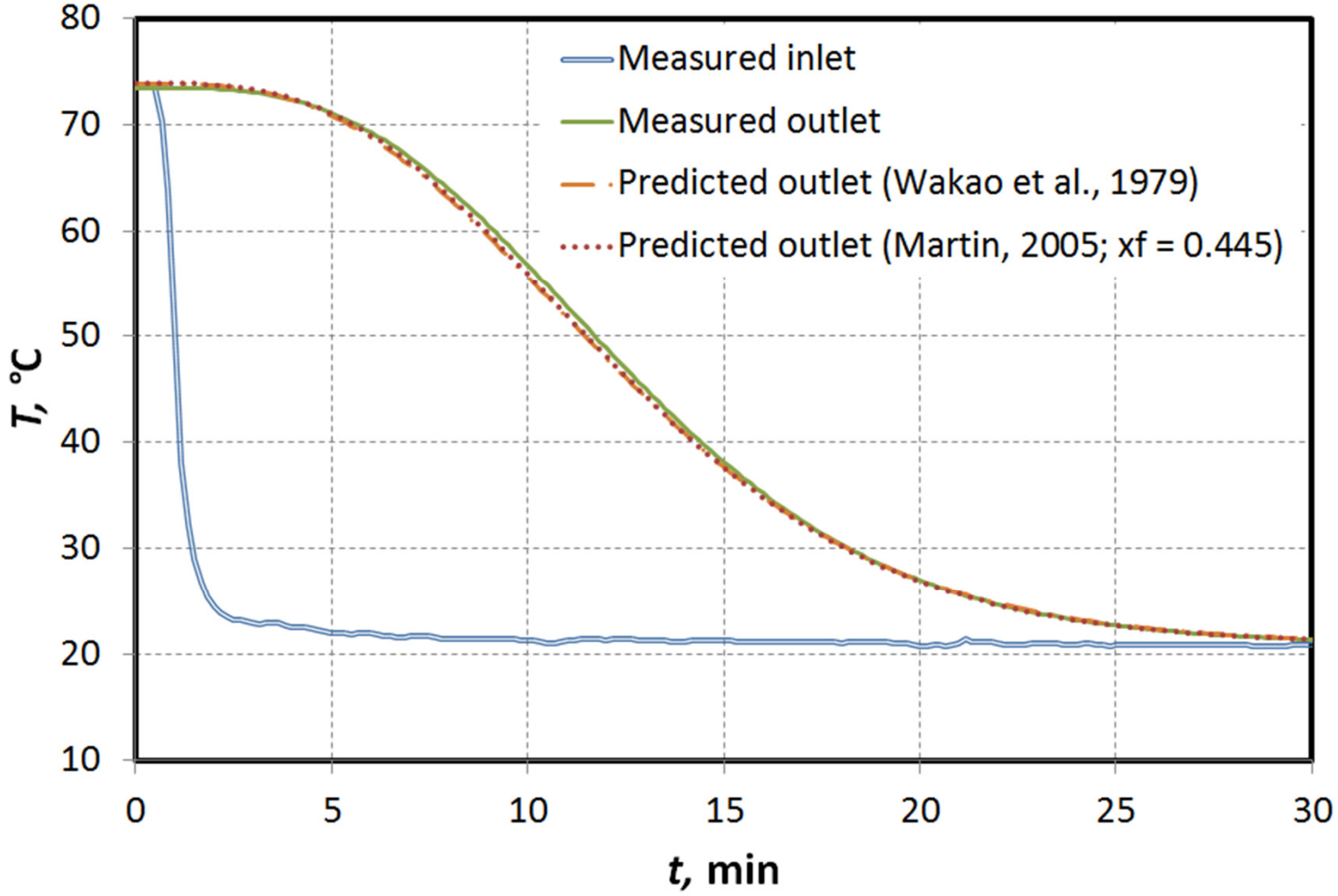
Heat transfer test – glass spheres



$Bi \approx 0.18;\ Re \approx 490$

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