UNIVERSITY OF CAMBRIDGE

The deep ocean seabed: where biology meets engineering

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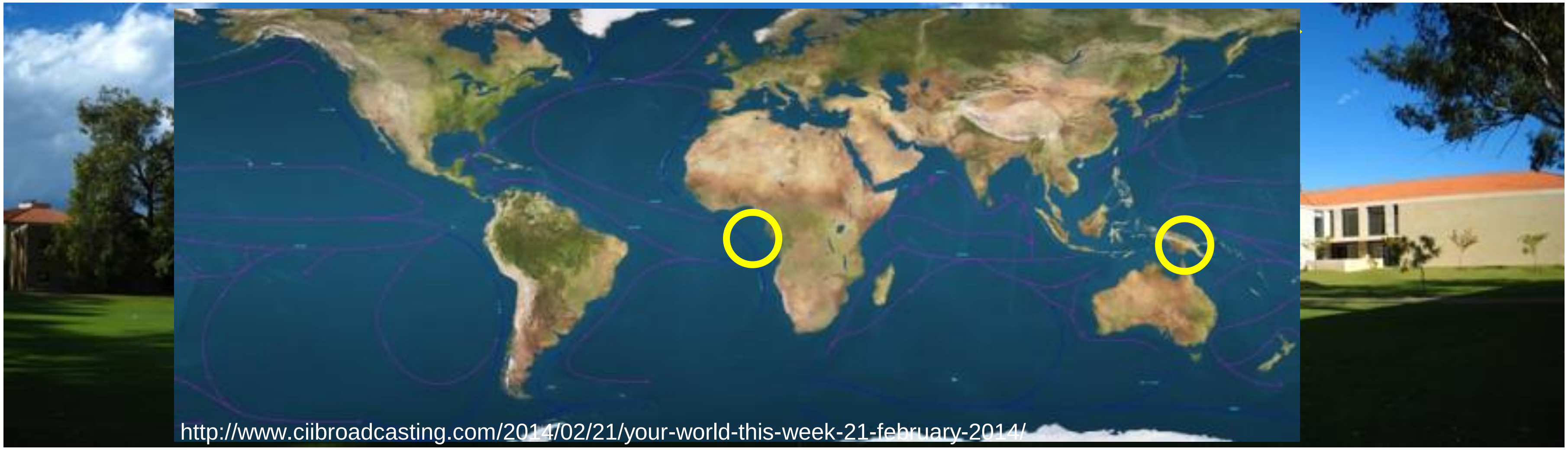
Talk outline

- Background: what drove the research
  - Deep-water offshore pipeline design
  - Imaging observations of seabed sediment
- Biologically altered sediment
  - Influence on soil properties
  - Micromechanical observations
- Concluding comments

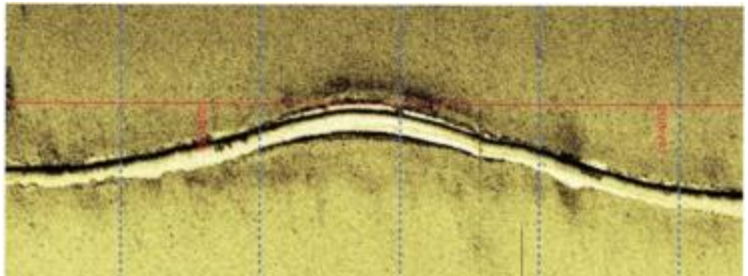
Where it all started

- A meeting at the University of Western Australia:
  - MK- “I’d like to do a PhD that links geology with engineering…”
  - MDB- “Well…what about looking at the behaviour of hot-oil pipelines on deep-water seabed ‘crusts’ from the Gulf of Guinea?”

