PARIS 2017

CORE IMAGE PROPERTY LOGGING
for rock typing and core-to-log upscaling purposes

Ulf Böker, Michael C. Drews, Kuncho D. Kurtev, Andrew C. Aplin

Caprocks JIP Objective: "To integrate seismic, petrophysical, rock mechanical and geochemical data to produce methodologies with which to (a) quantify seal risk and (b) define the rates, mechanisms and pathways by which petroleum migrates vertically through kilometre-scale sequences of fine-grained sediments."

Introduction

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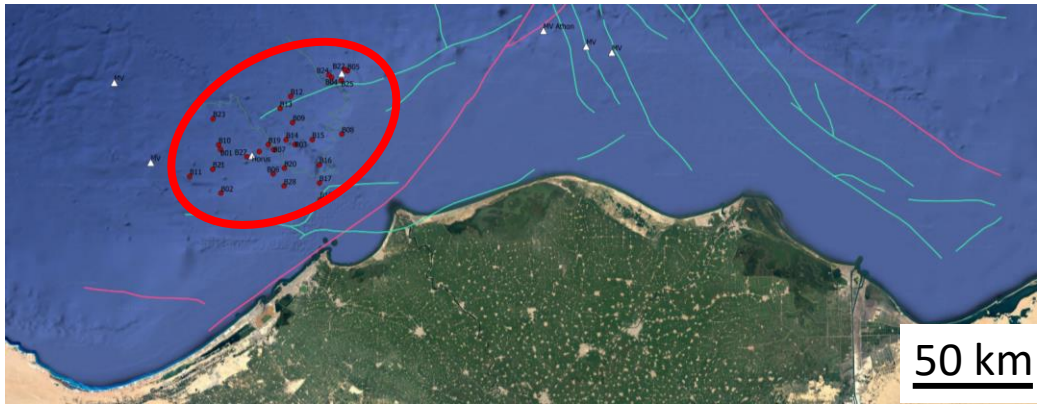
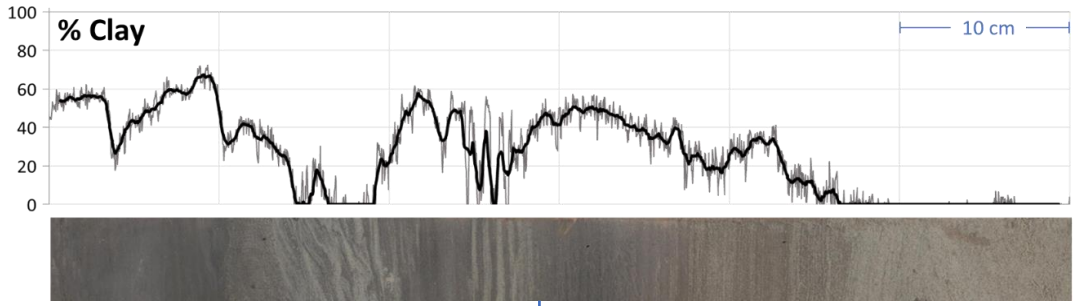
Nile Delta case study, offshore Egypt

- Pliocene slope channels + overbank
- Hemipelagites, turbidites, debris flows etc.
- Analyzed 650 m core in 4 priority wells

