GEOTEK

Core Scanning Services

James Shreeve – Sales Director

james@geotek.co.uk

Why are Core Scanning Instruments Required?

- Drilling/sampling core material is expensive
- Basic or advanced laboratory testing is expensive
- Therefore there is a need:
  - **To maximise data recovery from every metre**
  - **Understand core heterogeneity**
  - **Identify key geological/engineering horizons**

But…core analysis must be in a time-efficient and cost-effective way

Under-Utilized Resource of Information

Geotek Core Analysis Instrumentation

Standard Multi-Sensor Core Logger (**MSCL-S**)		Hyperspectral Core Imaging System (**HCIS**)	
XZ Multi-Sensor Core Logger (**MSCL-XZ and MSCL-XZXRF**)		laserscan	Geotek LIBS Core Scanner Arriving in 2022 
XYZ Multi-Sensor Core Logger (**MSCL-XYZ and MSCL-XYZXRF**)		boxscan	
X-ray CT Machines (**XCT, RXCT, VXCT, PXCAN**)		floodXcan	 

Available Sensor Technology for MSCL Systems

	Sensor	Compatible MSCL
Physical Properties	Attenuated Gamma Density and Porosity	MSCL-S
	P-wave and S-wave Transducers	MSCL-S
	Non-Contact Electrical Resistivity	MSCL-S
	Magnetic Susceptibility	MSCL-S, MSCL-XZ, MSCL-XYZ, BoxScan
	Spectral and Total Natural Gamma	MSCL-S
	Color Spectrophotometer	MSCL-S, MSCL-XZ, MSCL-XYZ
Chemistry and Mineralogy	Olympus Vanta XRF	MSCL-S, MSCL-XZ, MSCL-XYZ, BoxScan
	He-flushed Geotek XRF	MSCL-XZ, MSCL-XYZ
	Laser Induced Breakdown Spectroscopy (LIBS)	MSCL-XZ, HyperScan*
	VIS and VNIR/SWIR Point Sensor	MSCL-S, MSCL-XZ, MSCL-XYZ, BoxScan
Imaging	SpecCam 4 VNIR/SWIR Hyperspectral Camera	MSCL-S, HCIS-S, HCIS-B
	3D Laser Core Imaging	BoxScan, HCIS, CIS
	Geotek linescan camera (Visible and UV)	MSCL-S, MSCL-XZ, MSCL-XYZ, BoxScan, HCIS, CIS

- **Multiple** sensors can be installed onto one MSCL system
- MSCL systems are **modular** and sensors can be added or removed as required
- MSCL systems can be **upgraded** with sensor technology in the future

