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COMITÉ FRANÇAIS DE MÉCANIQUE DES SOLS ET DE GÉOTECHNIQUE

GBMS BGGG

Journée Scientifique et Technique commune CFMS et GBMS du 17 mars 2026

Construire dans l'argile : Regard croisé Franco-Belge

Comportement géomécanique de l'Argile de Boom

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Université de Liège

With the support of ONDRAF/NIRAS

LIÈGE université Sciences Appliquées

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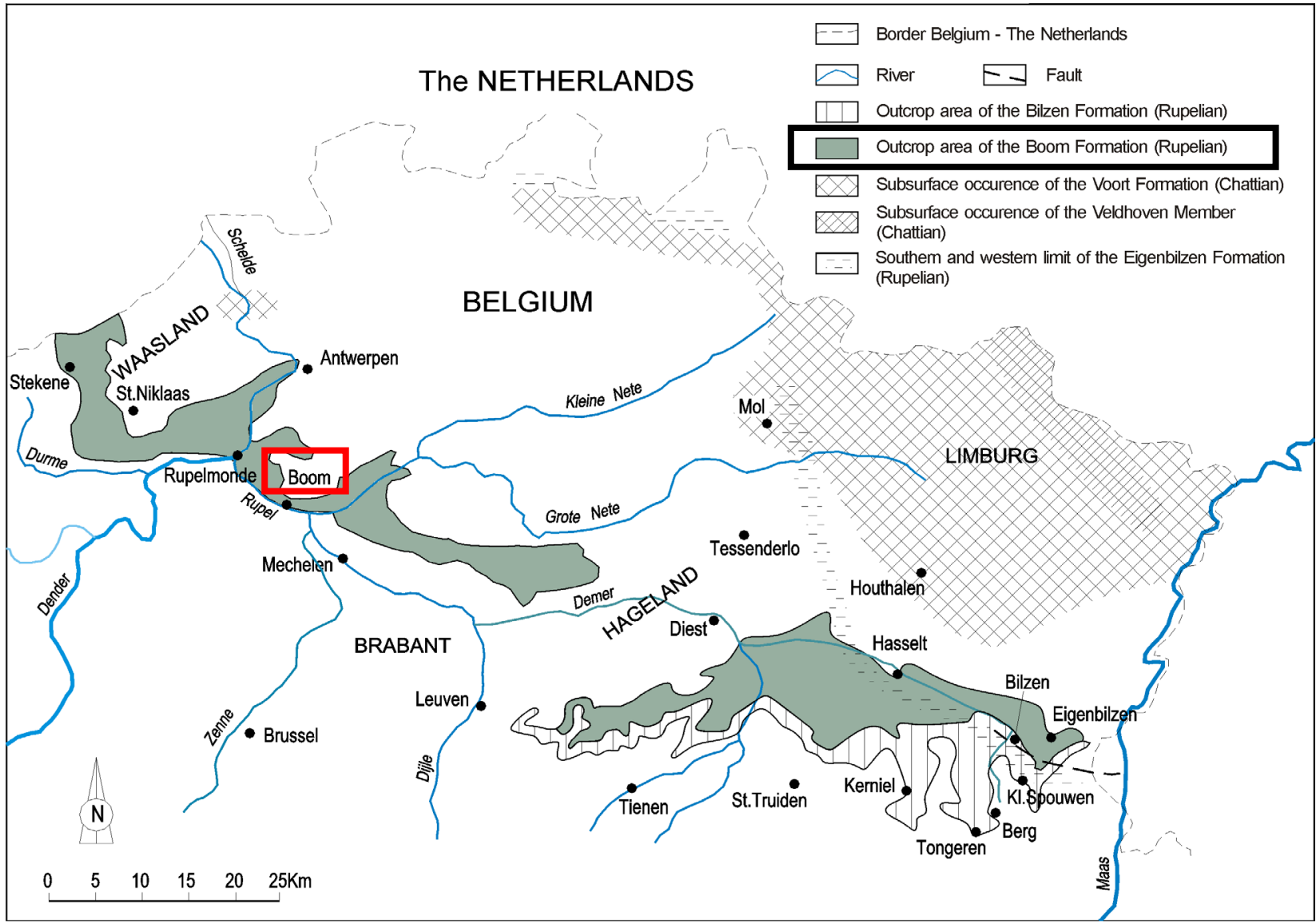
Contextualization

Boom Clay – Key history facts

- **Name origin**: Boom Clay is named after the town of Boom in Belgium, where it naturally outcrops.
- **Geological age**: It formed during the Oligocene, about 30 million years ago.
- **Historical use**: The clay has been extracted since at least the Middle Ages for brickmaking, floor tiles and roof tiles.
- **Industrial expansion**: During the 19th-century industrial era, numerous clay pits and brick factories operated along the Rupel and Scheldt rivers.



[N. Vandenberghe et al., 2014]

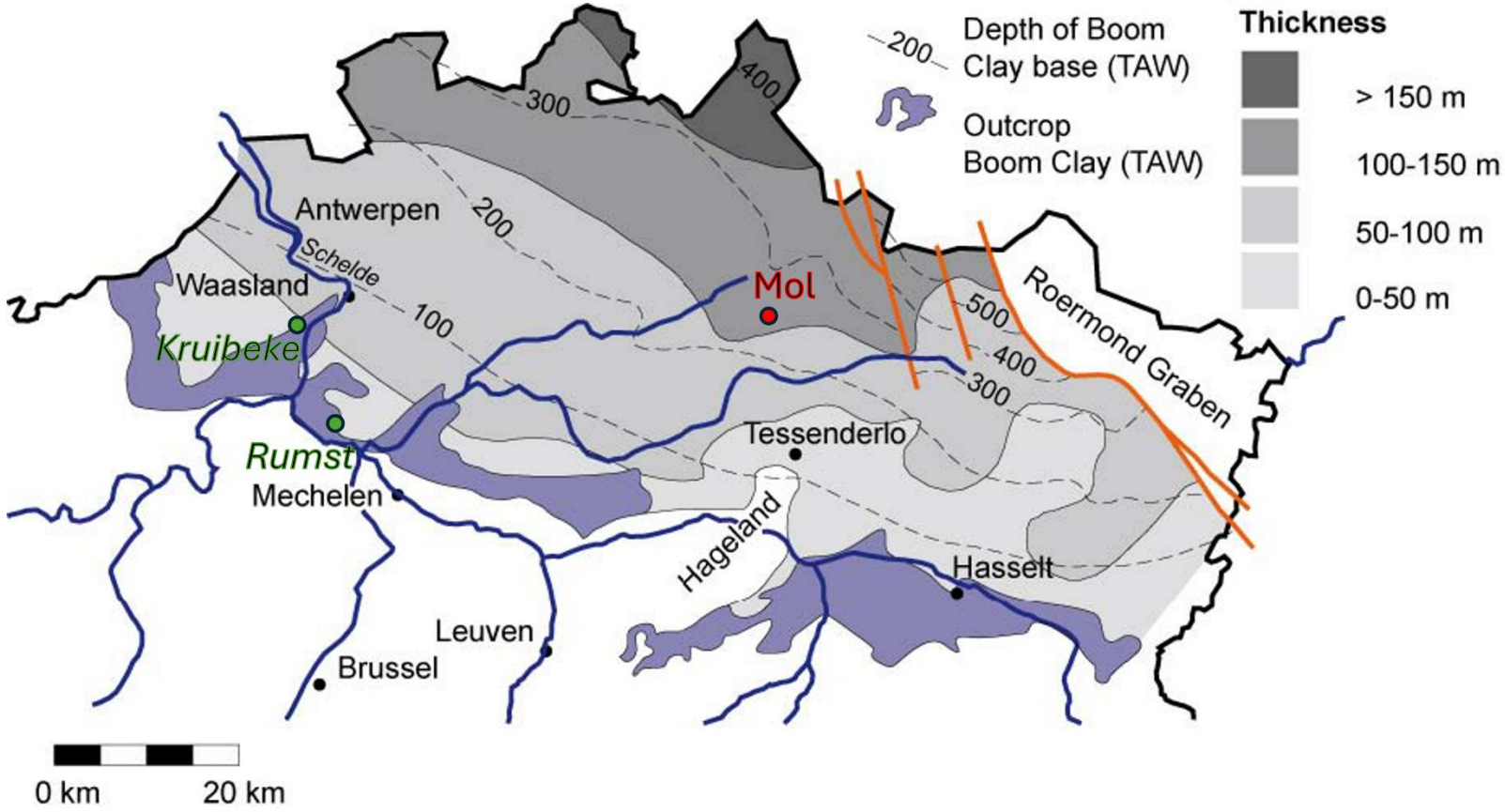
Contextualization

Boom Clay – Key history facts

- **Current exploitation**: Today, industrial extraction is limited to two active sites: Rumst and Kruibeke (Burcht).

- **Potential host of Deep Geological repository** : Research started in 1975 with the first deep borehole in the Campine area (Mol)

Until 1975, studies on Boom Clay focused mainly on its **properties for brick production and for construction projects** (such as the Antwerp harbour). With the **start of deep geological repository research**, attention shifted **from Antwerp agglomerations to the Campine area**, and **from surface investigations to subsurface studies**.

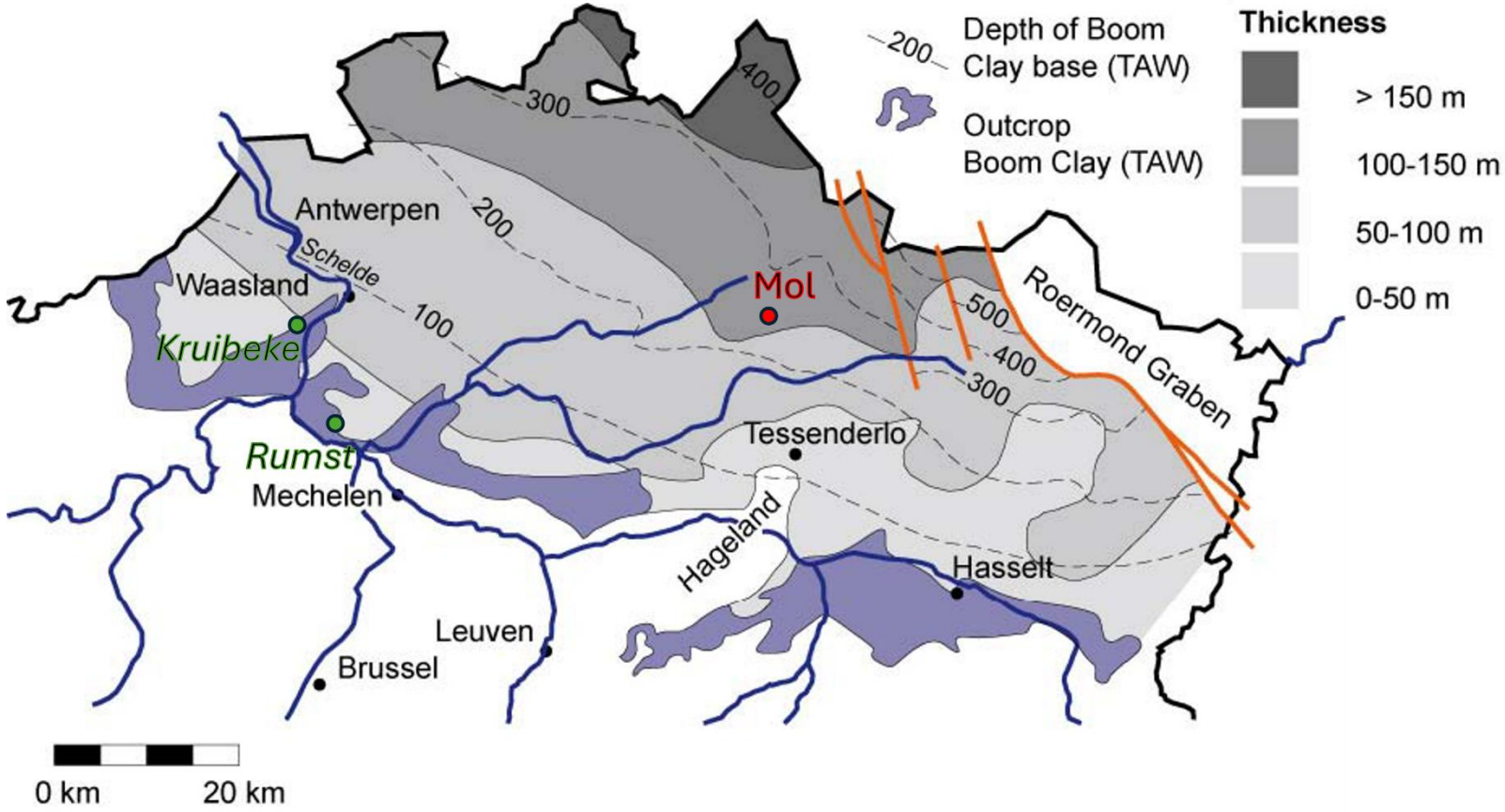


[P. Delage et al., 2008] modified after [Mertens et al., 2003]

Contextualization

Boom Clay – Geological/Geographical setting

- In the Campine area, North-Eastern part of Belgium
- Dip of 2% towards North – Northeast and thickens in that direction.
- Thickness of maximum 80 m where it outcrops, 140m max in the subsurface of the Campine



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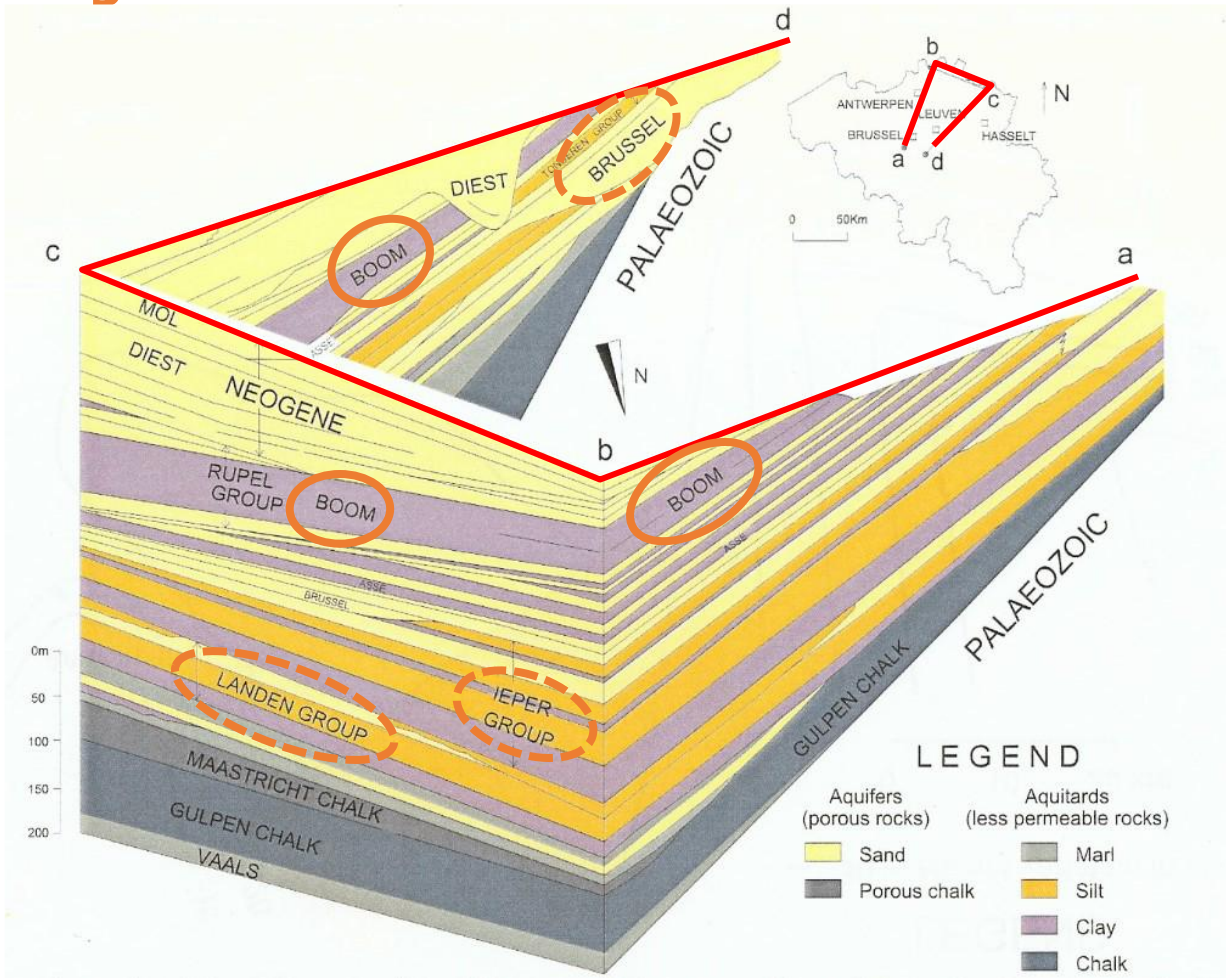


[ONDRAF/NIRAS 2013]

Contextualization

Boom Clay – Geological setting

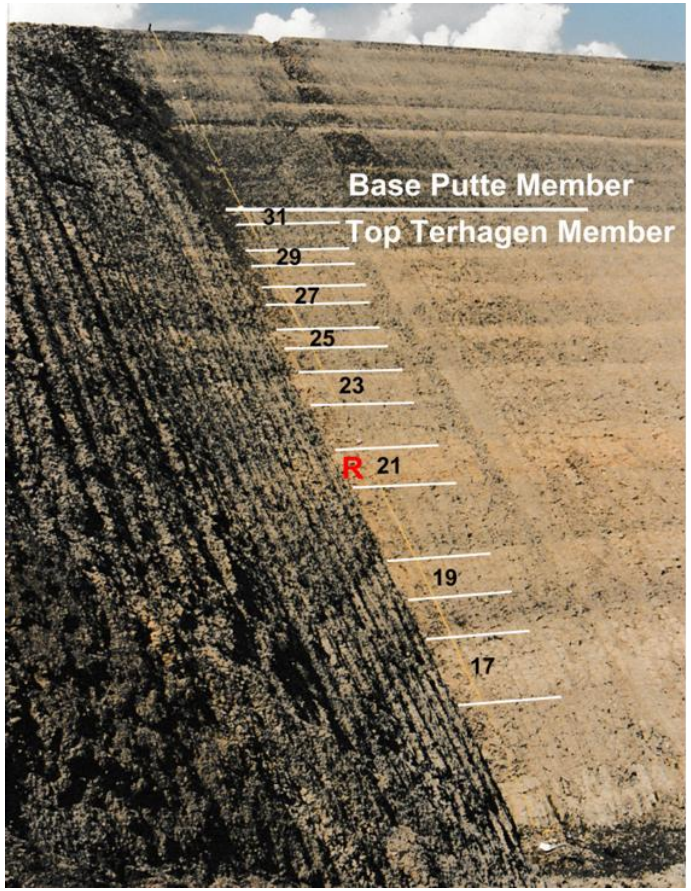
Main feature: a regular alternation of silt-rich and silt-poor layers.