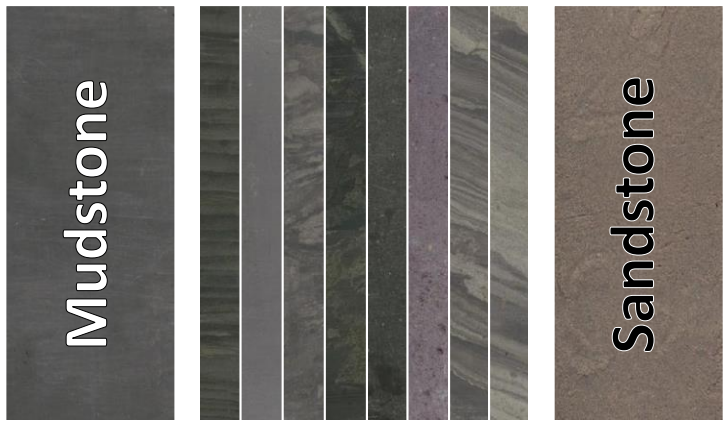


Objective

- Obtain grain size logs from core images

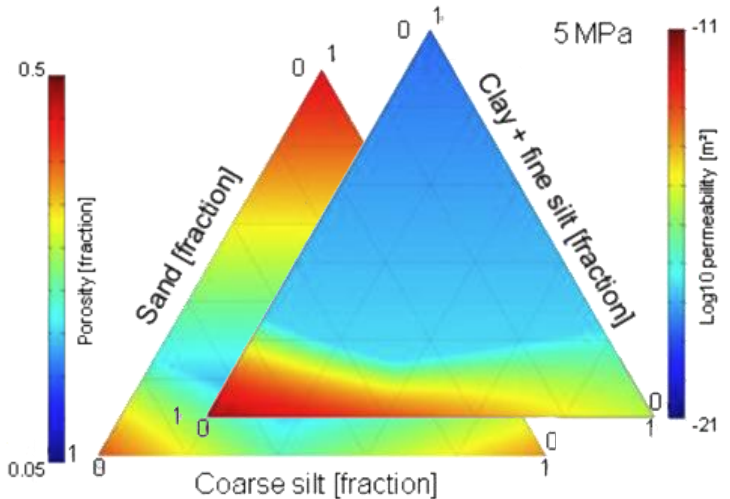


Motivation



Support rock typing…

<u>and</u> caprock flow models



Integrated Rock Typing Approach

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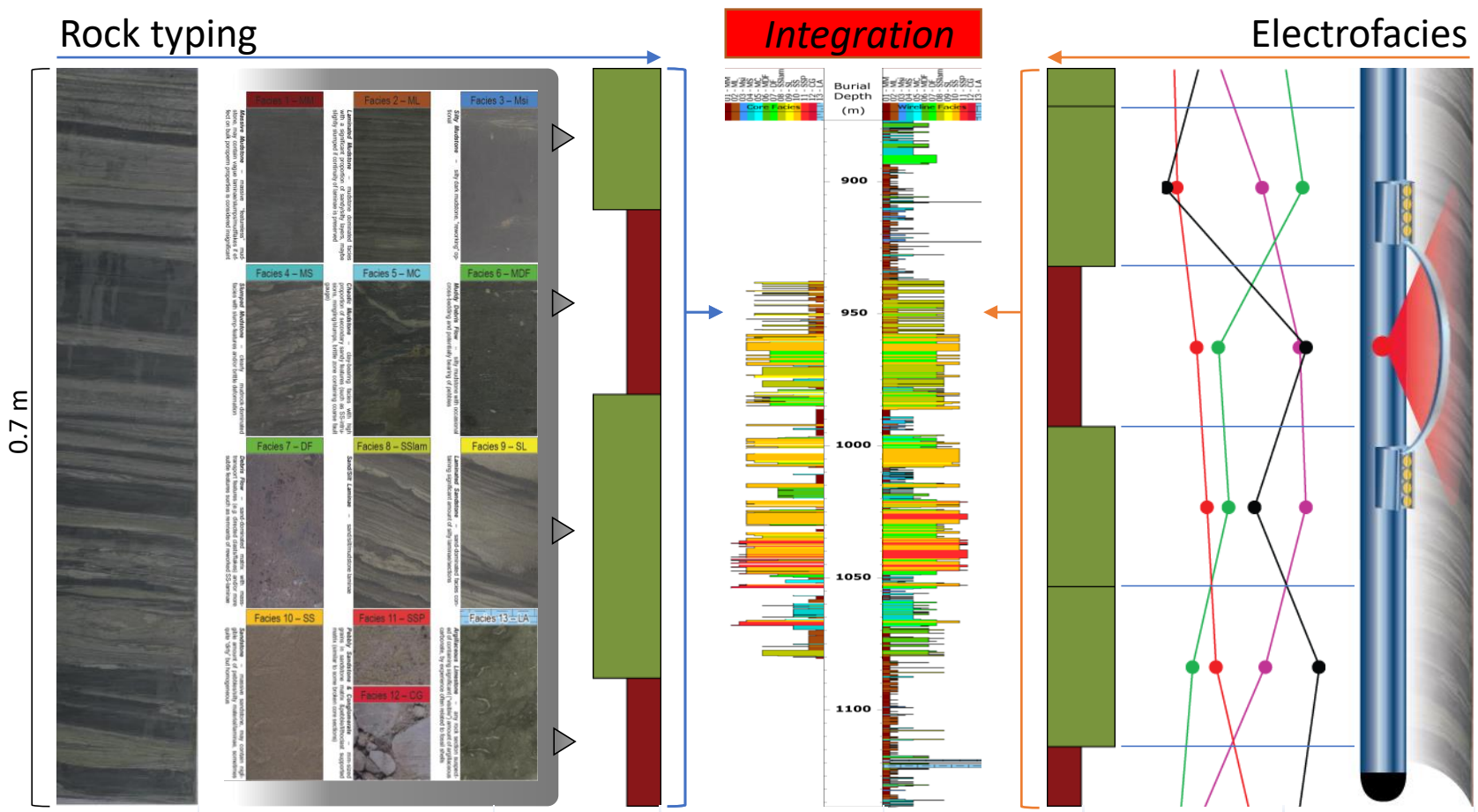
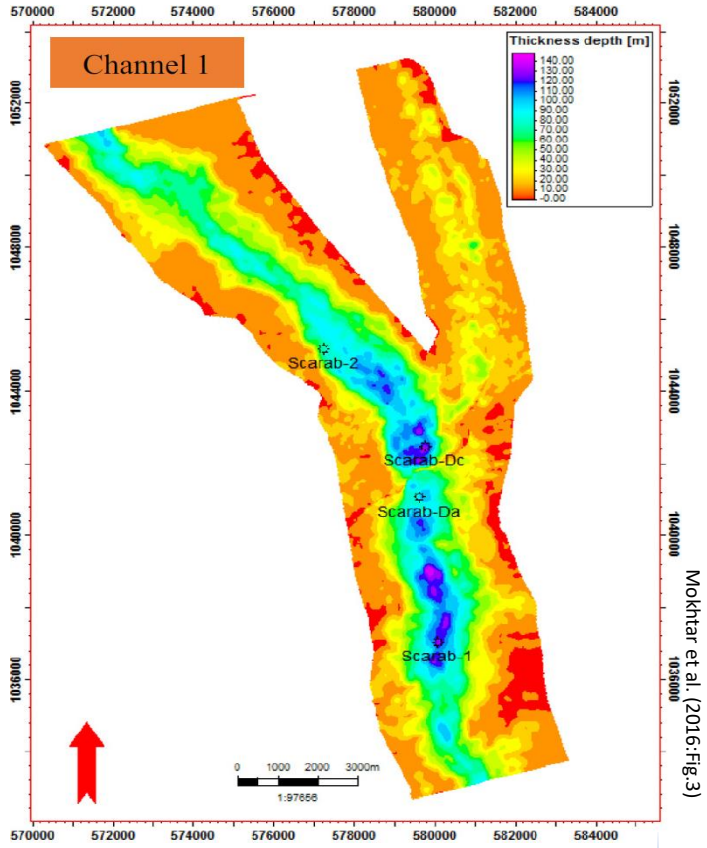
Core domain | Borehole domain | 3D seismic domain

Rock typing

Integration

Electrofacies





Mokhtar et al. (2016:Fig.3)

Core | Information | Geology | Zones? | Output | Zones?! | Well logs | Formation

Conventional channel reservoir

Integrated Rock Typing Approach

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Core domain

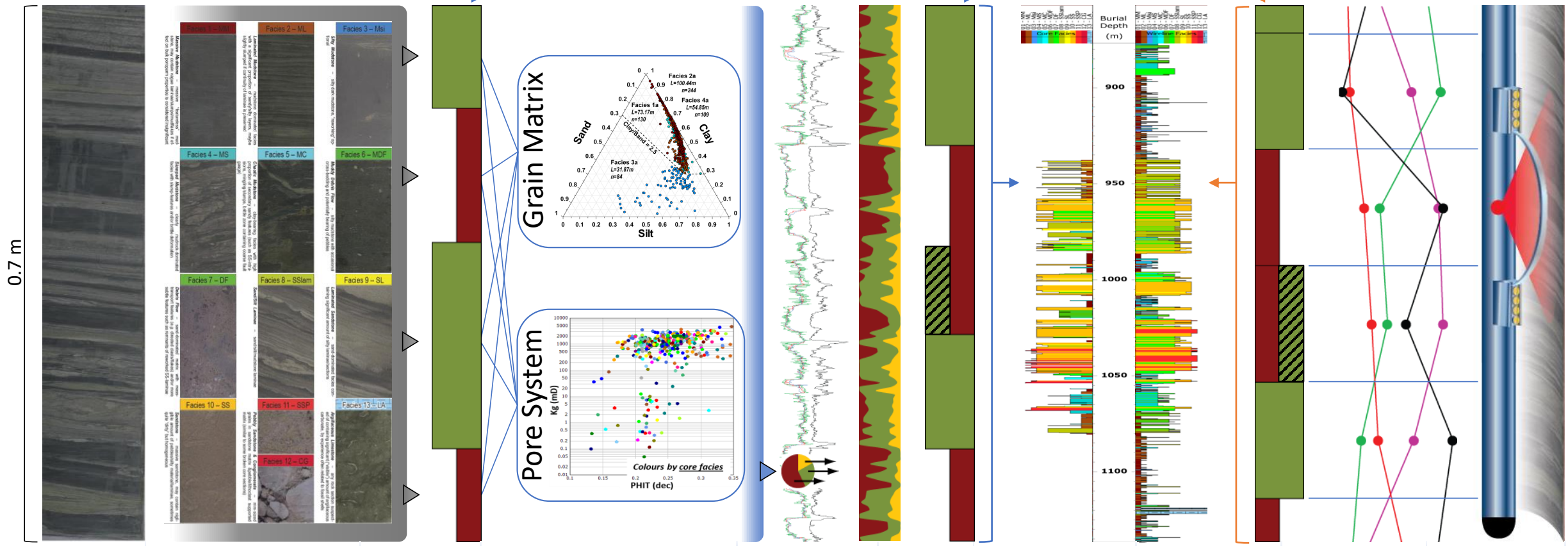
Borehole domain

Rock typing

Validation

Integration

Electrofacies



Core | Geology | Zones? | Petrophysics | Pixel logs | Zones! | Output | Zones?! | Well logs | Formation