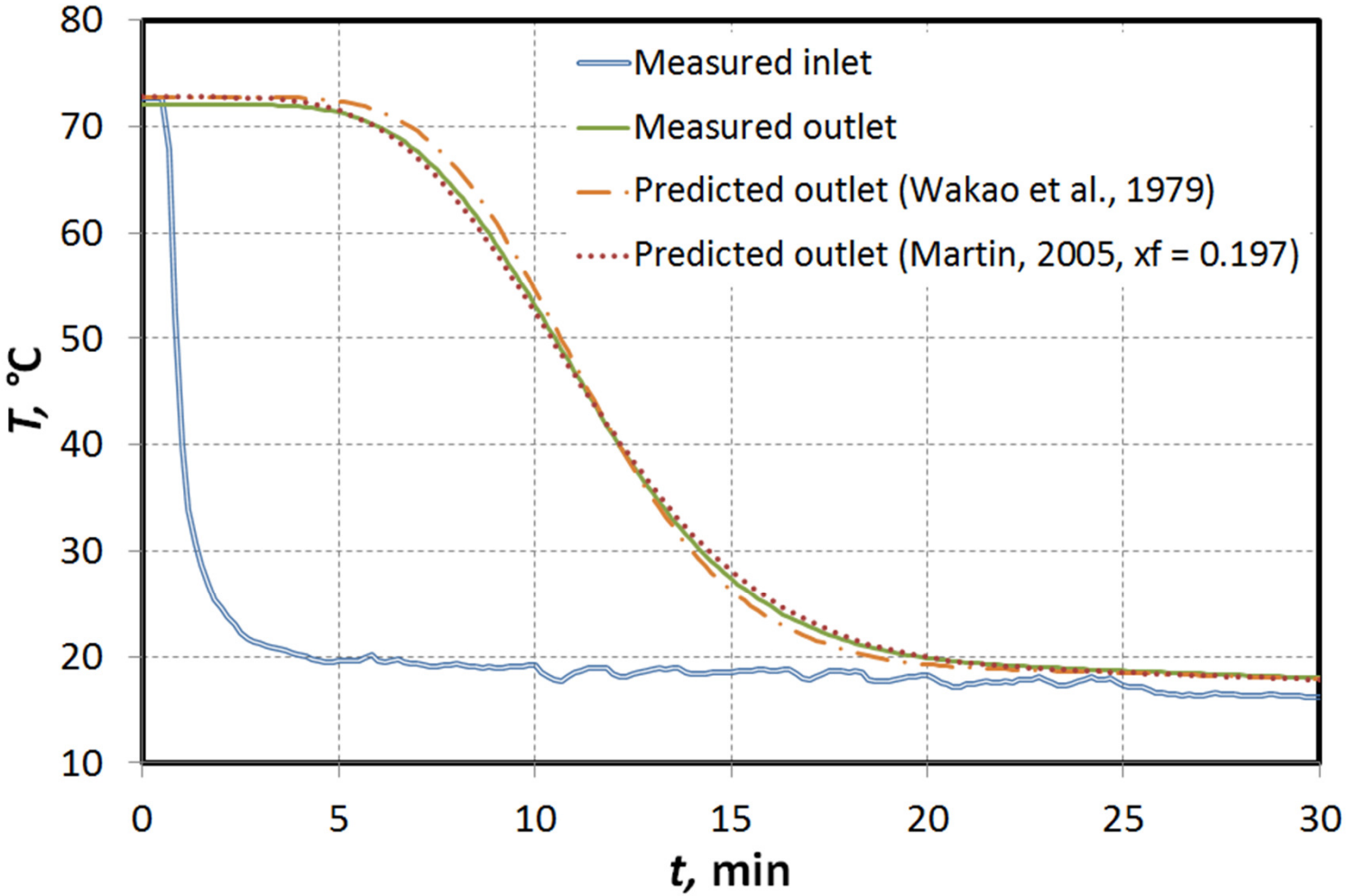
Heat transfer test – "13 mm" crushed rock



$Bi \approx 0.12$; $Re \approx 280$ (cross-current)