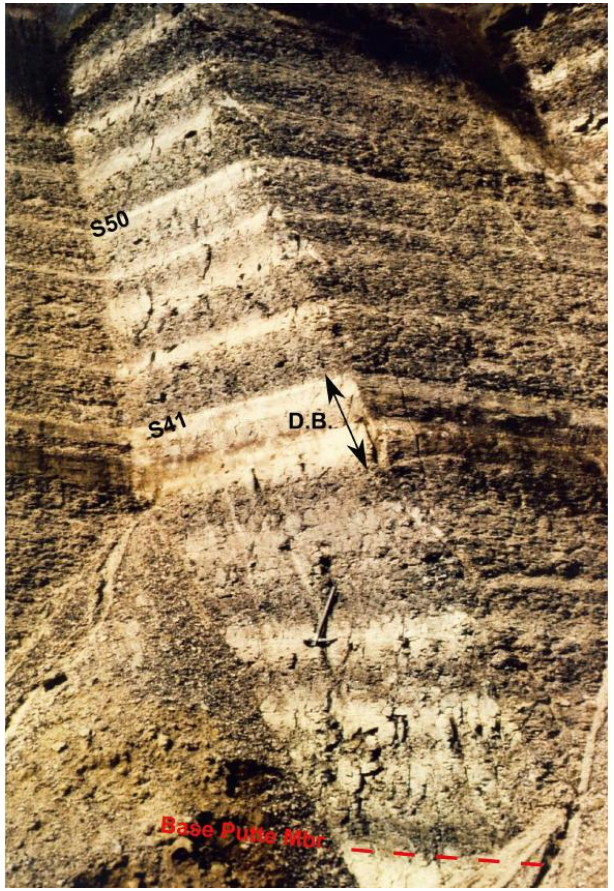
Due to erosion, some layers that appear in the subsurface do not appear in the outcrop.

Key marker layers: such as the Double Band, Pink Band, and S50, S60, S80 , make it possible to correlate the surface outcrop stratigraphy with the subsurface relatively easily.

Subdivided into 4 members :

- Boeretang Member
- Putte Member
- Terhagen Member
- Belsele Waas Member





[Vandenberghe and Wouters, 2024]

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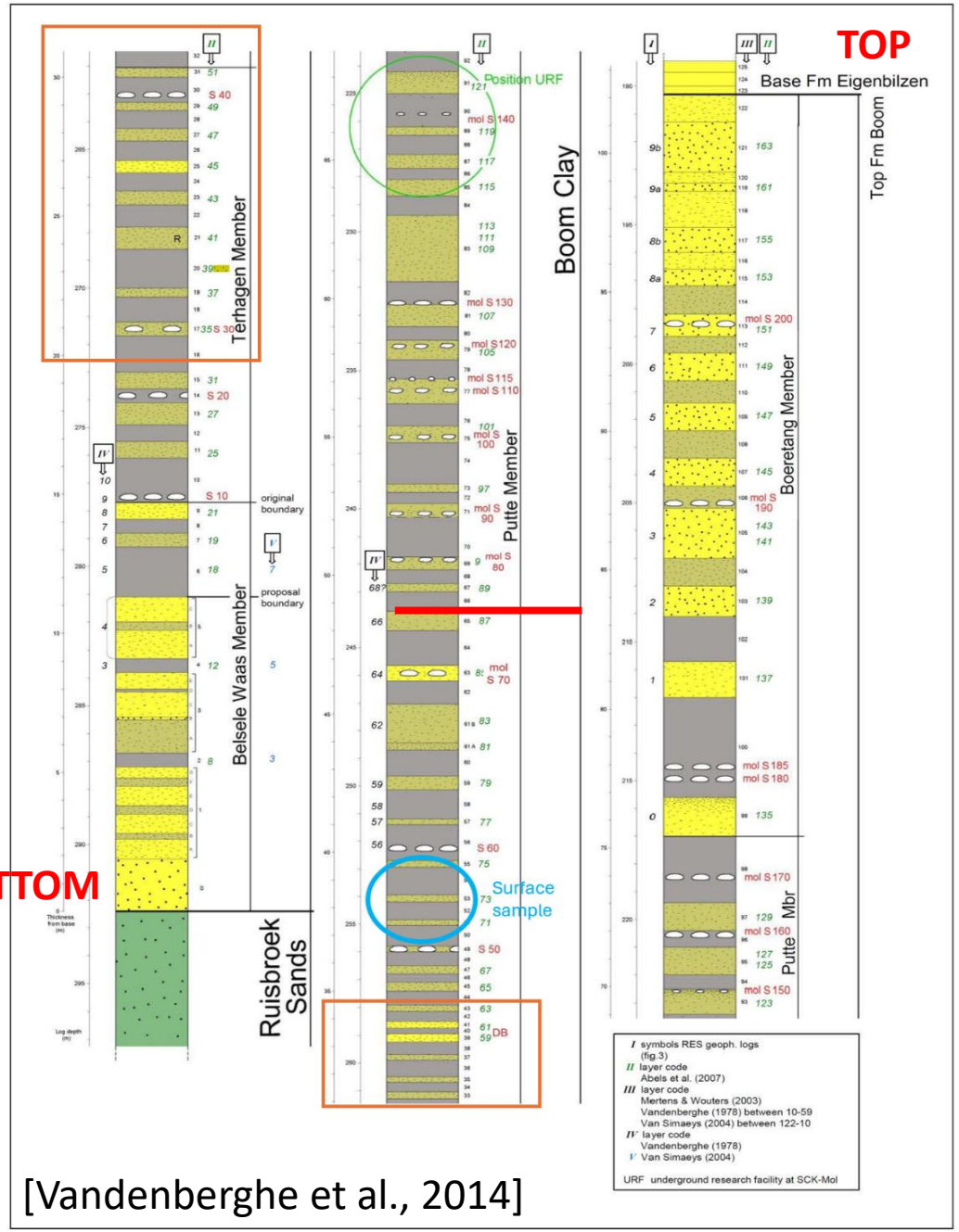
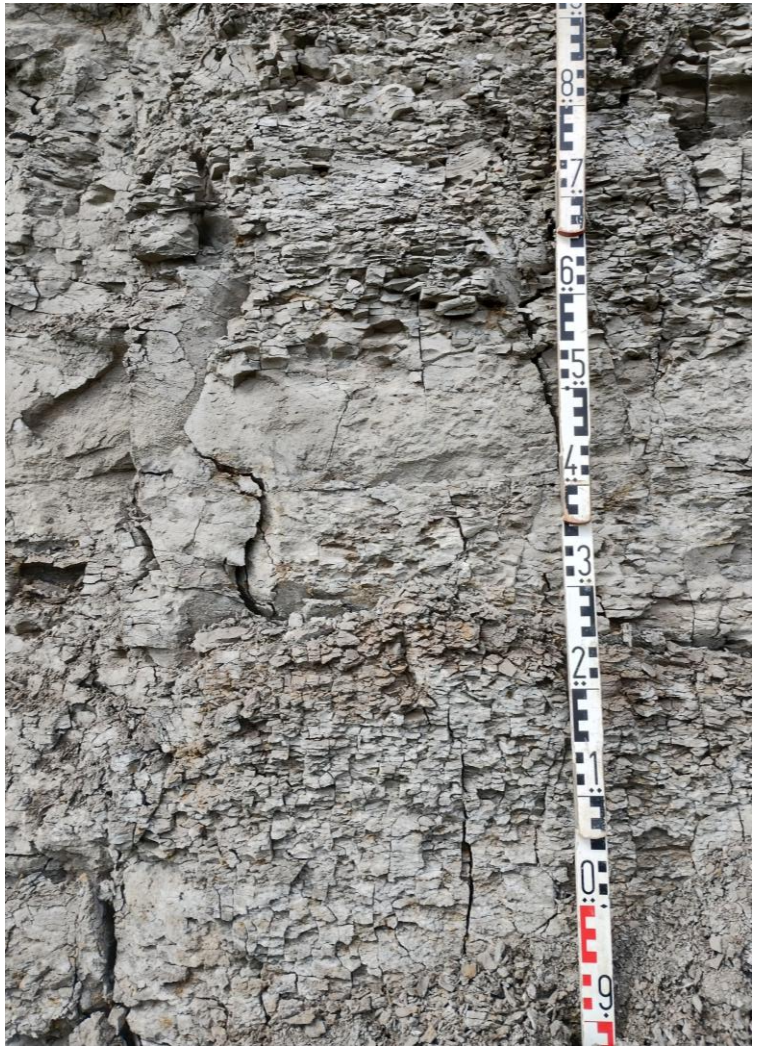


[Vandenberghe et al., 2014]

Contextualization

Boom Clay – Geological setting



Rumst quarry © B. François

Contextualization

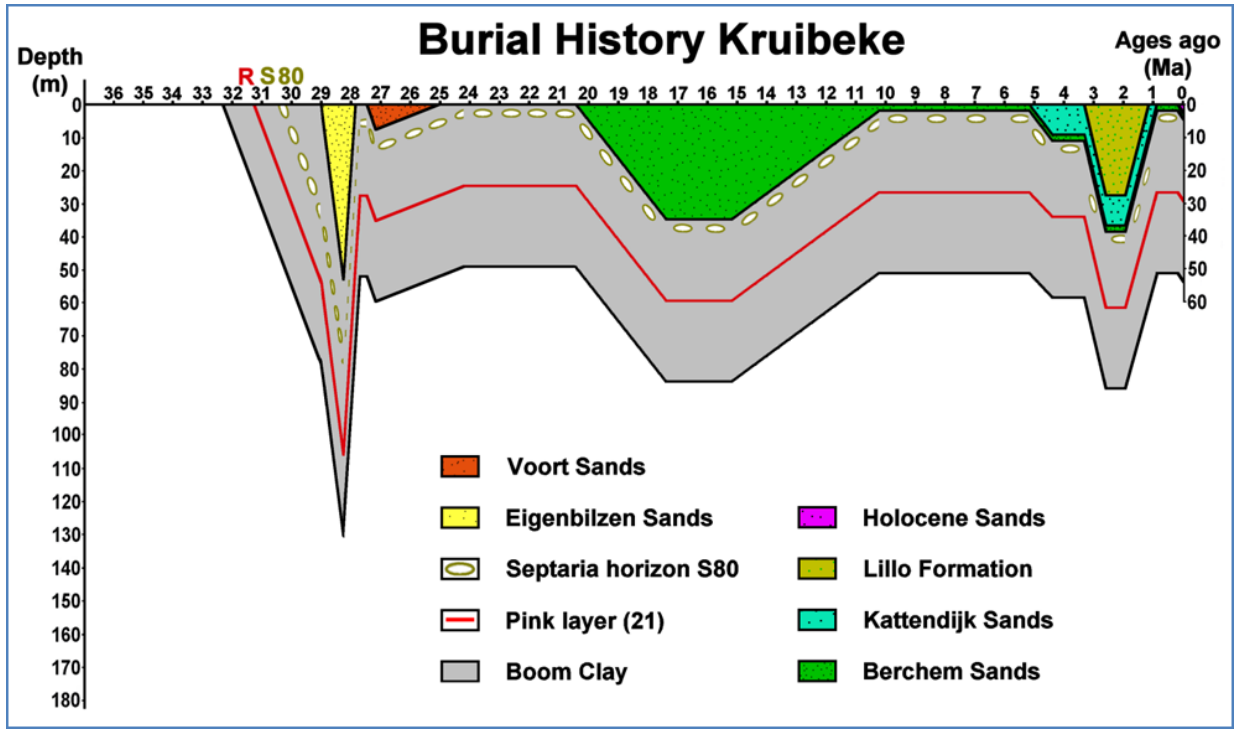
Boom Clay – Geological setting

The septarian carbonate concretions from the Boom Clay (Belgium) consist mainly of authigenic minerals such as micrite (< 70% bulk volume) and pyrite (~ 3%).

Contextualization

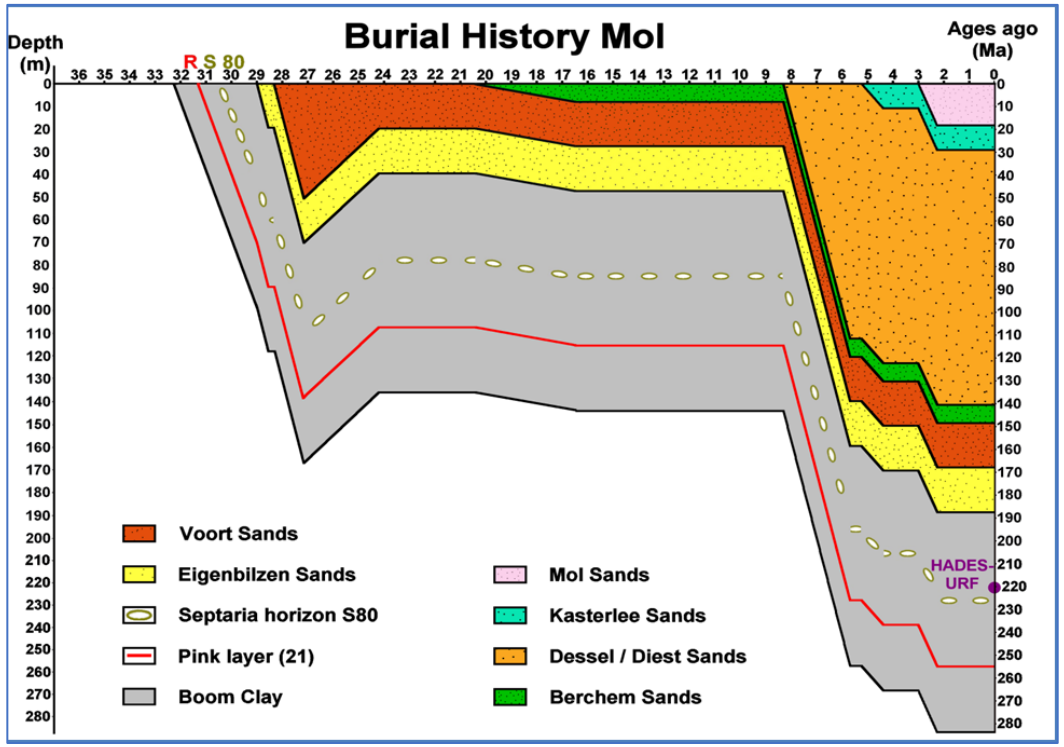
Boom Clay – Geological setting

- **Overconsolidated because** at a shallower depth that it was once (29 Ma ago).
- Reasonable to assume that **swelling** has occurred.
- All layers **above S80** have been **eroded**.



