Streamlining Log Calibration Workflows by Incorporation of Continuous, Digital Mineralogy Data*

Jenny Omma[1], Adam K. Moss[2], Gavin Hunt[3], Richard A. Williams[3], and Mar Cortés López[1]

Search and Discovery Article #42198 (2018)**
Posted May 7, 2018

*Adapted from oral presentation given at AAPG International Conference and Exhibition, London, England, October 15-18, 2017

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Abstract

Log interpretation models aim to determine subsurface rock properties by combined interpretation of a range of electronic log and lab test datasets. Knowledge of the rock's mineralogy greatly enhances the selection of calibration parameters and reduces model uncertainty. Standard mineralogical techniques including sedimentological core logging, optical petrography and X-ray diffraction yield useful but incomplete analogue datasets that can be difficult to incorporate into larger scale digital workflows and selection of calibration parameters remains challenging. To address this, we present log calibration workflows improved by incorporation of two fully digital Big Data petrographic techniques: short wave infrared spectroscopy (SWIR; SpecCam®) and scanning electron microscope-energy dispersive spectroscopy (SEMEDS; QEMSCAN®). Using SWIR, the entire core face is digitally imaged, providing a visual and digital mineralogical map of the core. A continuous, sub-millimetre mineral abundance log is generated, with ability to derive detailed carbonate, sulphate and clay mineral information, (i.e. differentiating clay polytypes and their crystallinity). Detailed logs of hydrocarbon and hydroxyl/water content and distribution are also generated. The SWIR data allow optimal selection of SEM-EDS sampling points, which are then used to normalise the continuous SWIR log and provide micron scale textural information. Generated datasets include modal mineralogy, porosity, pore size distribution, pore shape and aspect, grain size and distribution per mineral species, pore lining phases and elemental maps. The combined pore- to core-scale SWIR and SEM-EDS dataset enables more robust determination of petrophysical calibration parameters, improving the log calibration workflow. This methodology will be illustrated with a clastic sequence from the Upper Jurassic Fulmar Formation from well 21/16-2 of the Durward-Dauntless Field, West Central Shelf, UKCS. Examples from this reservoir section will be shown to illustrate methods to calibrate a number of log interpretation models including shale volume from gamma logs, density log porosity models and clay bound water. The fine scale mineralogy data are also used to help build thin bed interpretation models. We will demonstrate methods for upscaling high-resolution mineral data to the log scale and its use in evaluating heterogeneity on multiple scales.

Streamlining log calibration workflows by incorporation of continuous, digital mineralogy data

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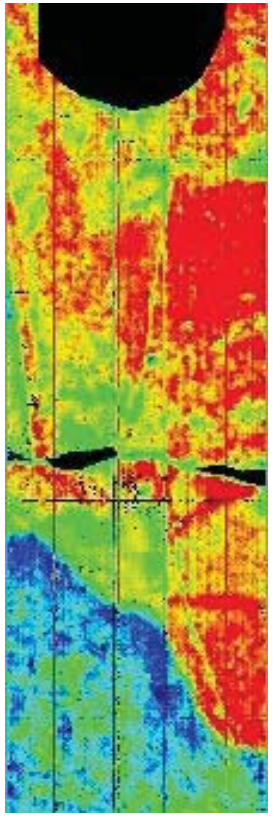
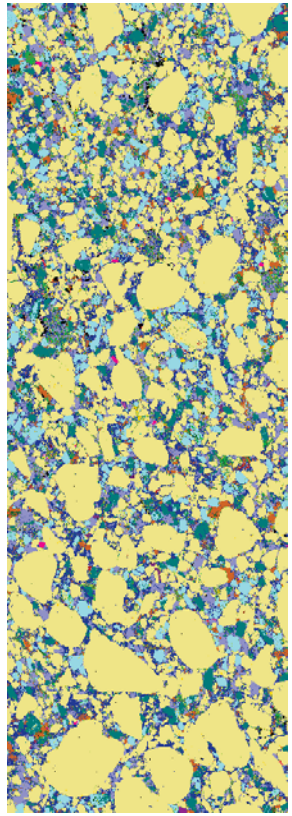
Rocktype

Talk outline

- Rocks are complex systems
- Digital mineralogy
- SpecCam technology, QEMSCAN technology
- Case study: SpecCam + QEMSCAN data for log calibration
  - Hydrocarbon
  - Illite
  - Dolomite
  - Porosity



6 cm across



0.5 cm across

Rocks are complex systems

… with characteristics responding to 10’s-100’s of variables:

- Provenance, climate, deposition, diagenesis
- Mineral phase - quartz, feldspars, clays, heavy minerals, iron phases, carbonates…
- Organic material
- Fluids – water, brine, oil, gas
- Texture, lamination, bedding, bioturbation
- Burial history - temperature, pressure, effective stress, time, pH
- Many I missed….

Understanding controls on complex systems

…occurs through algorithmic analysis of large, multivariate datasets, in order to deconvolute the significance of dependent variables.

- Big N sample sets
- Automated sample analysis
- Coherent and Big datasets
- Data science