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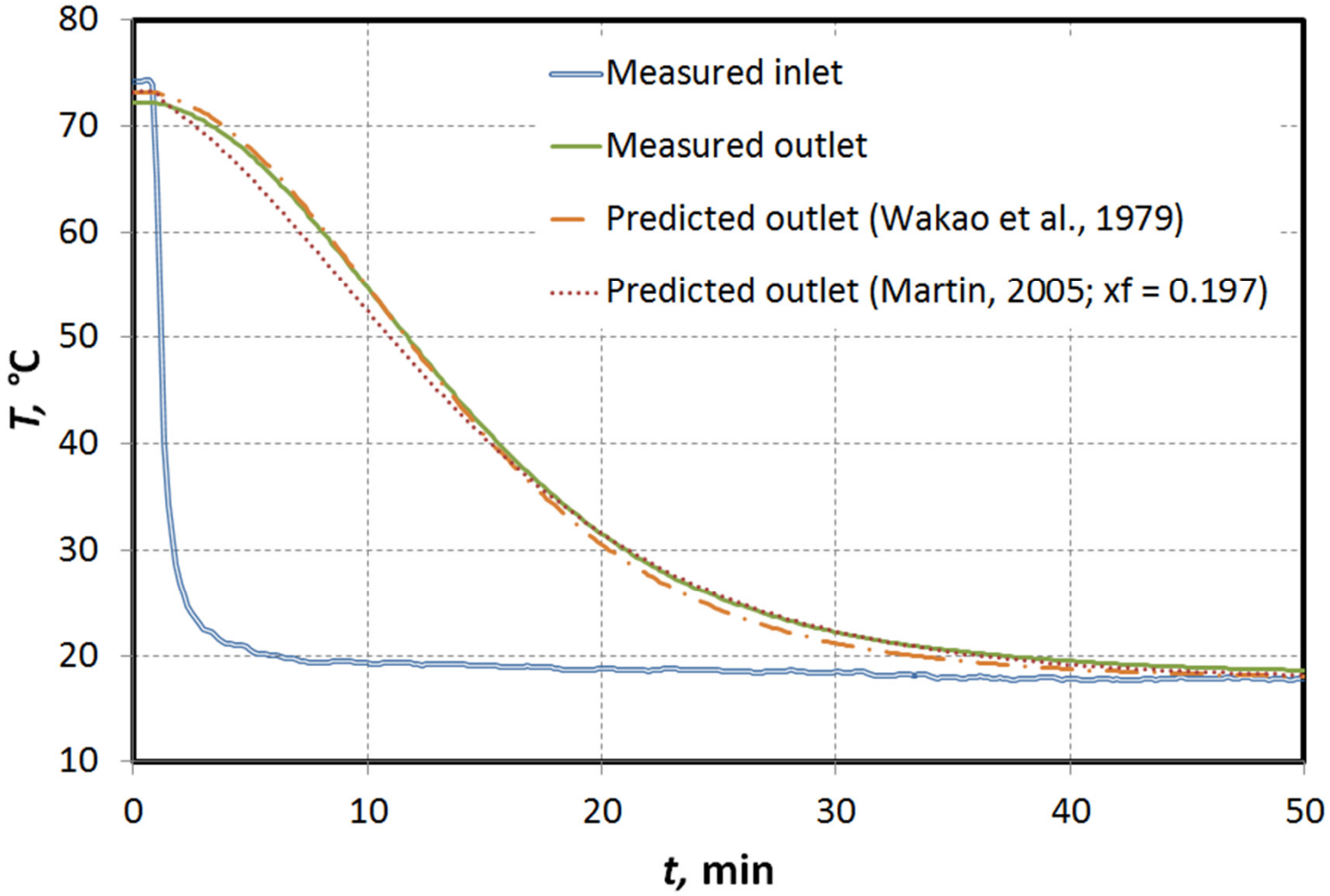
Heat transfer test – "26 mm" crushed rock



$Bi \approx 0.21$; $Re \approx 690$ (counter-current)