[J. Mertens et al., 2003]

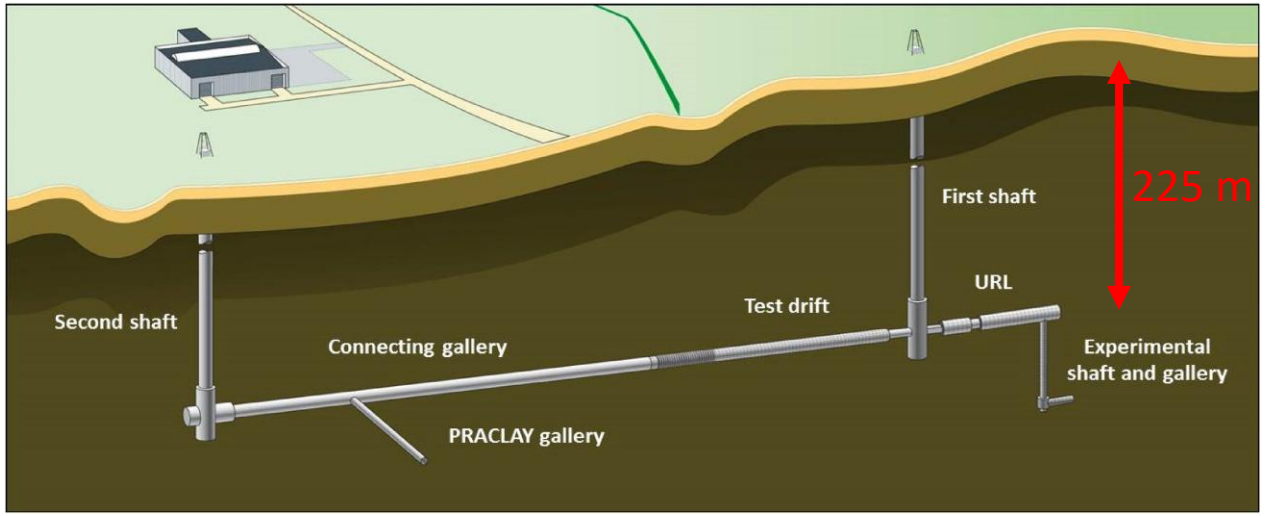
- Should be **normally consolidated** because never burried deeper
- It is not the case **(OCR=2.5)** → Likely due to **aging/secondary consolidation/chemical bounding**).

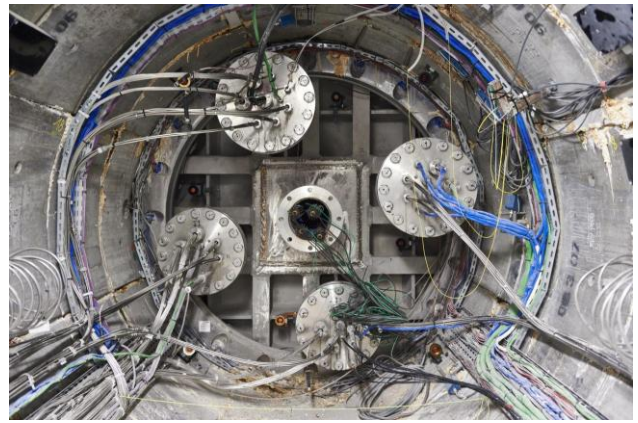


Contextualization

HADES : Underground Research Laboratory, Mol, Belgium

- Almost 50 years of studies on Boom Clay.
- More than 40 years of study on Boom Clay at 225m depth
- Mechanical, chemical, thermal, hydraulic characterization of Boom Clay at various scales





www.hadeslab.be

State of the Art

Key challenges associated with Boom Clay testing

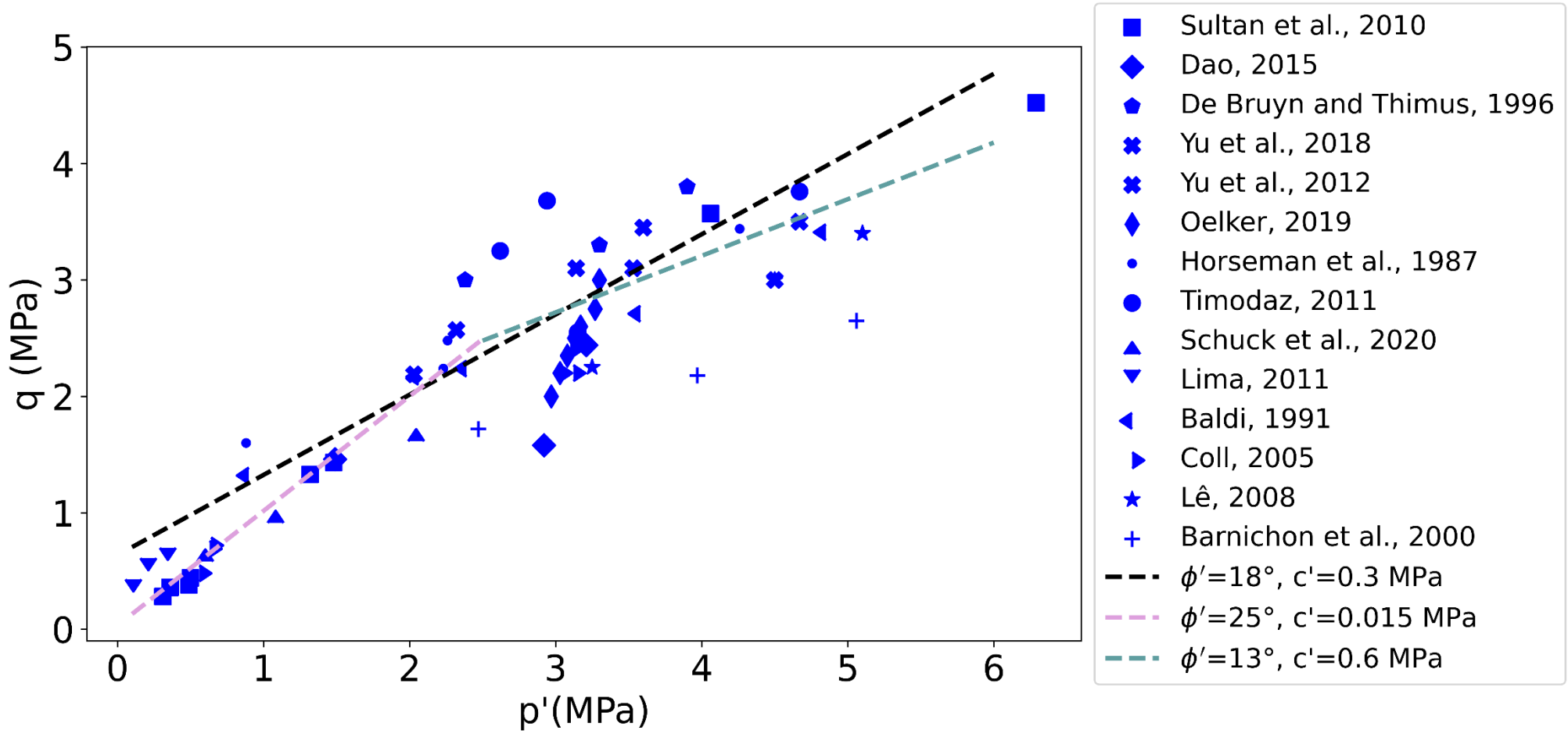
- **High-capacity triaxial equipment required** (standard soil-mechanics triaxial cell is not sufficient)
- **Highly swelling material** (challenging saturation process)
- **Very low permeability** (drained triaxial tests become extremely long)
- **Anisotropic behavior**
- **Need for synthetic pore water**

State of the Art

Results of triaxial tests in the literature

- Results from various studies do not always show the same outcomes.

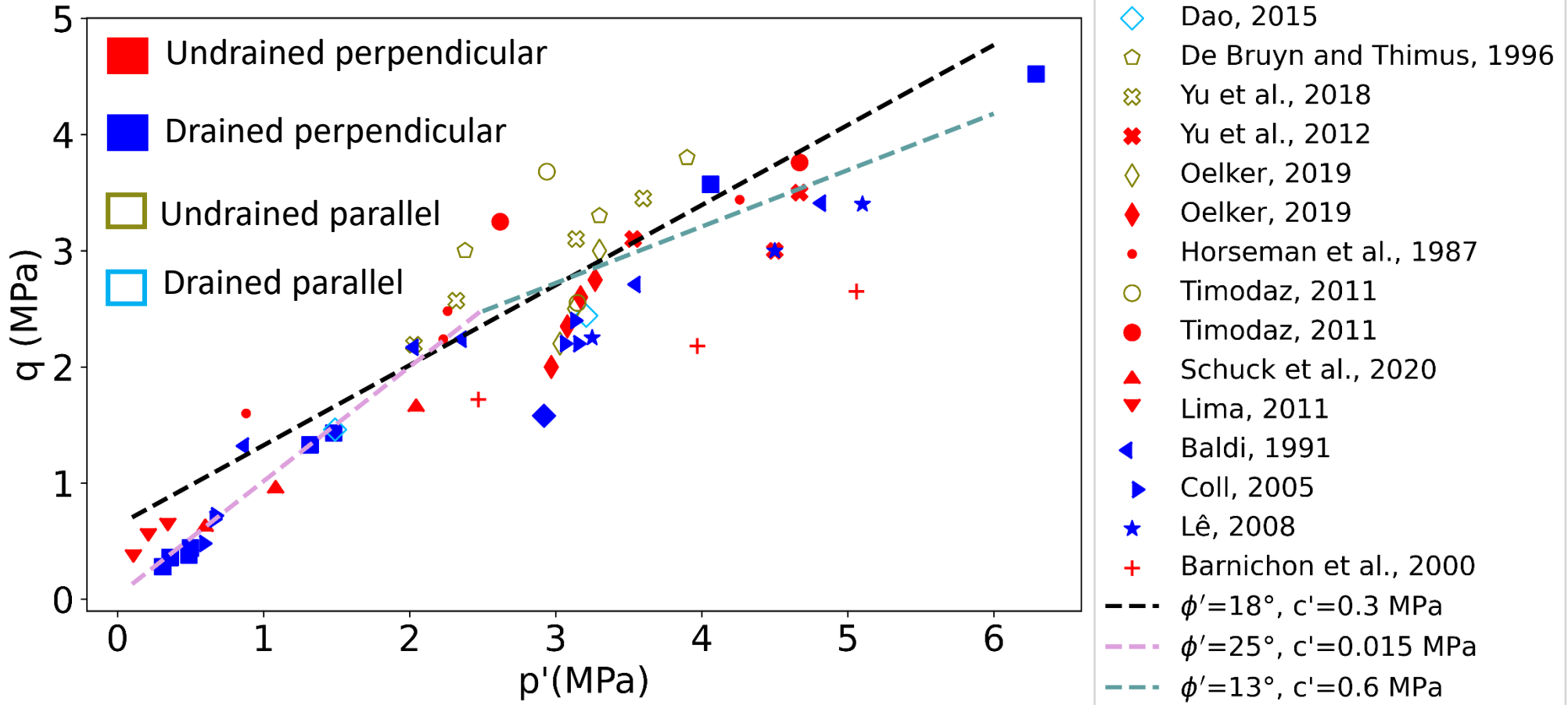
- It is believed that these differences partially come from variations in experimental protocols.



State of the Art

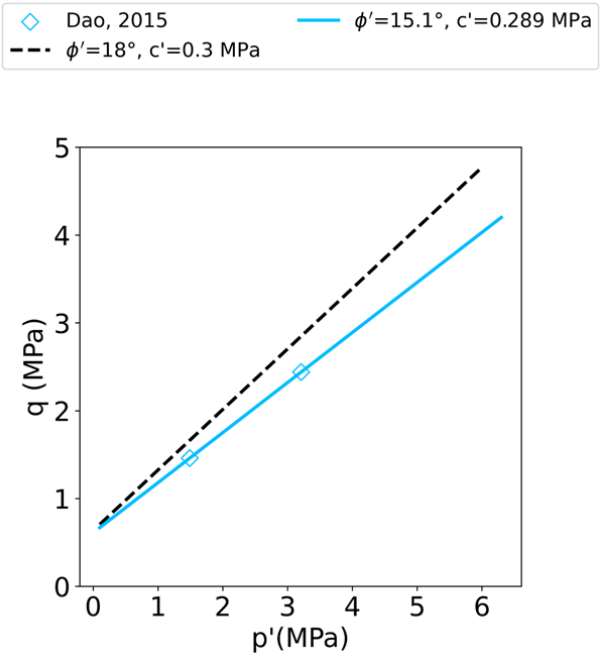
Results of triaxial tests in the literature

- Two main differences in the protocol :
  - Drainage conditions
  - Loading direction relative to the bedding plane.



