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► To cite this version:

Agnès Duri-Bechemilh, Sandra Mandato, Bernard Cuq, Thierry Ruiz. Stress distribution inside a powder bed: does Janssen's model applicable locally in a granular medium. 7. World Congress on Particle Technology (WCPT7), May 2014, Pekin, China. hal-01606814

HAL Id: hal-01606814

<https://hal.science/hal-01606814>

Submitted on 3 Jun 2020

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WCPT 7

T1.2 Particle property and inter-particle force characterization

**Stress distribution inside a powder bed:
does Janssen's model applicable locally
in a granular medium?**

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**What is the local stress distribution
in an ensiled granular media ?**



What is the local stress distribution in an ensiled granular media ?

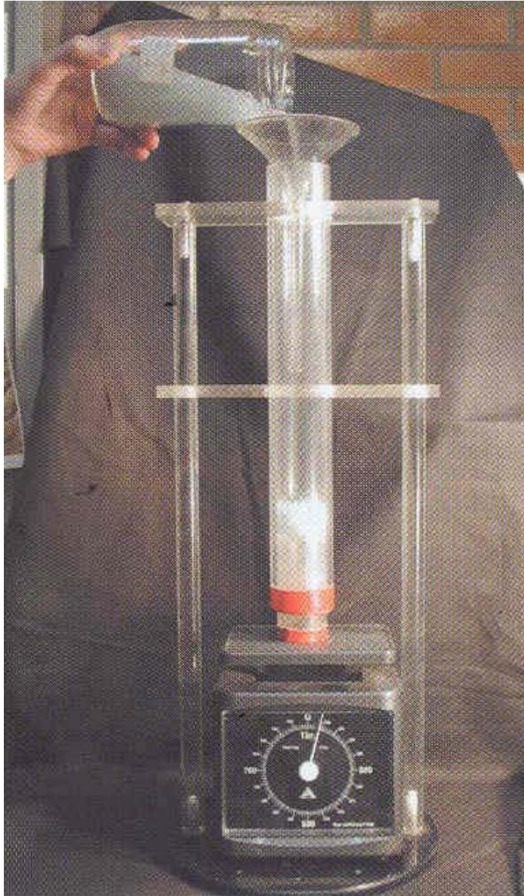


Applications:

- ” Stability of silos
- ” Initial state before powder flowing (mixing processing...)

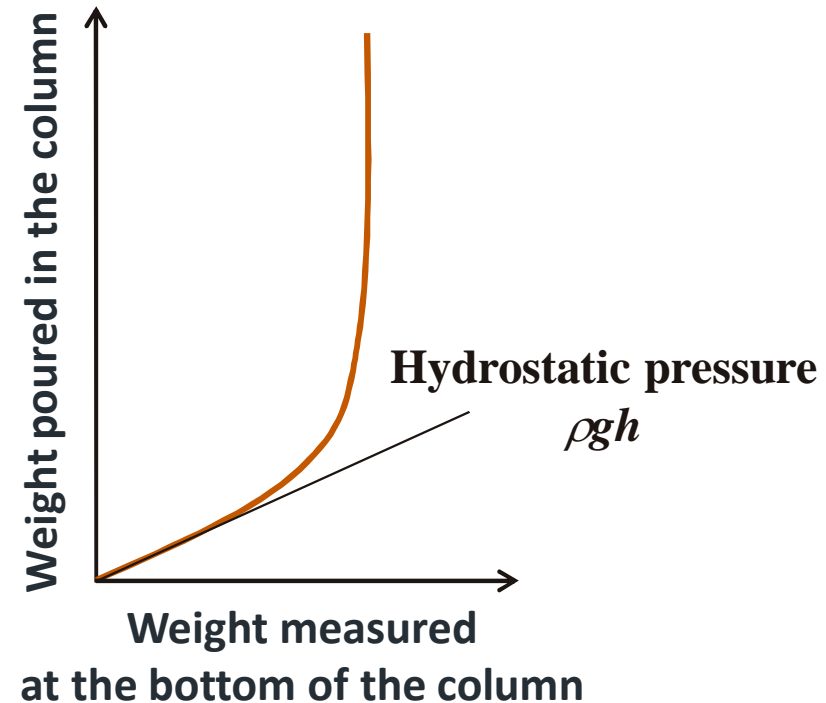
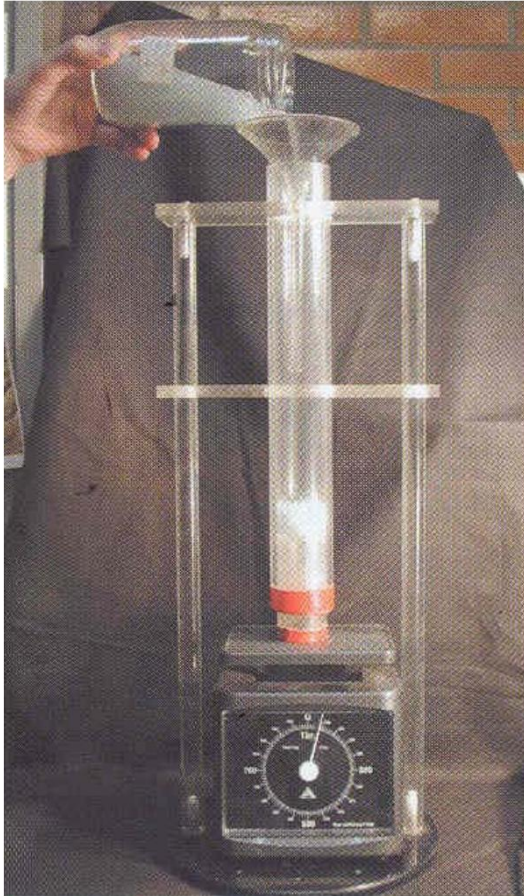
The well-known Janssen's experiment (1895)

Weight measurement at the **bottom** of a cylindrical grain column



The well-known Janssen's experiment (1895)

Weight measurement at the bottom of a cylindrical grain column



From a certain height of bed, any powder addition does not make any variation of mass weighed at the bottom

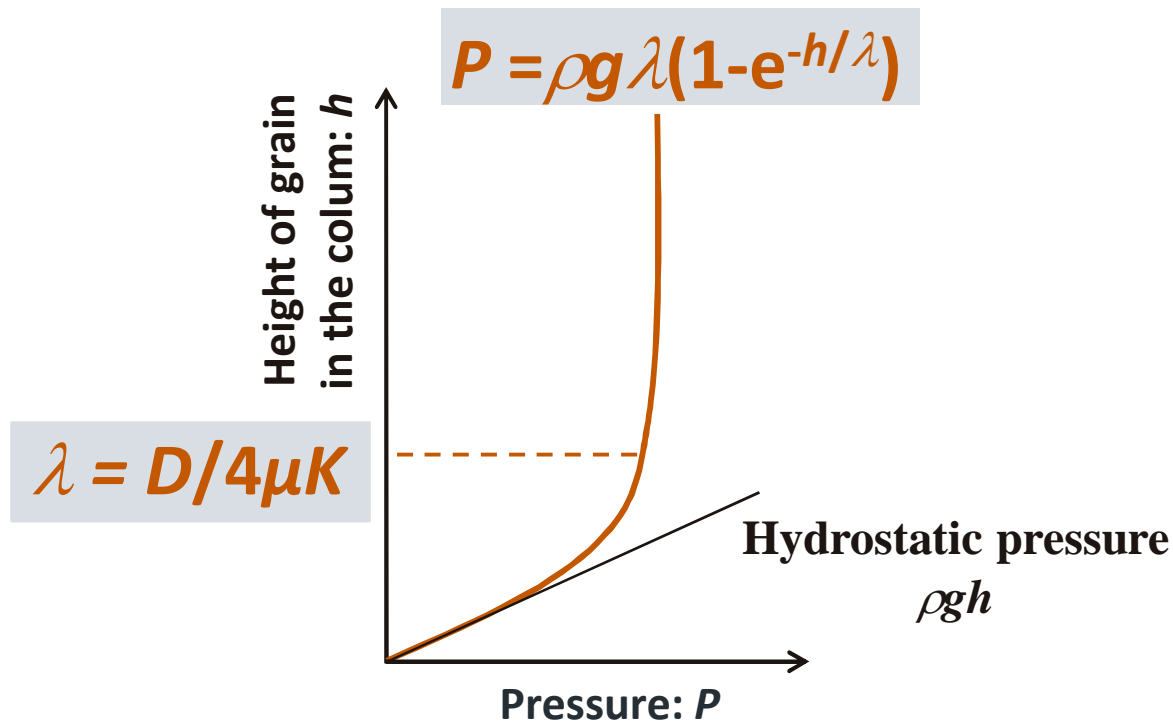
Pressure at the **bottom** of a cylindrical grain column