We need digital mineralogy data

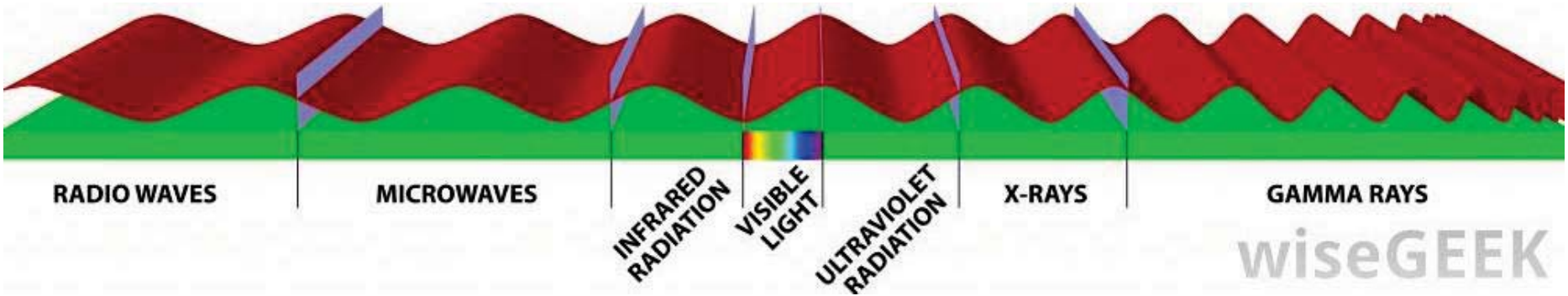
2 digital mineralogy techniques

SpecCam by S-Map

QEMSCAN™ by ThermoFisher SCIENTIFIC

Short Wave Infra Red spectroscopy

SEM – Energy Dispersive spectroscopy



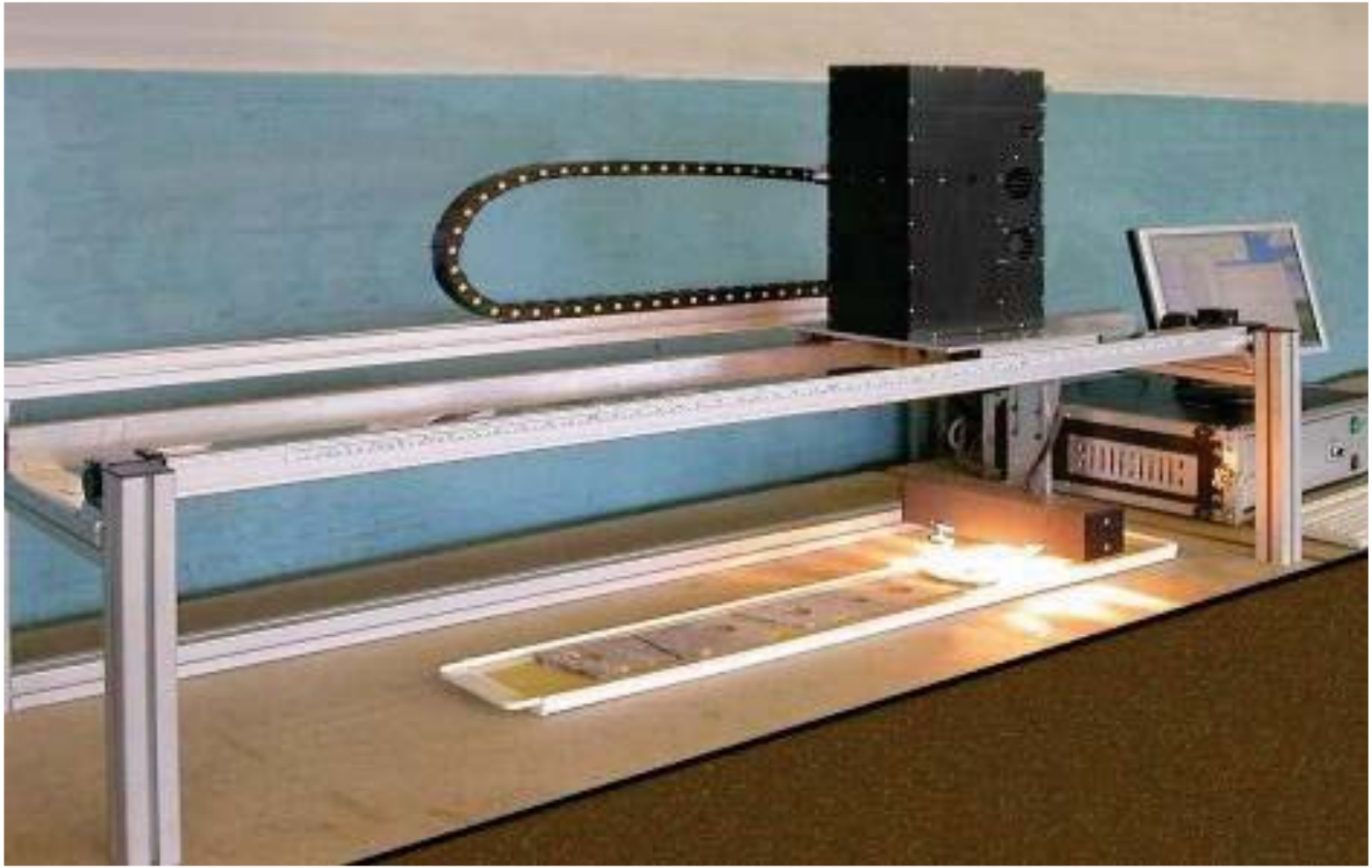
molecular

atomic

SpecCam technology

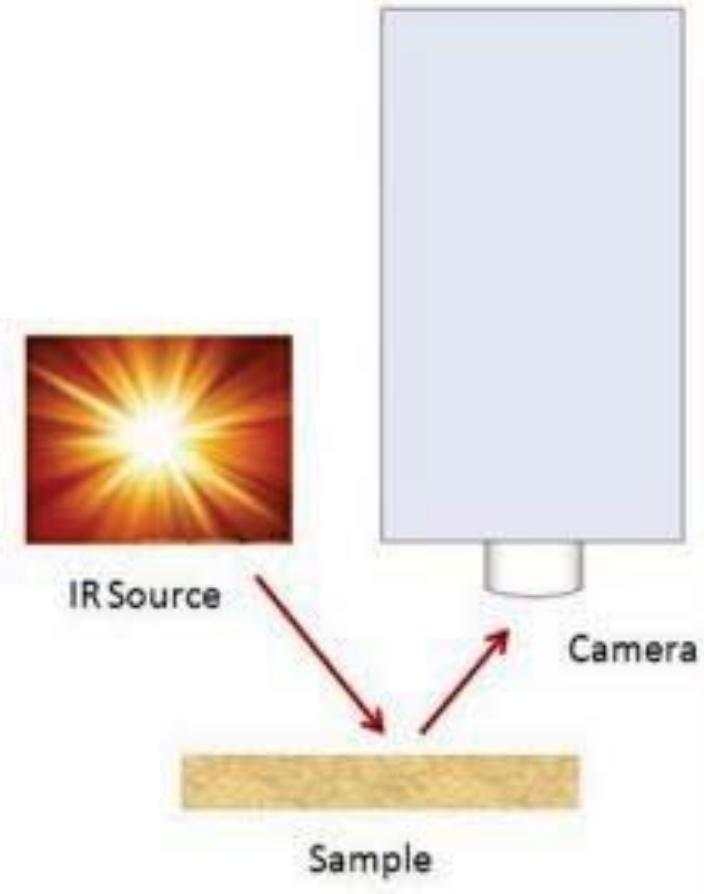
SpecCam

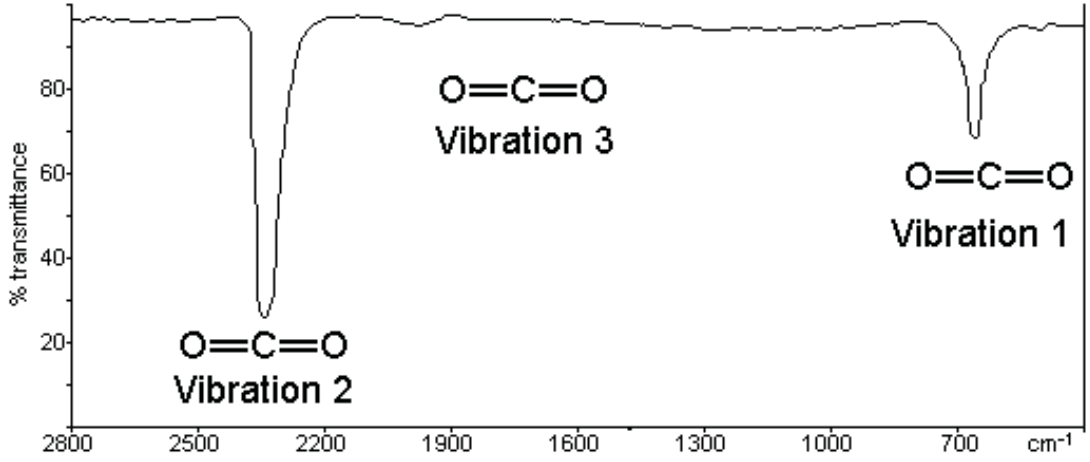
SWIR: Short Wave Infra Red Spectroscopy



SpecCam

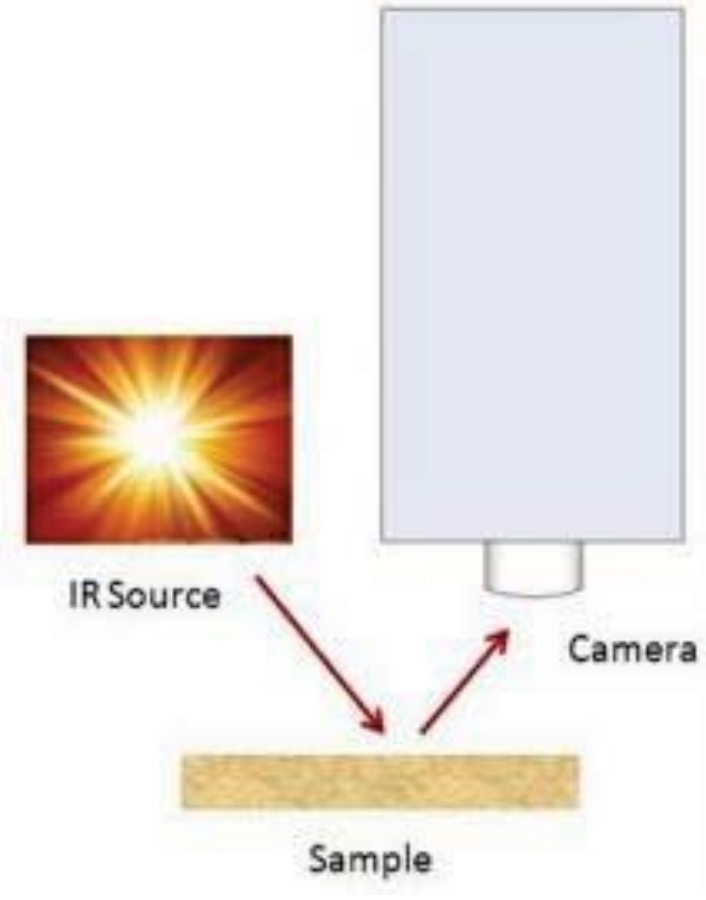
SWIR: Short Wave Infra Red Spectroscopy

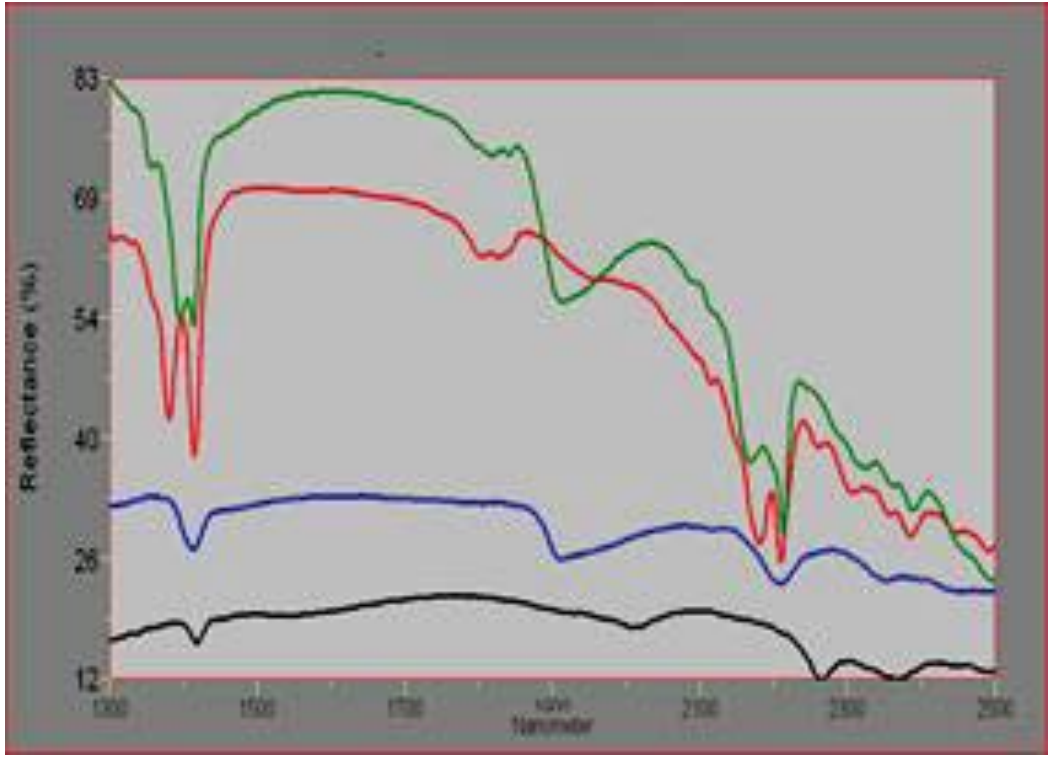




SpecCam

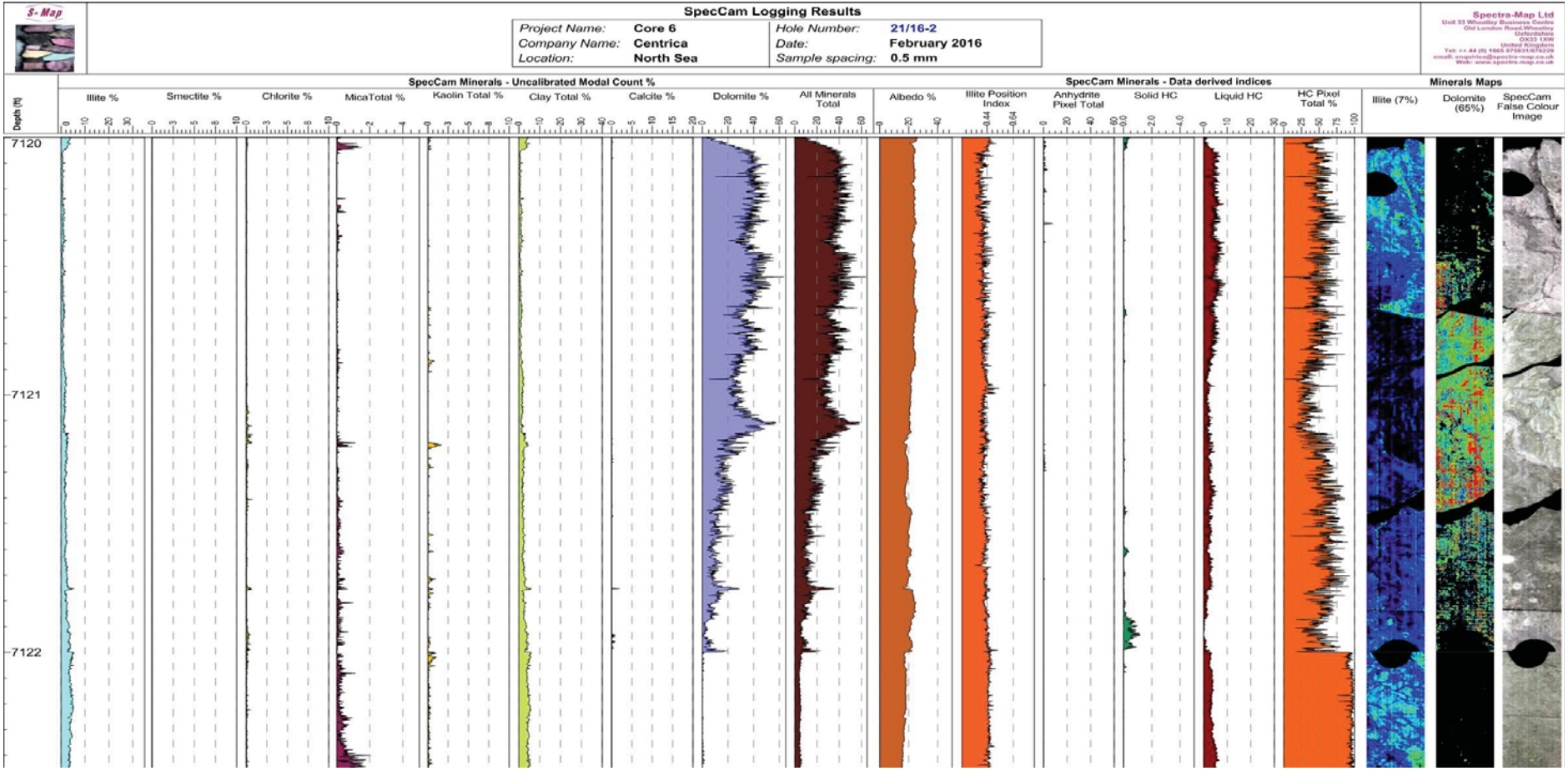
SWIR: Short Wave Infra Red Spectroscopy





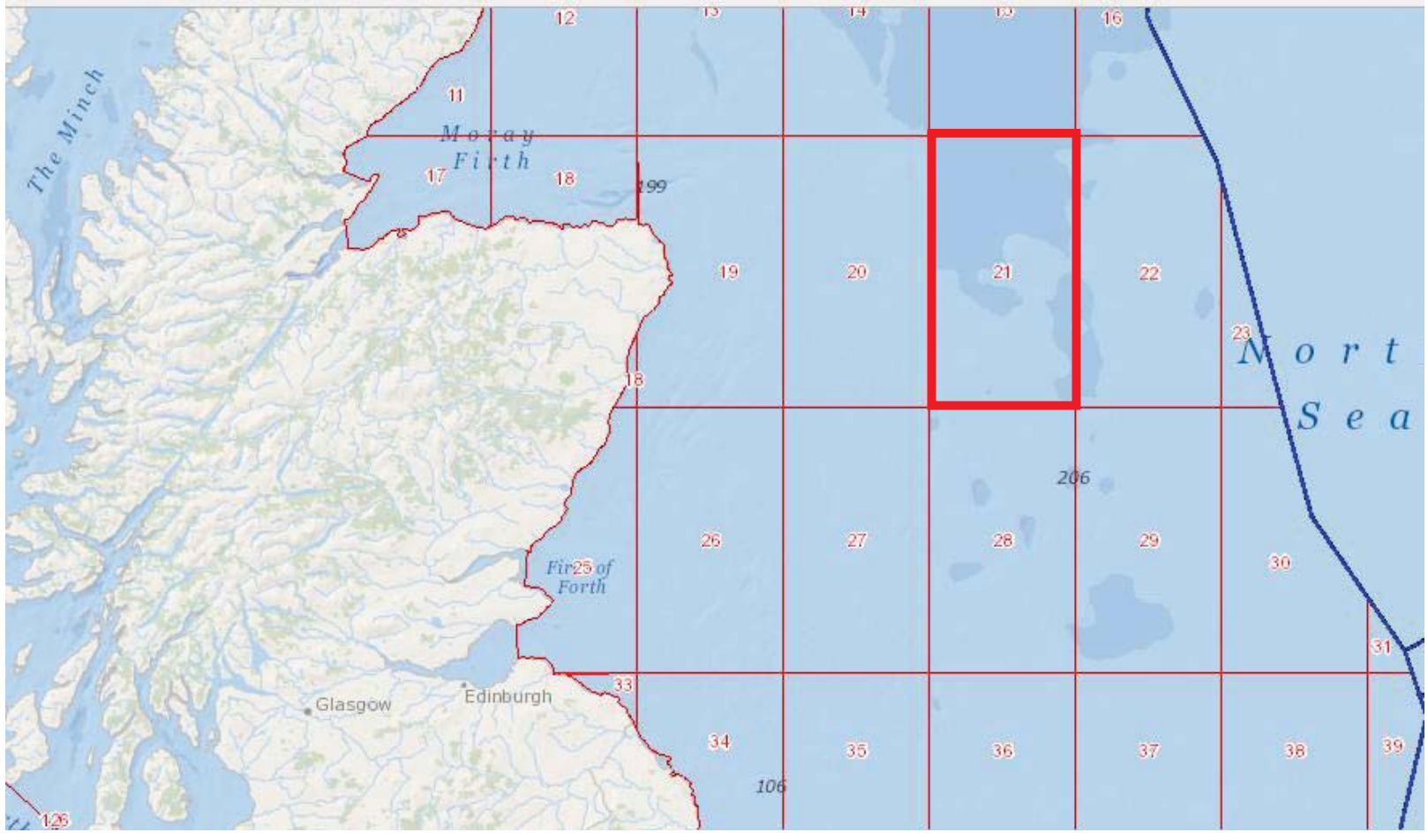