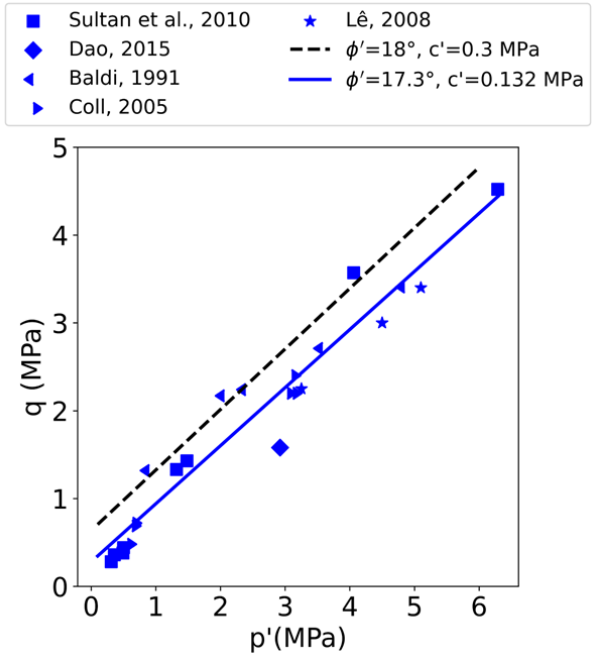
State of the Art

Results of triaxial tests in the literature



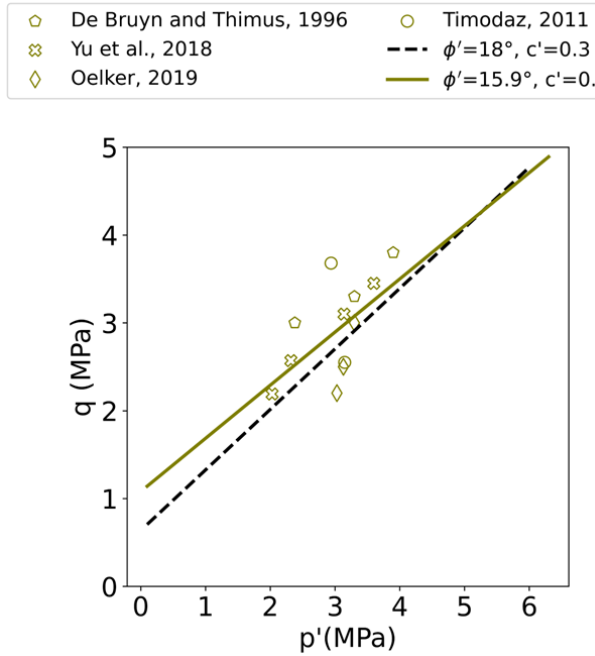
Drained parallel

ϕ' = 15.1°
c' = 289 kPa



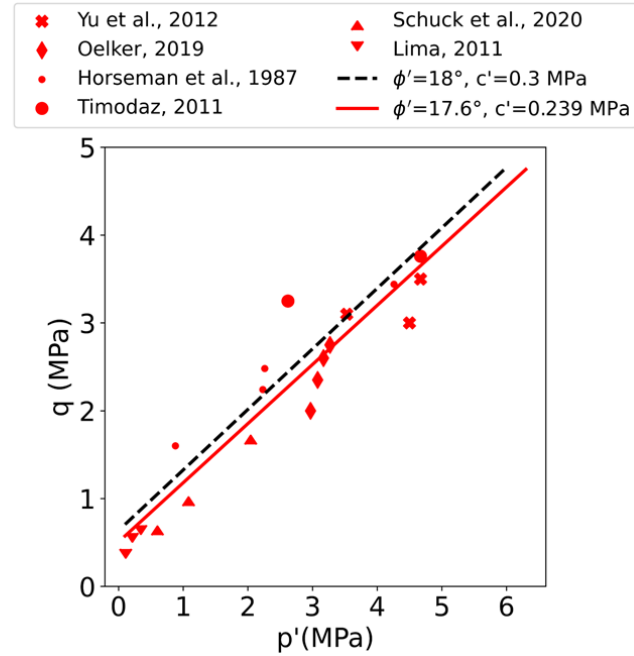
Drained perpendicular

ϕ' = 17.3°
c' = 132 kPa



Undrained parallel

ϕ' = 15.9°
c' = 510 kPa



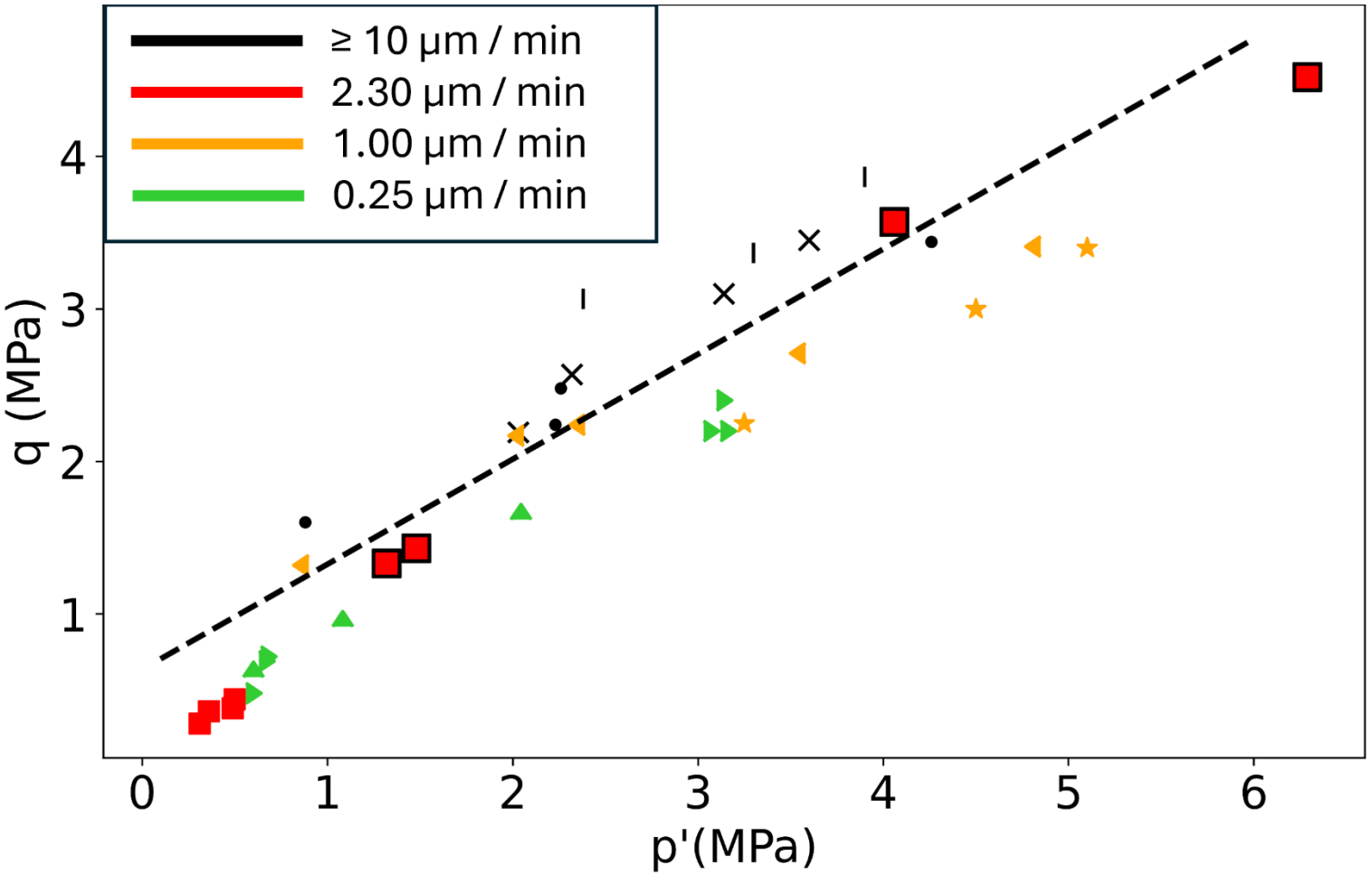
Undrained perpendicular

ϕ' = 17.6°
c' = 239 kPa

State of the Art

Results of triaxial tests in the literature

- Shearing rate also has an influence.

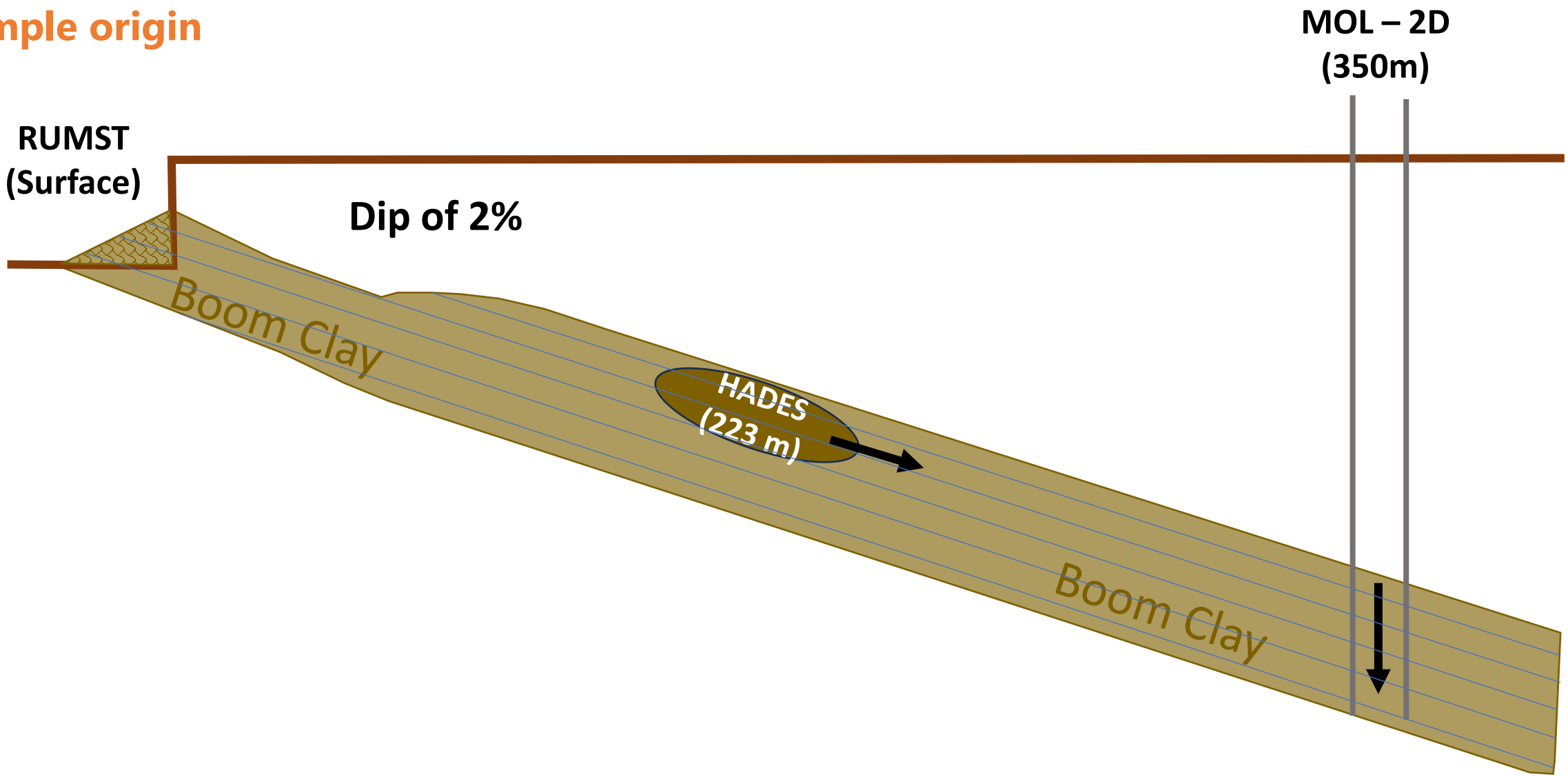


Yu et al., 2018 (20 μm/min) CU ‖
Horseman et al., 1987 (15 μm/min) CU ⊥
De Bruyn and Thimus, 1996 (10 μm/min) CU ‖
Sultan et al., 2010 (2.3 μm/min) CD ⊥
Baldi, 1991 (1.0 μm/min) CD ⊥
Lê, 2008 (1.0 μm/min) CD ⊥
Coll, 2005 (0.25 μm/min) CD ⊥
Schuck et al., 2020 (0.25 μm/min) CU ⊥
ϕ'=18°, c'=0.3 MPa (ref Boom Clay)

Isotropically consolidated to 9 MPa

Materials

Sample origin



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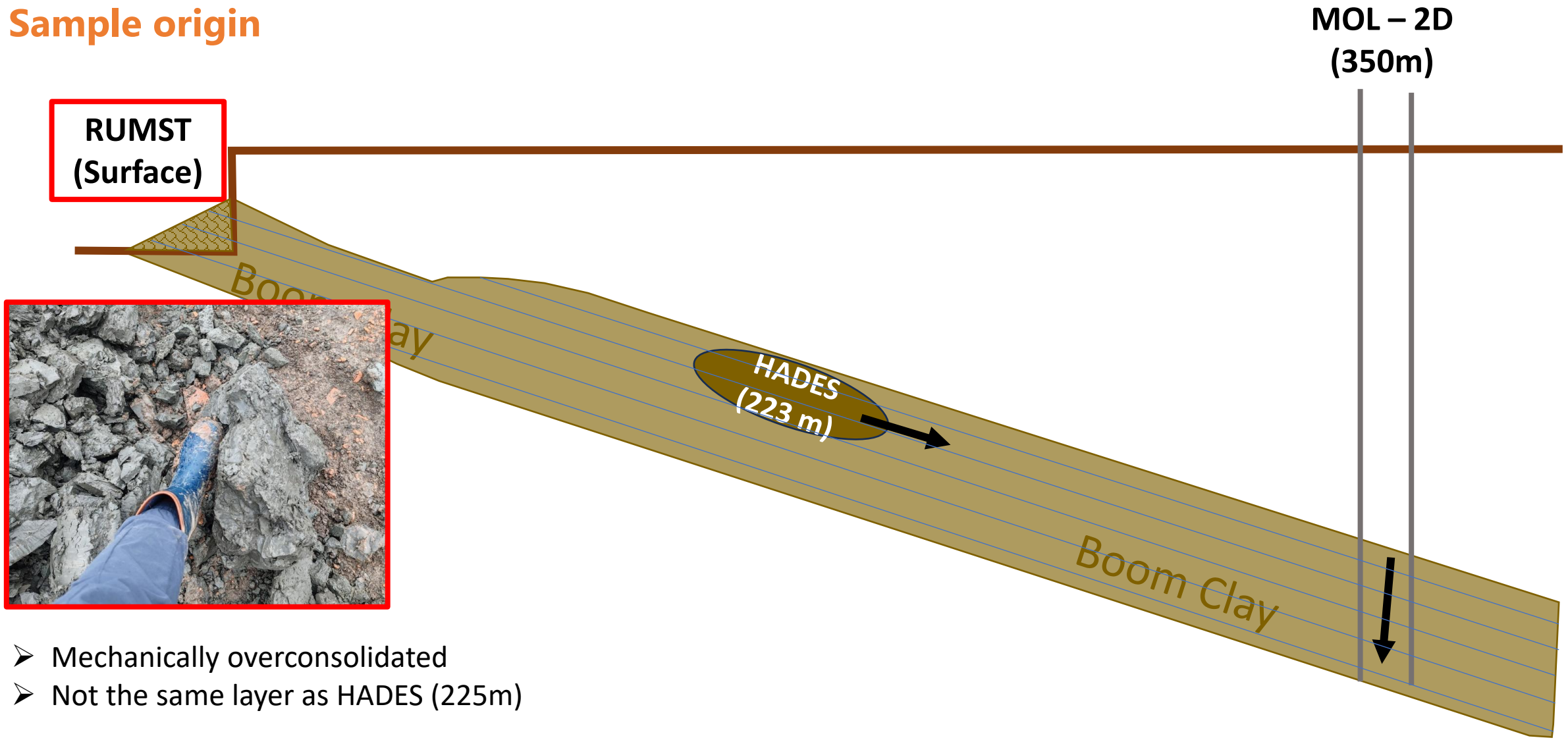
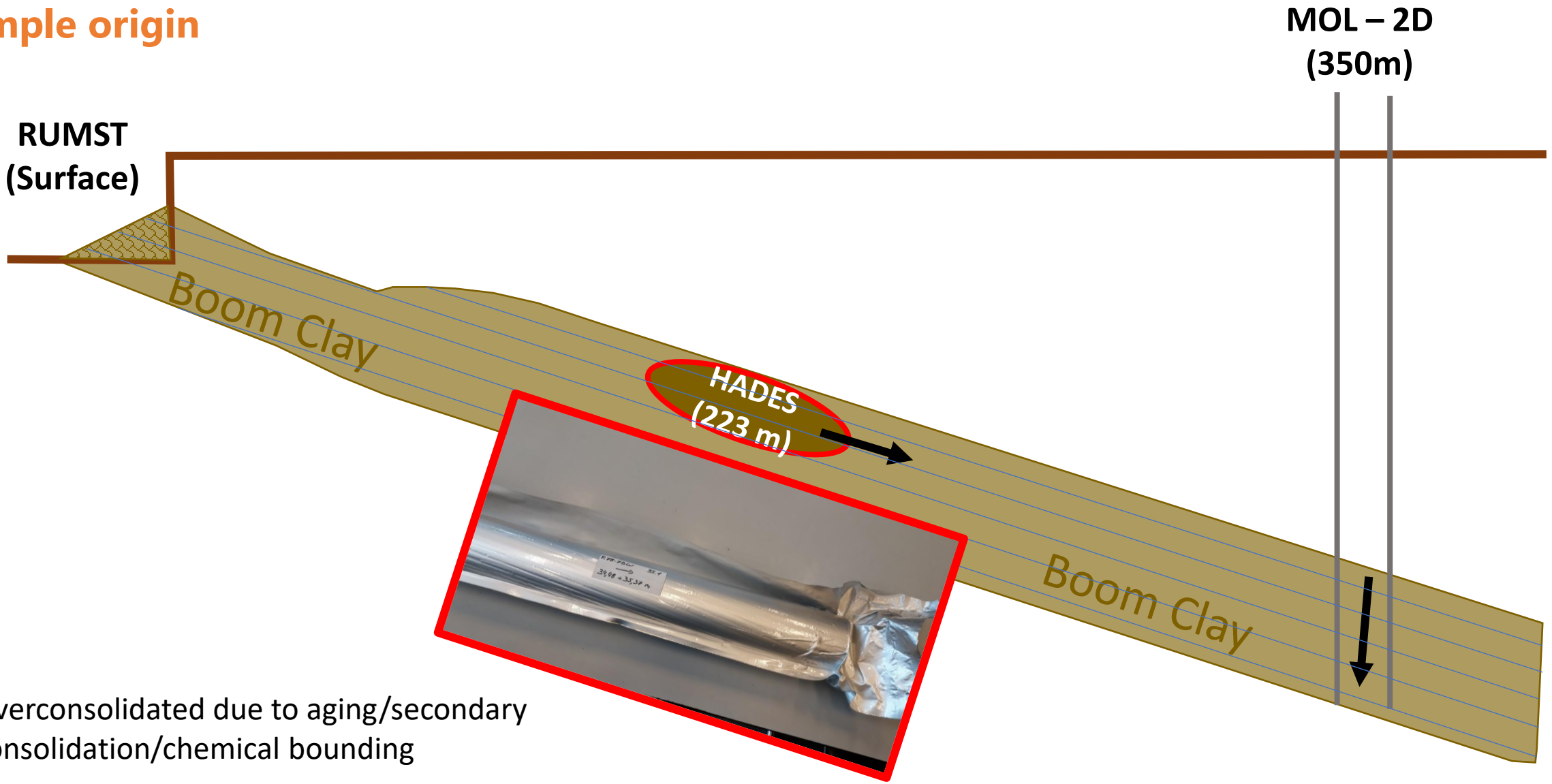


- Mechanically overconsolidated
- Not the same layer as HADES (225m)