Rationale

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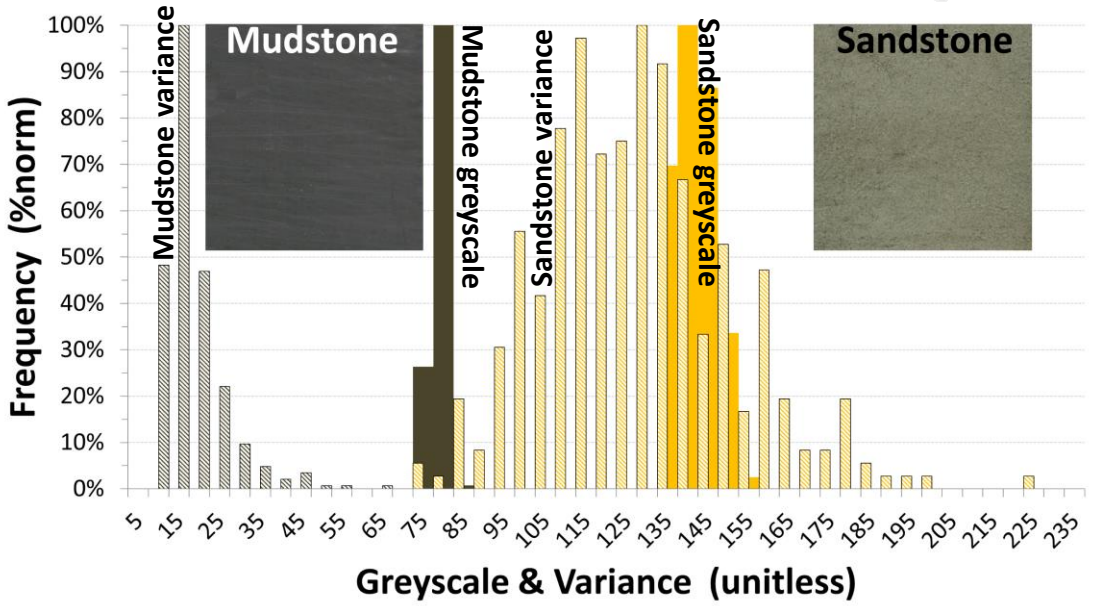
Grain sizes from photographs?

- Pixels in greyscale: 0 (black) to 255 (white)
- Ideal clay (<2µm): dark + uniform shading
- Ideal sand (>63µm): light + grain shadows
- … how about silt (2–63 µm) ?

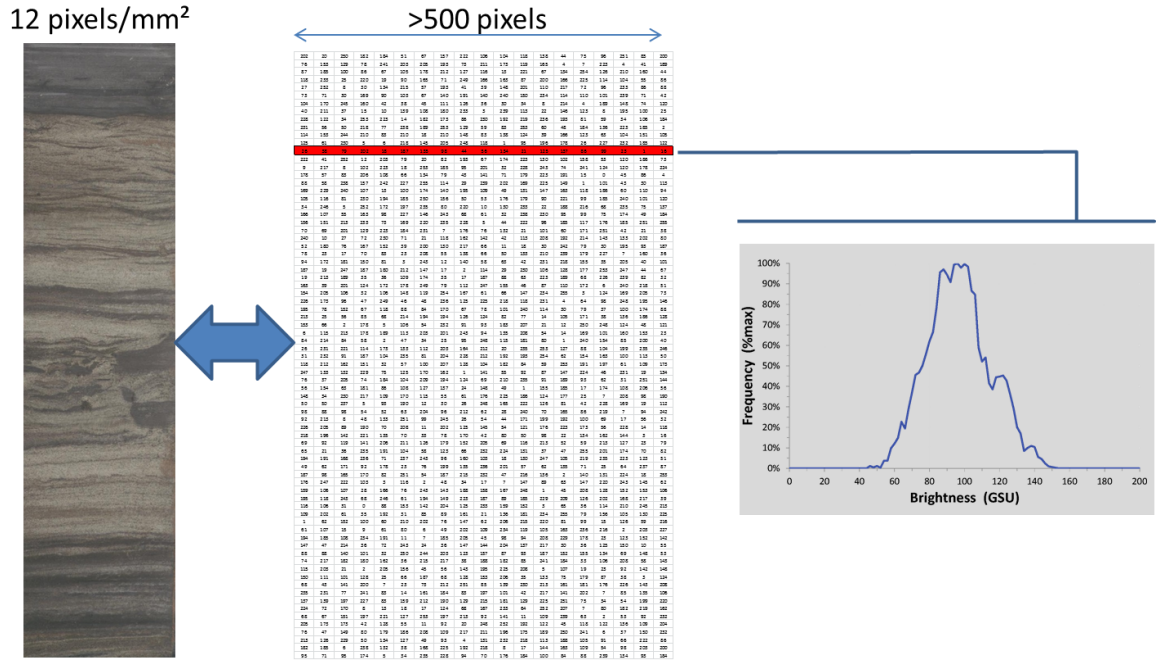


Statistical parameters from pixel rows

- Working hypothesis: horizontal bedding
- Preprocessing: non-rock → white (255)
- Generate parameter logs per row
  - Arithmetic average
  - Mode and median
  - Variance