MSCL-S with 9 sensors incl. XRF

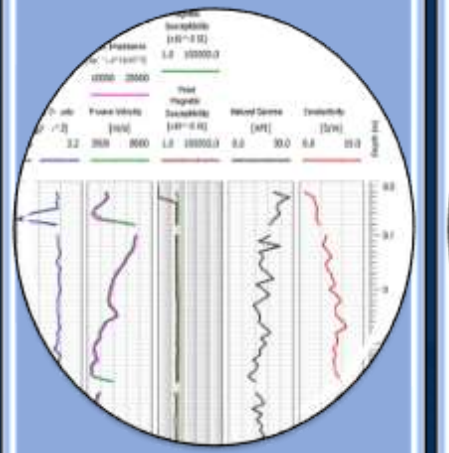
A Core Digitisation Workflow

Analyse

Manage

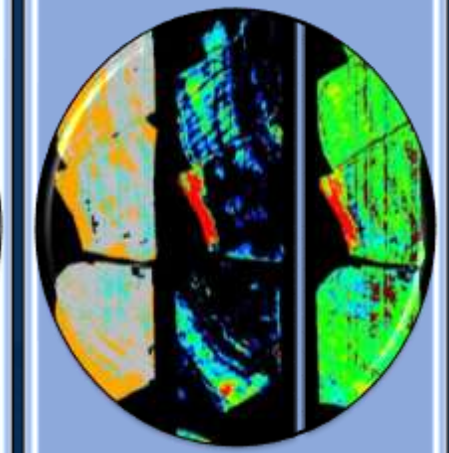
Archive

Available Services



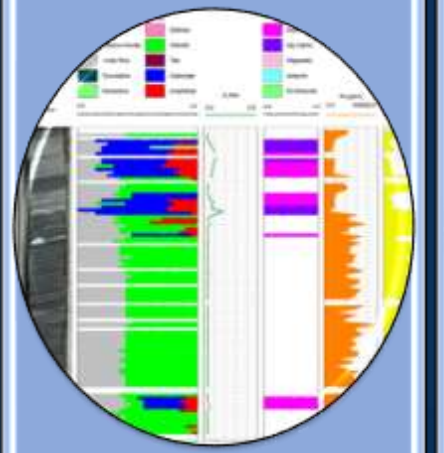
Petrophysical and Mechanical Properties

Output: Density, Vp/Vs, Mag. Sus., Elec Res., API, K,U,Th.



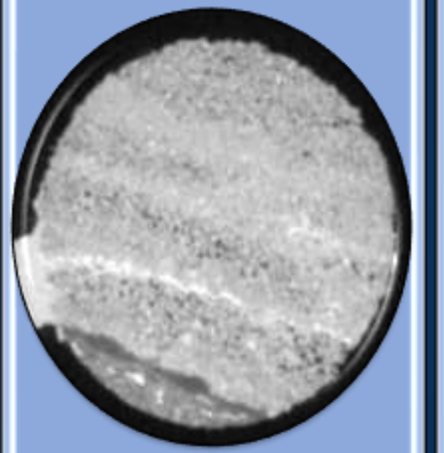
Hyperspectral Imaging

Output: Mineral maps and profiles, development of specific mineral models



Chemistry and Mineralogy

Output: Wet/Dry Core photography, XRF, ASD VNIR/SWIR, Mag. Sus., Structural Measurements



X-ray CT

Output: Axial views, orthogonal slabs, radiographs, laminography, unwrapped slabs, etc.

Core Photography

Output: Visible and UV imaging, Wet and Dry imaging

Integrated Multi-Sensor Core Scanning Services

How to Rationalise a Big Data Scanning Program?

Multi-Sensor Core Digitisation

Exploratory Level Scanning

Practical resolution that is fit for purpose to create the digital archive

High throughput (50 to >100 m per day) with low data volumes (<1GB per m)

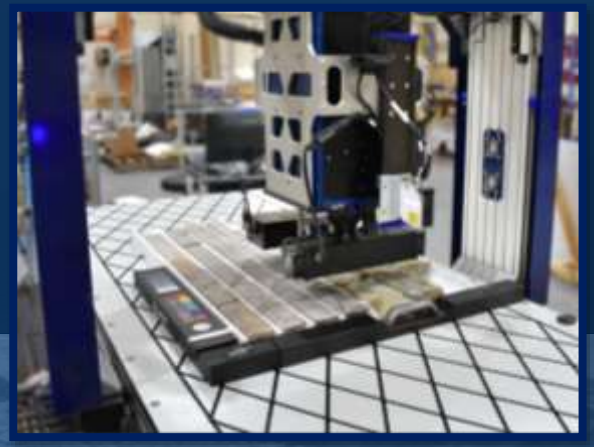
Detailed Level Scanning

Enhance the understanding of the geological strata

High resolution (<5 cm per point) with lower throughput (10s m per day) and higher data volumes (>>1Gb per m)

Core or Cuttings – Geotek can scan it!

- Geotek core scanning equipment is capable of scanning:
  - Whole Core
  - Slabbed Core
  - Core still in liners (Metal or Plastic)
  - Chips / Cuttings
  - Soils / pulps
- The form factor of the material and its competence will have an effect on: compatibility of sensor technology and quality of data output.
- Geotek guide customers through the process of establishing the scope of work using our 30 years of core scanning experience



Core Scanning Services at the Lab

- Full laboratory spaces available at Daventry, UK; Salt Lake City, USA; and Rio De Janeiro, Brazil
- Lab services also available in Stavanger, Norway; College Station, Texas; and Perth, Australia