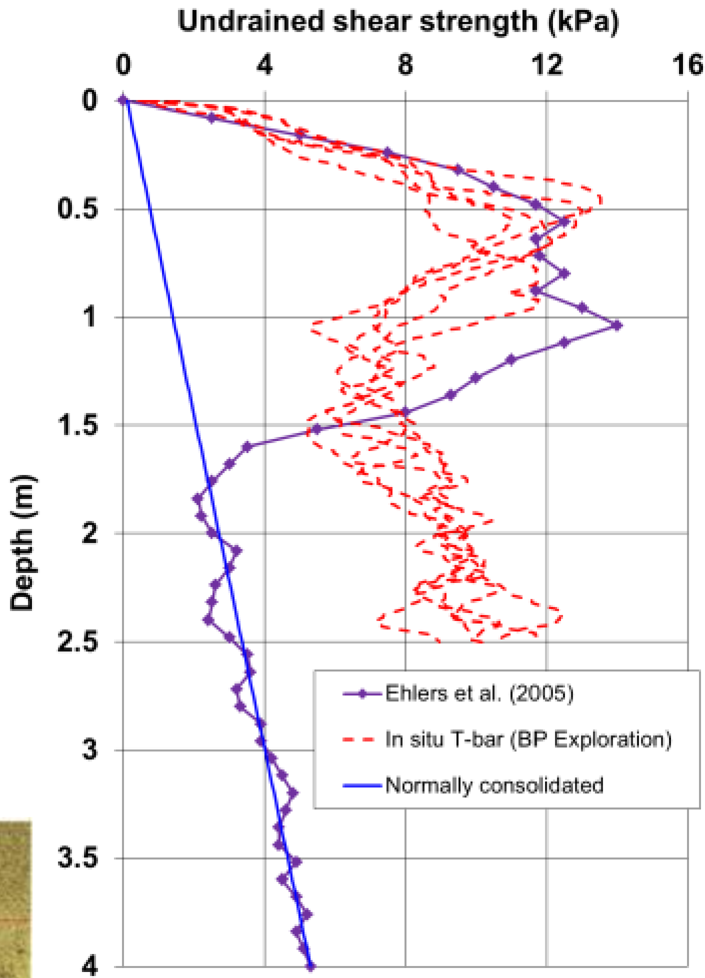


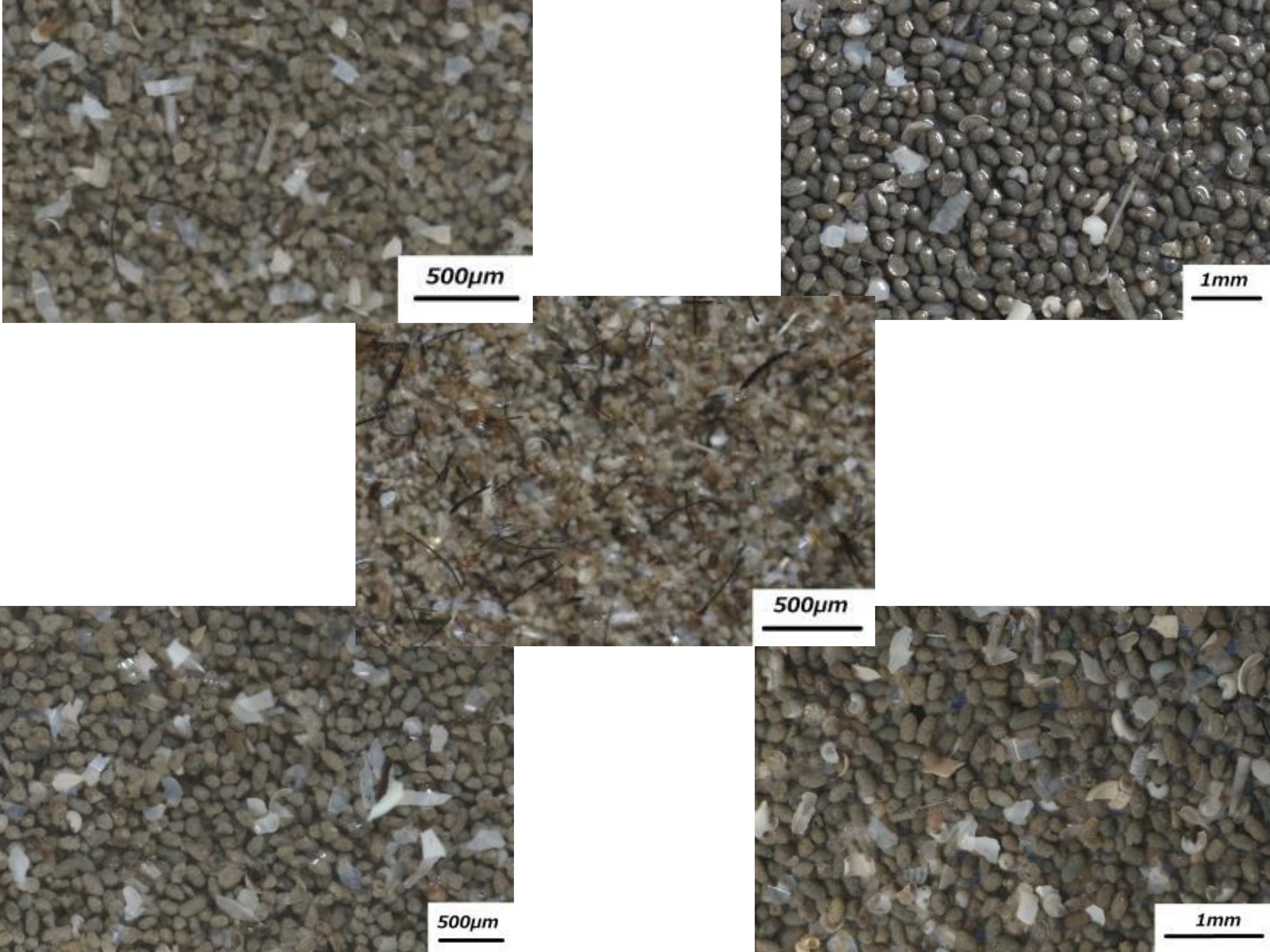
Background: hot-oil pipelines on deep ocean clay crusts