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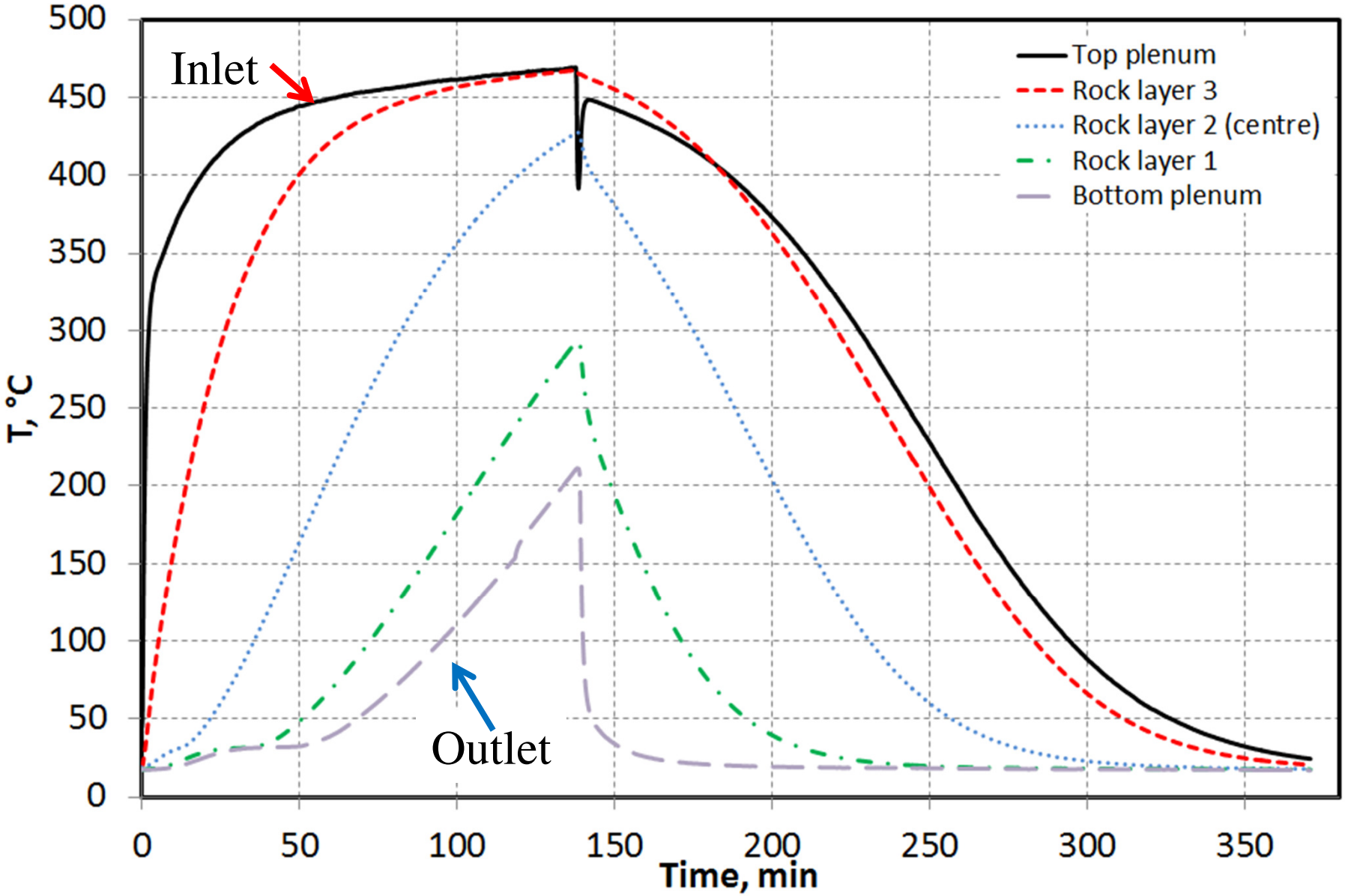