Core Scanning Services in the Field





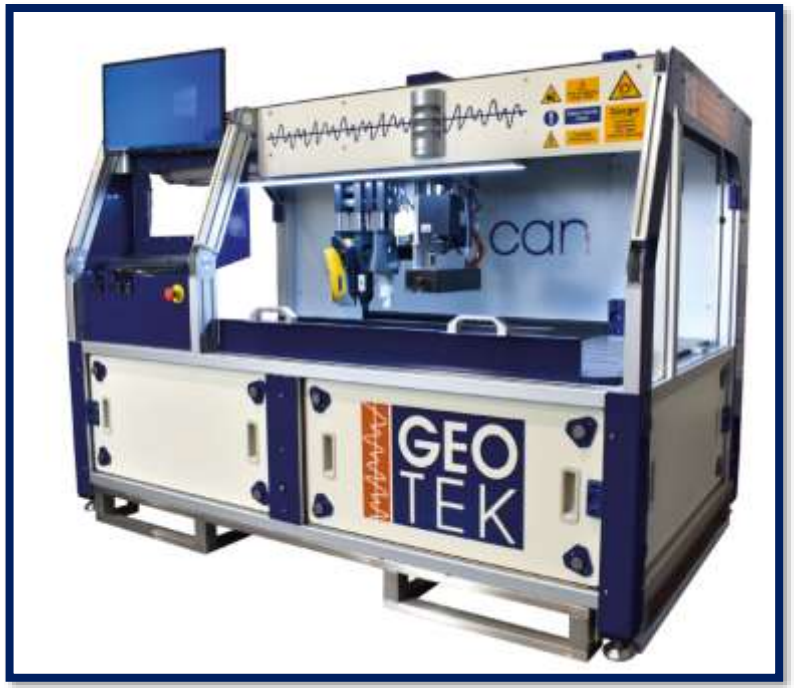

- Geotek have **decades of experience** of bringing core scanning labs to the core. We can install equipment into **customers facilities**, onboard **offshore** vessels, fit-out **container labs**, or within **temporary buildings**.
- Field-based services are **perfect for core repositories for large core volume scanning**, or where customers want to have a **rapid data turn around**
- Geotek field-based services **include Geoscientists** who commission, operator and process the data in the field.

Lease Services: boxscan

- BoxScan is a field-deployable multi-sensor core scanning system that is available for lease on a day rate basis
- Modular sensors and pricing structures. Only lease what you want!
- BoxScan can be fully remotely installed and training is remote (where good internet connection is available)

- Onboard ML and interpretation software for:
  - Automated core curation and extraction of rock quality parameters
  - VNIR/SWIR mineral interpretation

pXRF chemistry | Magnetic susceptibility | UHD linescan core photographs | VNIR/SWIR mineralogy | RGB profiles | Structural logging | Core boxes/ Chips