  } *Brightness* logs

  } *Coarseness* logs



Grain size analysis of core plugs

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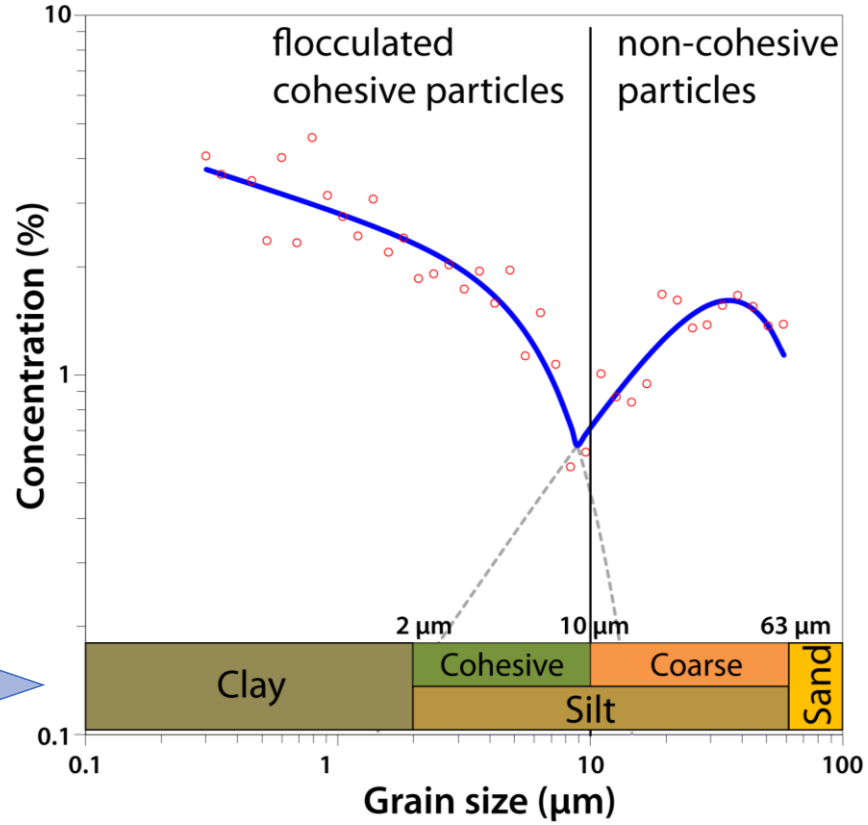
Sampling and processing

- Plugs taken after core slabbing, sampling bias on clay-rich strata
- Sample preparation: gentle saturation-freeze-thaw cycles
- Laser Particle Size Analyses



Model Calibration Workflow

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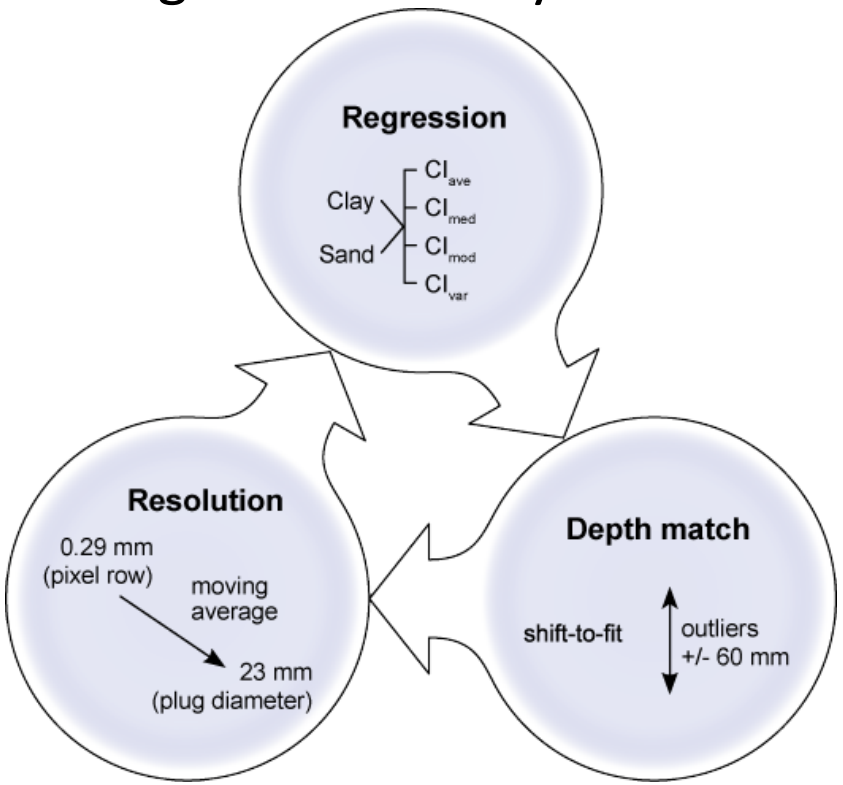
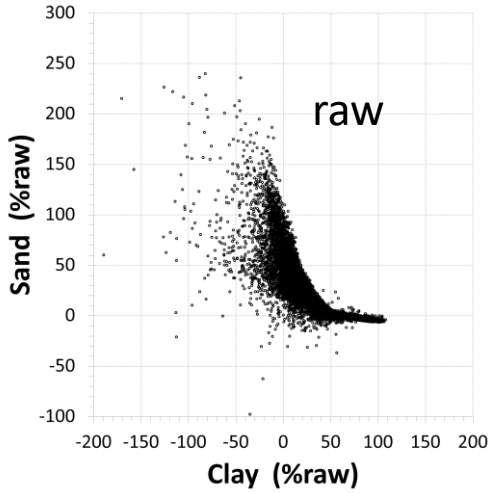
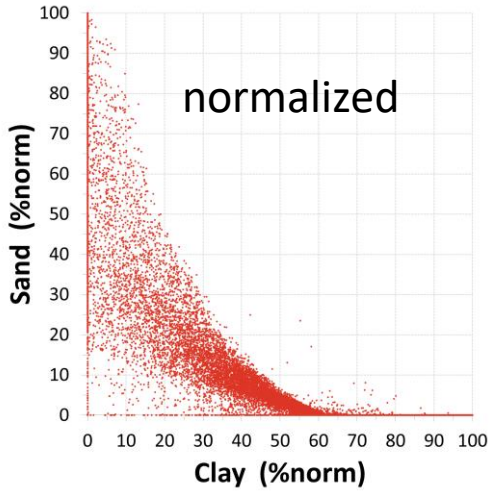
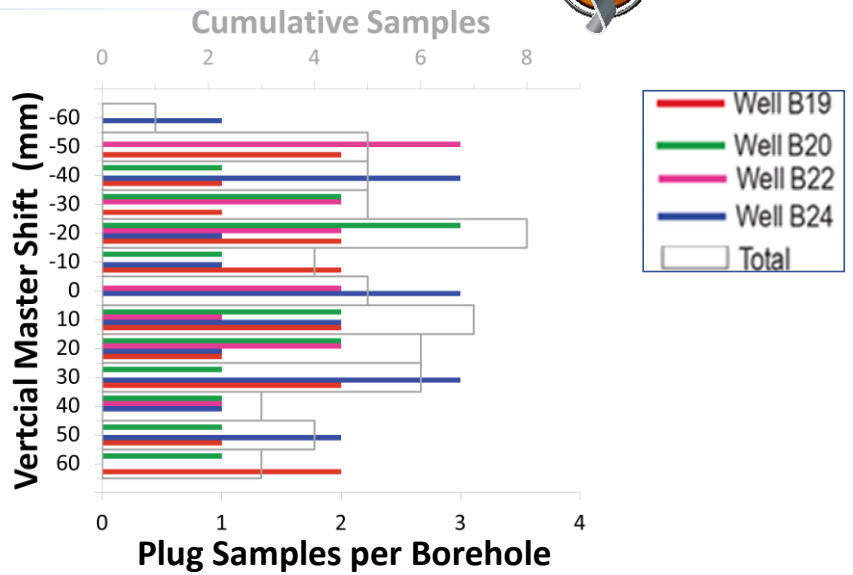
Iterative approach