SpecCam

SWIR: Short Wave Infra Red Spectroscopy

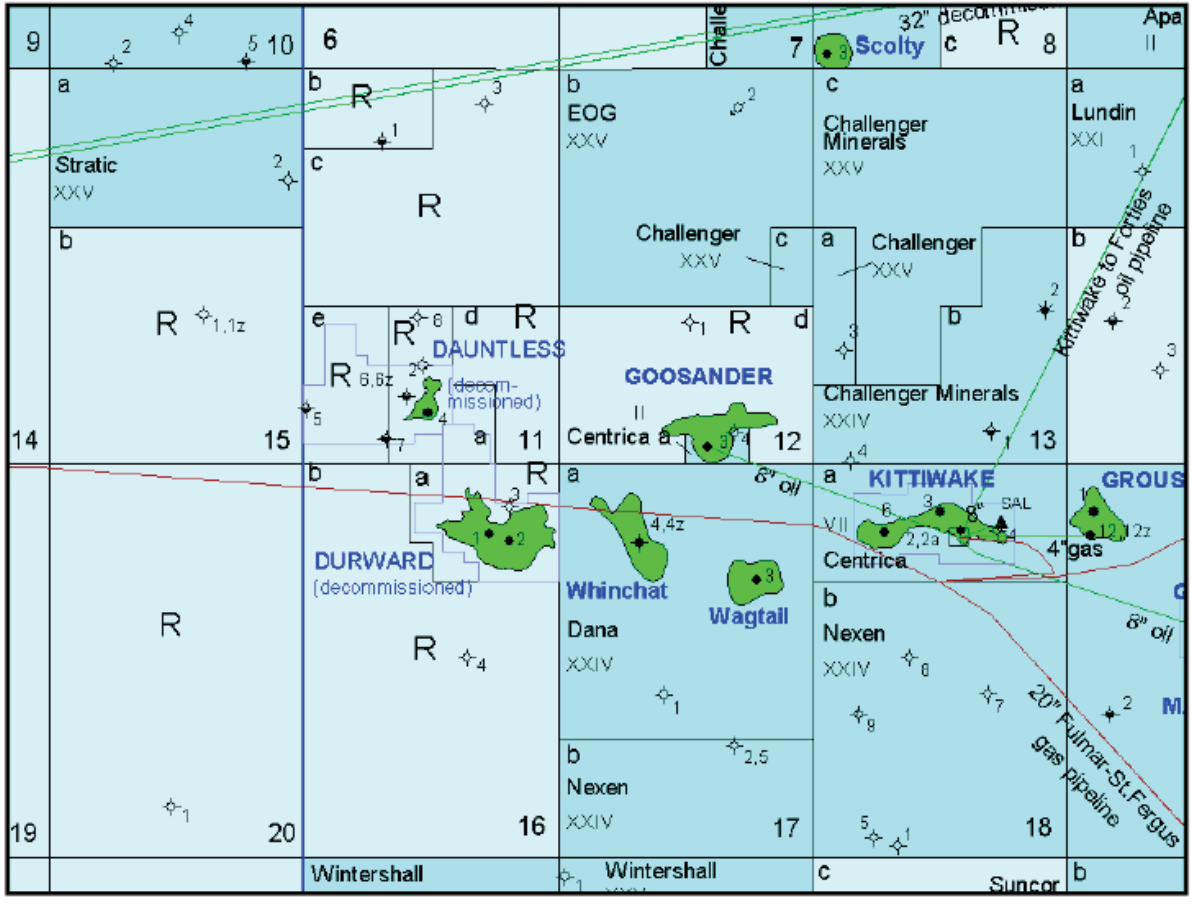


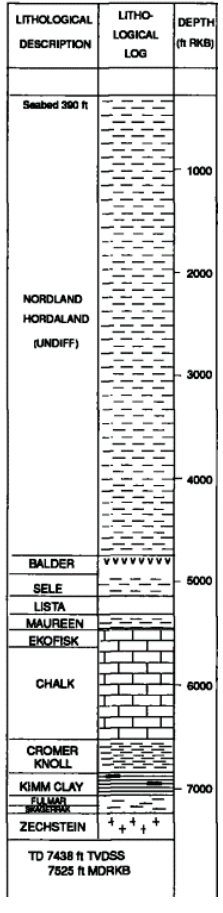
Example data

Central North Sea, Quad 21, Block 16

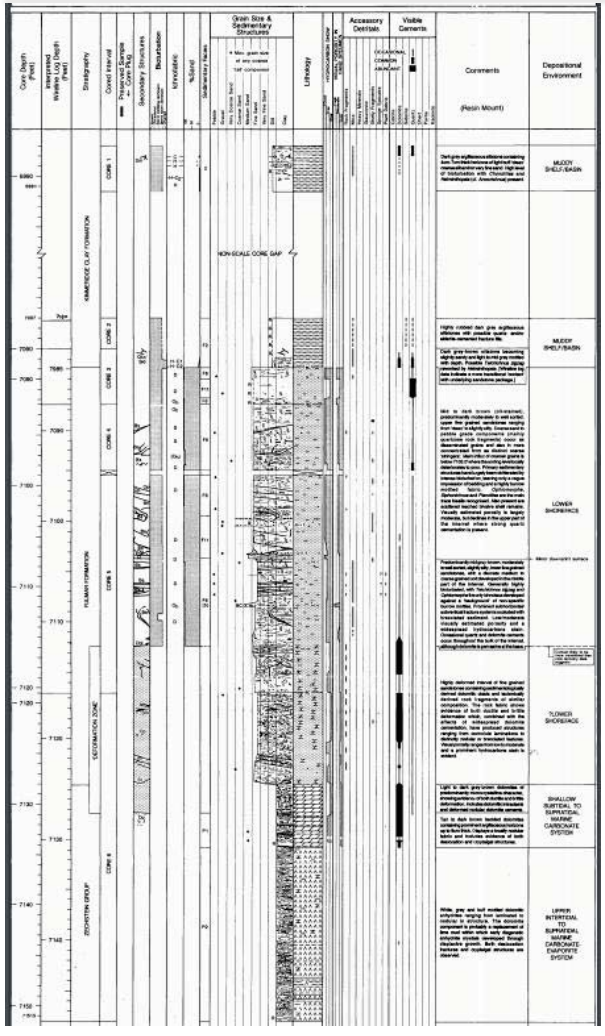


Durward field, well 21/16-2

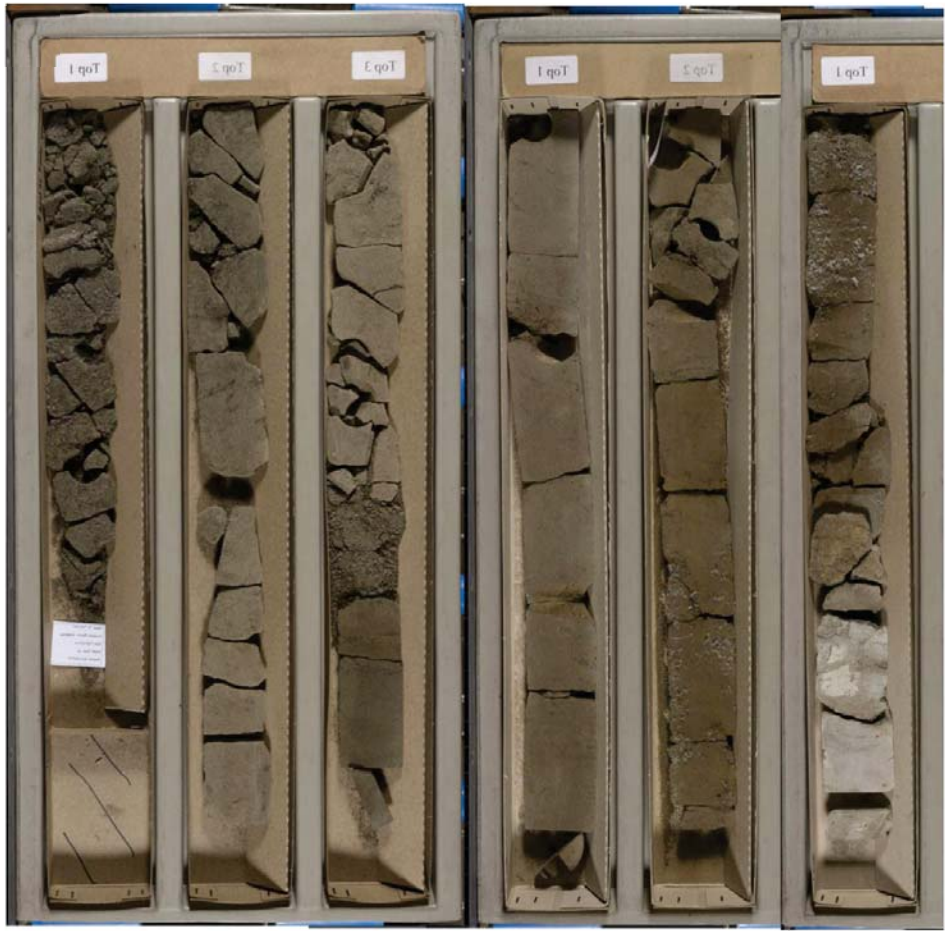




Well 21/16-2: 18 ft (6 m) core, 7099-7117 ft



AAPG 2017

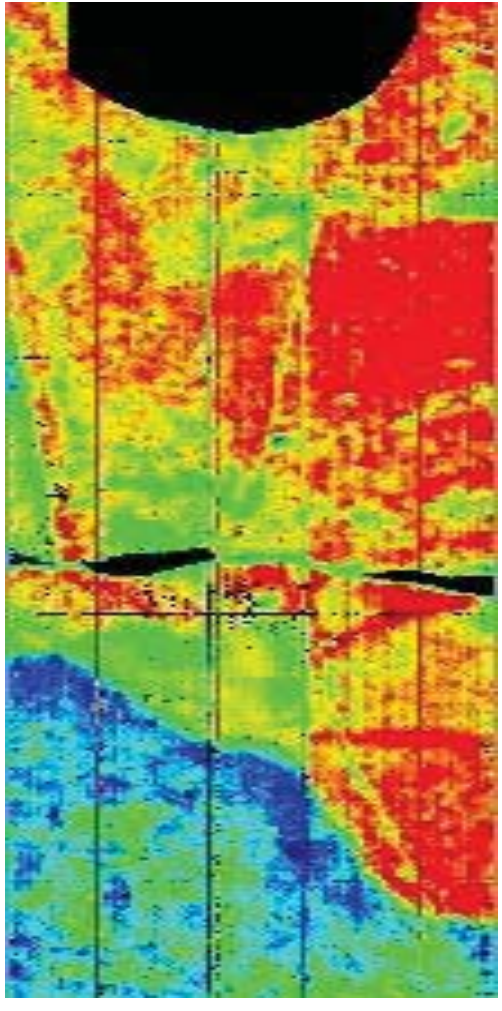


Petex 2016

SpecCam datasets

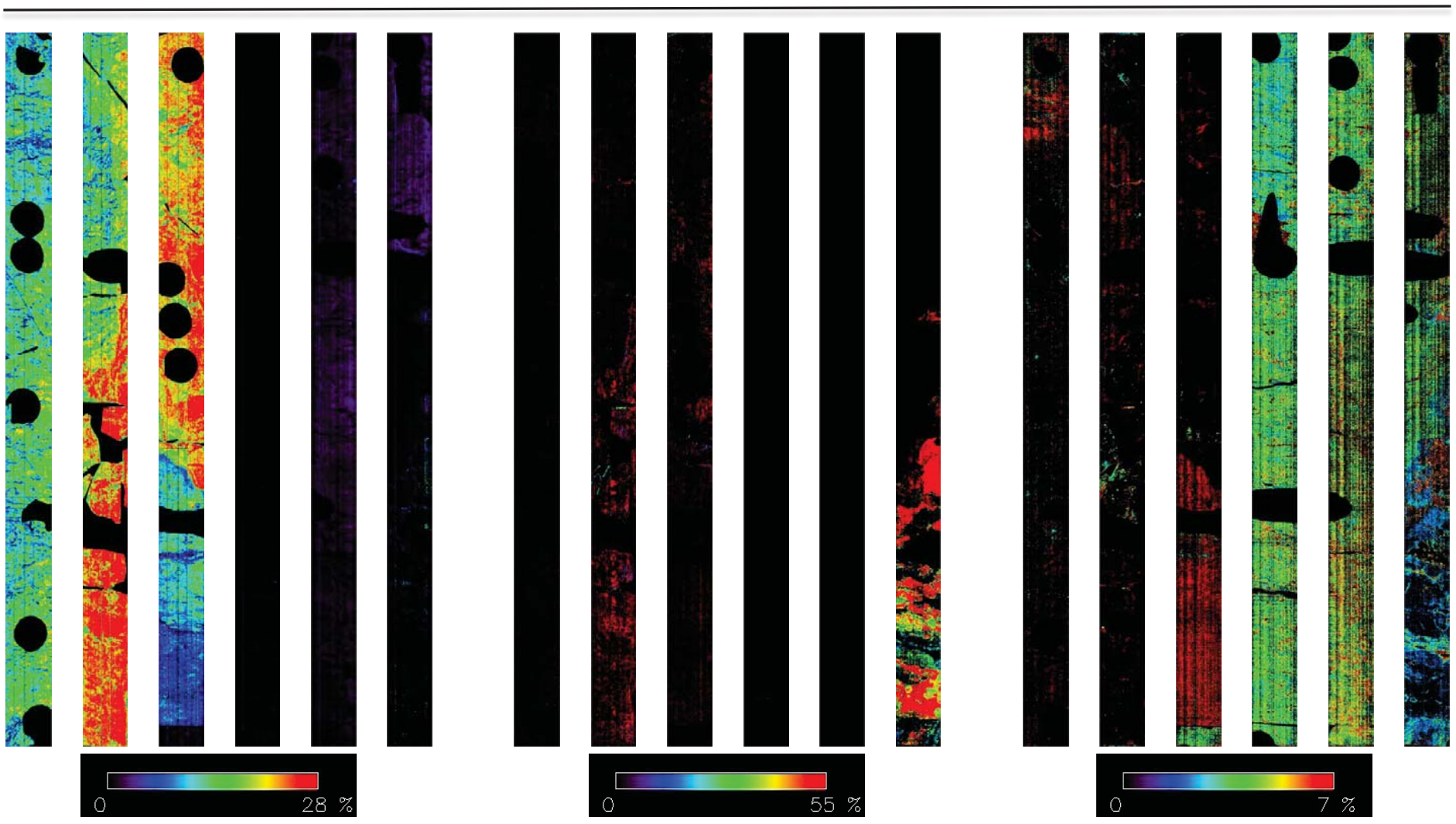
hydrocarbon-solid (%)
hydrocarbon-liquid (%)
dolomite (%)
calcite (%)
illite (%)
smectite-illite (%)
smectite (%)
glauconite (%)
corrensite (%)
paragonite (%)
muscovite (%)
phengite (%)
mica-illite (%)

kaolinite-lo (%)
kaolinite-hi (%)