- Crust location: West coast of Africa
  - Water depths: 500 to 2000m
- Hot oil flowing through cold pipelines
  - Thermal expansion→ pipe walking and buckling
- Rely on interface friction to control the movement of pipelines



After Bruton et al. (2007)

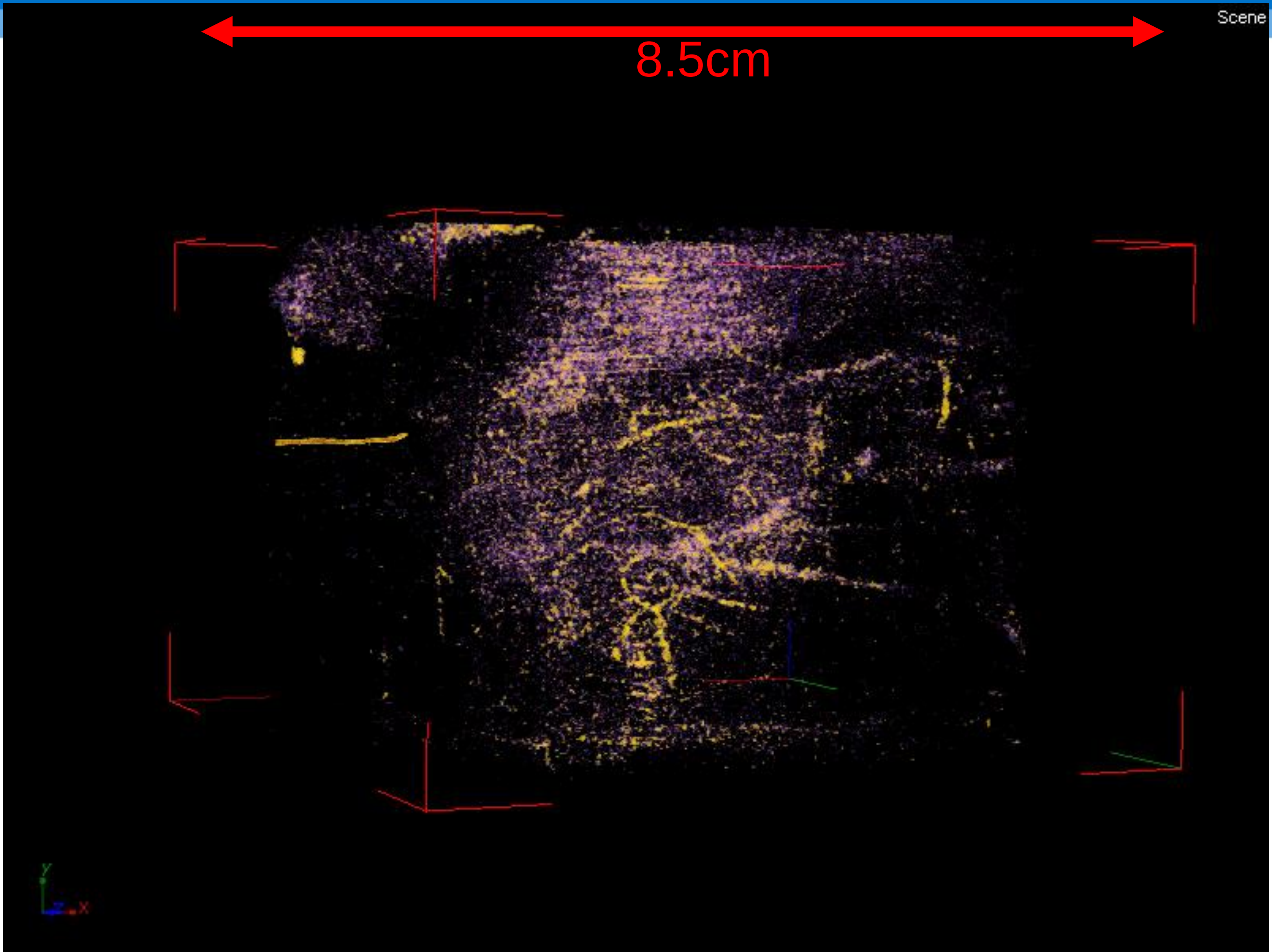



500µm
1mm
500µm
500µm
1mm

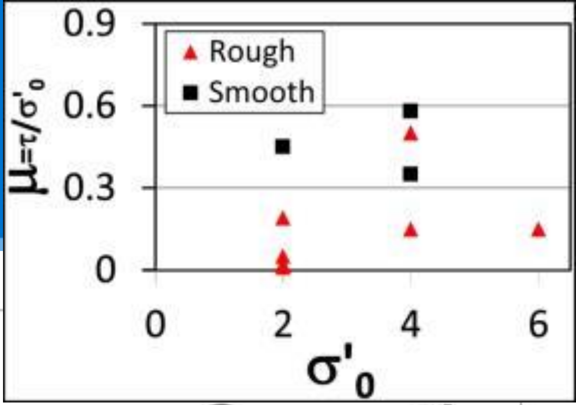
‘Biologically-structured’ soil

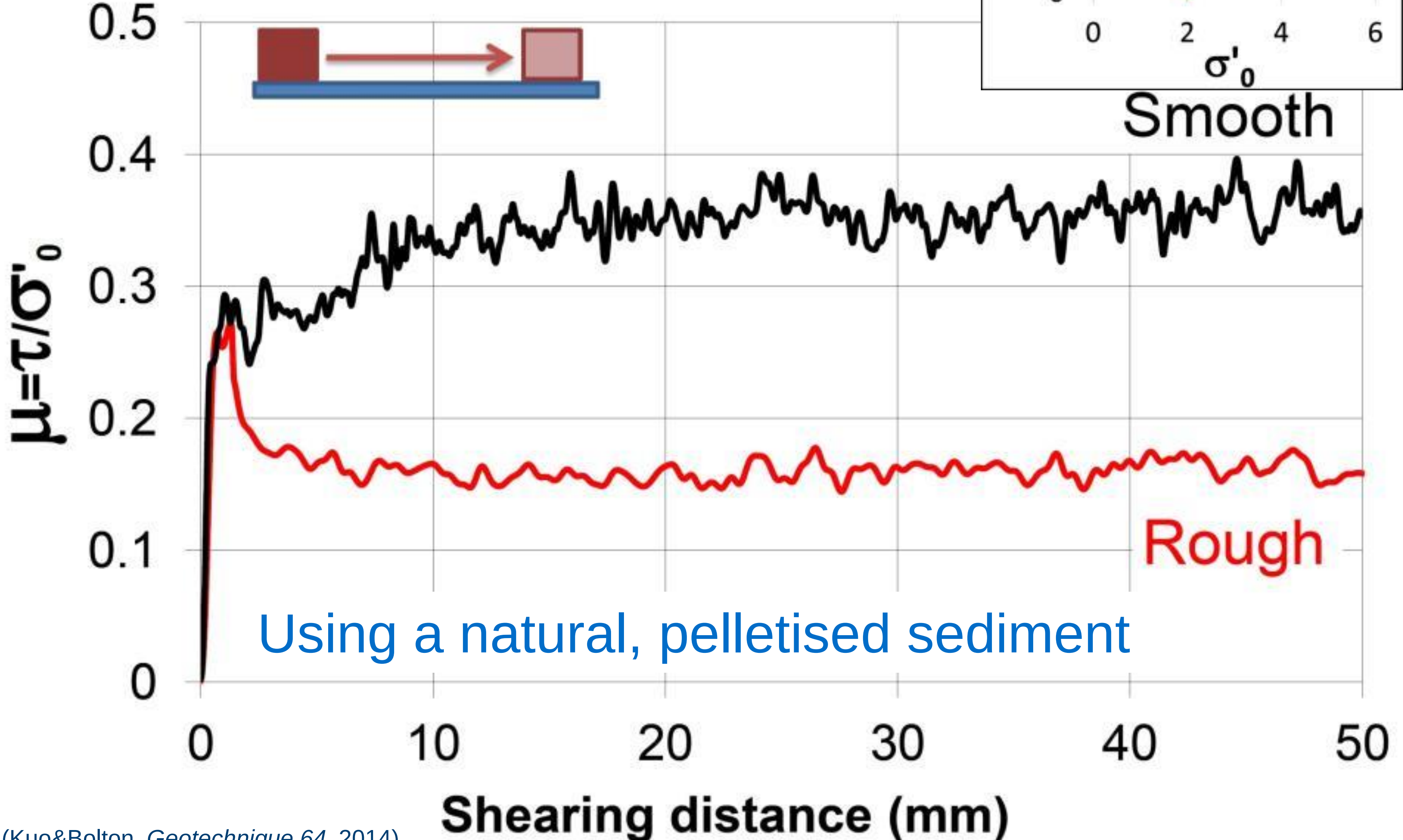
Pellets biologically created…chemically altered to glauconite