Added Data Value

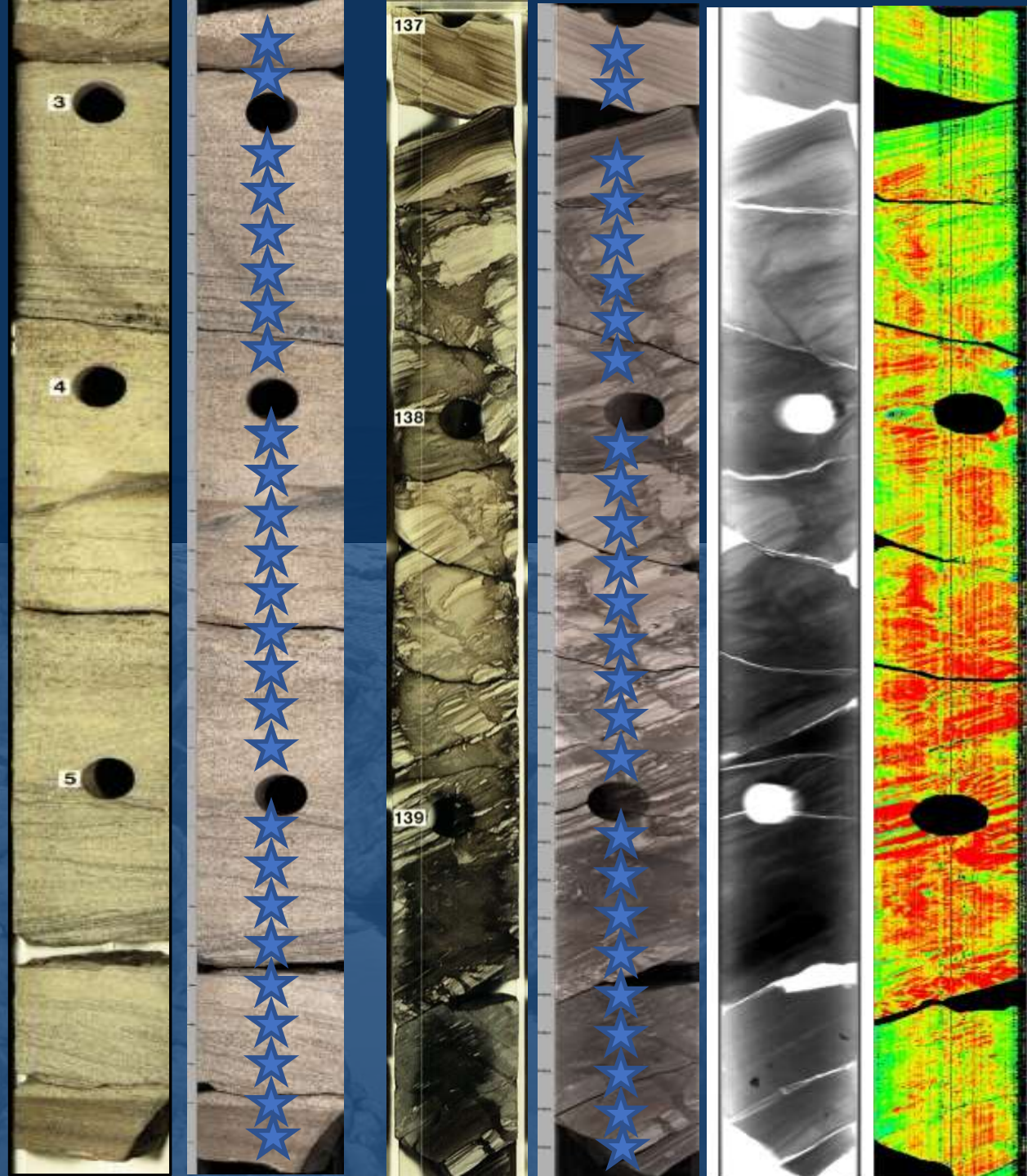
- 1 x 1.5” core plug per ft over a 3ft 4” core
- 3 discrete measurements per m

Core Scanner data - Provides stratigraphical context for discrete measurements

- Measurement every 10 cm would give 3 times the number of data points per ft
- Image colour, resolution, and depth registration improved
- X-ray images to identify hidden features
- Mineralogical maps to improve understanding of clay distribution and composition

- Creates a digital record that can be viewed in detail not possible when originally drilled

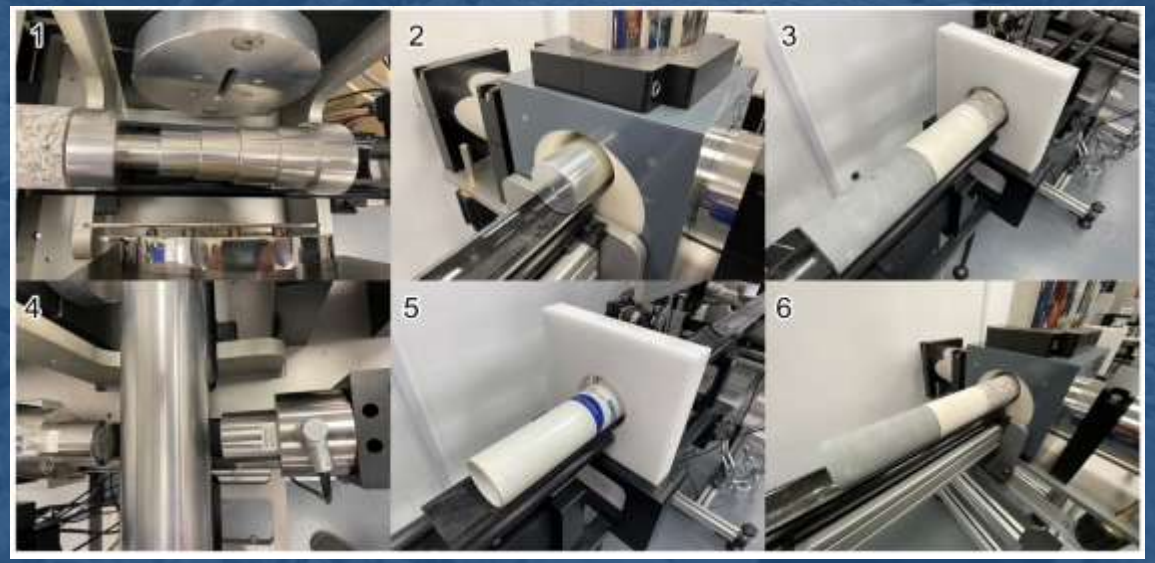
- A modern dataset acquired on stratigraphy still in production but from archived material with no core destruction and no requirement to drill new material