dickite (%)
halloysite (%)
chlorite (%)
clay_total (%)
bassanite (%)
gypsum (%)
zircon (%)
zeolite (%)
epidote (%)
albedo (%)

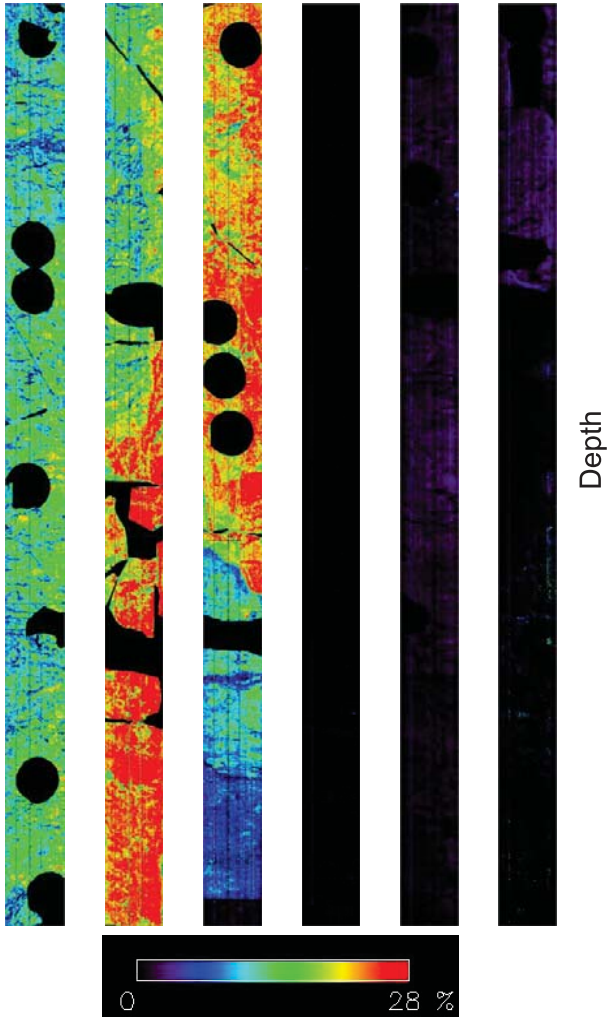


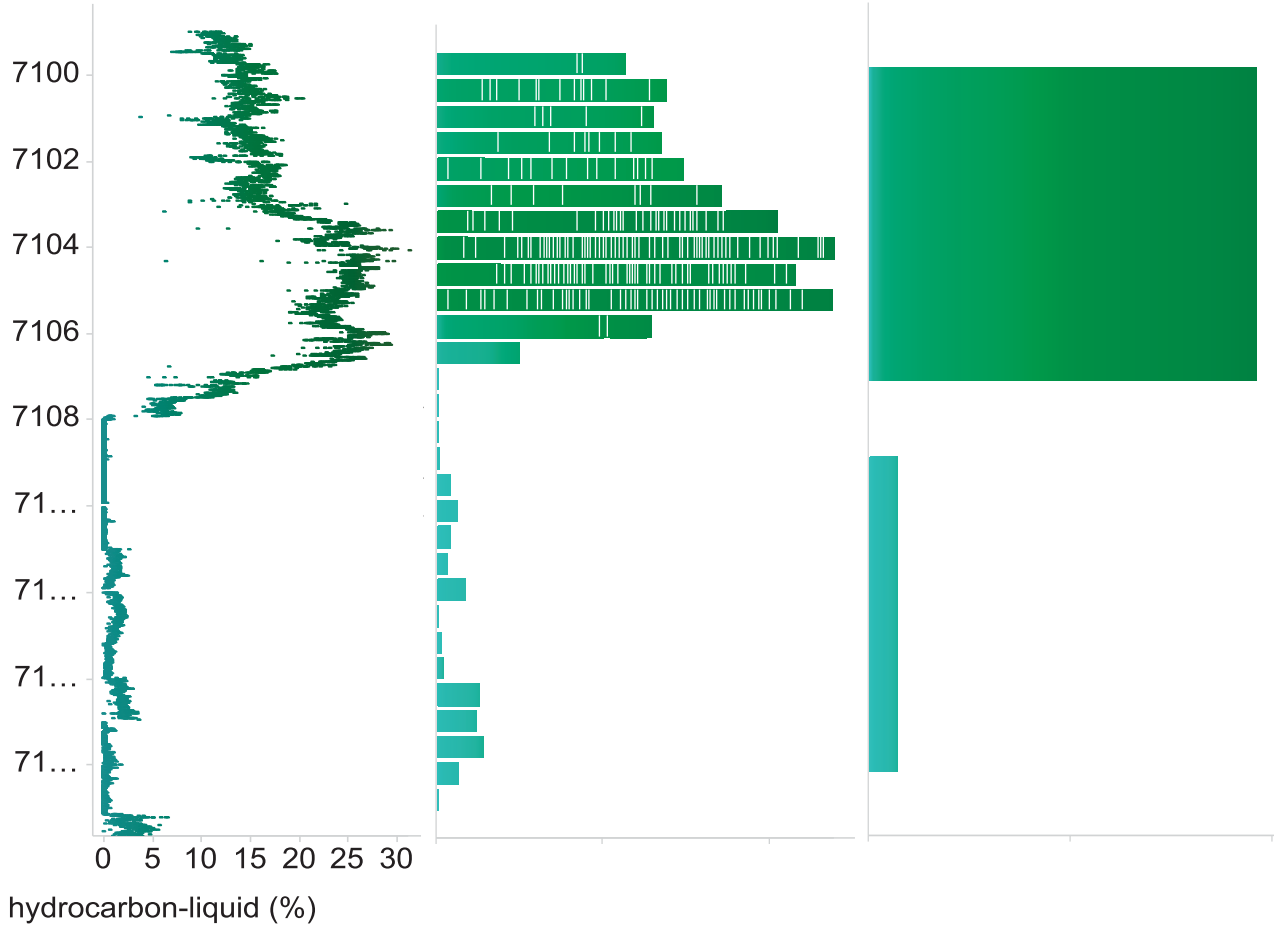
SpecCam datasets & log calibration uses

Hydrocarbon (%)	STOIIP, Saturation-height modelling, Water saturation calculation
Dolomite (%) (+ QEMSCAN textures)	Gamma ray calibration, Cement indices
Illite (%)	Permeability calibration
Clay_total (%)	Shale volume calculation, Archie
Albedo (%) (+QEMSCAN porosity)	Porosity estimation, STOIIP

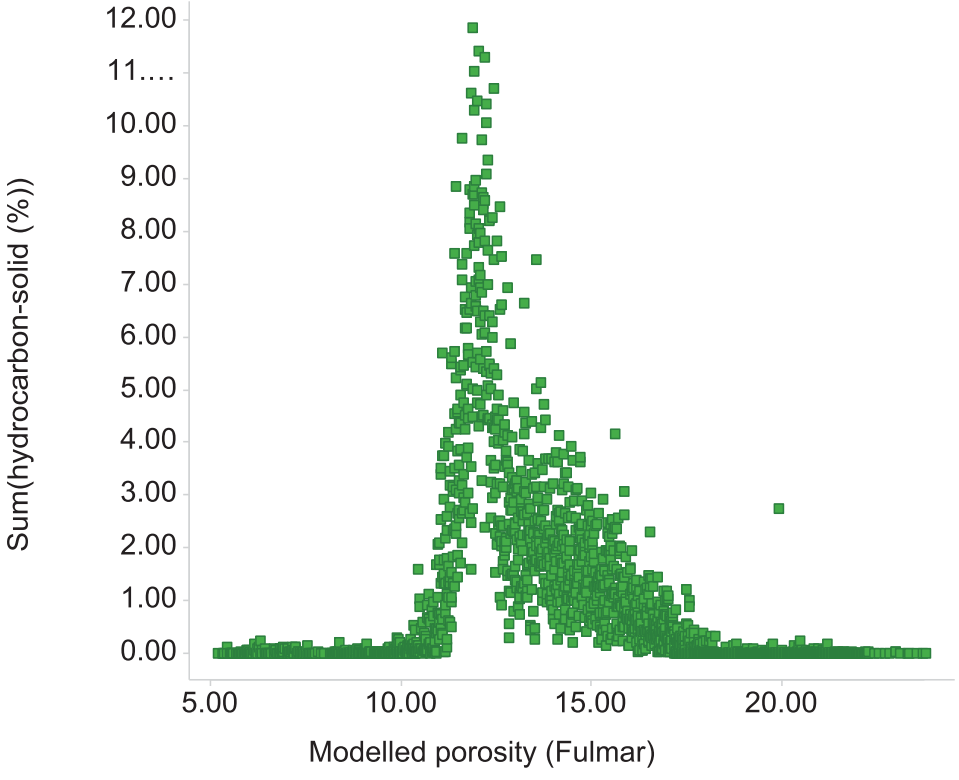

Liquid hydrocarbon %
Dolomite %
Illite %
0
28 %
0
55 %
0
7 %

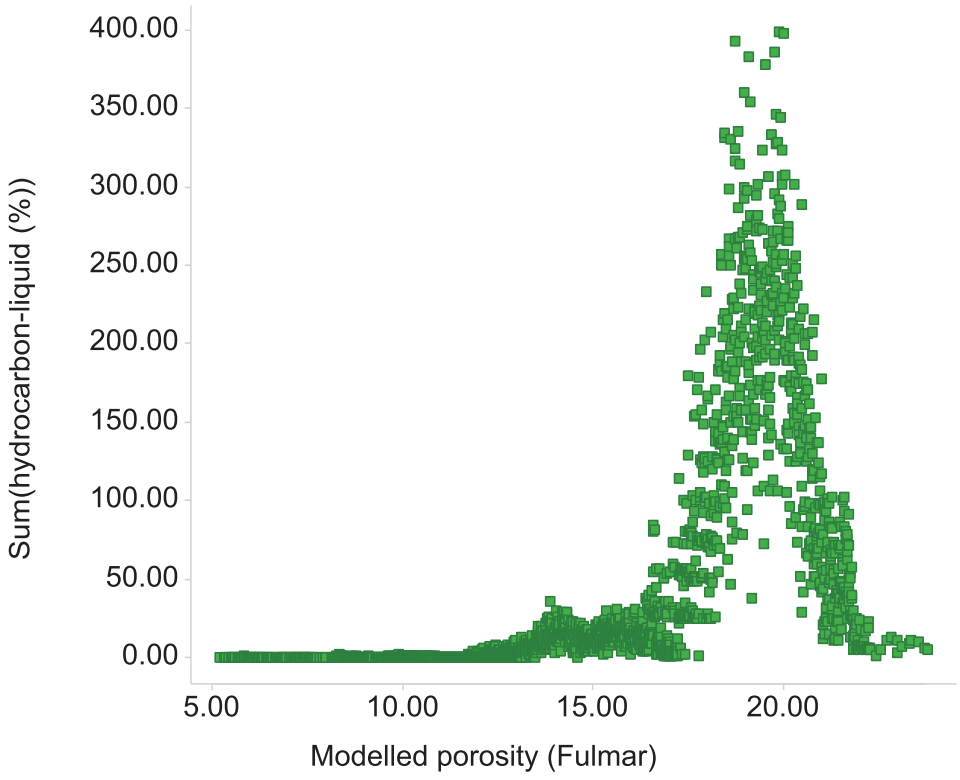
Liquid hydrocarbon (%)