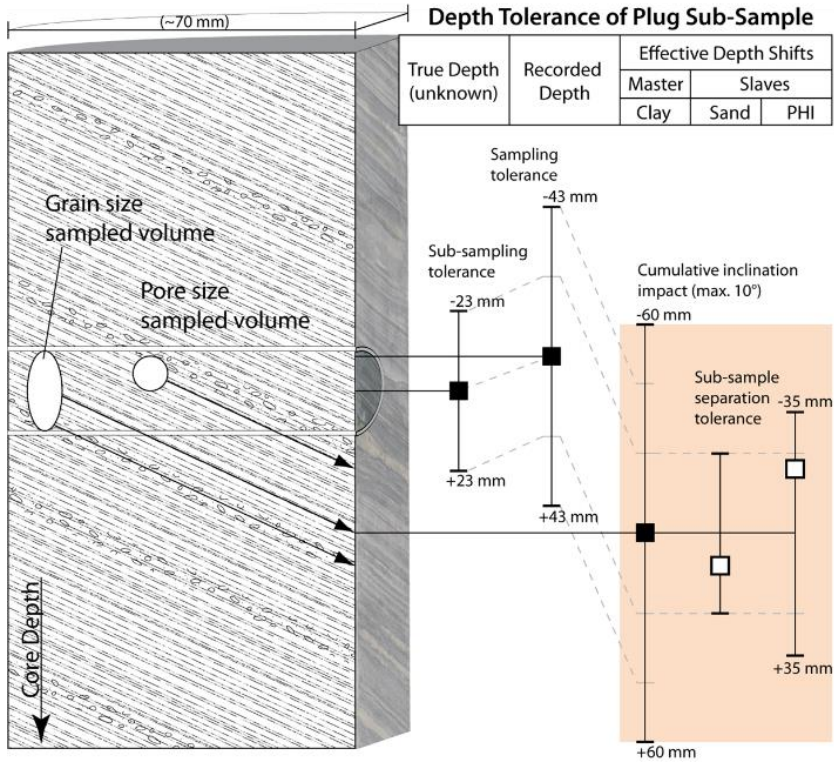
- Use of data from single (reference) borehole
- Set sample depth offset
- Set resolution of pixel curves
- Regression of clay & sand











$$\text{Clay [\%]} = 140 + 6.83 \cdot CI_{ave} - 7.75 \cdot CI_{med} - 0.242 \cdot CI_{var} \mid R^2 = 0.95$$

$$\text{Sand [\%]} = -8 - 0.796 \cdot \exp(CI_{ave}/20) + 0.918 \cdot \exp(CI_{med}/20) + 0.0675 \cdot CI_{var} \mid R^2 = 0.99$$

Image Log Harmonization Workflow

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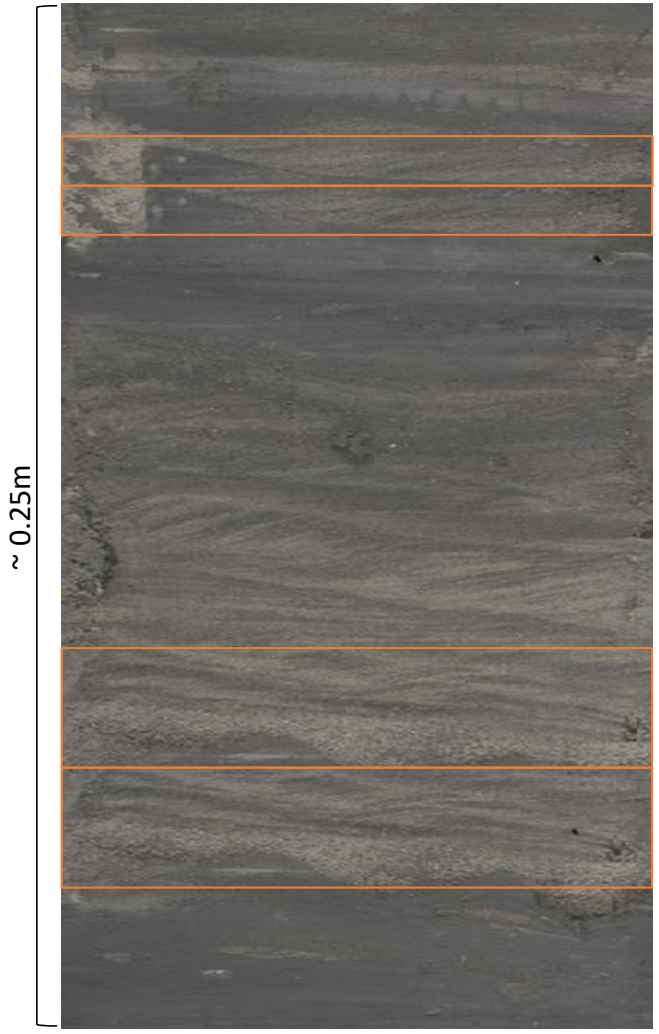
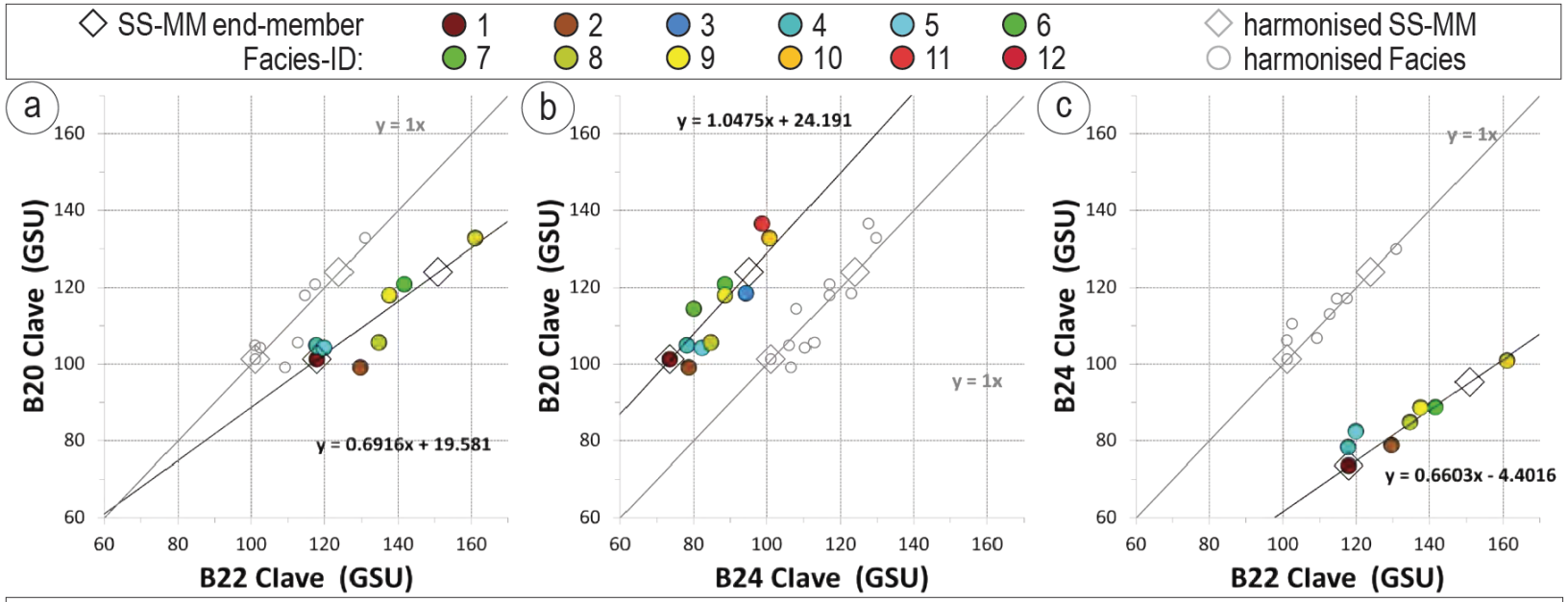
Compensation for differential core handling prior photography