- 3 hypotheses:
- “ **Lateral uniformity** of the vertical stress (layer model)
 - “ The **horizontal stress** is **proportional** to the **vertical stress**
 - “ **Slipping at the wall** (Coulomb criterion)

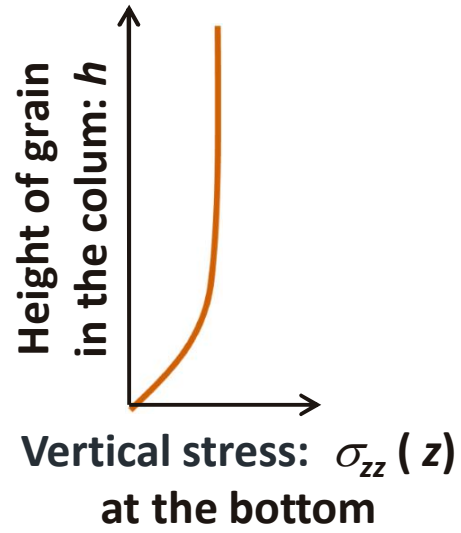
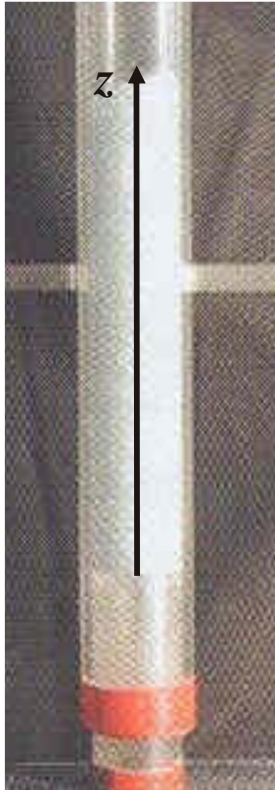
Janssen's model

Pressure at the bottom of a cylindrical grain column

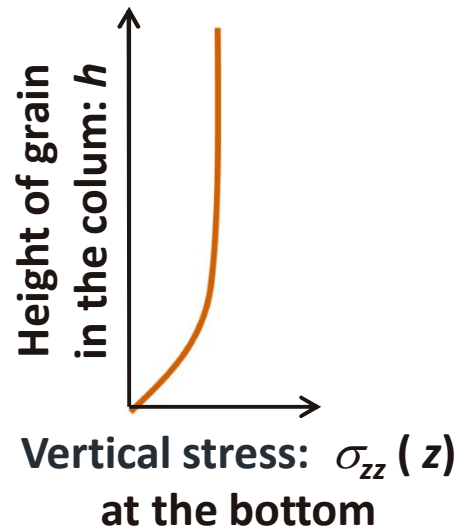
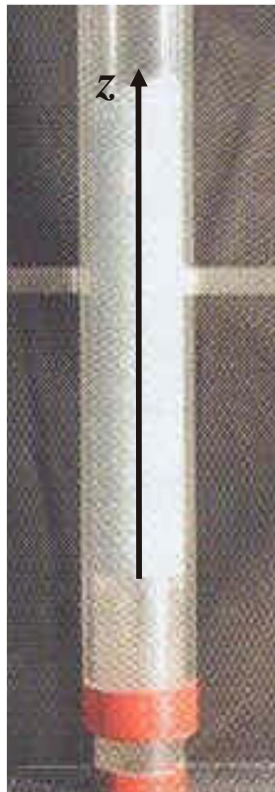
- 3 hypotheses:
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 - “ The horizontal stress is proportional to the vertical stress
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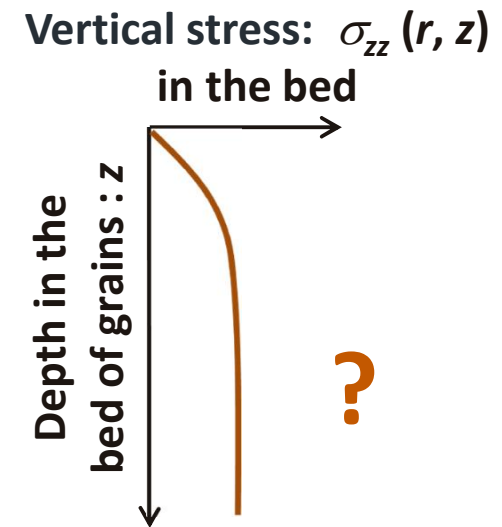
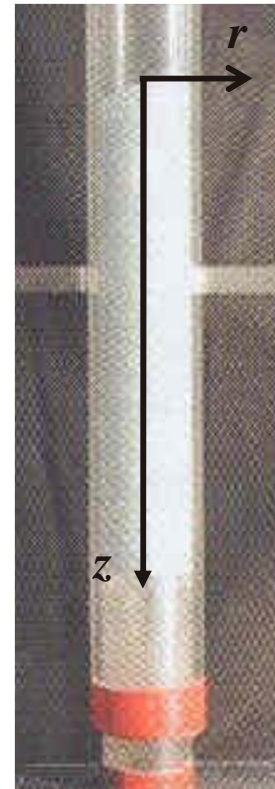
Weight deflection into lateral sides of the column



BOTTOM

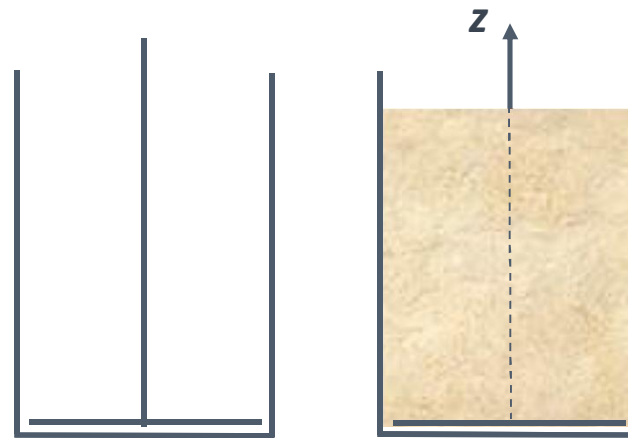


BOTTOM

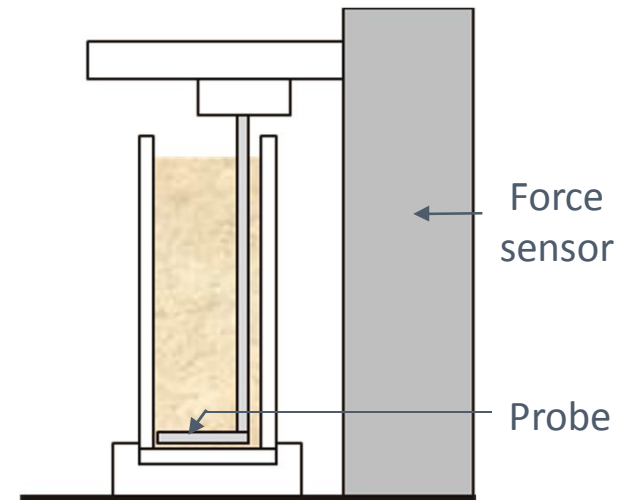


BULK

Profile of the local vertical stress in an ensiled granular media?
Effect of the particle size?

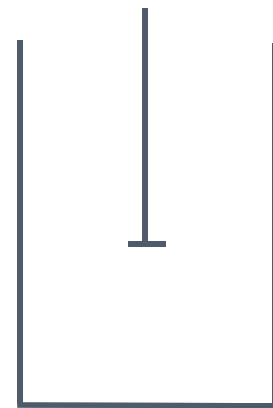
Rheological deviceJanssen's experiment: large probe

Front view
Large probe

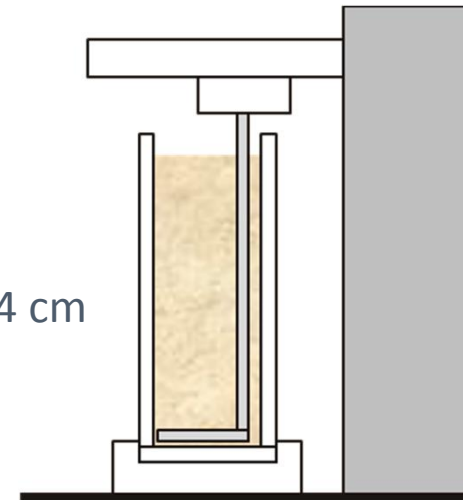
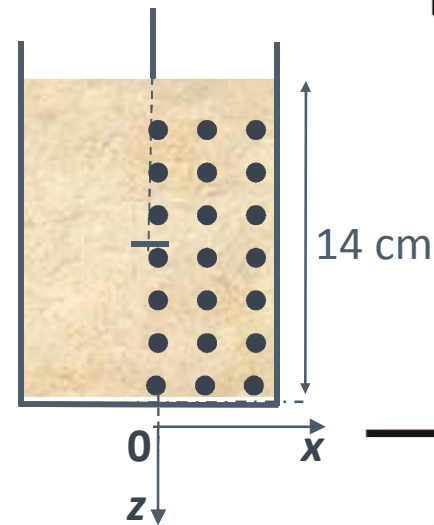