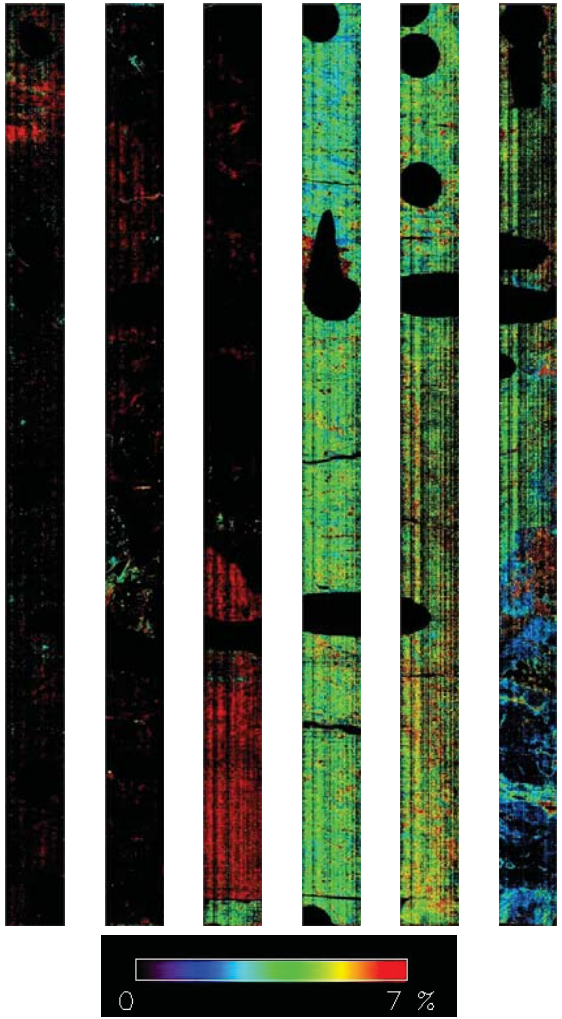


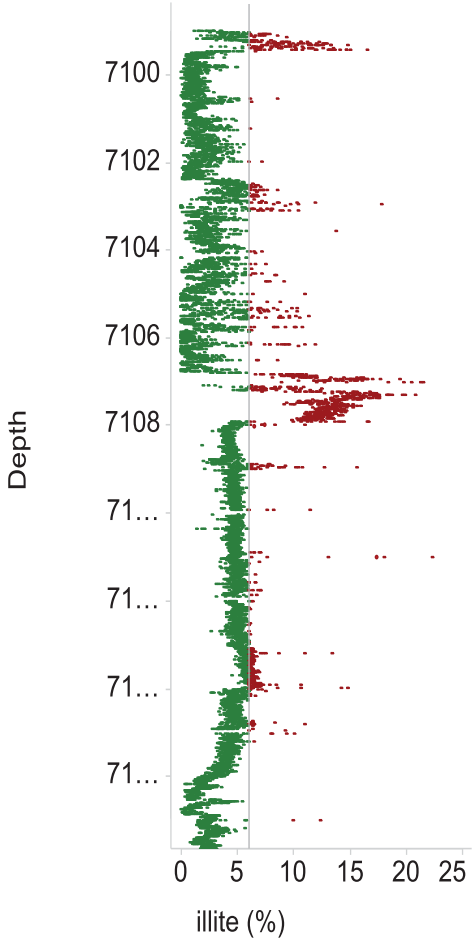
HC habitat

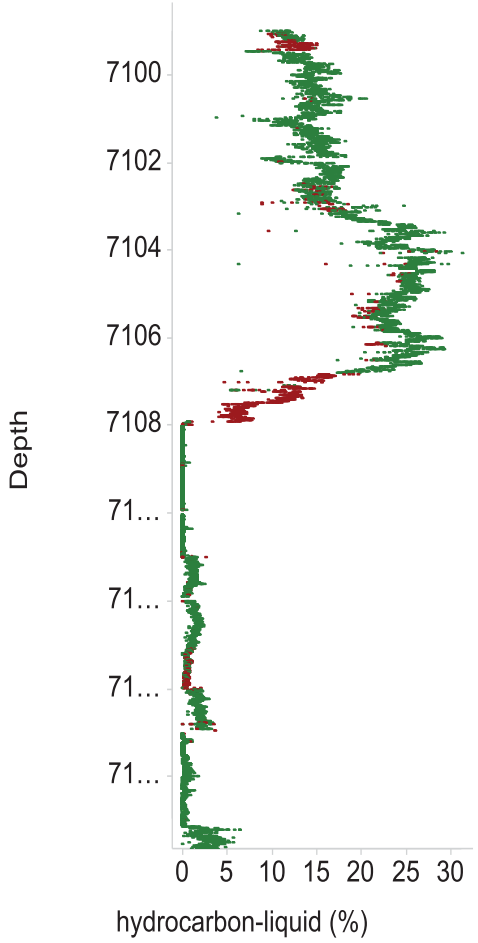

Sum(hydrocarbon-solid (%))
12.00
11....
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5.00
10.00
15.00
20.00
Modelled porosity (Fulmar)


Sum(hydrocarbon-liquid (%))
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
5.00
10.00
15.00
20.00
Modelled porosity (Fulmar)