Calibration and QAQC

- Calibration and QAQC are a fundamental part of Geotek core scanning services
- Geotek use a range of reference materials, rock standards, and CRMs to create a calibration and QAQC set that is suitable for each project and the core type

Instrument Platform	Sensor Technology	Calibration	Setup
BoxScan	Geoscan V Linescan Camera	White photographic card	N/A
	Laser Profiler	Known Reference height	N/A
	Olympus Vanta M XRF	Factory calibration	20s per point (10s per beam) using Geochem mode and 9 mm collimator
	ASD VNIR/SWIR Labspec Spectrometer	White spectrolon tile	100 measurements per point (c.10s) using contact probe
	Point Magnetic Susceptibility	Factory calibration	10s per point
MSCL-S	Gamma Density	Stepped aluminum bar	10s per point
	P-wave Velocity	Factory calibration	100 measurements per point
	Loop Magnetic Susceptibility	Factory calibration	10s per point
	Electrical Conductivity	Factory calibration	10s per point
	Natural Gamma	Rock calibration standards	30s per point
Hyperspectral Core Scanner	SpecCam 4 VNIR and SWIR hyperspectral spectrometer	White tile	N/A

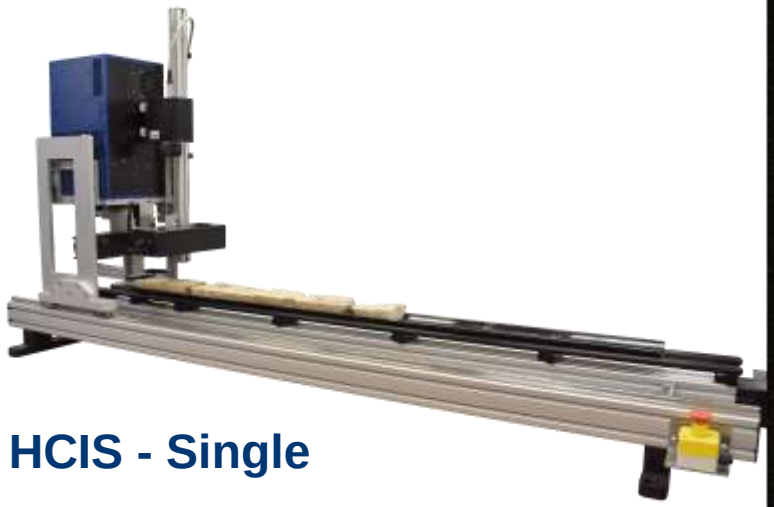


Core Imaging Systems

- **Linescan Imaging** for wet/dry visible imaging or UV
- **3D Laser scanning** for core for core curation and rock quality parameters
- VNIR and SWIR **hyperspectral imaging** for mineralogy
- Onboard **core curation software and mineralogical interpretation software (MINSPEC)**
- **Fast** – visible imaging in 30s/m
- **Superior sensitivity** for hyperspectral with up to 1nm spectral resolution
- **Flexible** – single or core box platforms