Other biological structures: intricate network of burrows



Influence of pipeline roughness on interface friction value



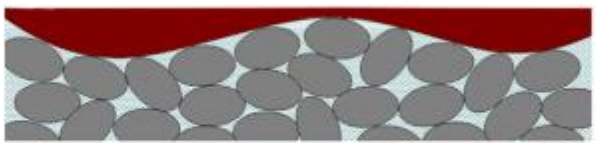


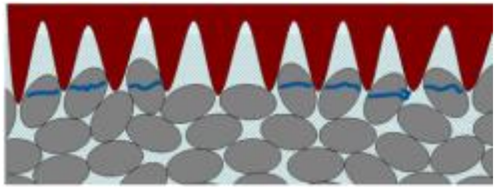
Using a natural, pelletised sediment

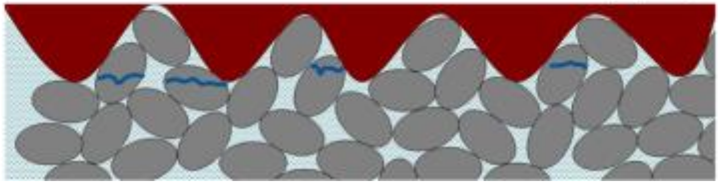
(Kuo&Bolton, *Geotechnique 64*, 2014)

Complicated micromechanics

- Intact pellets are ‘relatively strong’ in compression…but will they break when a rough pipeline moves over them?
  - Is this why a rough interface produces a lower interface friction value?