Illite baffles





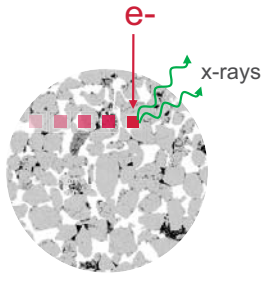


QEMSCAN technology

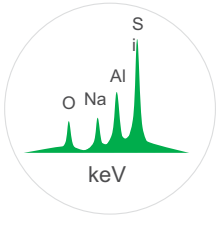
QEMSCAN technology

Core or cuttings

Polished surface



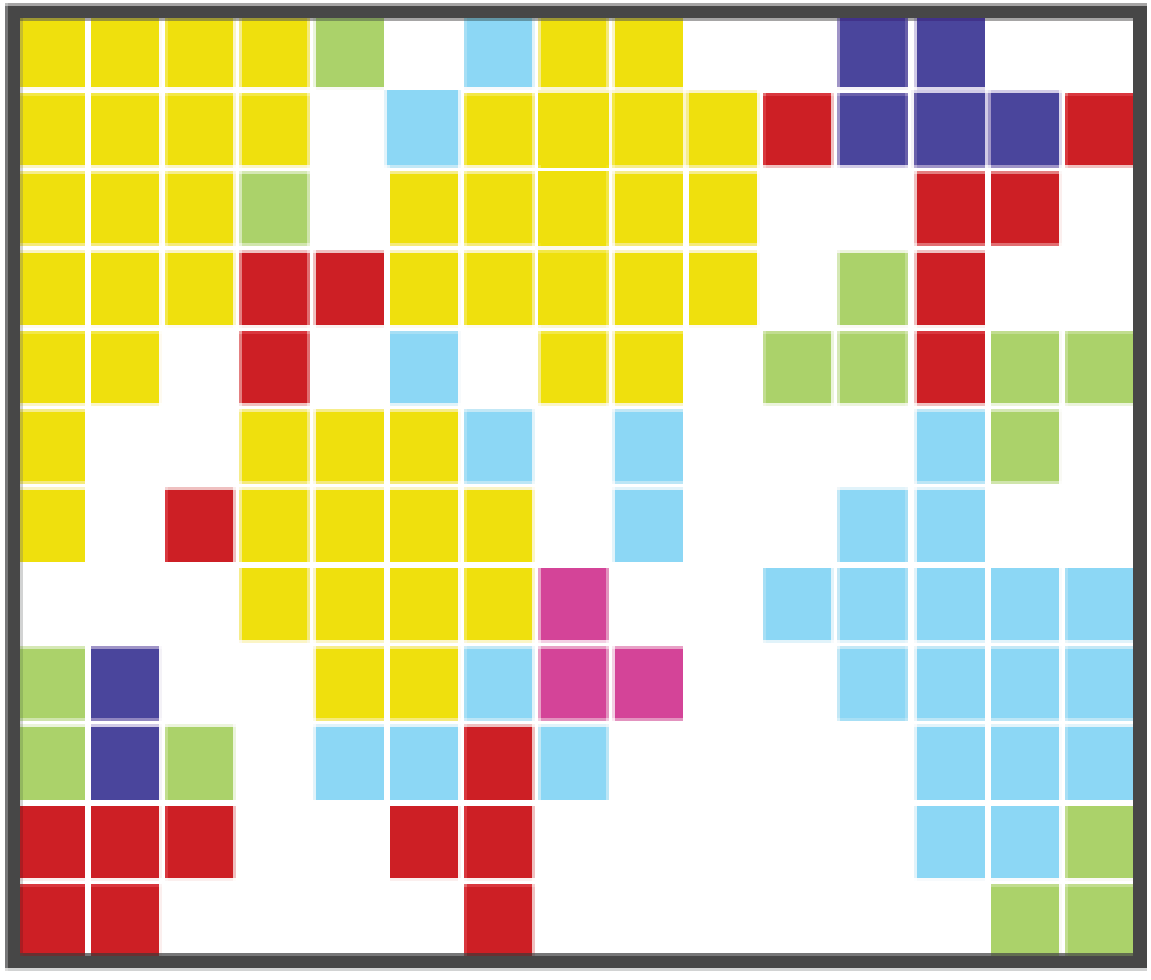
Point scan



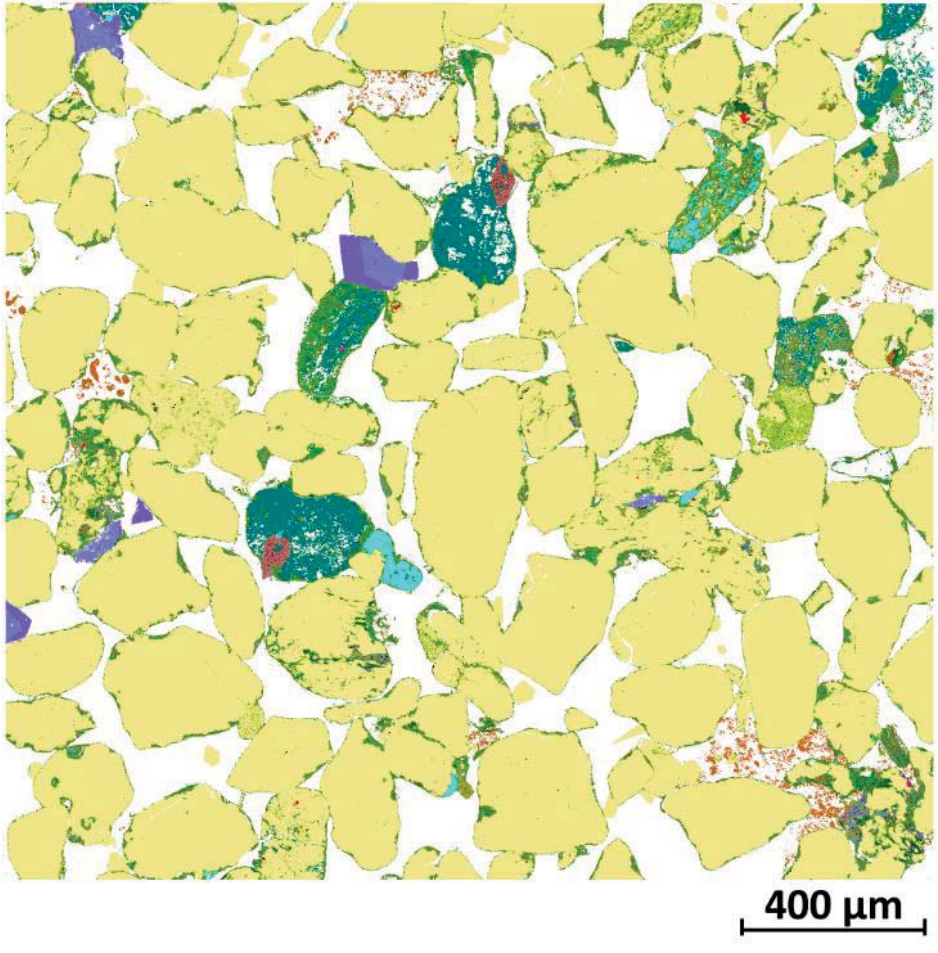
X-ray spectrum

Mineral match

QEMSCAN cartoon

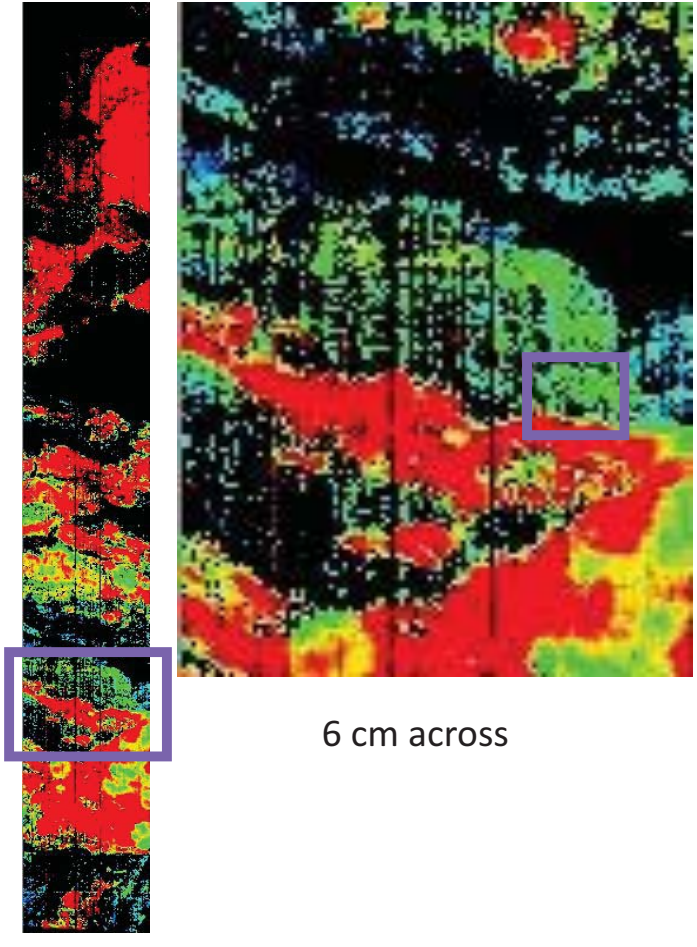


QEMSCAN data

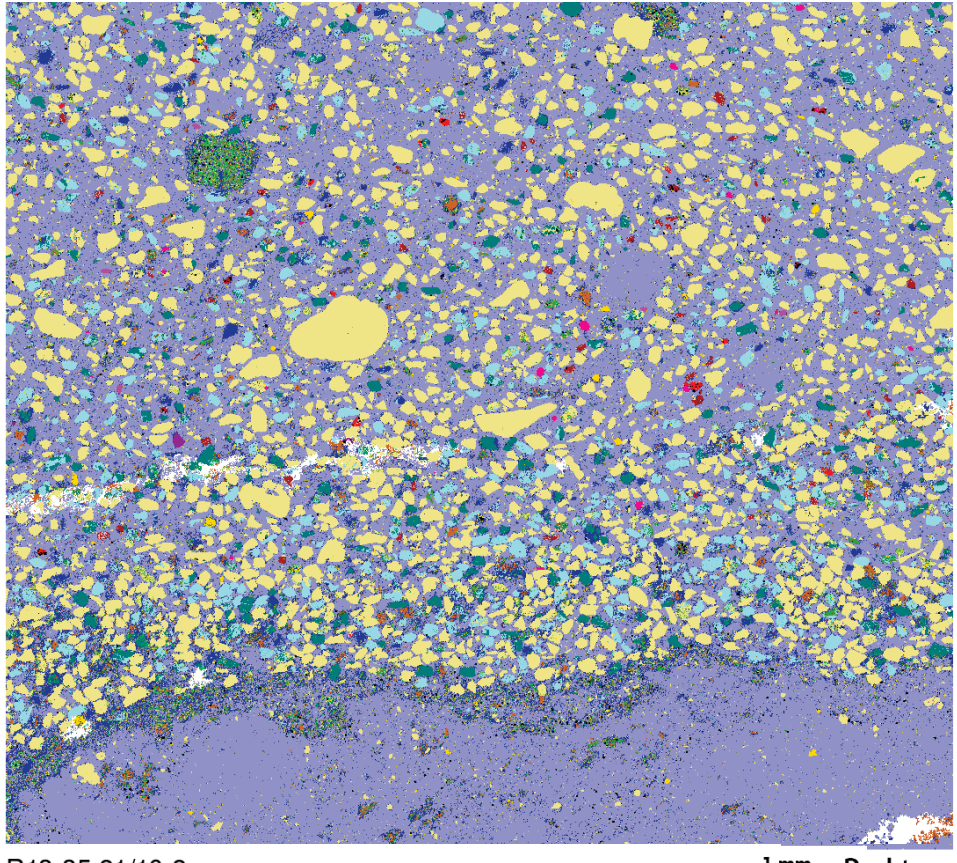


- Quartz
- KFeldspar
- Albite
- Oligoclase
- AndesineAnorthite
- Biotite
- Muscovite
- Illite
- Chlorite
- Kaolinite
- Glauconite
- Smectite
- QuartzClayMix
- OtherClays
- Zircon
- Tourmaline
- Garnet
- Epidote
- Titanite
- Kyanite
- Staurolite
- Amphibole_CPX
- OPX
- Rutile_Anatase
- CrSpinel
- Apatite
- Monazite
- Calcite
- Dolomite
- FeDolomite
- Ankerite
- Siderite
- FeOxides
- Pyrite
- Barite
- Anhydrite
- Halite
- OtherPhases
- Unclassified
- Porosity

Dolomite habit



6 cm across



R13-35 21/16-2

1.5 cm across

1 mm

Rocktype

Quartz
KFeldspar
Albite
Oligoclase
AndesineAnorthite
Biotite
Muscovite
Illite
Chlorite
Kaolinite
Glauconite
Smectite
QuartzClayMix
OtherClays
Zircon
Tourmaline
Garnet
Epidote
Titanite
Kyanite
Staurolite
Amphibole_CPX
OPX
Rutile_Anatase
CrSpinel
Apatite
Monazite
Calcite
Dolomite
FeDolomite
Ankerite
Siderite
FeOxides
Pyrite
Barite
Anhydrite
Halite
OtherPhases
Unclassified
Porosity

SpecCam + QEMSCAN workflow

Step 1: SpecCam core scanning

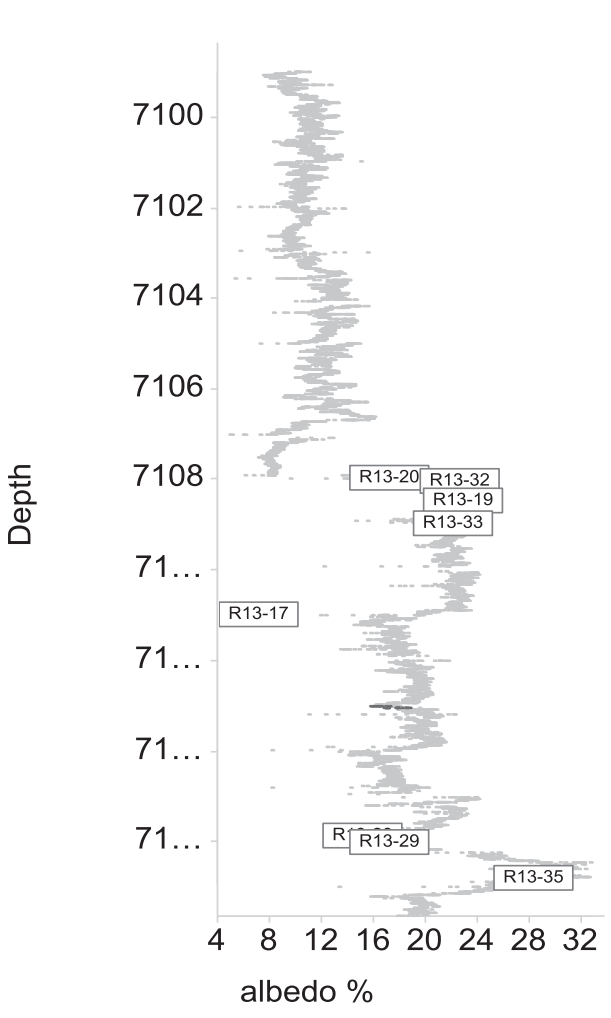
Step 2: SpecCam dataset rock typing

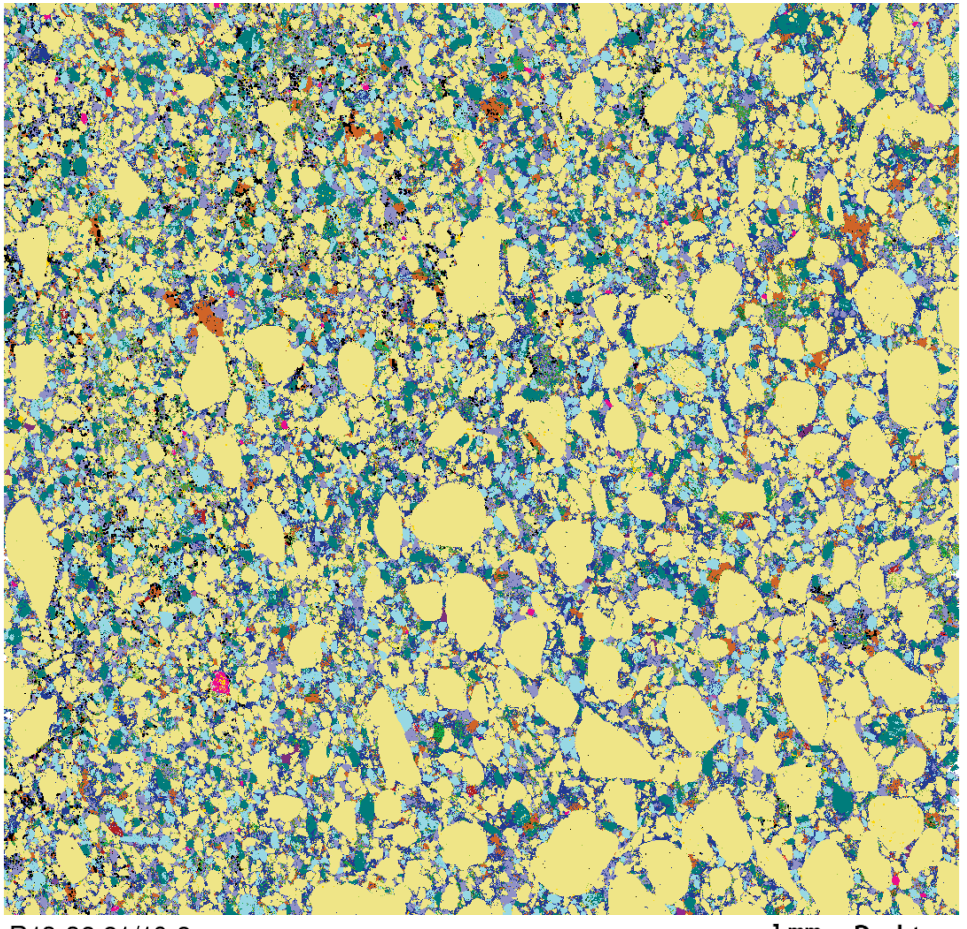
Step 3: QEMSCAN point sample selection

Step 4: QEMSCAN analysis & calibration of SpecCam data

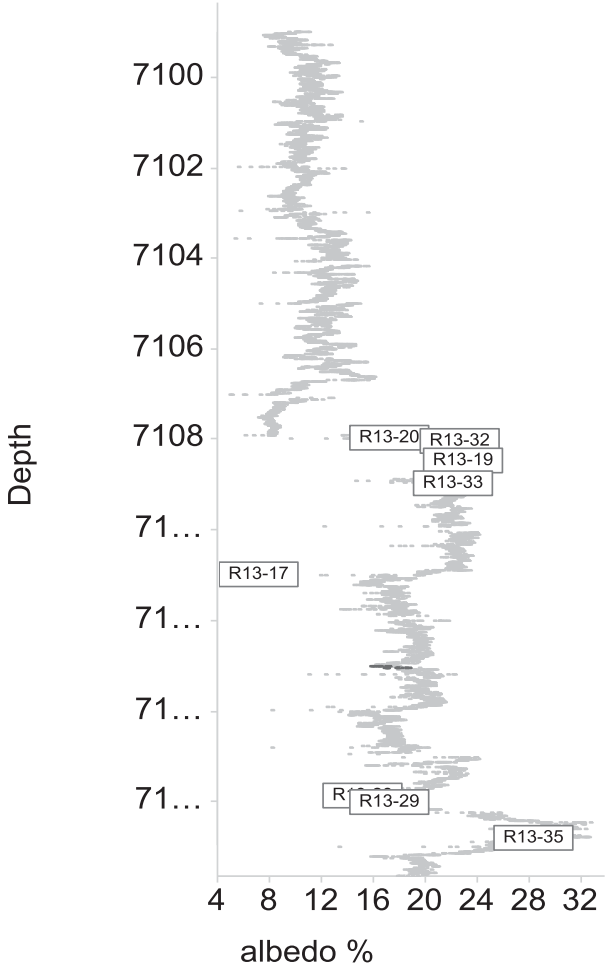
Step 5: Calibrated dataset further calculations, incl upscaling of properties