Materials

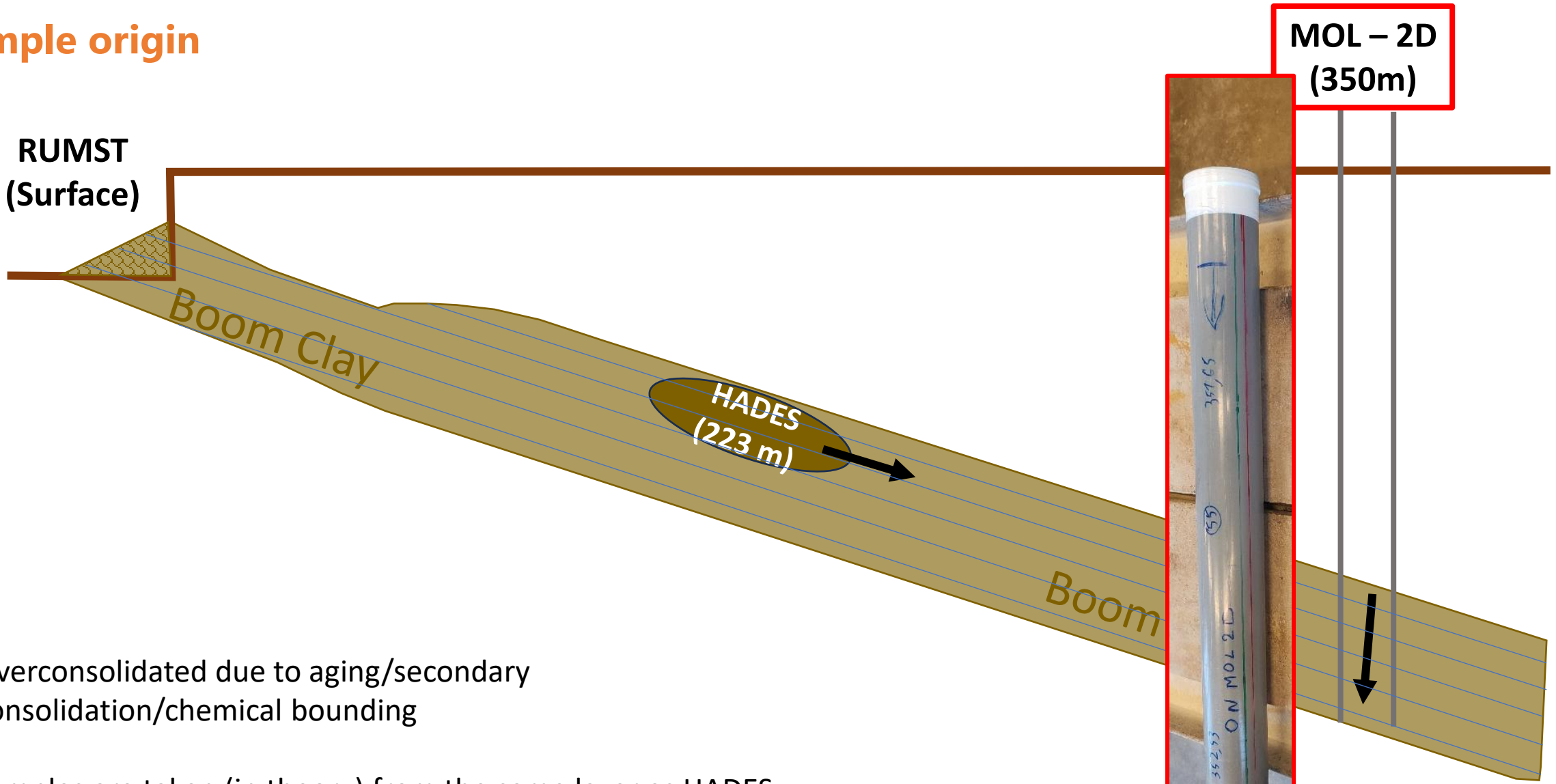
Sample origin



- Overconsolidated due to aging/secondary consolidation/chemical bounding

Materials

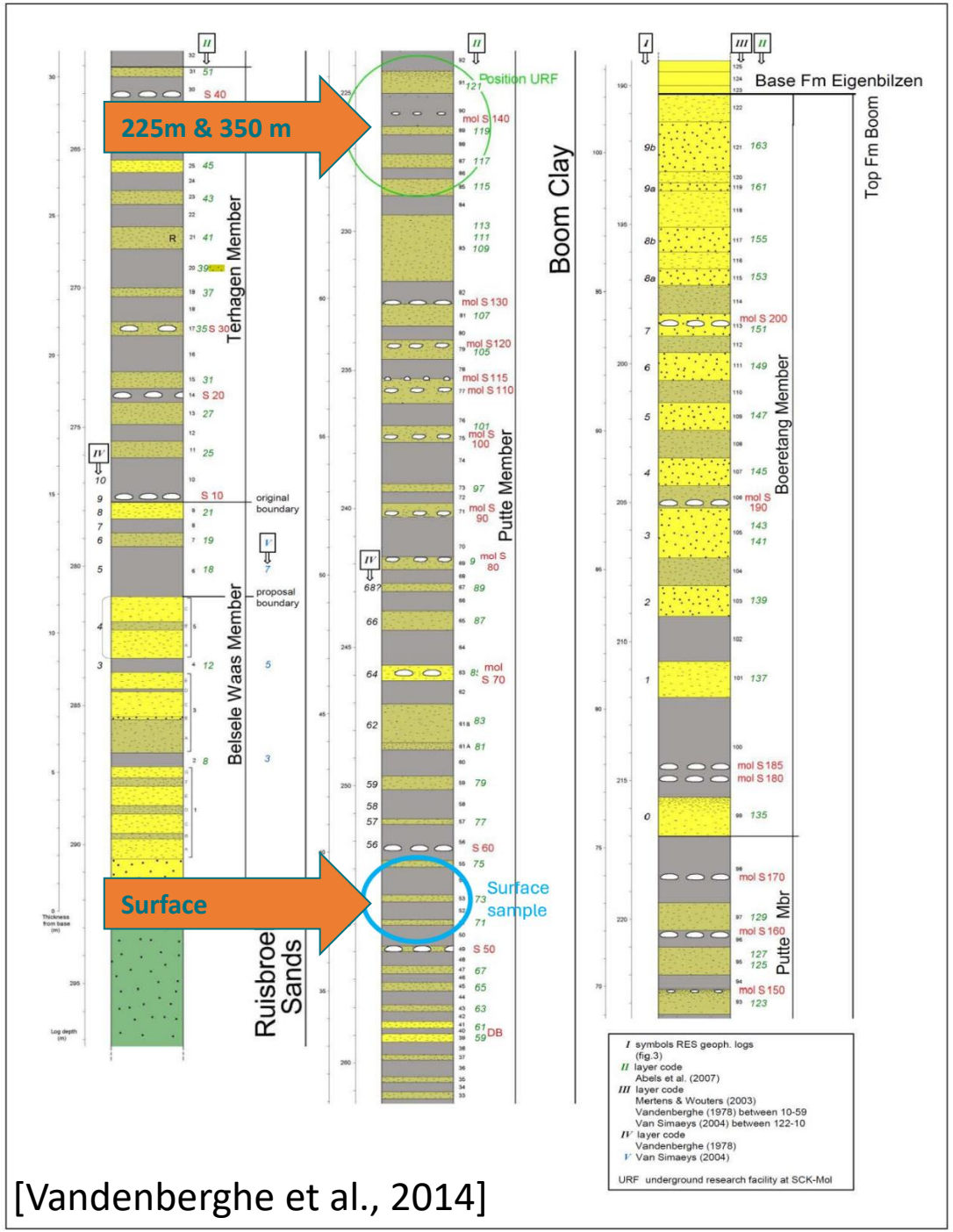
Sample origin



- Overconsolidated due to aging/secondary consolidation/chemical bounding
- Samples are taken (in theory) from the same layer as HADES.

Materials

Sample origin

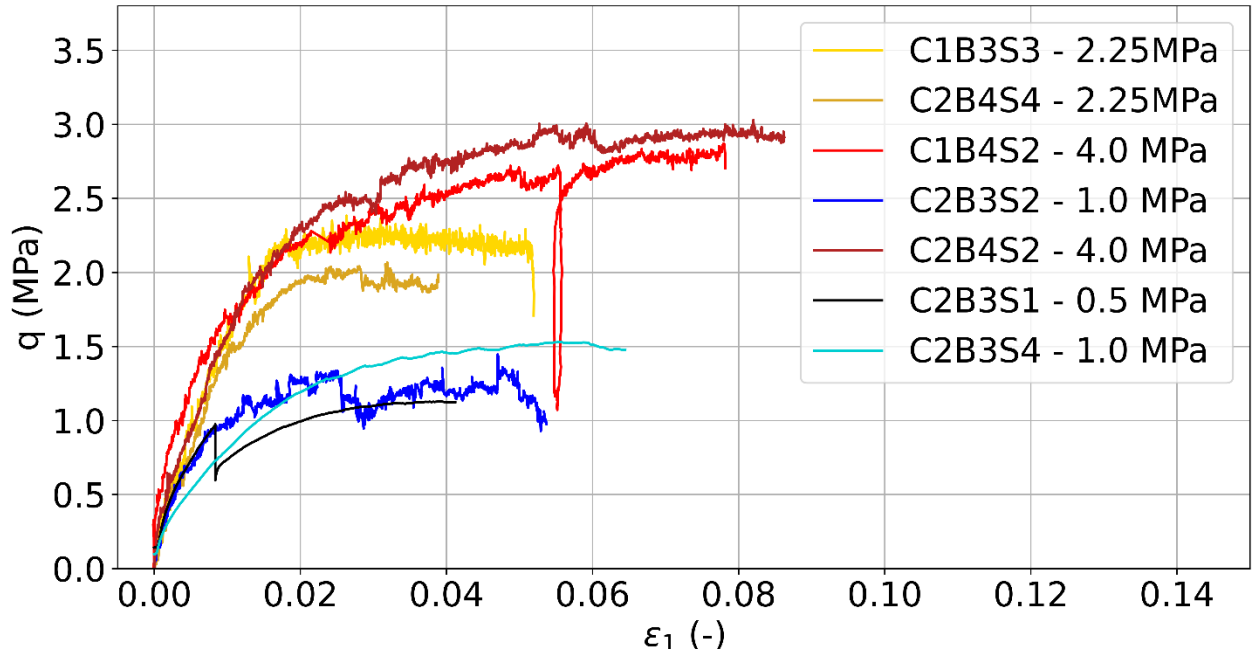


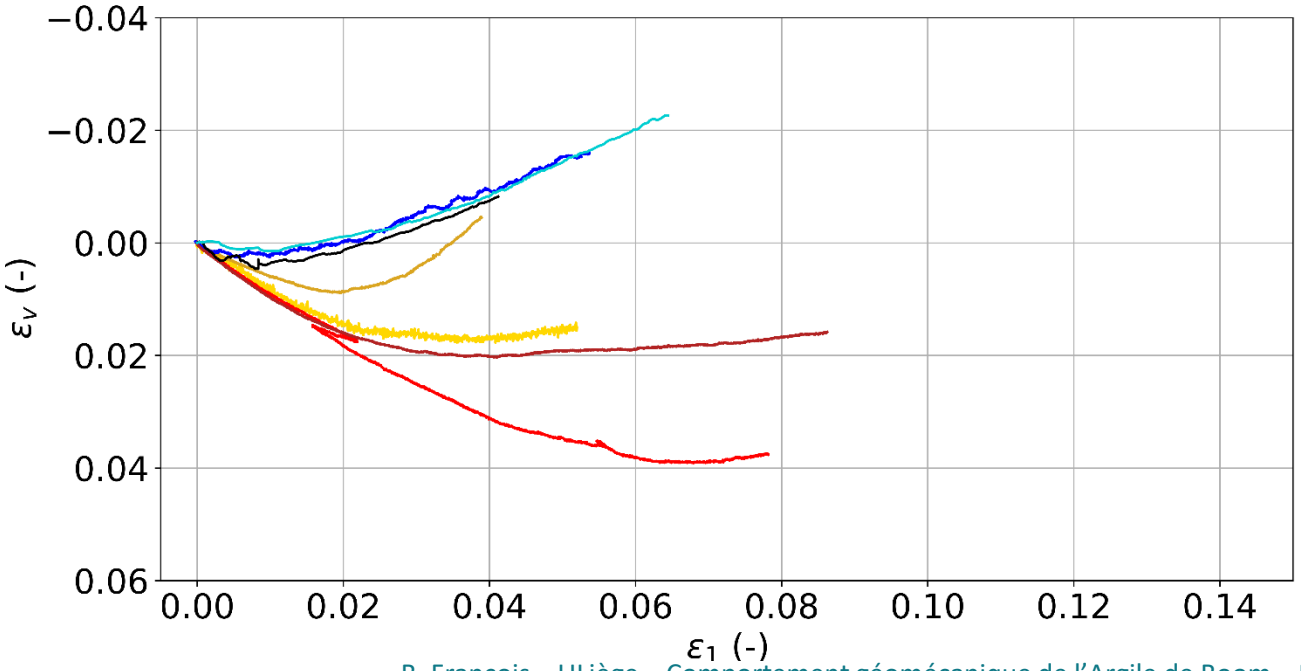
[Vandenberghe et al., 2014]

Results

Triaxial tests

- Tests on samples from **225 m depth** (HADES)
  - Reproducible for the same confinement.



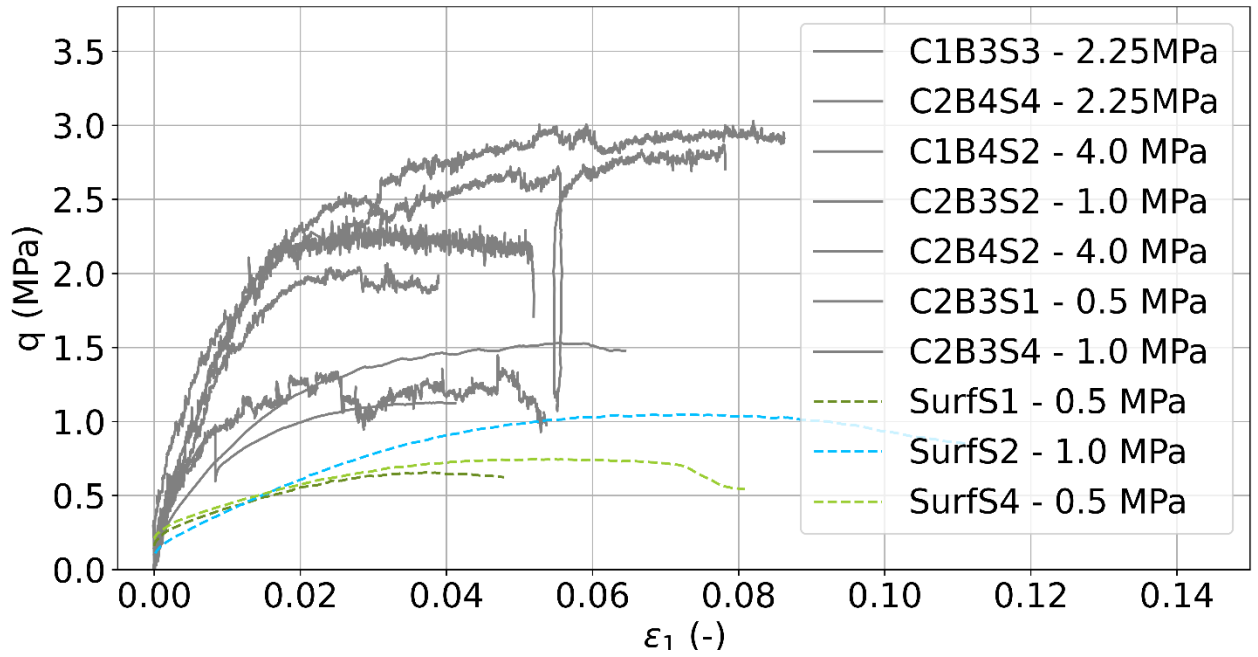


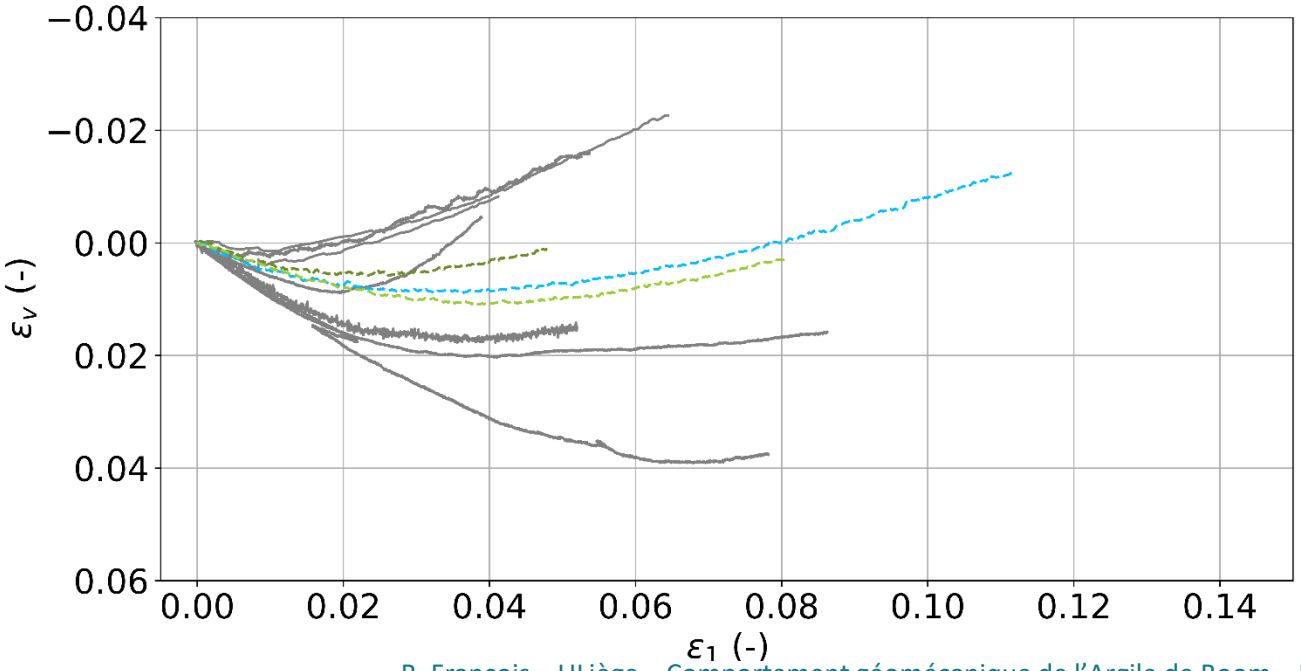
Results

Triaxial tests

- Tests on samples from 225 m depth (HADES)
  - Reproducible for the same confinement.