Moisture-related issues

Image duplication issues





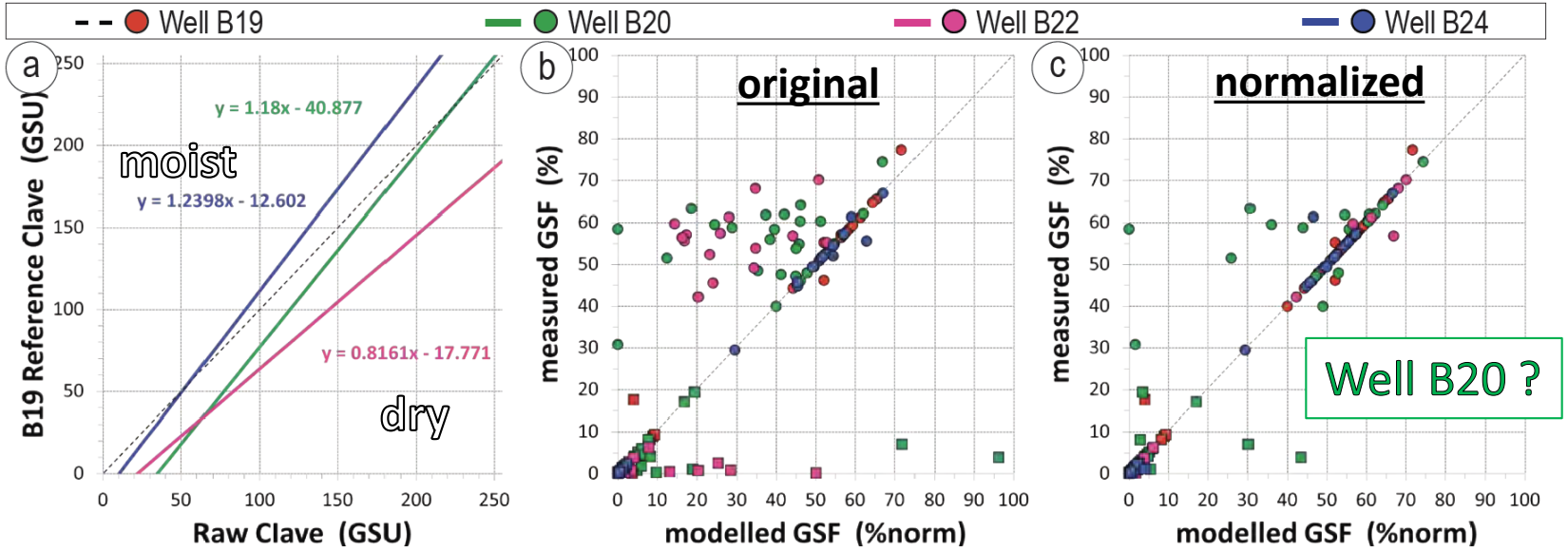
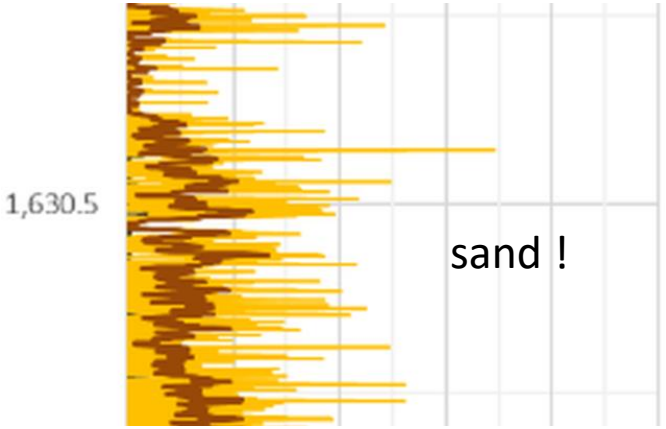
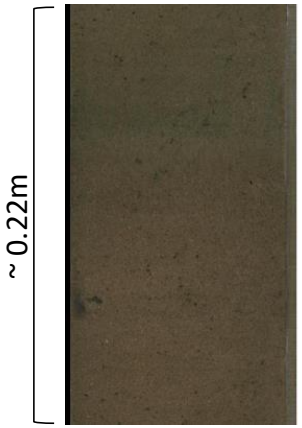