Dry Wet Dry Wet

CIS - Single



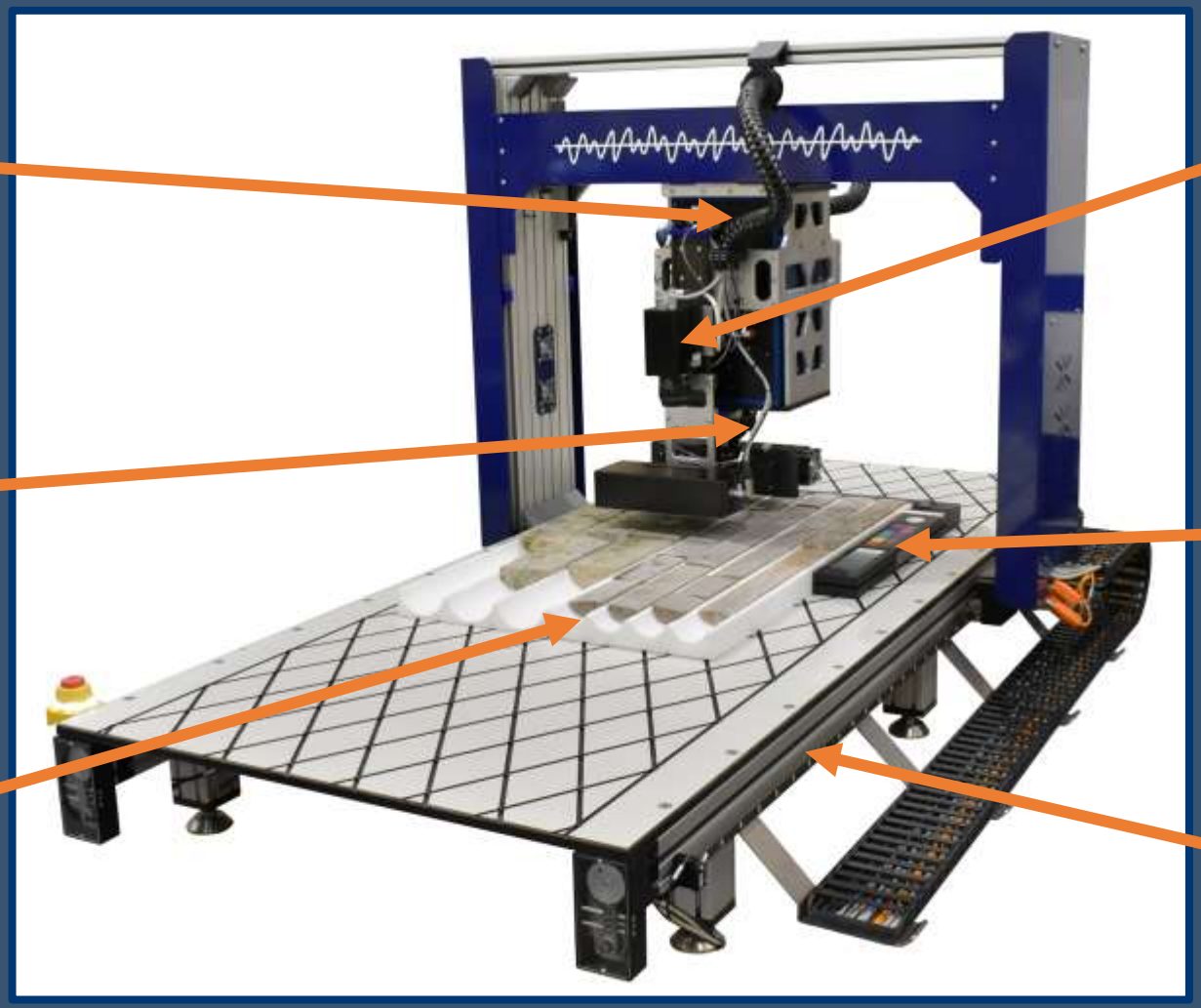
HCIS - Single

Hyperspectral Imaging for Boxes of Core & Cuttings HCIS-B

SpecCam VI HSC (VNIR + SWIR) with Fully automated MINSPEC live data processing

Scanning laser for core curation with onboard ML for core segmentation

Flexible measurement bed for core or cuttings