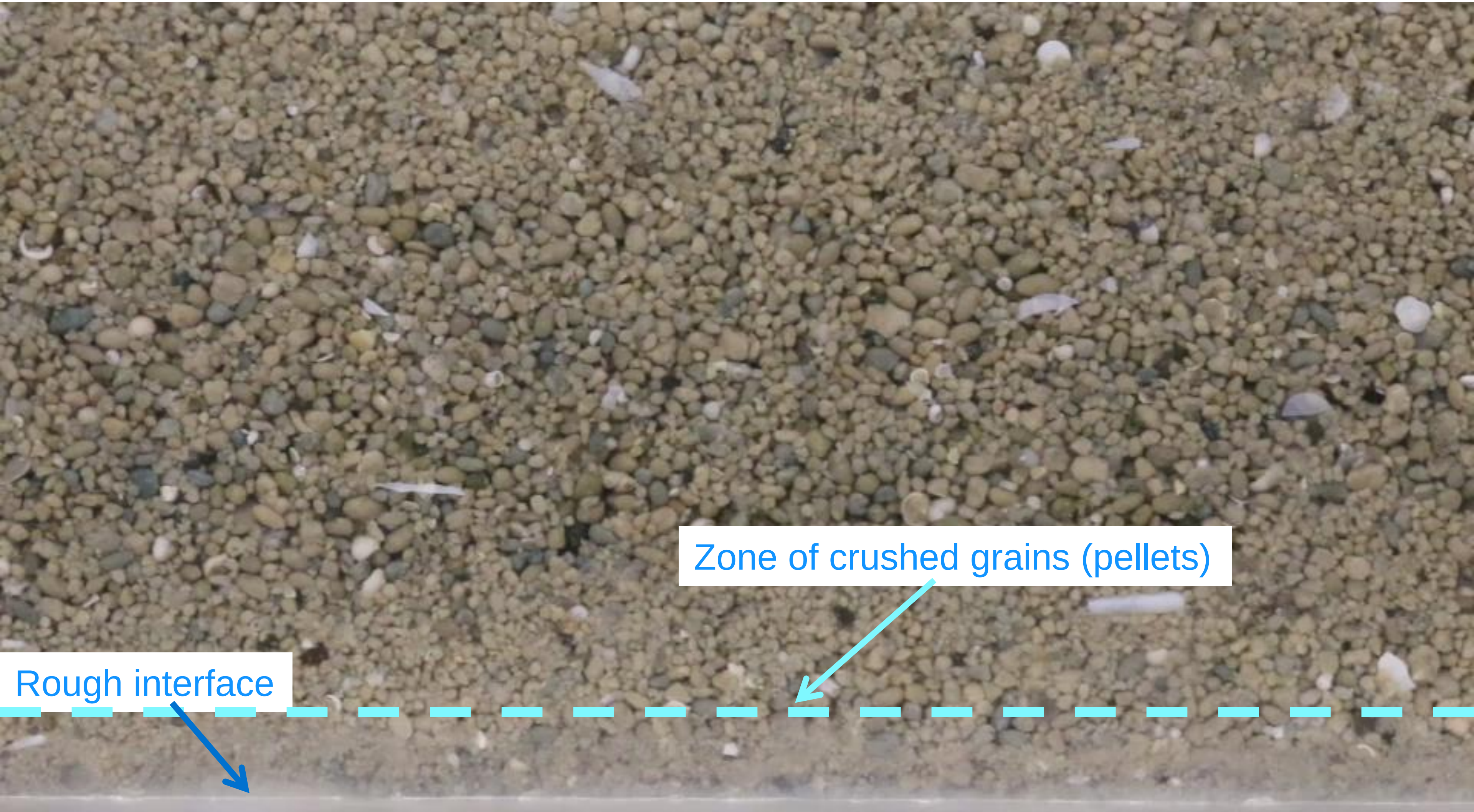




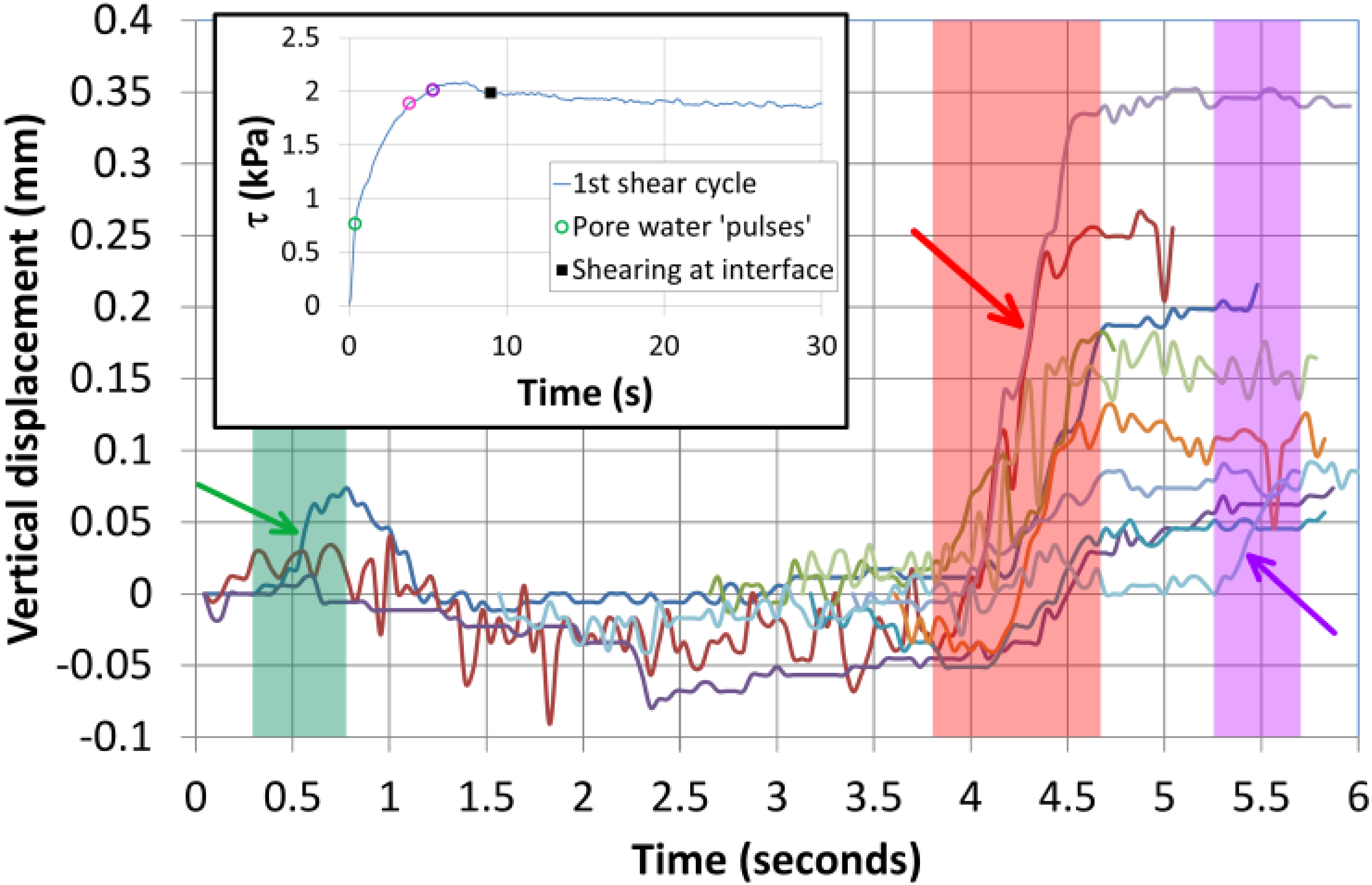
- A preliminary investigation into:
  1. Pellet sample shearing against rough interface
  2. ‘No pellet’ sample shearing against rough interface
  3. Natural soil containing pellets against a smooth interface