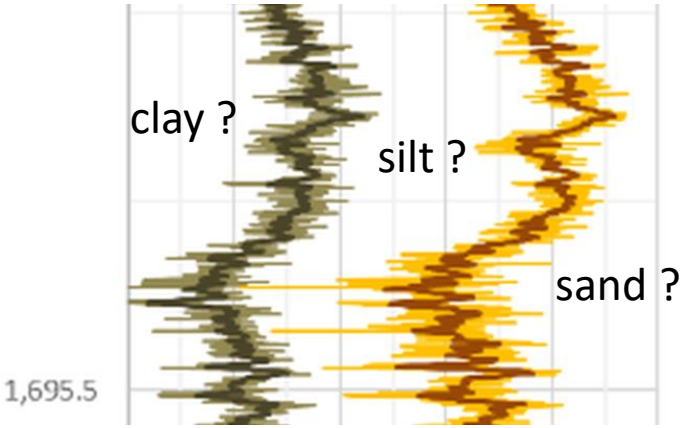
Image Log Harmonization Workflow

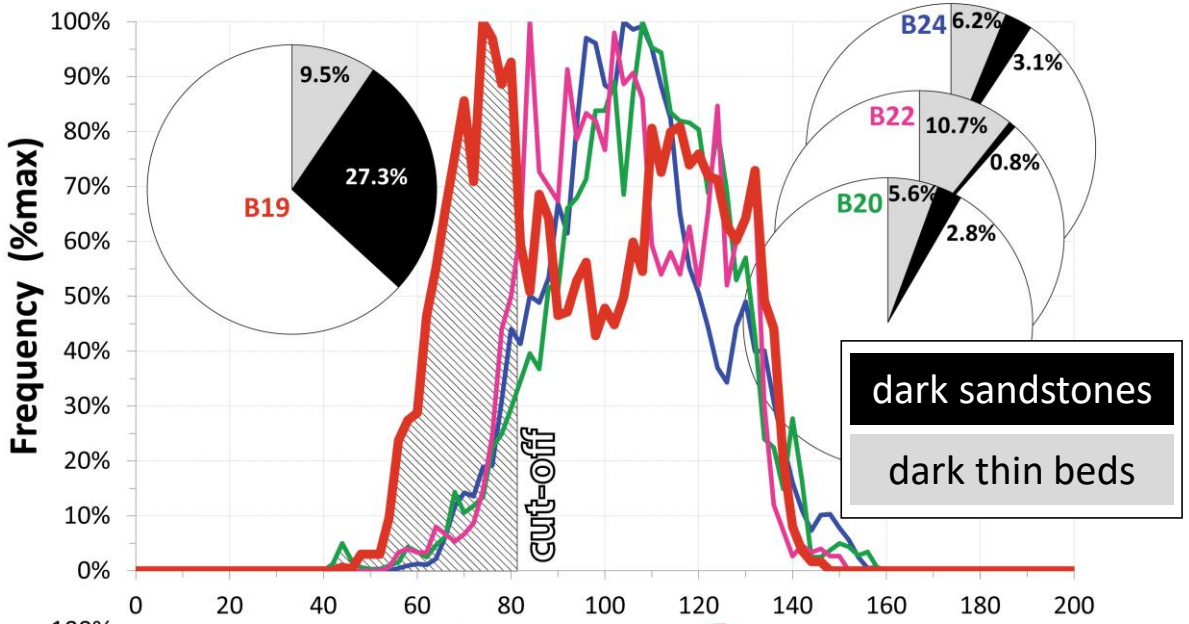
Normalization and model limitations

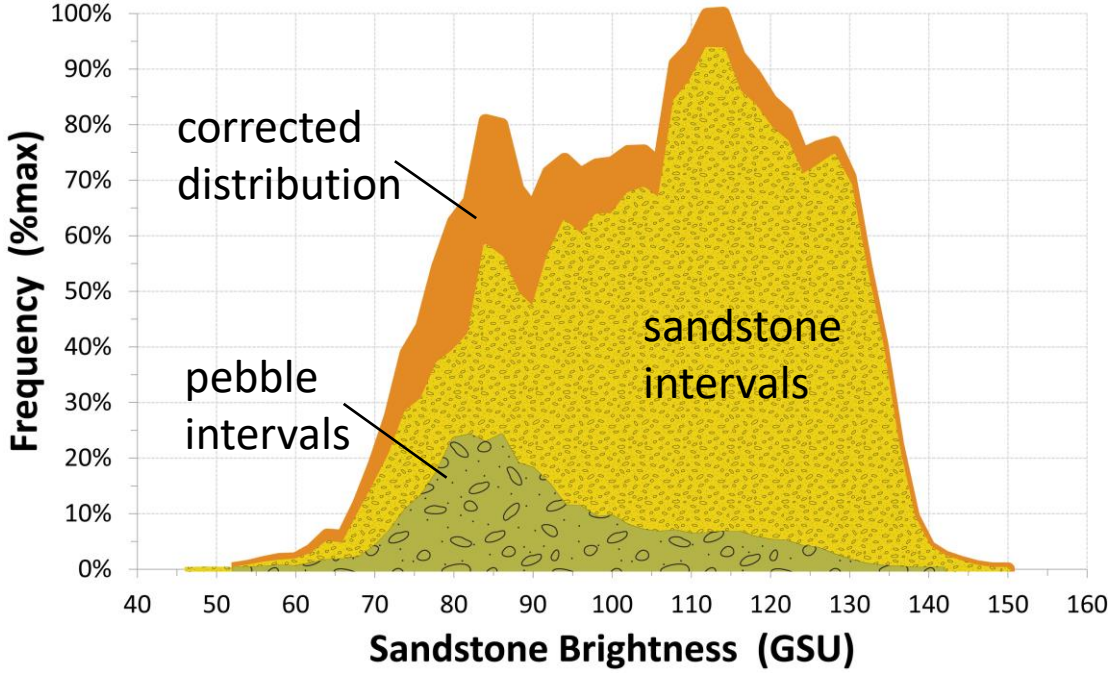
- Sampling bias: ≤ 20% sand grain size
- Dark sandstone anomalies suspected (B19)
- Commonly unimodal sandstone brightness