Side view
of the texture analyser

Measurement of the vertical stress
at the **bottom** of the cell
 $0 < z \leq 14$ cm (height of the bed)

2D rheological device**Local experiment: small probe**

Front view
Small probe

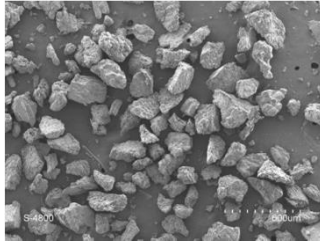


Side view
of the texture analyser

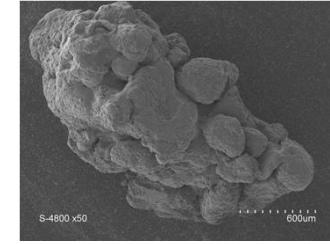
Measurement of the vertical stress
in the granular bed

$0 < x \leq 4 \text{ cm} \ \& \ 0 < z \leq 14 \text{ cm}$ (position in the bed)

2D-cartography of the local vertical stress

*Semolina*

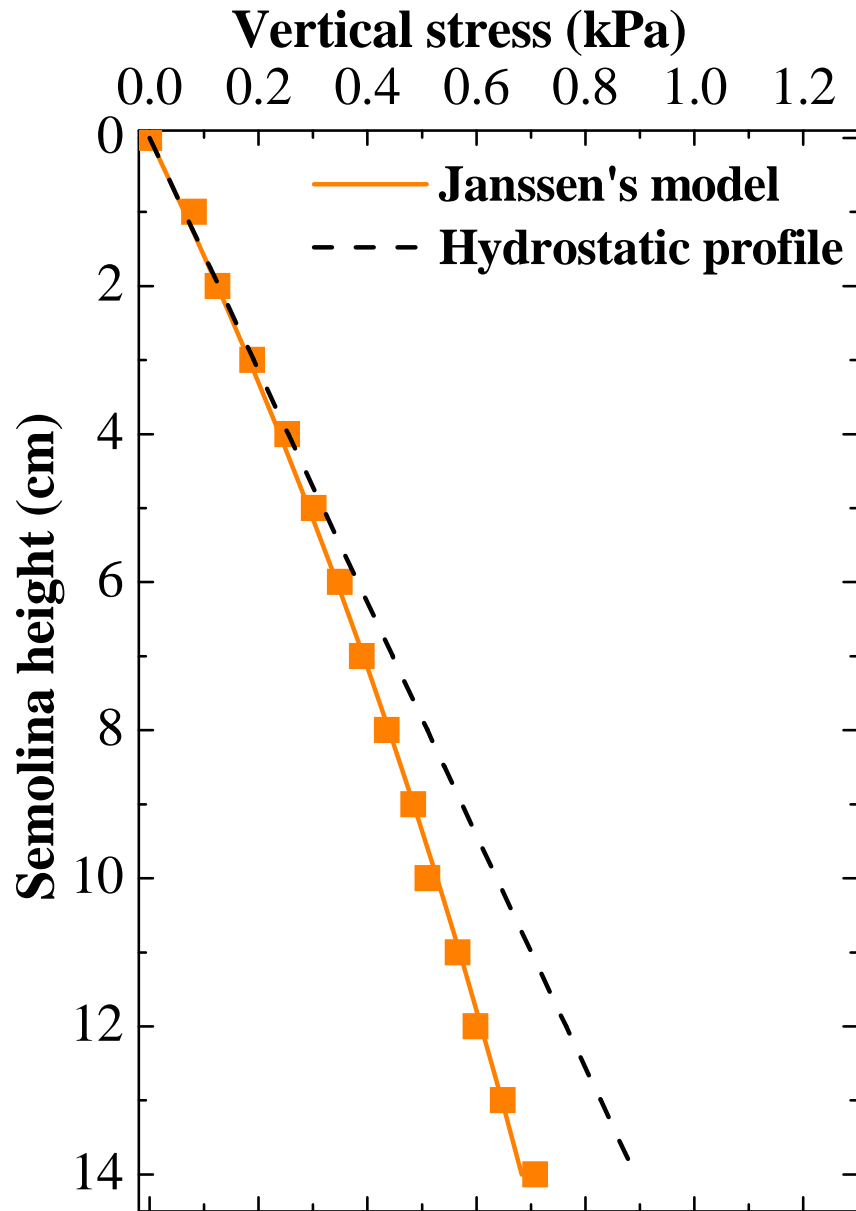
Wheat-based powders

*Couscous grain*

- “ **Native powder : durum wheat semolina** (pasta, noodle, couscous...)
 - Characterisation of the local vertical stress profiles
- “ **A range of 5 wheat-based powders : native and agglomerated particles**
 - Effect of the **size** and the structure on the local vertical stress profiles

Sample Name	d_{50} (μm)	dsp
Fine semolina	210	1.53
Medium semolina	300	1.46
Fine couscous	680	0.95
Medium couscous	950	0.54
Large couscous	1100	0.37

Janssen's profile



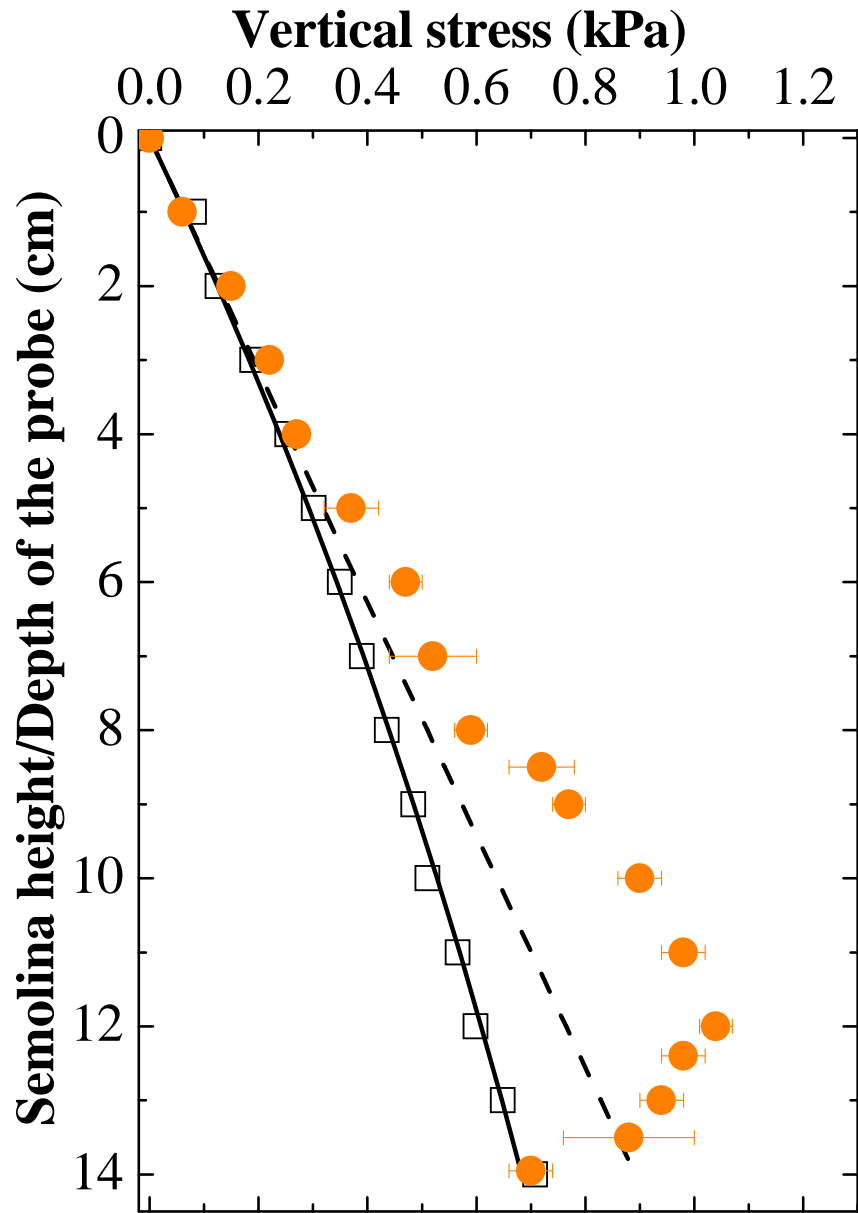
Janssen's profile:

“ Deviation from the hydrostatic profile

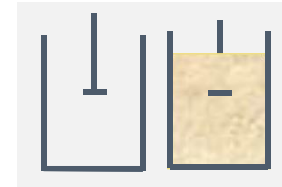
“ $\lambda = 23 \text{ cm}$

Screening of the weight by the lateral sides of the cell

Janssen & local vertical stress profiles in the center of the cell

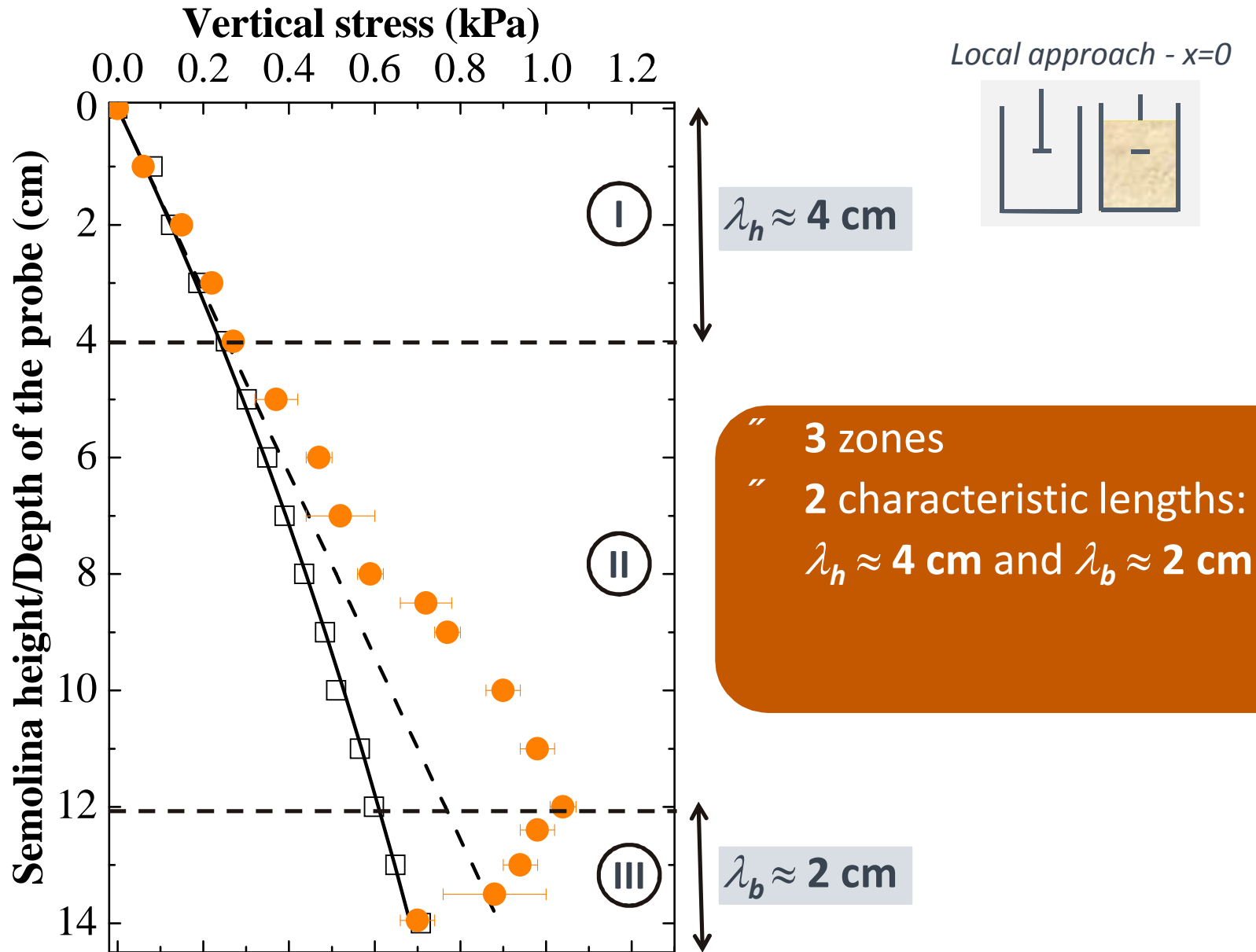


Local approach - $x=0$



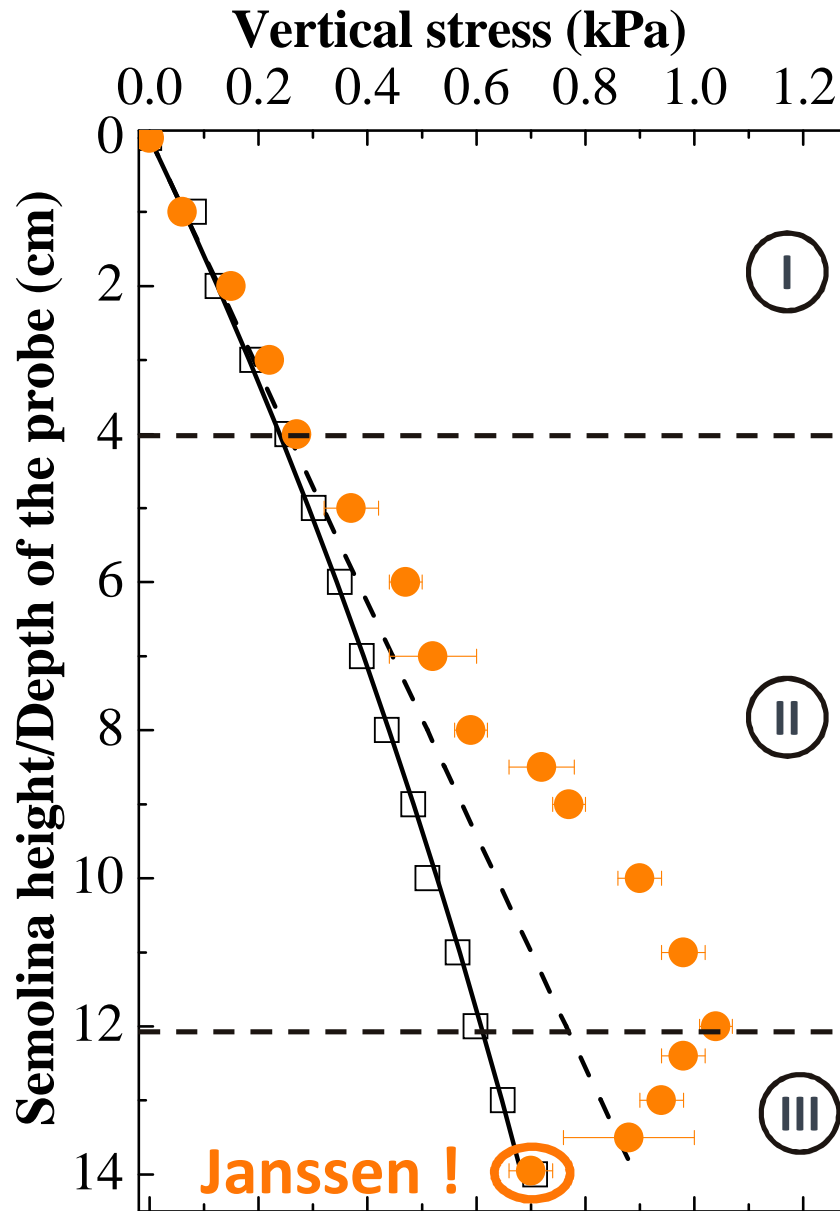
Local profile \neq Janssen's profile

Janssen & local vertical stress profiles in the center of the cell

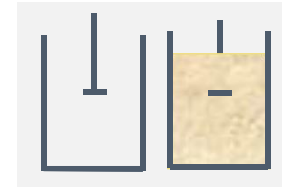


3 zones
 2 characteristic lengths:
 $\lambda_h \approx 4$ cm and $\lambda_b \approx 2$ cm