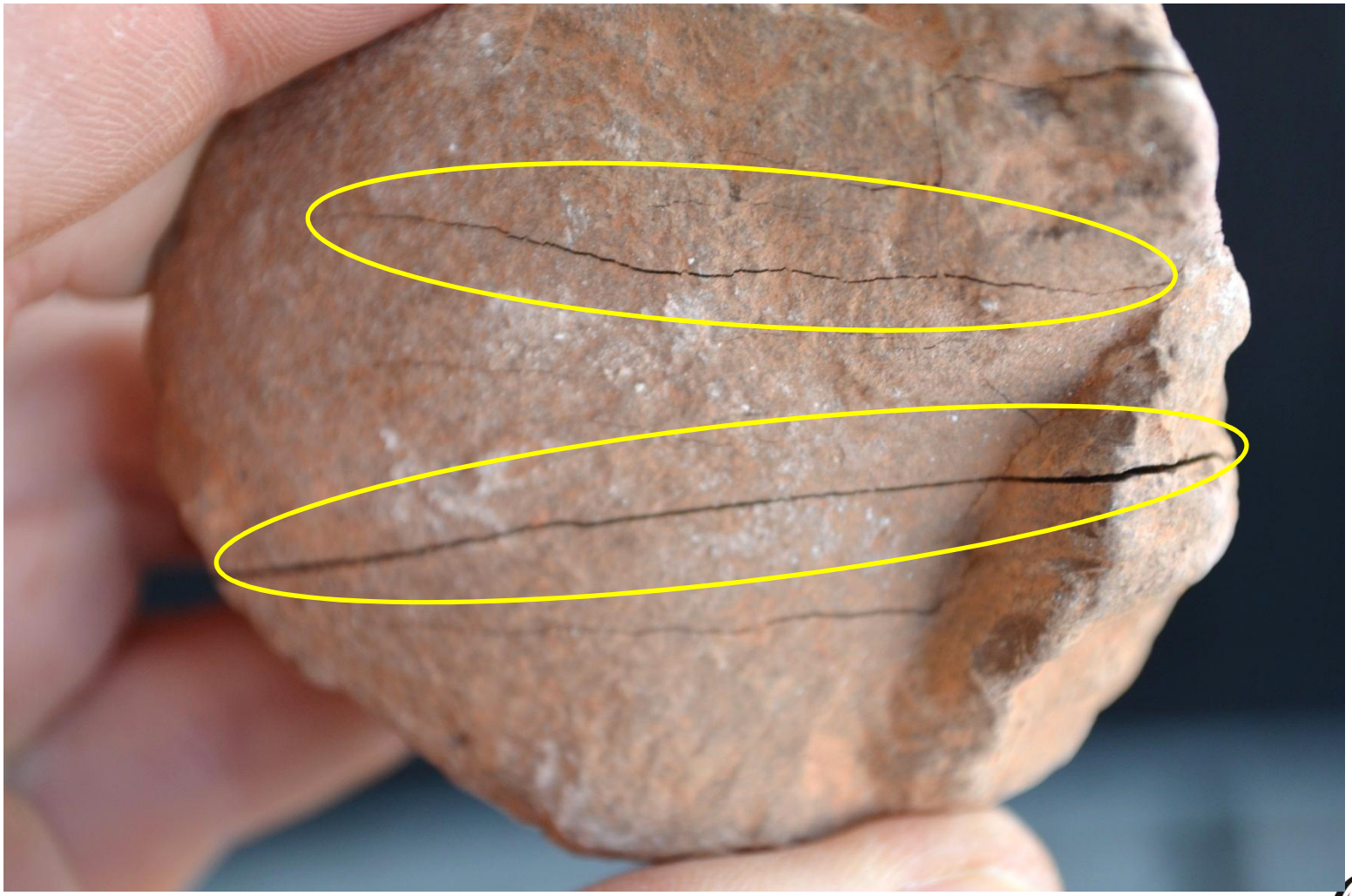
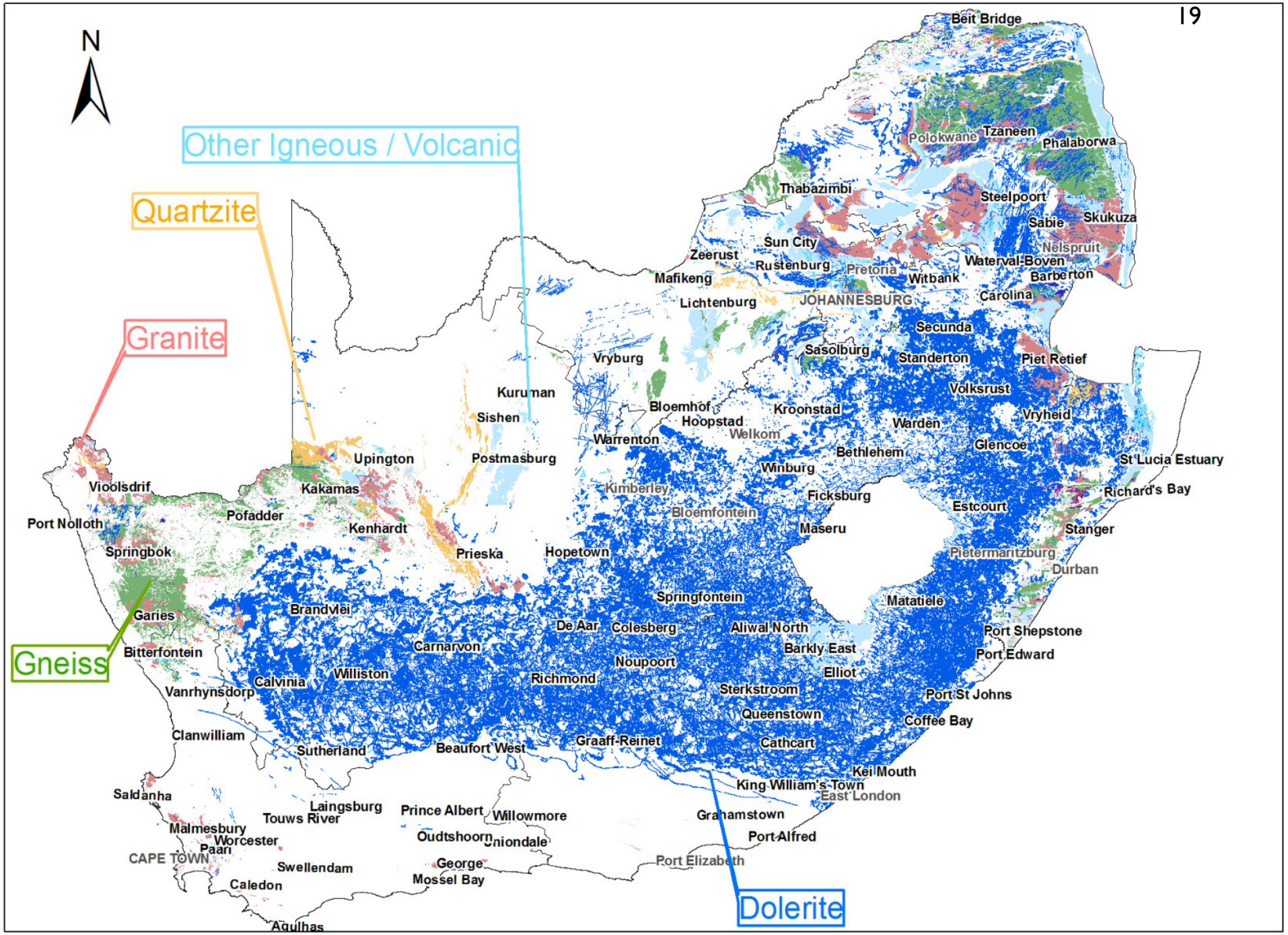
Sample temperature profile – charge-discharge