Results

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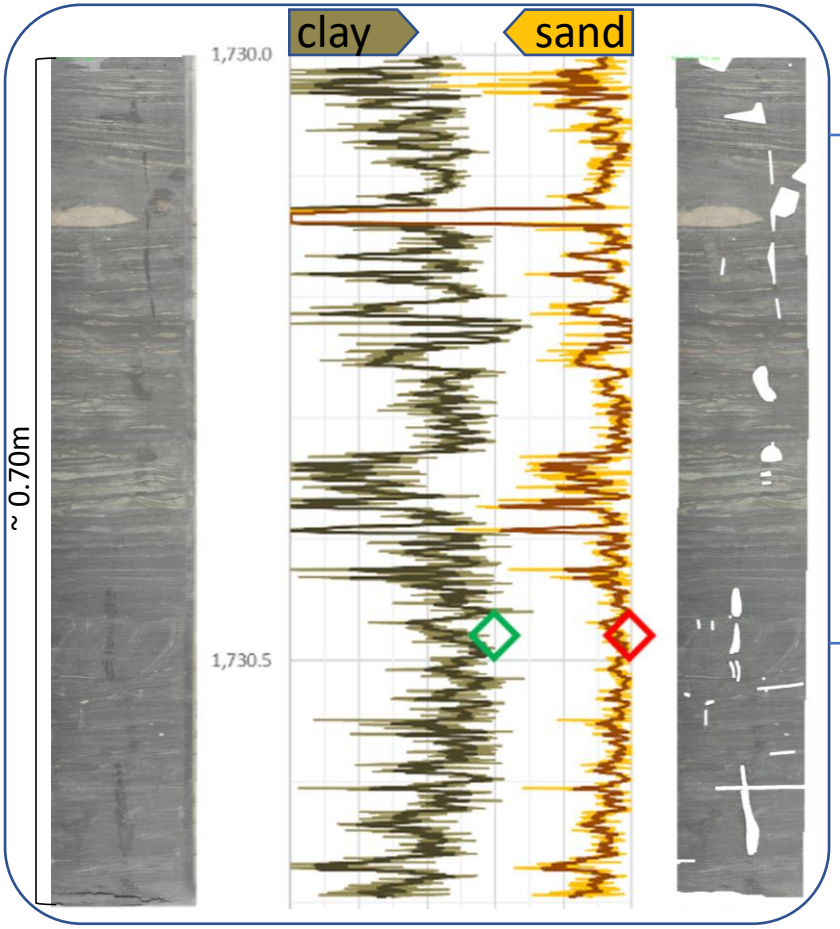
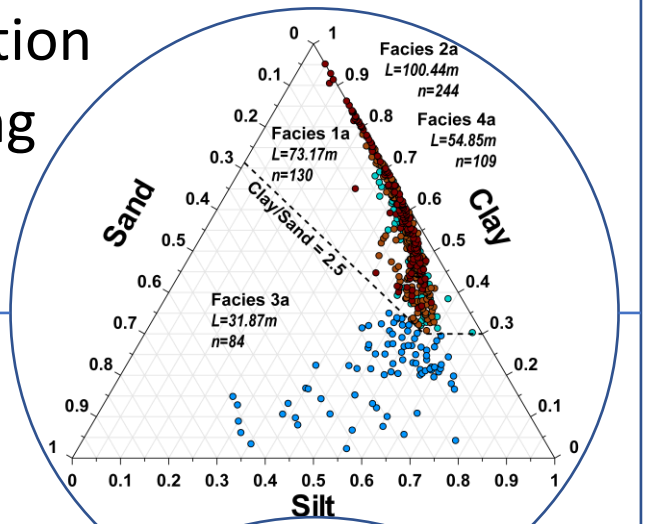
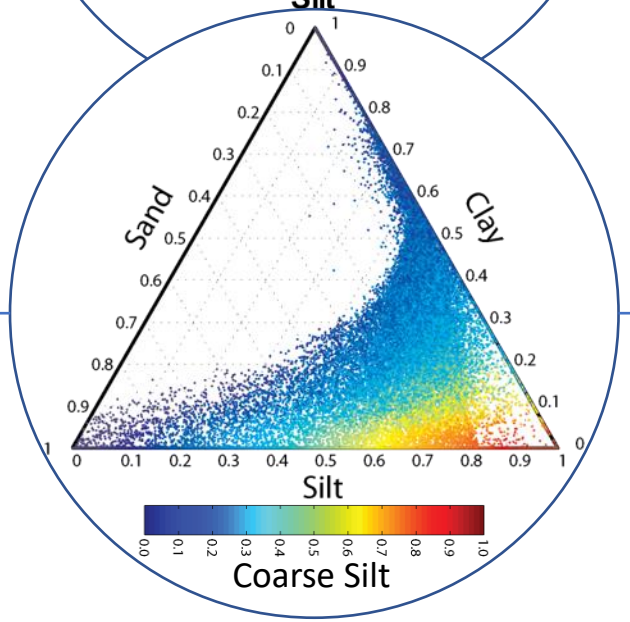
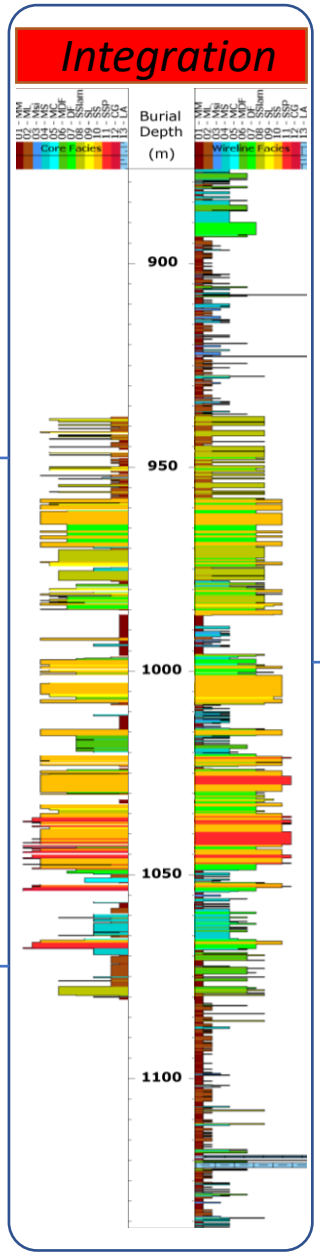
Mudrock facies processing

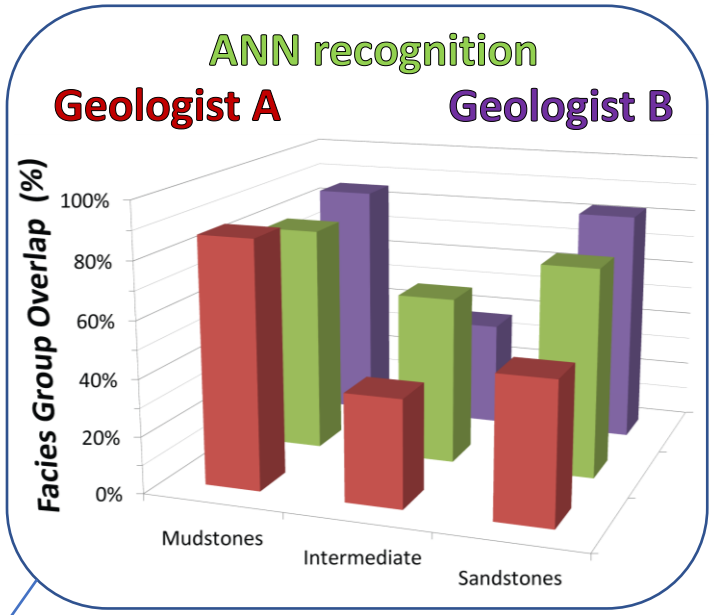
- Rock type QC via ternary grainsize diagrams
- ANN electrofacies recognition
- Facies-based flow modeling

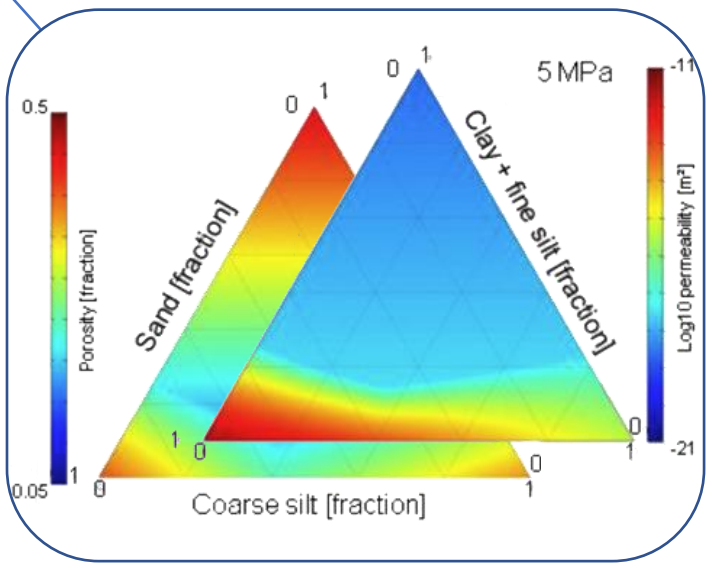












Conclusions

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Grain size logs from core images

- Robust empirical formulae for clay and sand modeling
- Linear function for moisture normalization
- Applications for mudrock characterization
  - Sampling bias, dark sandstone issues

Fit-for-purpose core handling required

- Post-slabbing plug samples required, reduce sampling bias
- Control plug depth & core moisture
- Avoid digital core image duplication (‚stitching‘)

Applications & Outlook

- Method supports rock typing in mud-rich sediments
- Thin-bed analysis (net reservoir, frequency content)
- Seal risk analysis (e.g. silt content), flow model applications
- Bedding angle & (2D) object recognition, RGB processing…