- Tests on samples from the **surface level** (RUMST)
  - $E_{surf} < E_{225m}$
  - More plastic behaviour

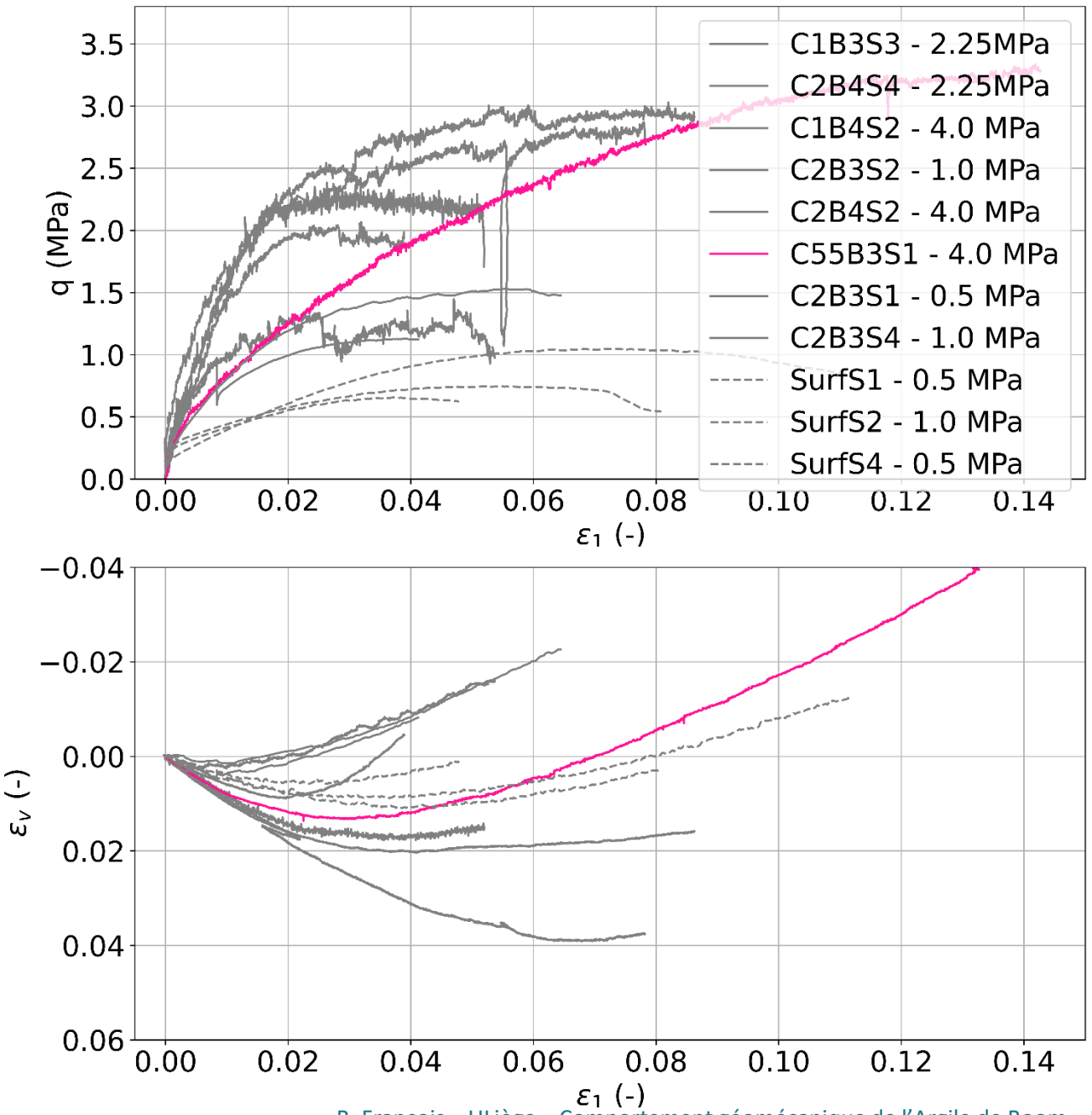




Results

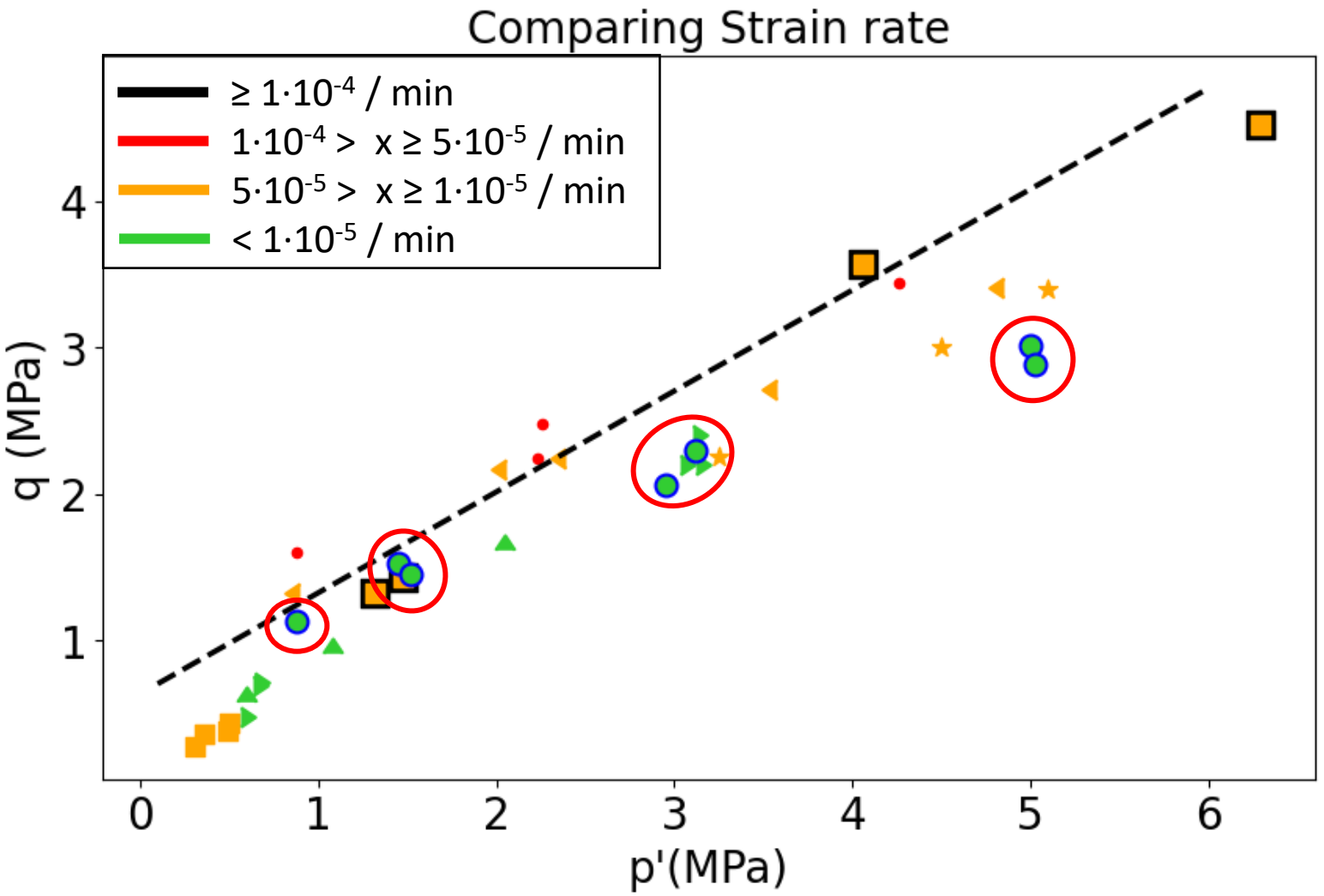
Triaxial tests

- Tests on samples from 225 m depth (HADES)
  - Reproducible for the same confinement.
- Tests on samples from the surface level (RUMST)
  - $E_{surf} < E_{225m}$
  - More plastic behaviour
- Test on sample from **350 m depth** (MOL-2D)
  - $E_{350m} \approx E_{225m}$
  - More plastic behaviour



Results

Triaxial tests : comparison with literature



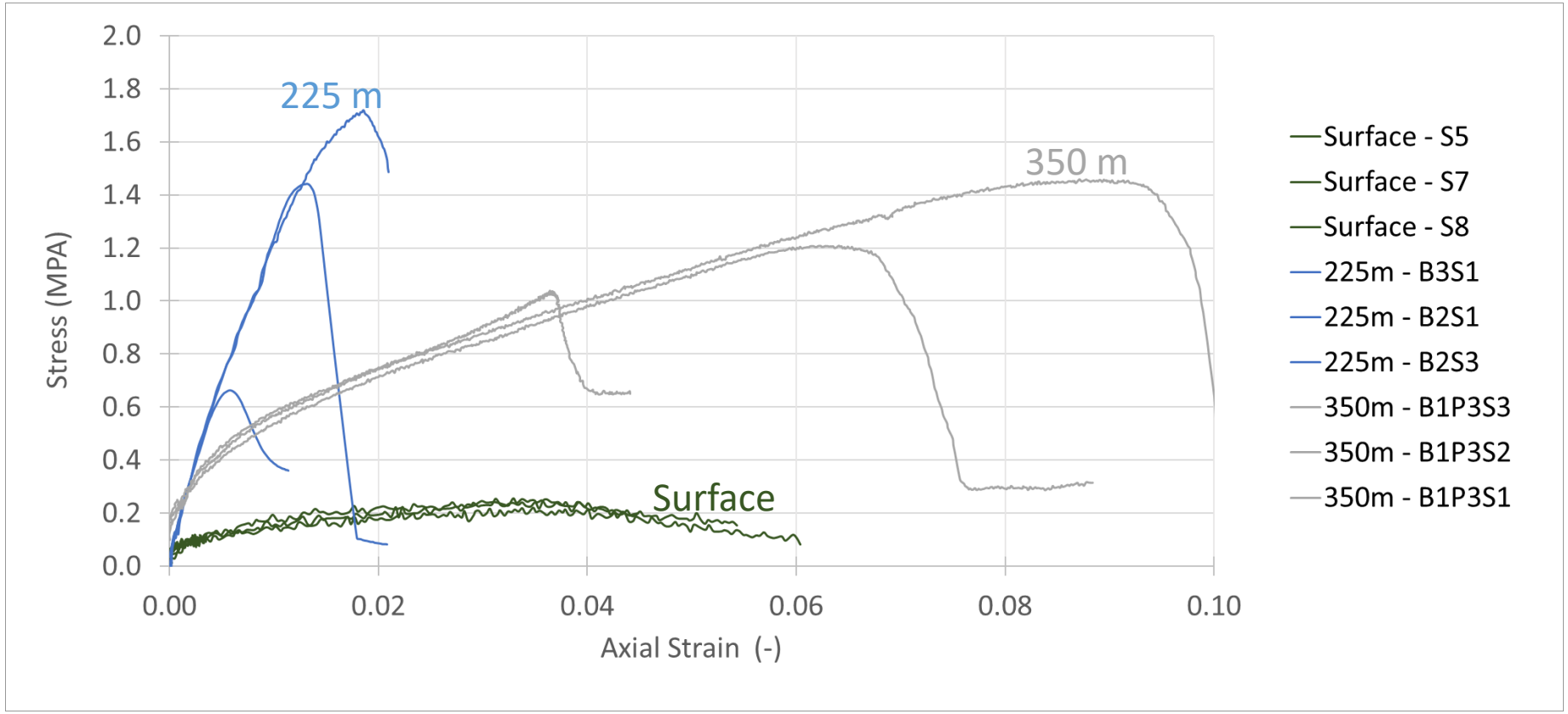
- Horseman et al., 1987 ($9.5 \cdot 10^{-5}/min$) CU ⊥
- Sultan et al., 2010 ($3 \cdot 10^{-5}/min$) CD ⊥
- Baldi, 1991 ($1.3 \cdot 10^{-5}/min$) CD ⊥
- Lê, 2008 ($1.3 \cdot 10^{-5}/min$) CD ⊥
- Coll, 2005 ($6.25 \cdot 10^{-6}/min$) CD ⊥
- Schuck et al., 2020 ($3.15 \cdot 10^{-6}/min$) CU ⊥
- This Study 225m ($3.3 \cdot 10^{-6}/min$) CD ⊥
- ϕ'=18°, c'=0.3 MPa (ref Boom Clay)

Isotropically consolidated to 9 MPa

Results

UCS

	W_L	W_P	IP
Surface	58 %	29 %	30
225 m	61 %	31 %	31
350 m	69 %	34 %	35



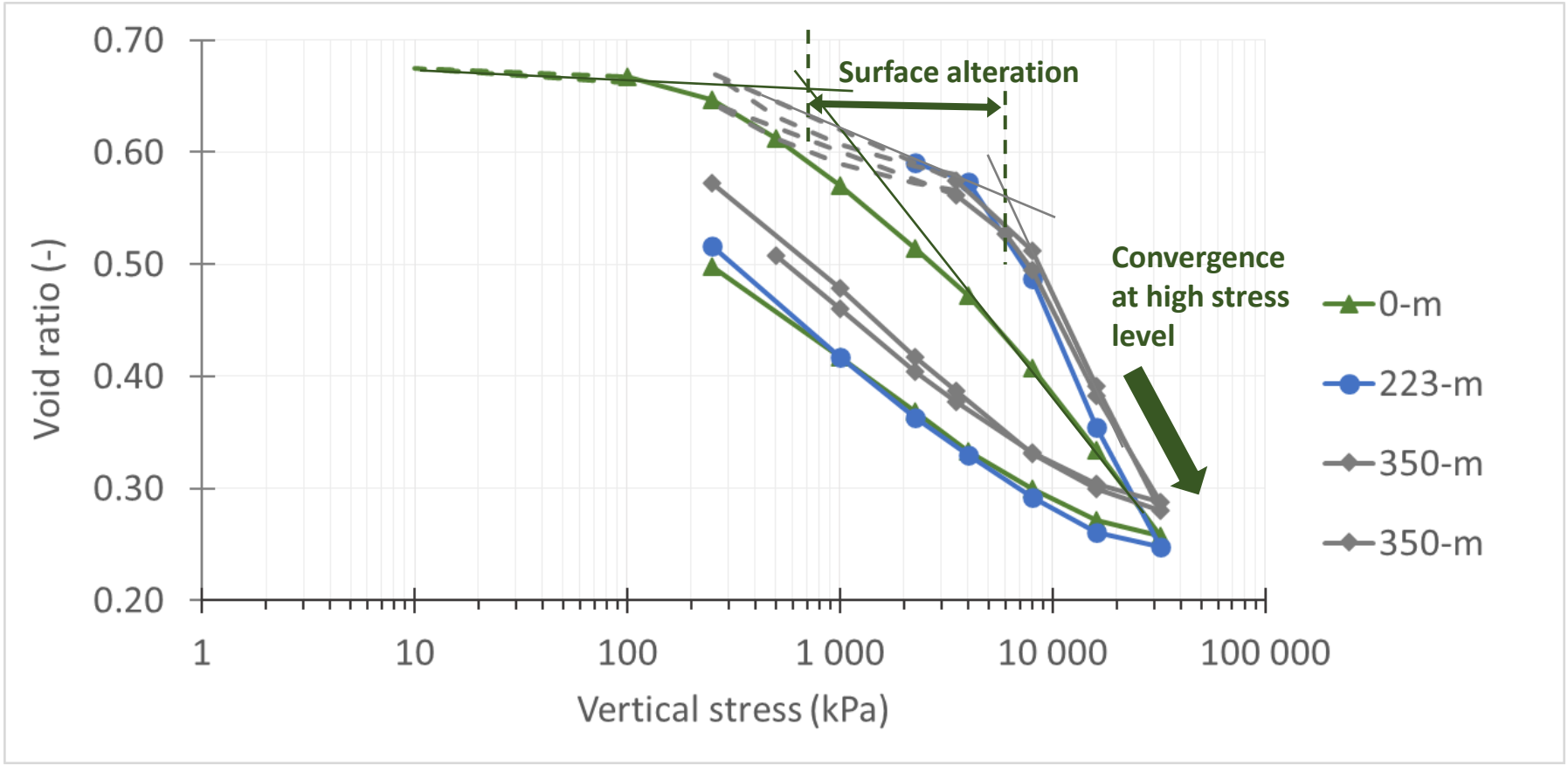
Results

Oedometer tests

1. Load sample to in-situ stress
2. After 1h, saturation of the sample
3. Unload sample to 250 kPa (or 10 kPa for surface sample)
4. Re-load to in-situ stress

5. Load to 32 MPa step by step
6. Unload to 250 kPa step by step.

Depth	Cc	Cs (unload)	σ'_p (MPa)
0 m	0.196	0.111	0.7
223 m	0.360	0.121	4.9
350 m	0.314	0.122	7.1