1. Shearing of pellet 'grains'

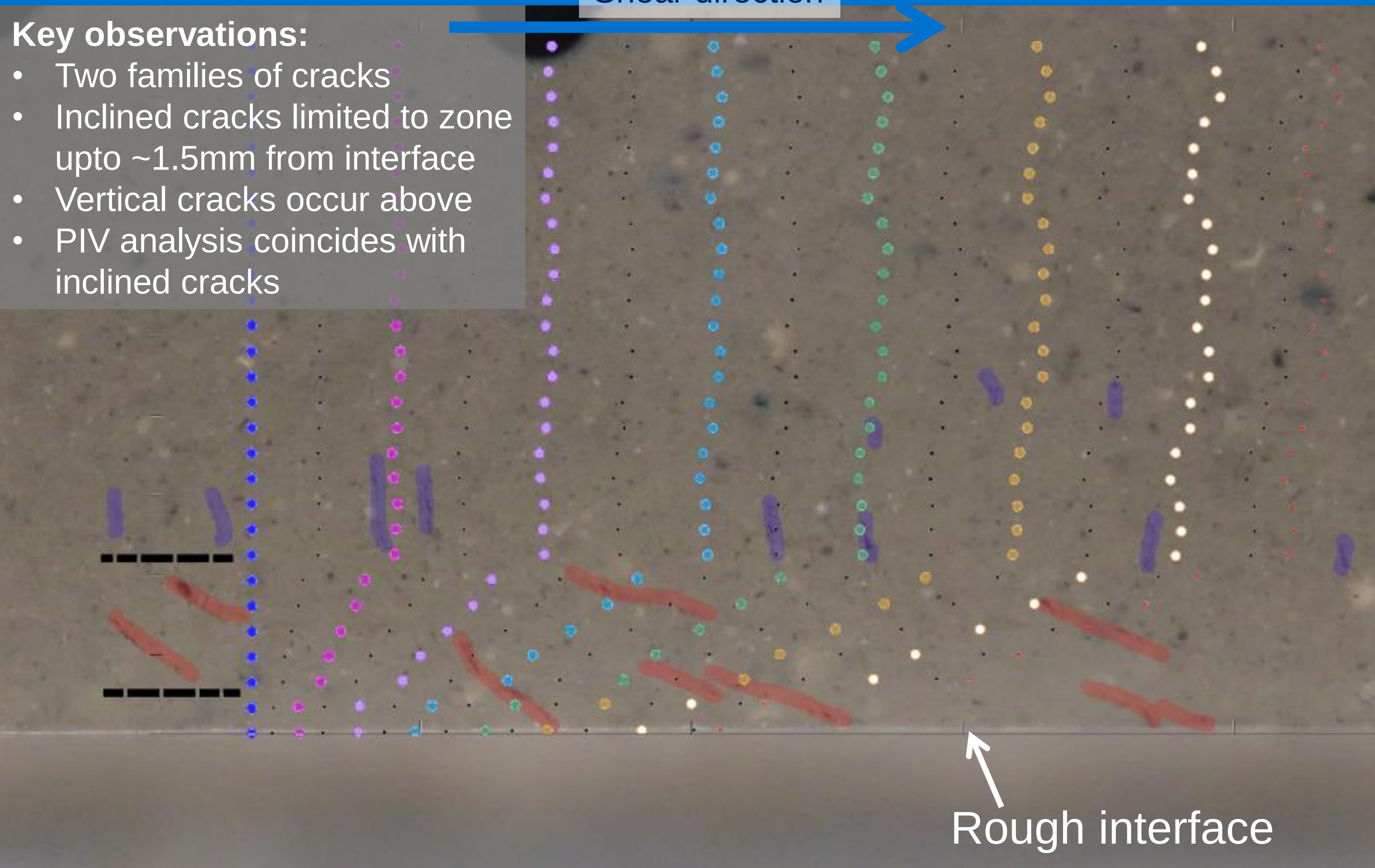
- Yes- pellet crushing occurs when shearing on a rough interface