Rock suitability: thermal stress




N
Other Igneous / Volcanic
Quartzite
Granite
Gneiss
Dolerite
Beit Bridge
Polokwane
Tzaneen
Phalaborwa
Thabazimbi
Steelpoort
Sabie
Skukuza
Sun City
Nelspruit
Zeerust
Rustenburg
Pretoria
Witbank
Waterval-Boven
Barberton
Mafikeng
Lichtenburg
JOHANNESBURG
Carolina
Secunda
Sasolburg
Standerton
Piet Retief
Vryburg
Volksrust
Kuruman
Bloemhof
Kroonstad
Vryheid
Sishen
Hoopstad
Welkom
Warden
Warrenton
Glencoe
Upington
Postmasburg
Bethlehem
St Lucia Estuary
Winburg
Viooldsrif
Kakamas
Kimberley
Ficksburg
Richard's Bay
Bloemfontein
Estcourt
Pofadder
Port Nolloth
Kenhardt
Maseru
Stanger
Springbok
Prieska
Hopetown
Pietermaritzburg
Durban
Springfontein
Matatiele
Brandvlei
Garies
De Aar
Colesberg
Aliwal North
Port Shepstone
Carnarvon
Barkly East
Bitterfontein
Noupoort
Port Edward
Williston
Elliot
Calvinia
Richmond
Sterkstroom
Port St Johns
Vanrhynsdorp
Queenstown
Coffee Bay
Clanwilliam
Graaff-Reinet
Cathcart
Sutherland
Beaufort West
Kei Mouth
King William's Town
East London
Saldanha
Laingsburg
Prince Albert
Willowmore
Grahamstown
Touws River
Malmesbury
Oudtshoorn
Uniondale
Port Alfred
Worcester
Paarl
CAPE TOWN
Swellendam
George
Port Elizabeth
Caledon
Mossel Bay
Agulhas

Conclusions

- Pressure drop
  - Importance of particle shape, roughness, arrangement
  - No general correlation
- Temperature profile & heat transfer
  - Existing correlations & numerical model work well up to ≈ 100 °C
  - Need to check radiation at higher temperatures
- Rock suitability & availability
  - Potentially suitable rock available in South Africa

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