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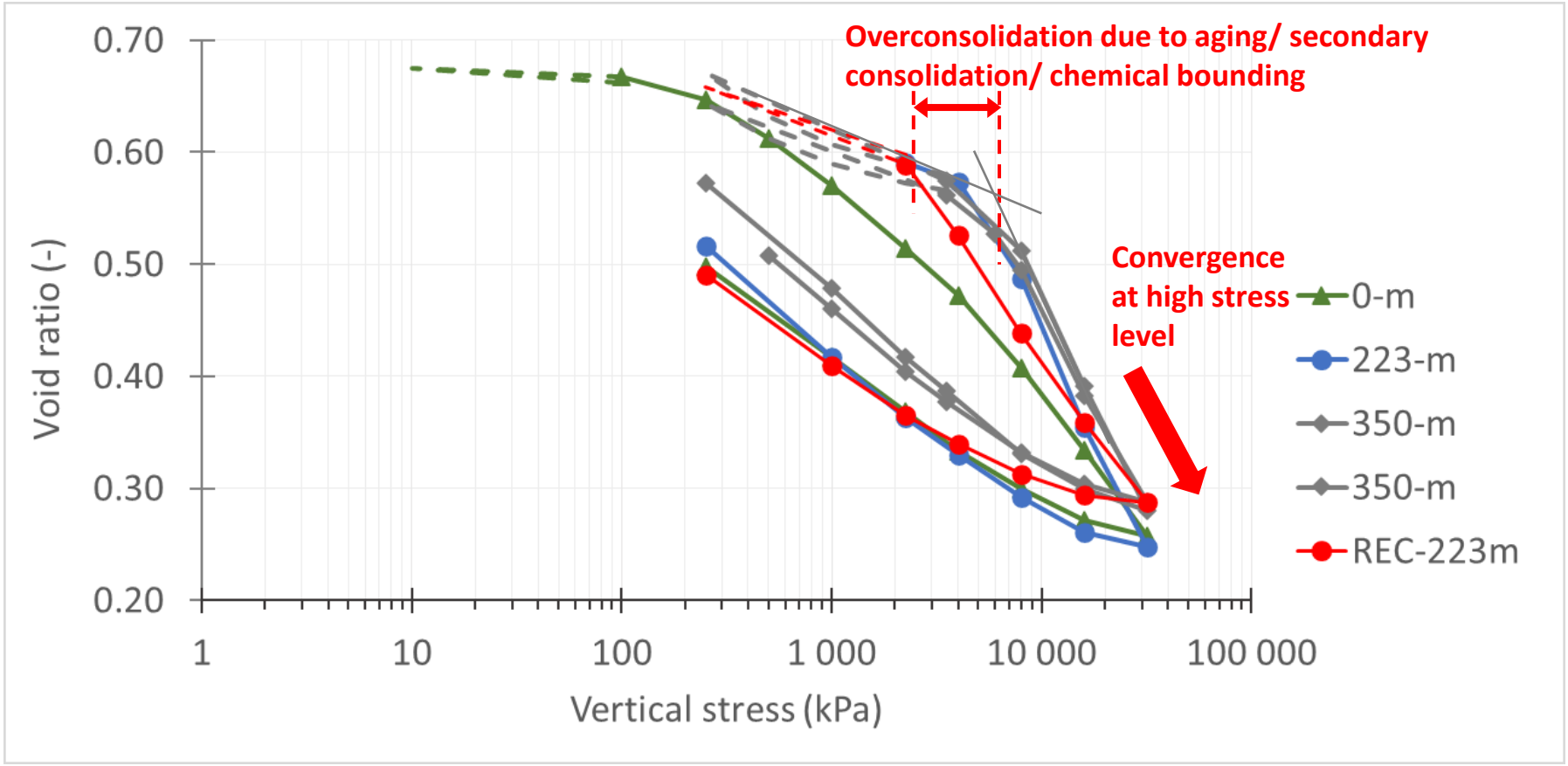
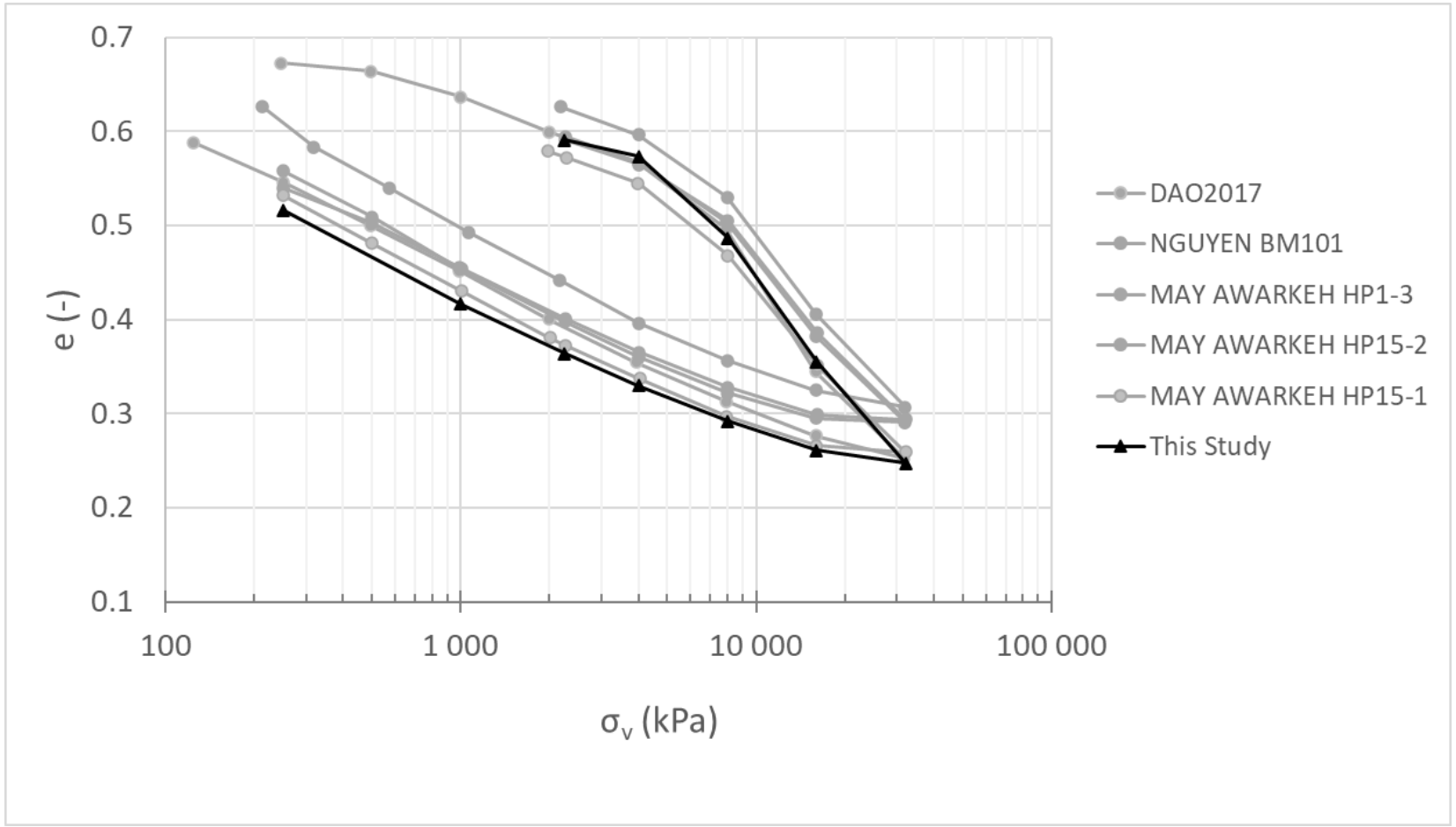


Results

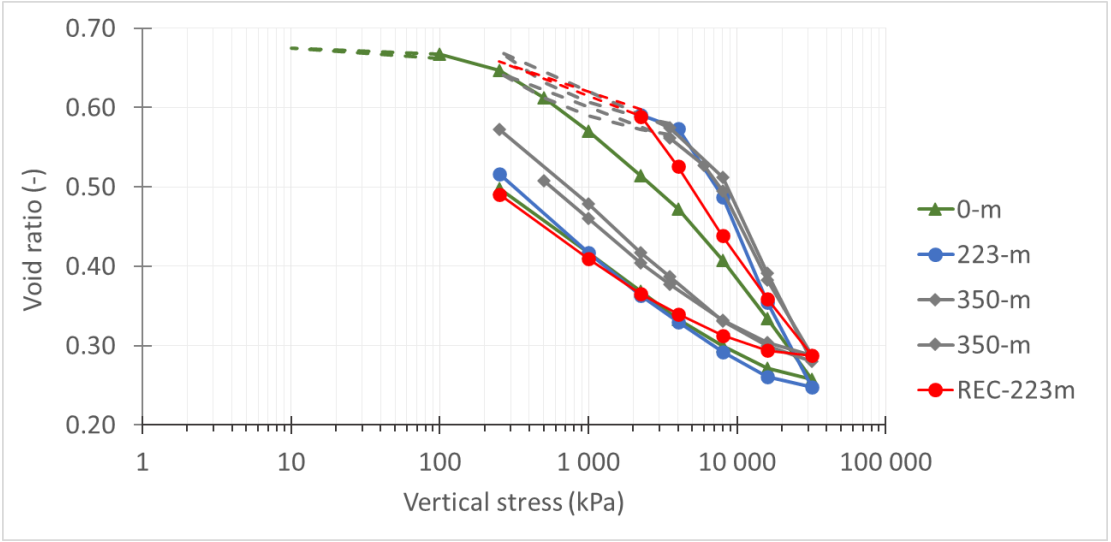
Oedometer tests 223 m : Comparison with literature

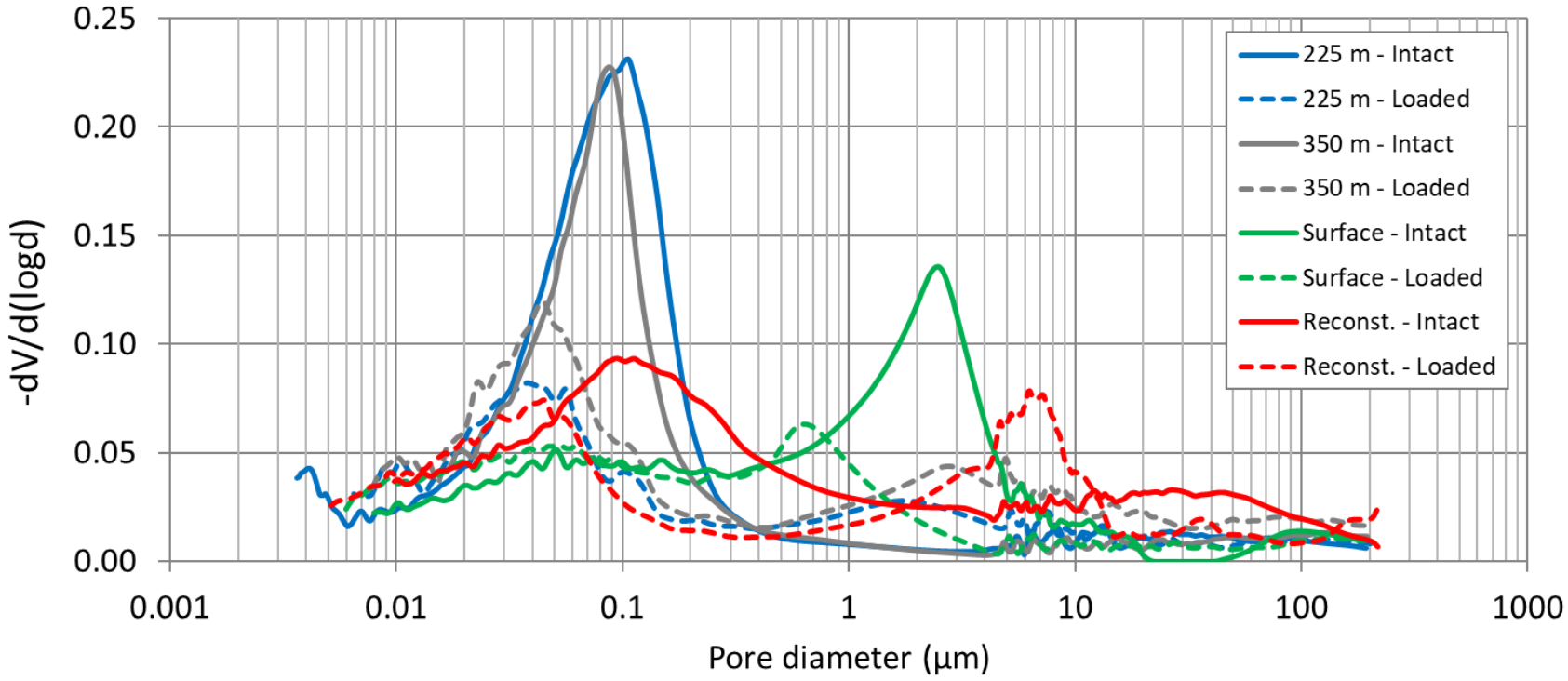


Results

Mercury intrusion porosimetry

- Pore size distribution **before and after oedometric loading** for the 4 kinds of specimen

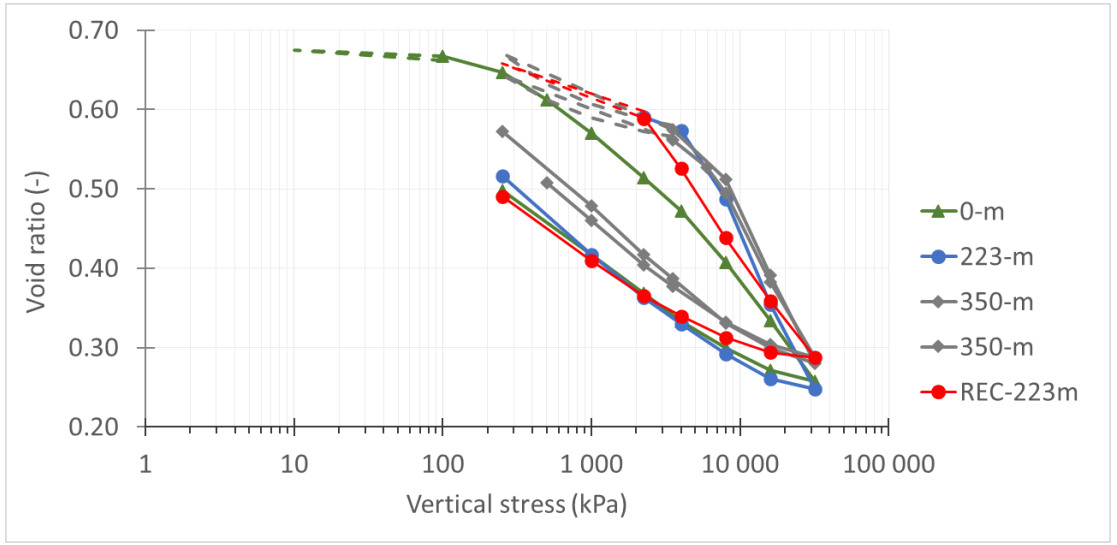


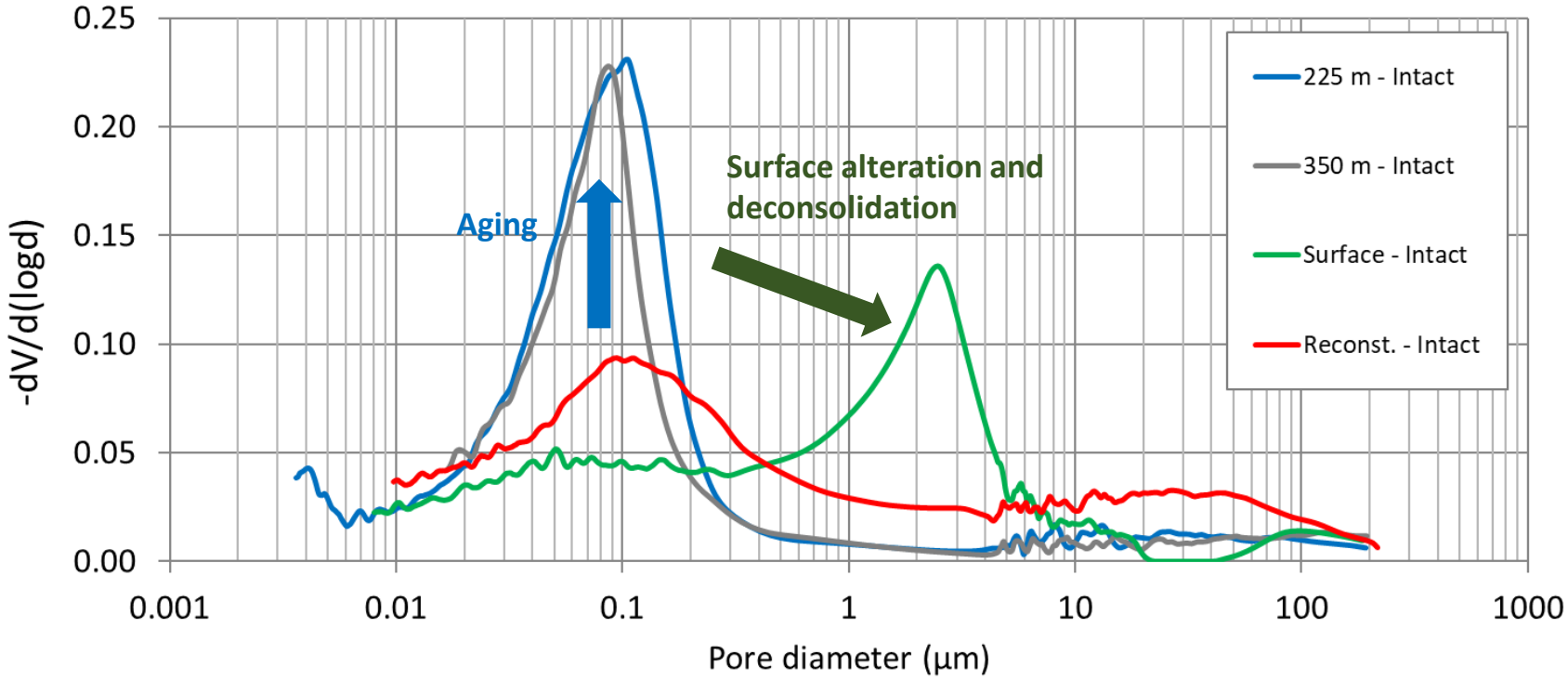


Results

Mercury intrusion porosimetry

- **Before loading** (intact specimen)