Janssen & local vertical stress profiles in the center of the cell



Local approach - $x=0$

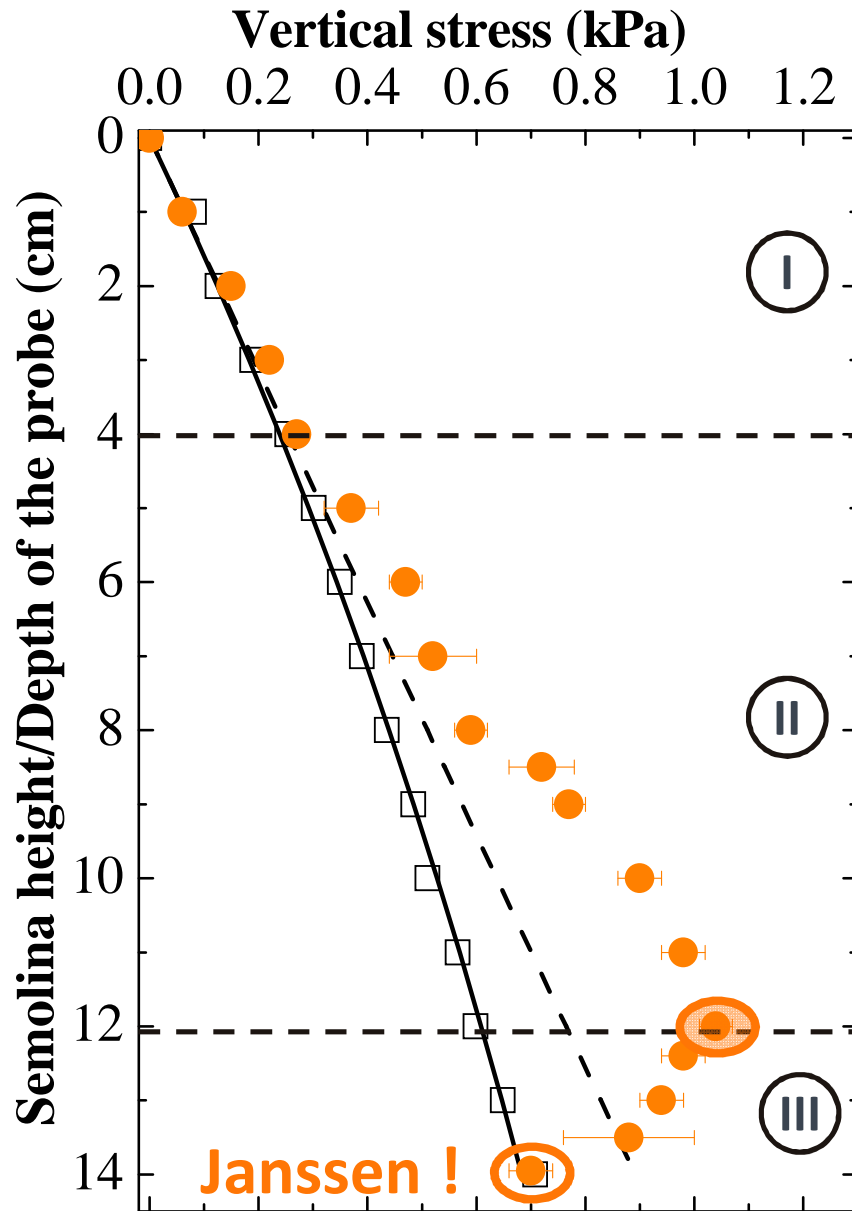


$\lambda_h \approx 4 \text{ cm}$

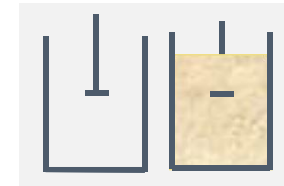
- ” 3 zones
- ” 2 characteristic lengths:
 $\lambda_h \approx 4 \text{ cm}$ and $\lambda_b \approx 2 \text{ cm}$
- ” Janssen value at the **bottom** of the cell !

$\lambda_b \approx 2 \text{ cm}$

Janssen & local vertical stress profiles in the center of the cell



Local approach - $x=0$

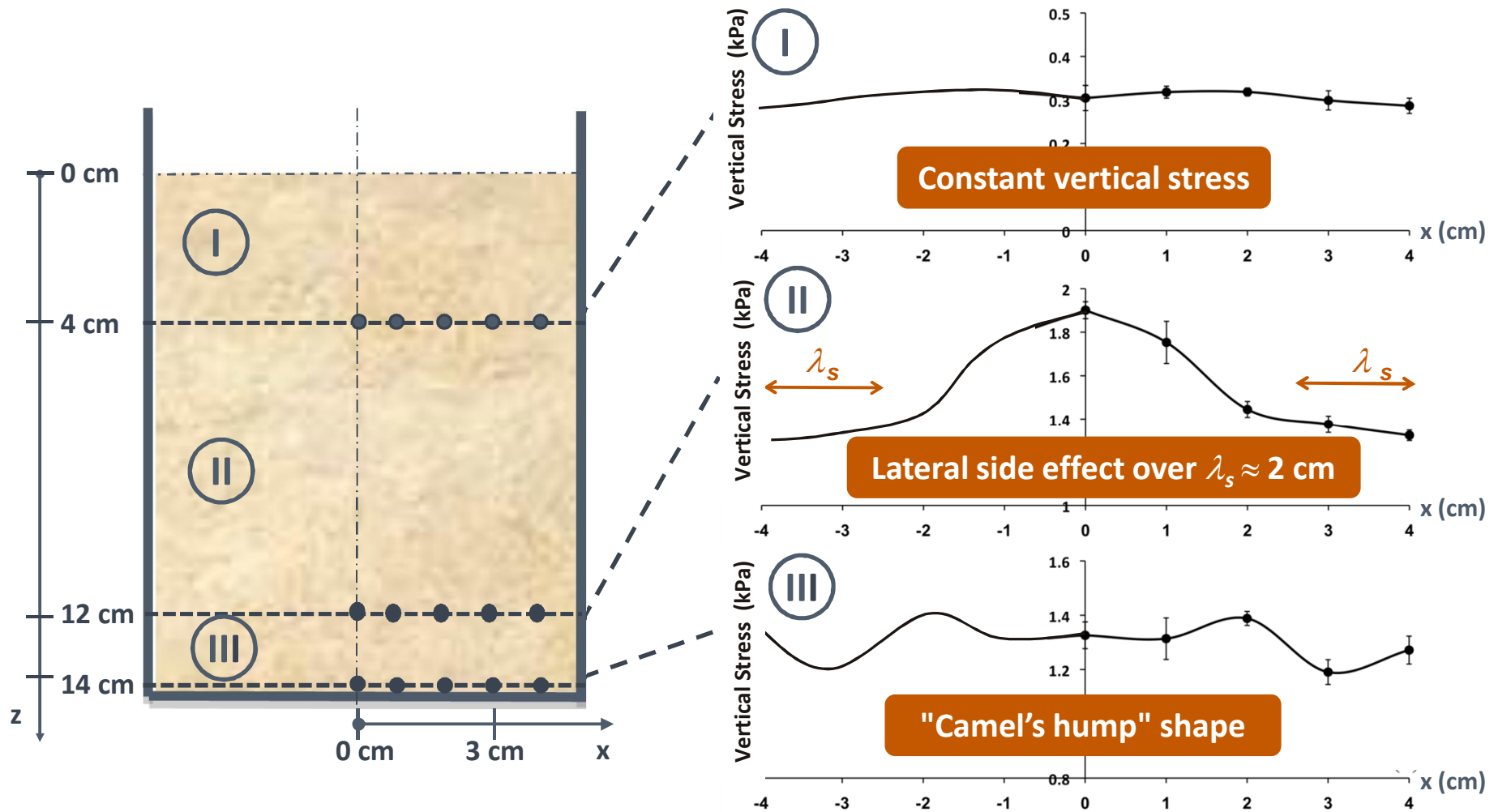


$\lambda_h \approx 4 \text{ cm}$

- ” 3 zones
- ” 2 characteristic lengths:
 $\lambda_h \approx 4 \text{ cm}$ and $\lambda_b \approx 2 \text{ cm}$
- ” Janssen value at the **bottom** of the cell !