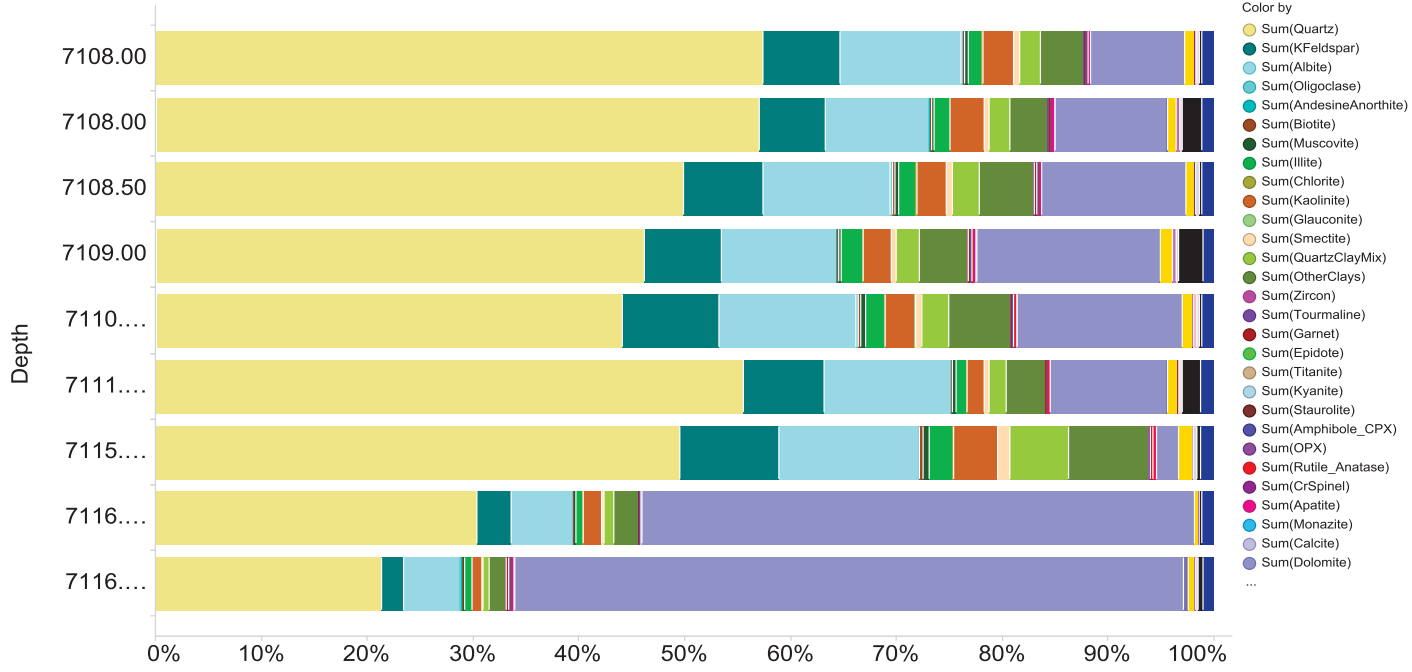
Albedo (%), QEMSCAN point samples



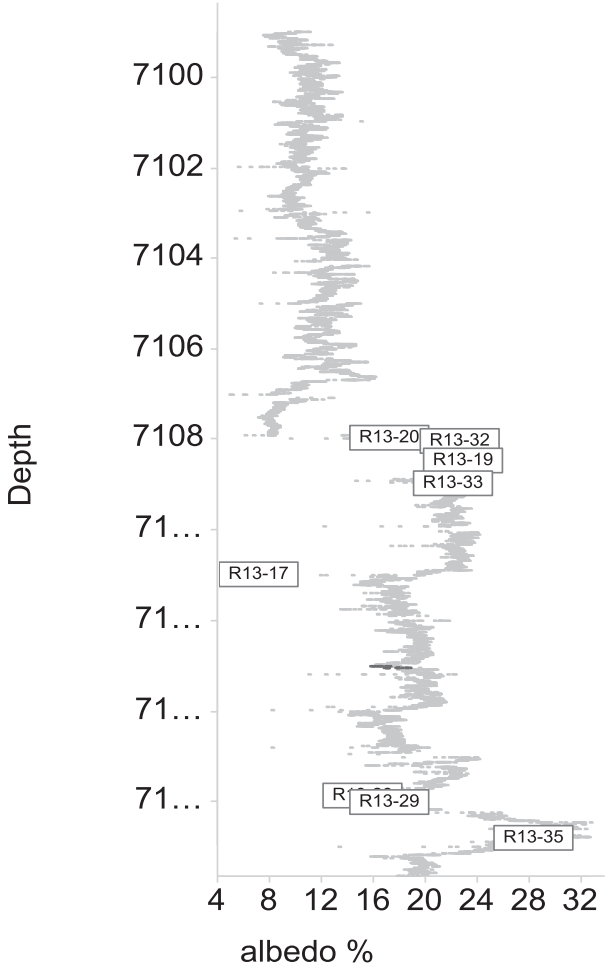


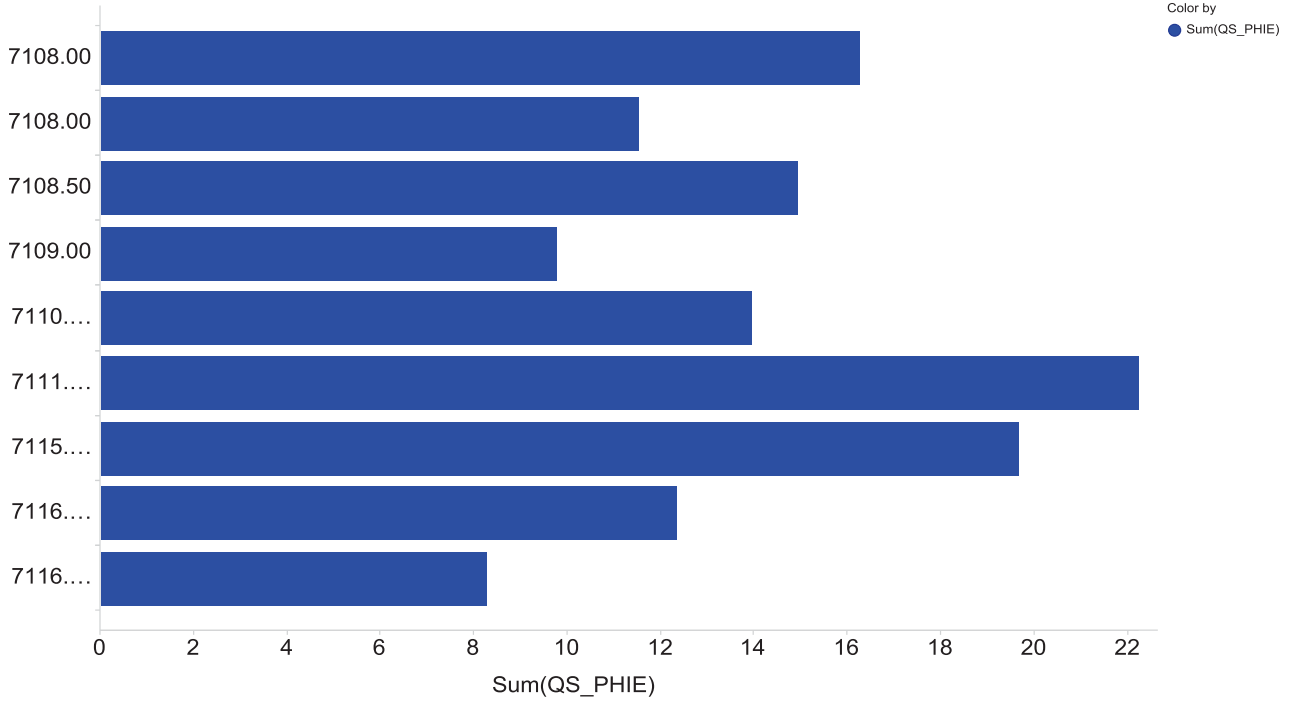
Albedo (%), QEMSCAN modal mineralogy



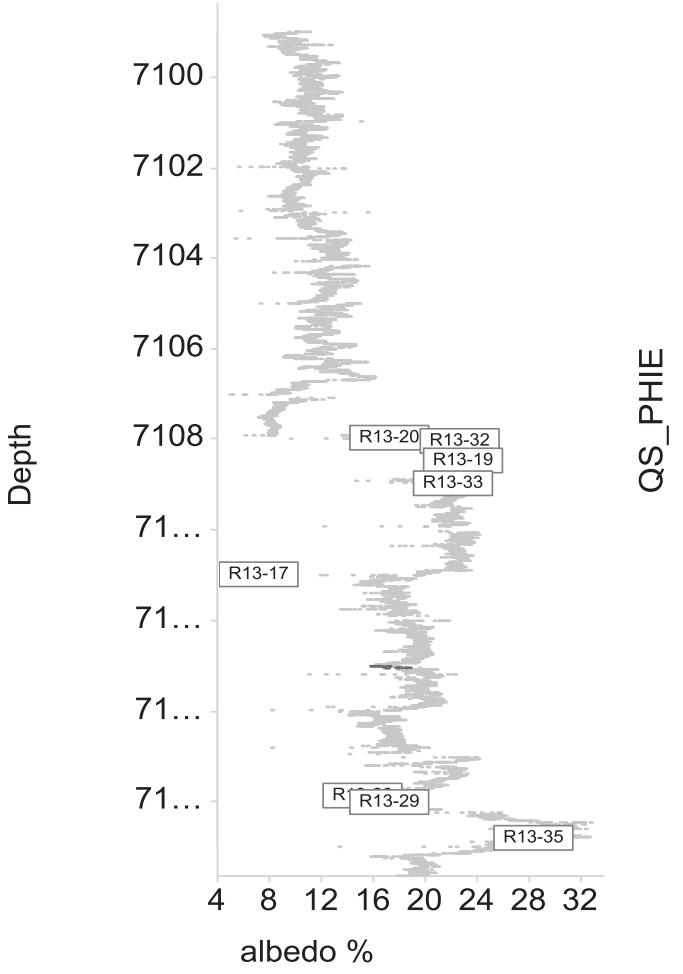


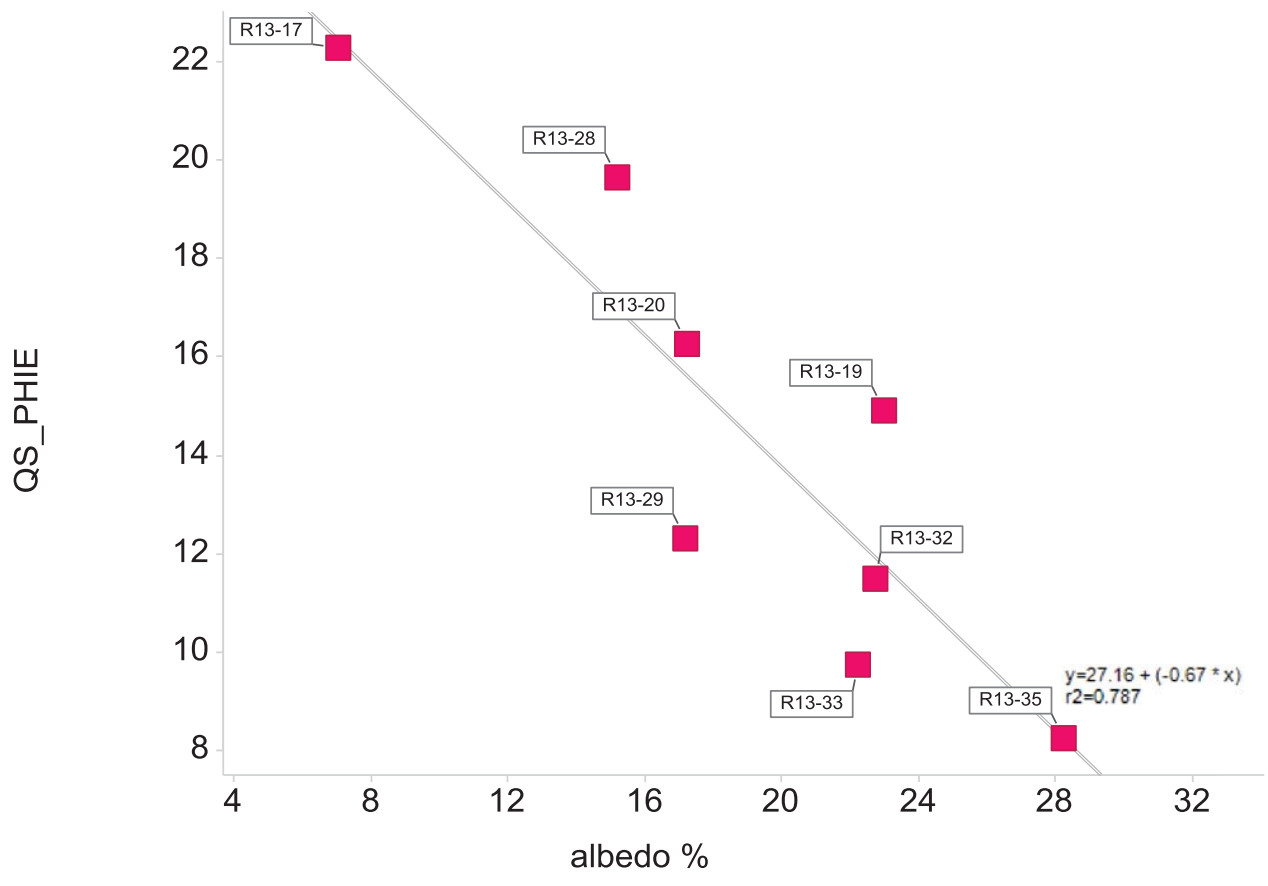
Albedo (%), QEMSCAN porosity



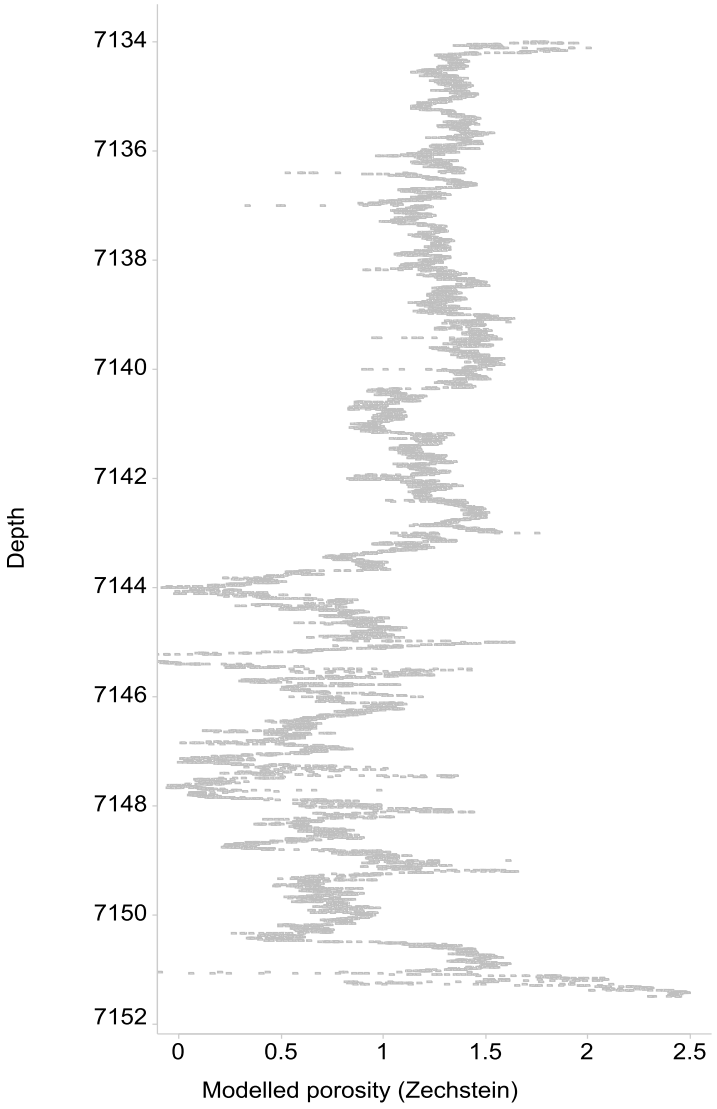


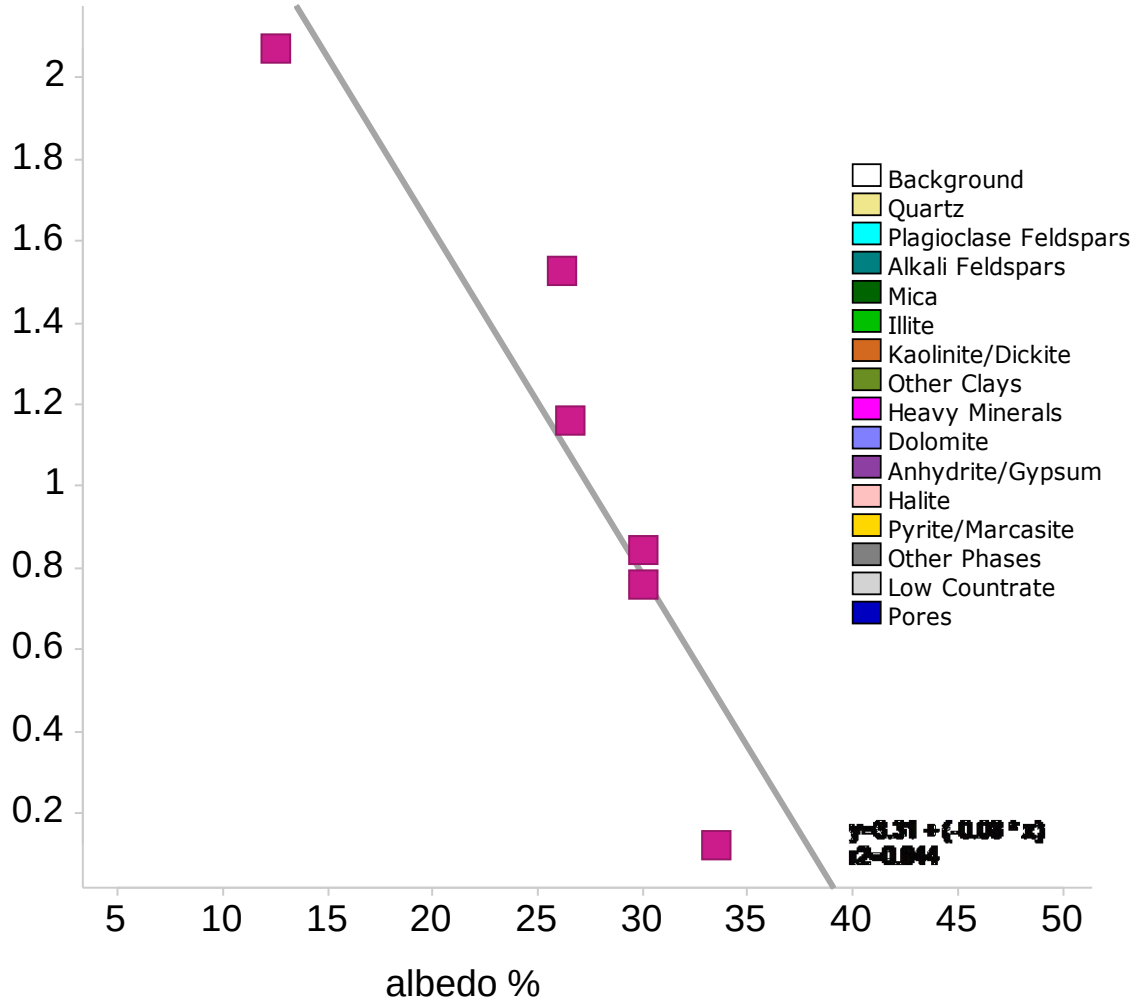