Pore water ‘pulses’ during shearing of pellets



2. And if there are no pellets?



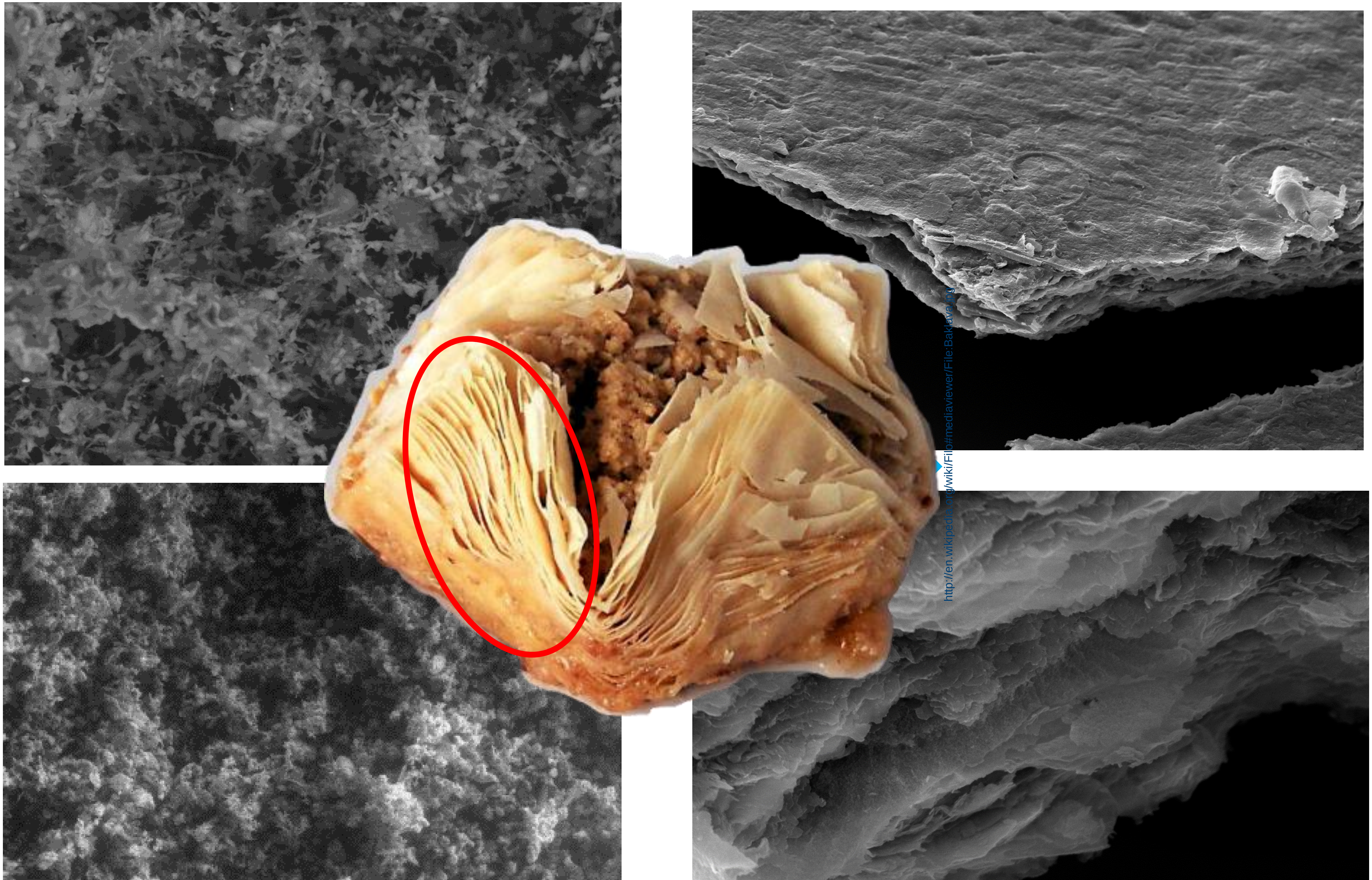
Key observations:

- Two families of cracks
- Inclined cracks limited to zone upto ~1.5mm from interface
- Vertical cracks occur above
- PIV analysis coincides with inclined cracks

3. How about a smooth interface?

- **An example shear test -**
- Heterogeneous deep-water Angolan silty clay
  - Pellets, agglomerates, diatoms, other detritus
- Monotonic shearing against a smooth interface for 22.8m
- Normal stress = 5kPa
- Shear rates = 0.5, 0.05, 0.005 and 0.0005mm/s

After shearing: evidence for re-structuring and realigning



Discussion of shearing behaviour

- Rough interface destroys natural structure
  - Crushing of ‘fresh’ pellets, generation of positive excess pore pressures (presented in Kuo&Bolton- this conference)
  - Formation of two families of cracks in soft clays (presented in Kuo- this conference)

- Smooth interface leaves natural structure intact?
  - At a ‘macro-scale’, largely yes?
  - At a ‘micro-scale’, perhaps no...
    - Evidence for re-ordering and re-structuring of clay fabric

Concluding comments

- Research observations
  - Seabed comprises biological structures including pellets and burrows
    - Choosing the correct scale (and tools) can sometimes be all it takes (Goldilocks)
    - Biological structures influence behaviour of pipelines
  - Particle crushing, crack formation, restructuring of original structure
  - Shearing with rough and smooth interfaces BOTH alter the soil structure: on the micro-scale
    - Rough interface → turbulent, destructive shearing
    - Smooth interface → sliding, realigning of structure

- A multi-disciplinary topic requiring more than just geology and engineering…
  - Biology, microbiology, zoology

“*...observe the small facts upon which large inferences may depend...*"

- Sherlock Holmes, The Science of Deduction, Sir Arthur Conan Doyle