$\lambda_b \approx 2 \text{ cm}$

Local vertical stress profiles in horizontal plane

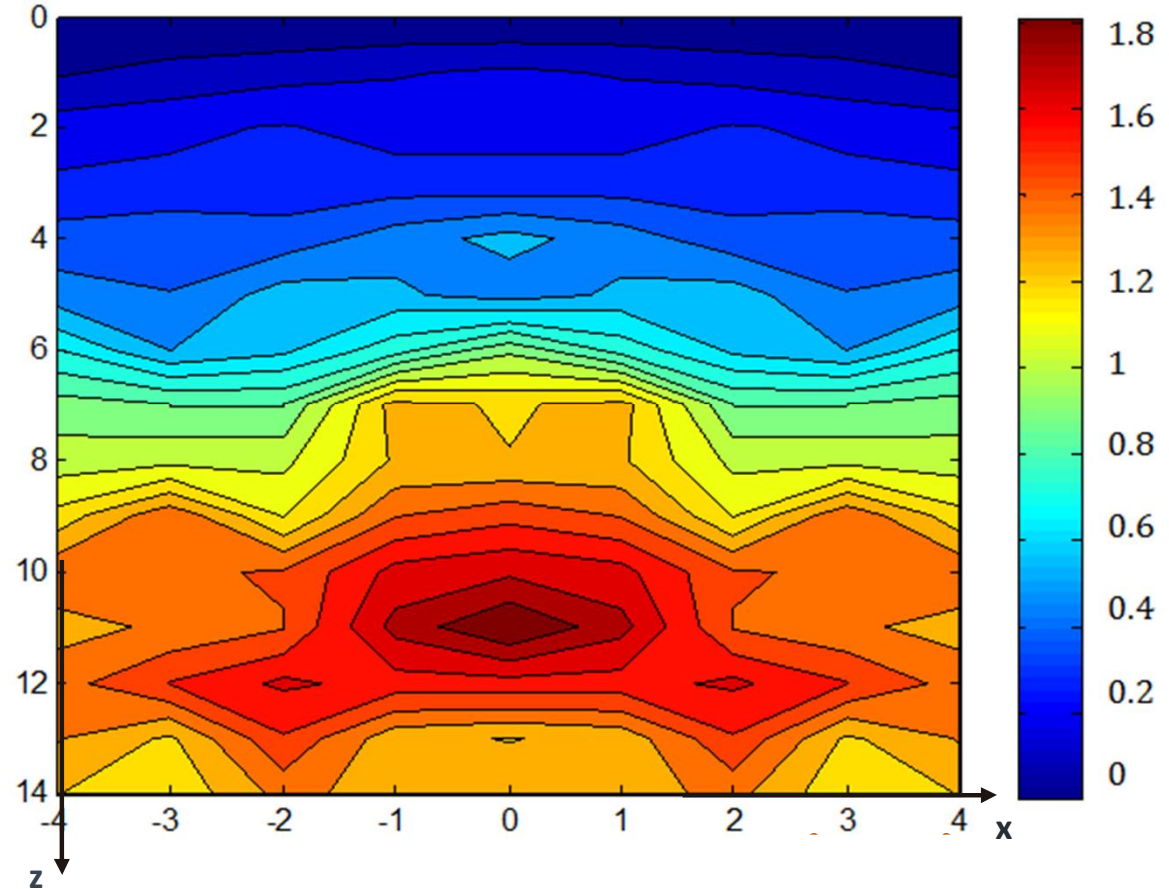


“ Zone I: Lateral uniformity of the vertical stress
 “ Zone II & III: Lateral inhomogeneity of the vertical stress
 ⇒ Janssen's hypothesis not checked for semolina