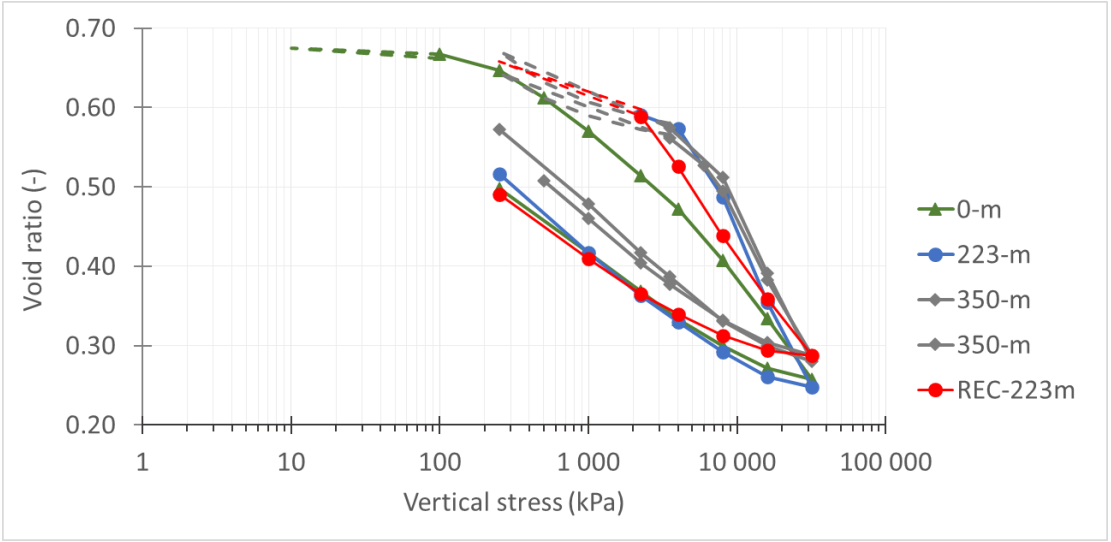


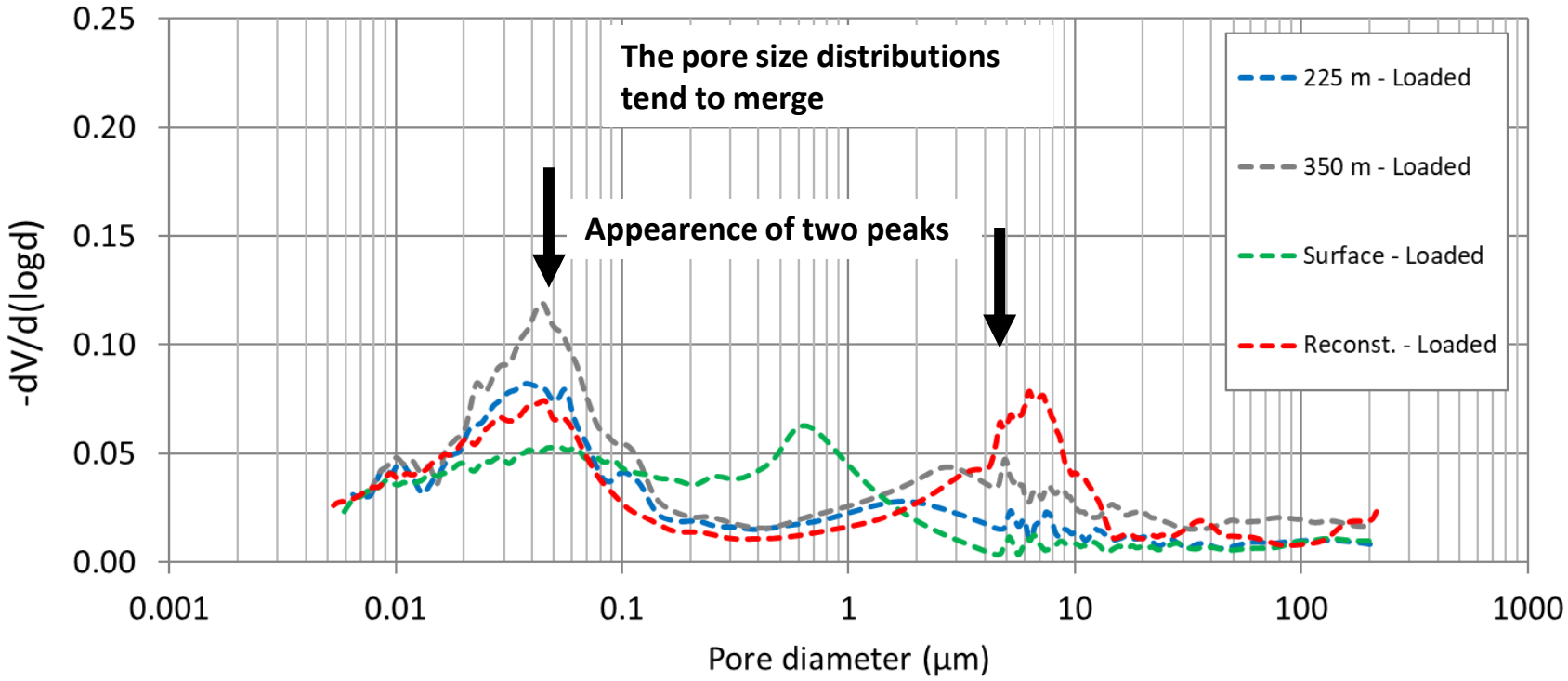


Results

Mercury intrusion porosimetry

- **After loading**

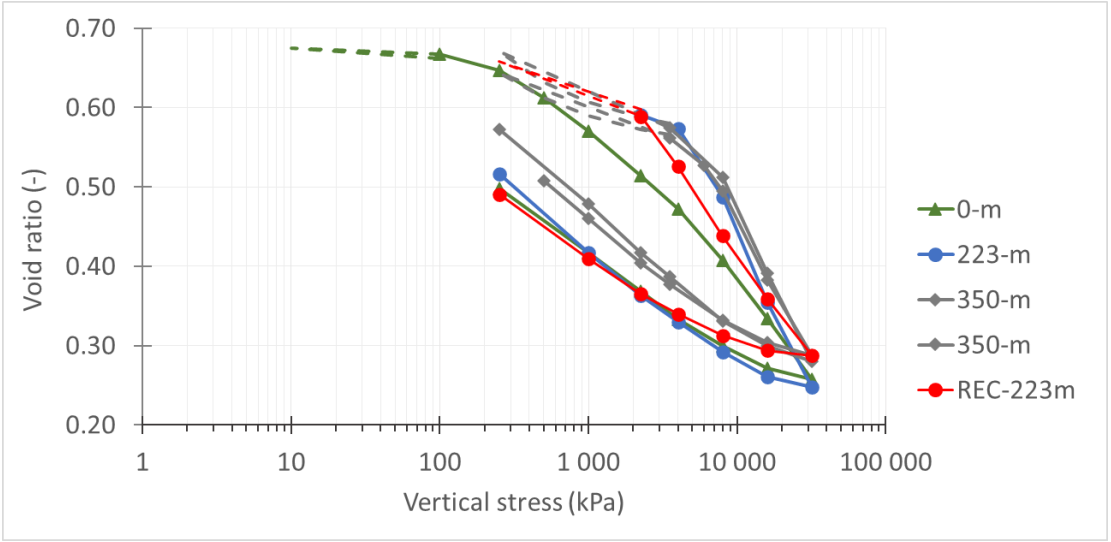


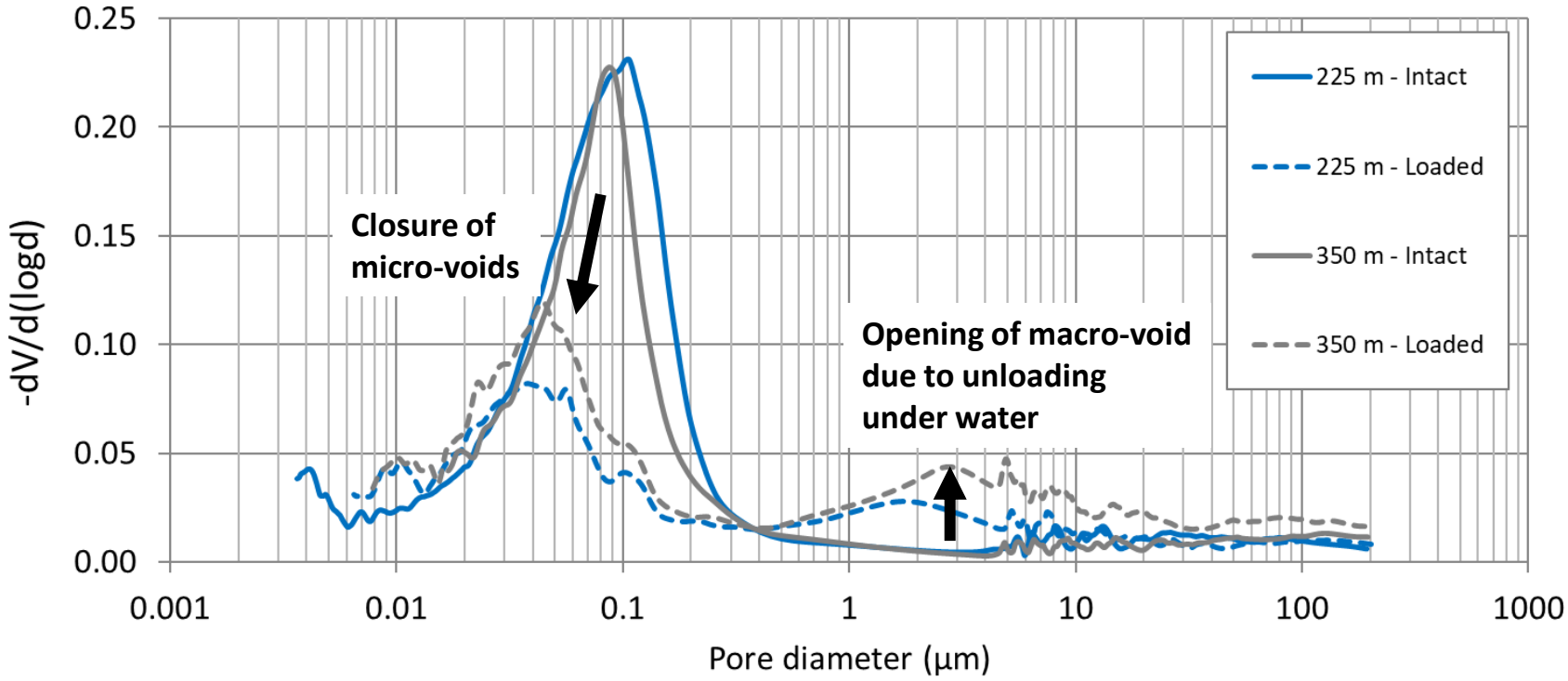


Results

Mercury intrusion porosimetry

- **Before/after loading**

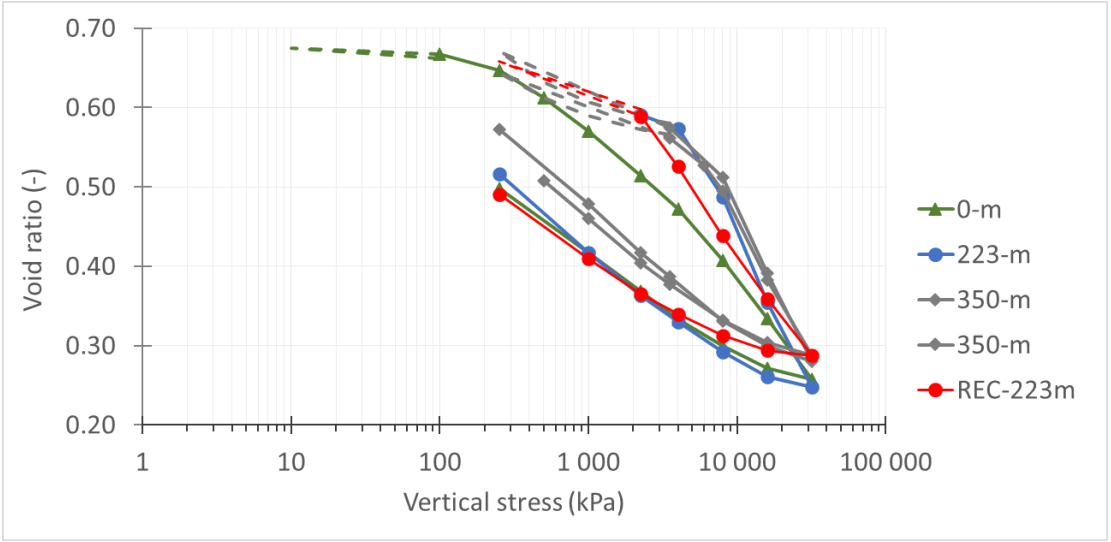


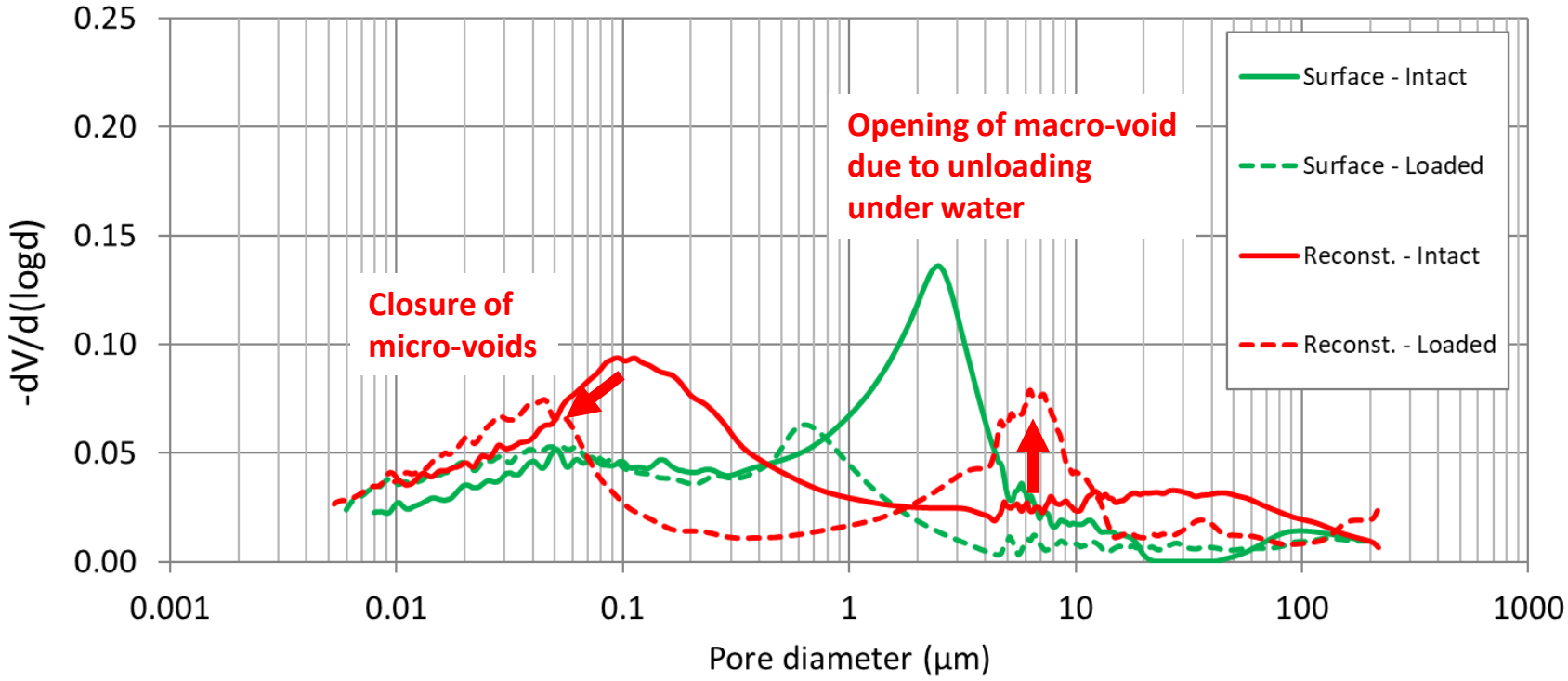


Results

Mercury intrusion porosimetry

- **Before/after loading**





Conclusions

- Boom Clay is a slightly overconsolidated plastic clay. This overconsolidation is due to mechanical overburden pressure (for surface samples) and aging (for deep samples).
- Its characteristics differ from place to place, as a function of the depth due to more silty or clayey deposit layers
- Triaxial test results reveal anisotropic and time-dependent responses
- Low permeability and swelling character make it a good candidate to host underground nuclear waste disposal

Thanks for your attention …

With the support of ONDRAF/NIRAS