Albedo (%) vs QEMSCAN porosity

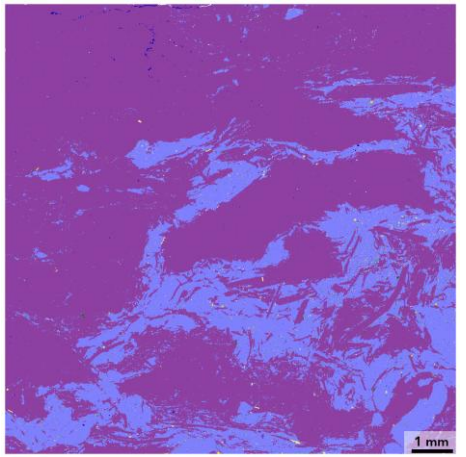


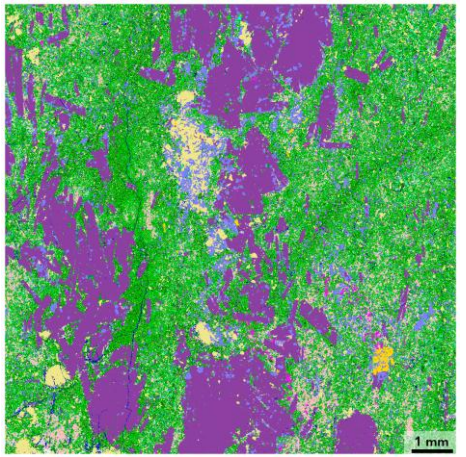


Albedo (%) vs QEMSCAN porosity – PETEX (Zechstein)

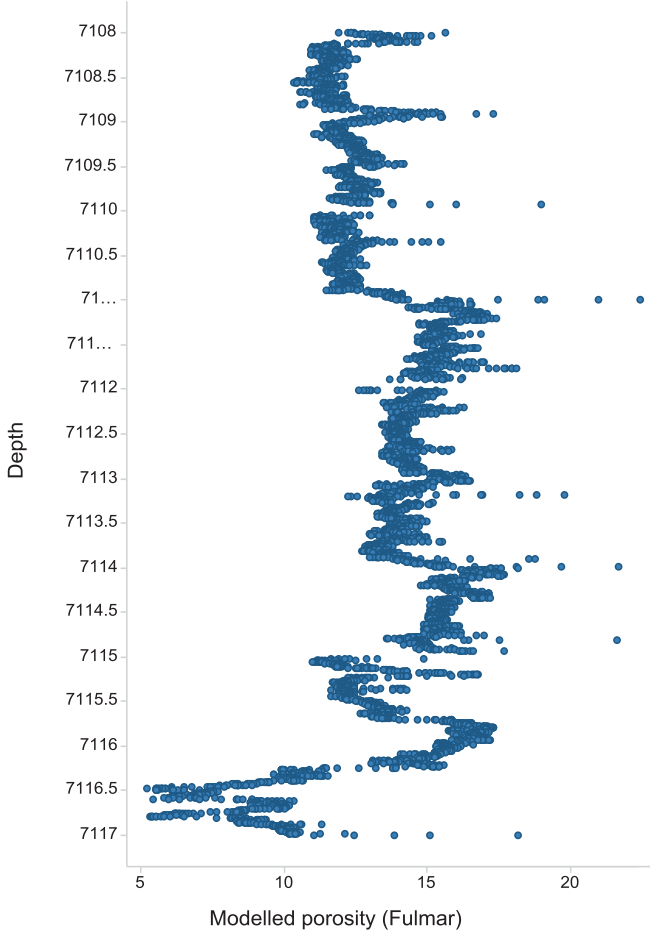


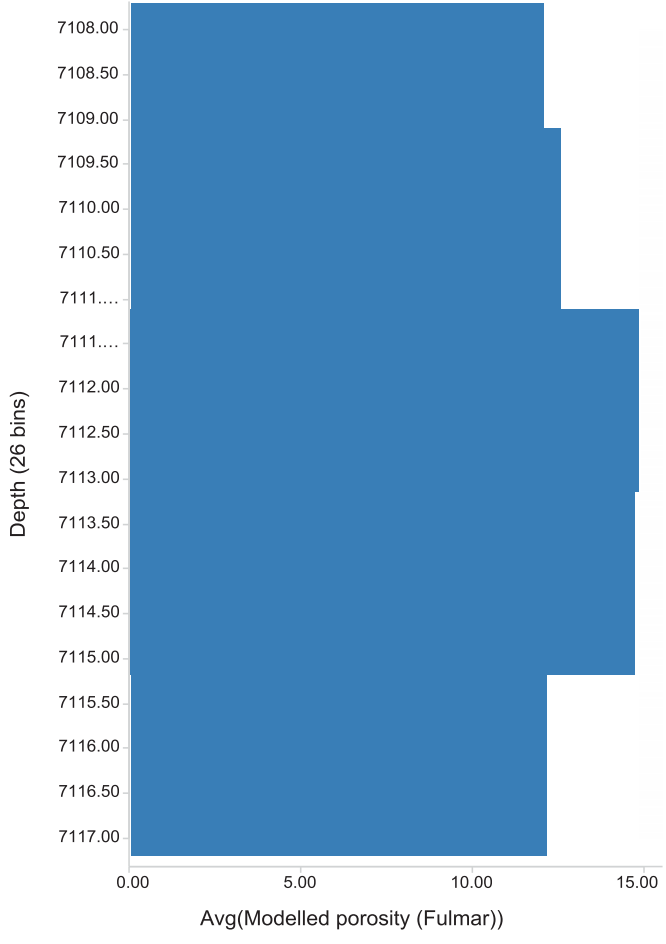






Modelled porosity at 0.5 mm below OWC





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Rocktype