2D iso-stress cartography

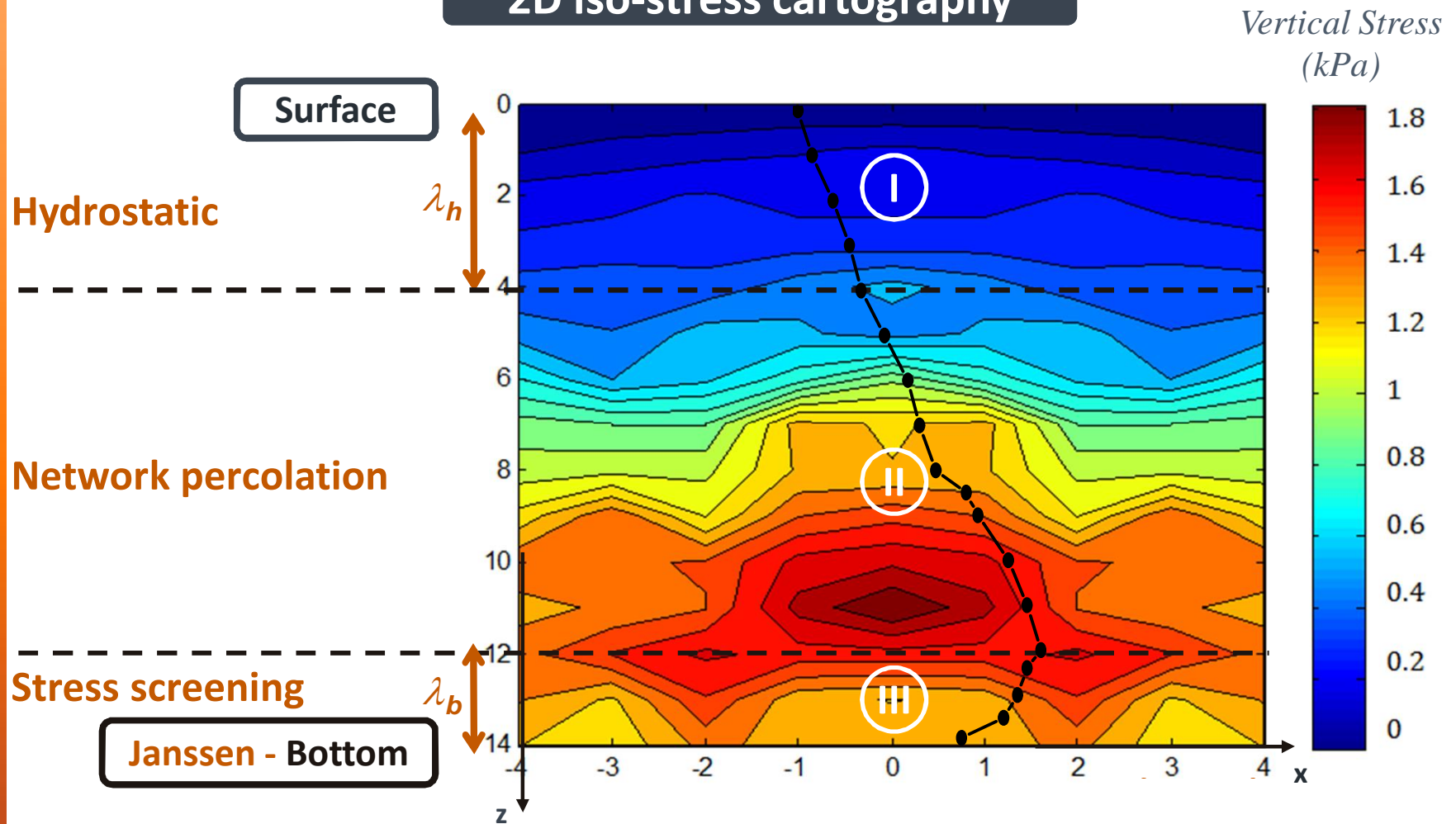
Surface

*Vertical Stress
(kPa)*

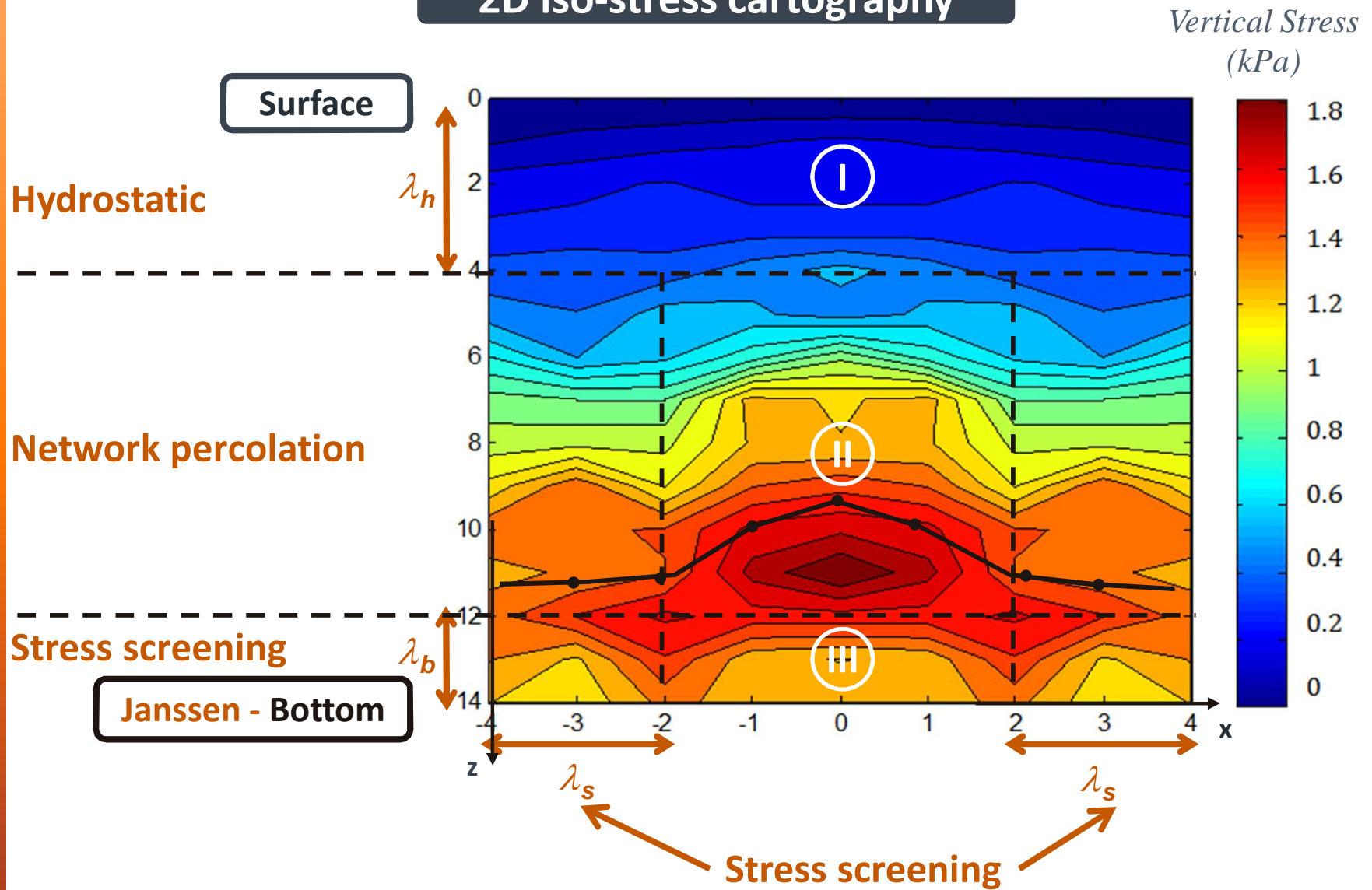


Bottom

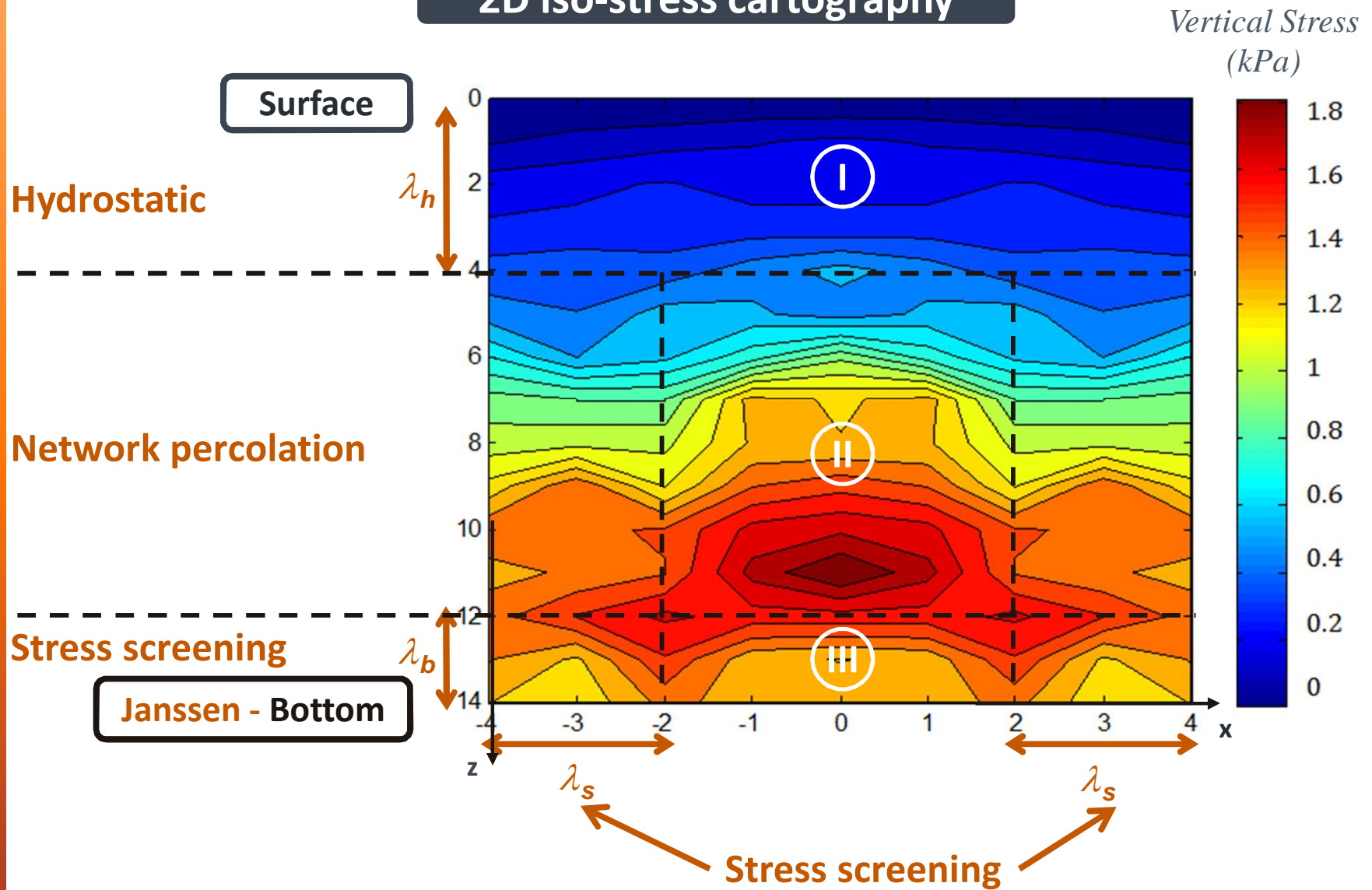
2D iso-stress cartography



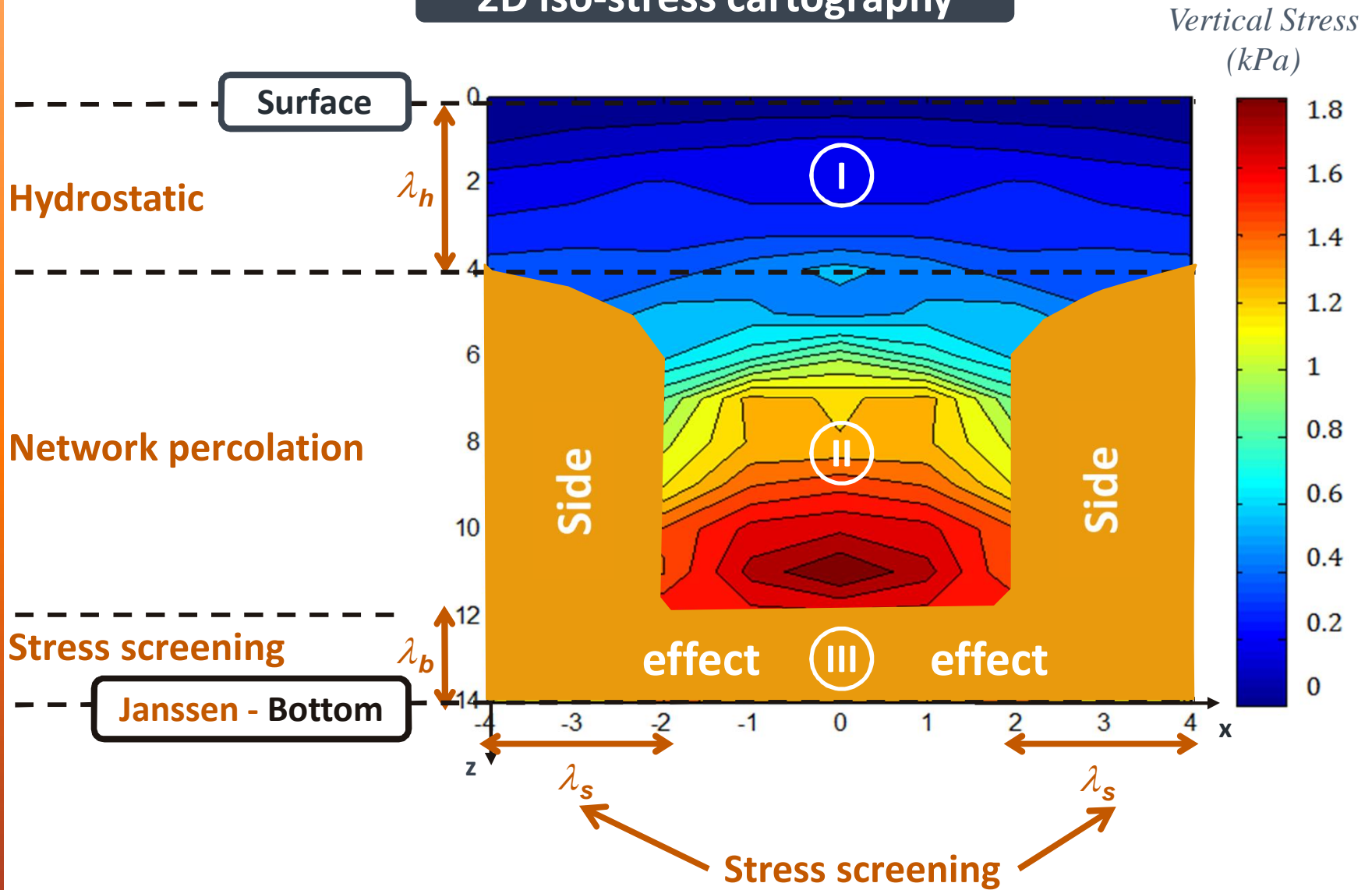
2D iso-stress cartography



2D iso-stress cartography

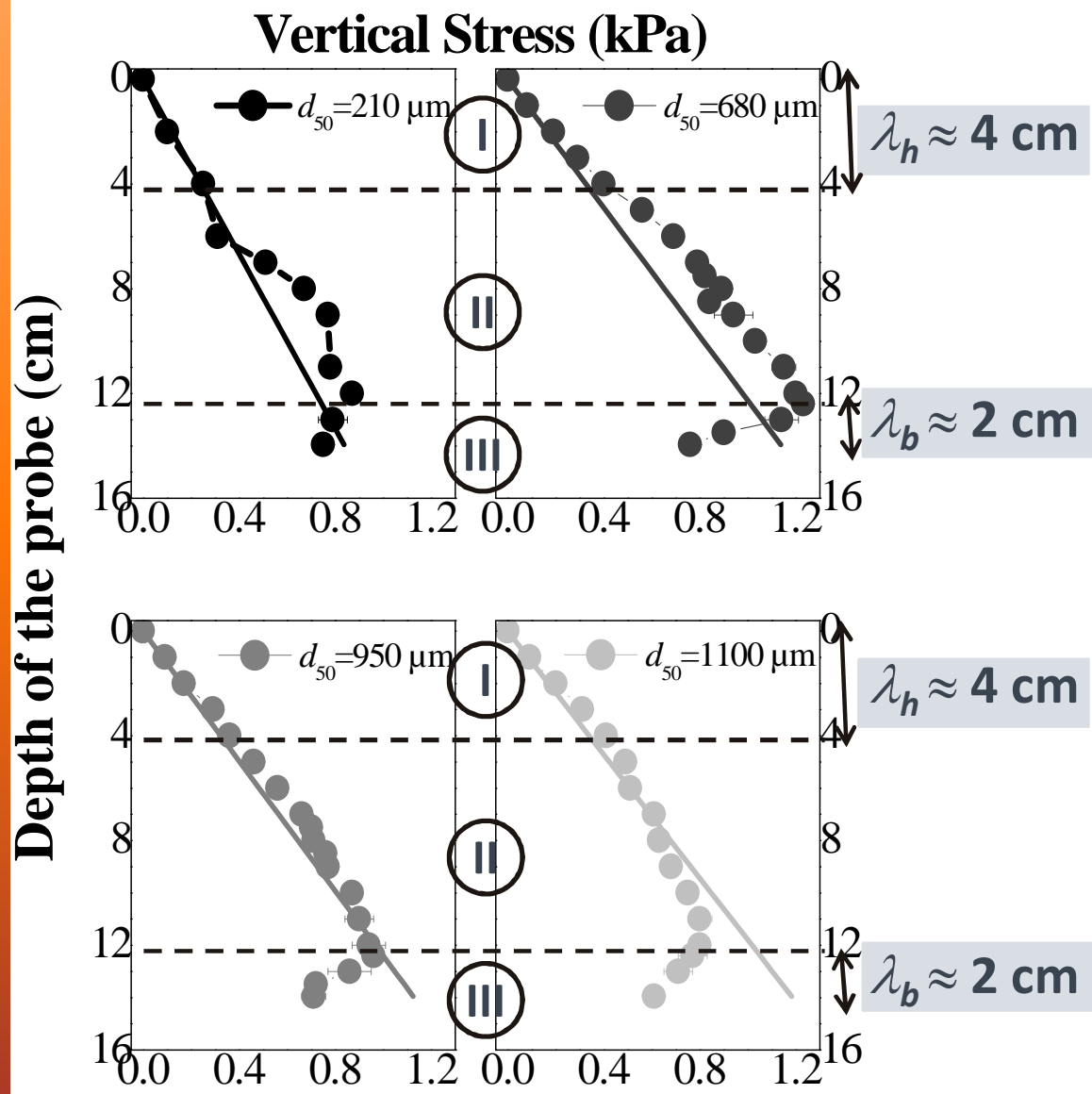


2D iso-stress cartography



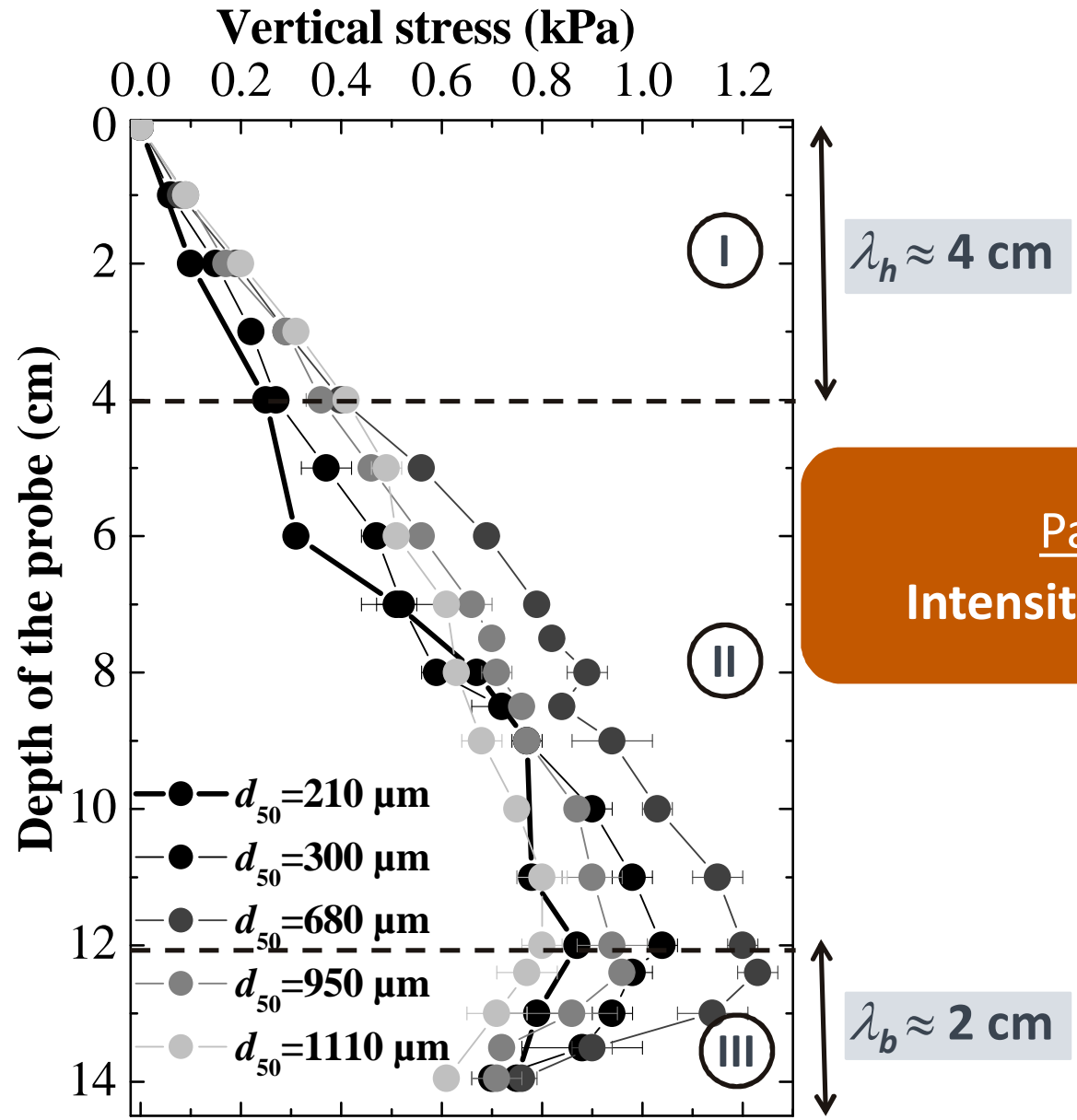
The bottom is a side as an other...

Particle size effect ?



Particle size
does not affect:
" Shape of the profile
" Characteristic lengths

Particle size effect ?



Particle size affects :
Intensity of the local vertical stress

- “ **Generic device** implementation for measuring **2D-cartography** of the **vertical stress** in **ensiled granular powders**.
- “ **Non-equivalence** between **global** and **local** vertical stress measurements **except** at the **bottom** of the cell (**semolina**).
- “ **Particle size affects** the **intensity** of the **local vertical stress** but **not** the **shape** of the vertical stress profile and the **characteristic lengths**.

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T1.2 Particle property and inter-particle force characterization

Thank you for you attention

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