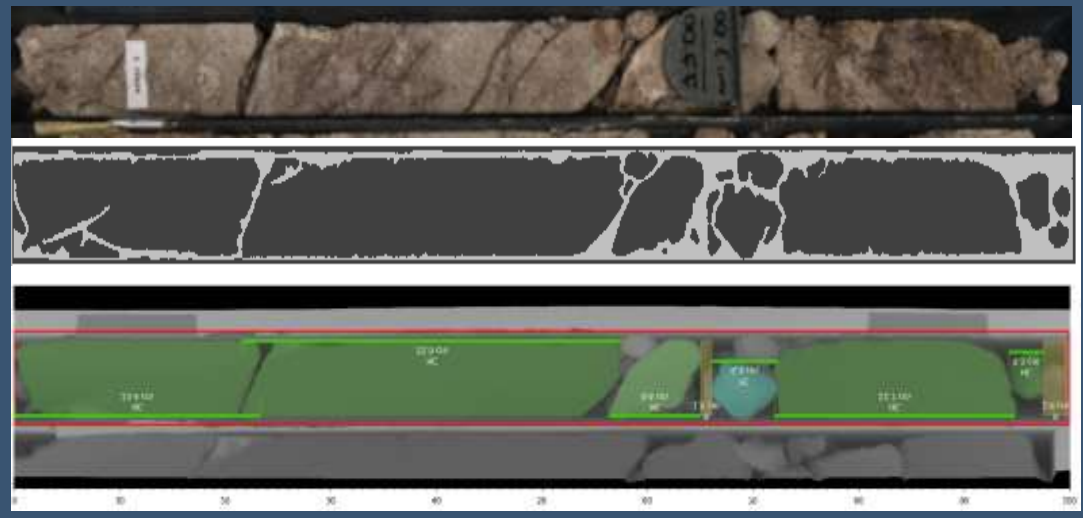
GeoScan VI Linescan Camera for wet/dry or VIS/UV core photography (100-400 ppcm)

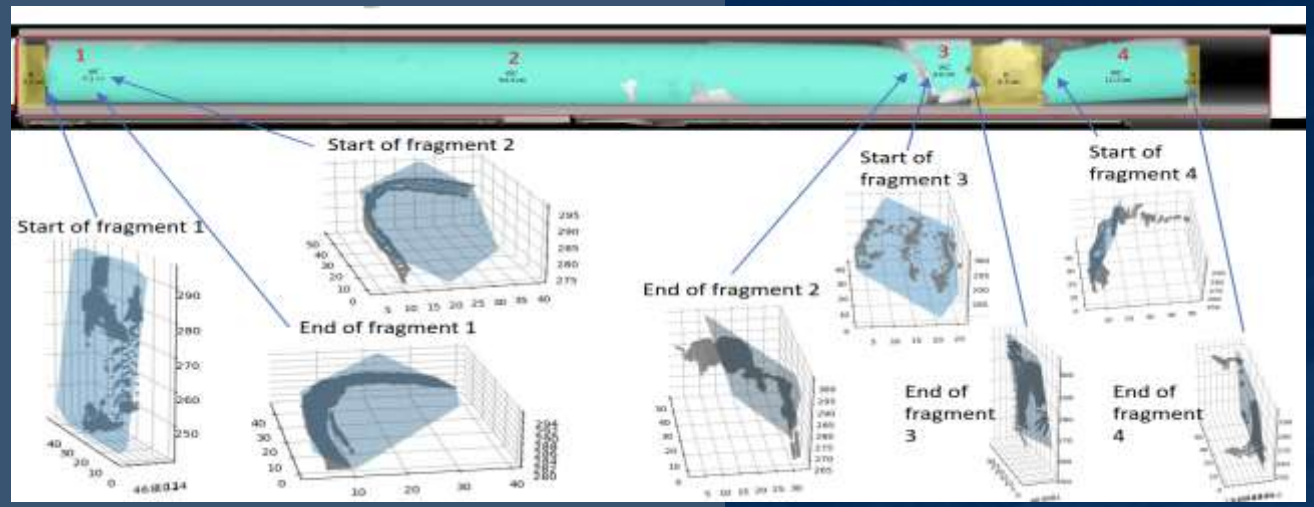
Integrated QAQC bar with automated routines

Fully automated motors with accurate positioning to 0.01 mm

Onboard Automated Core Curation Software

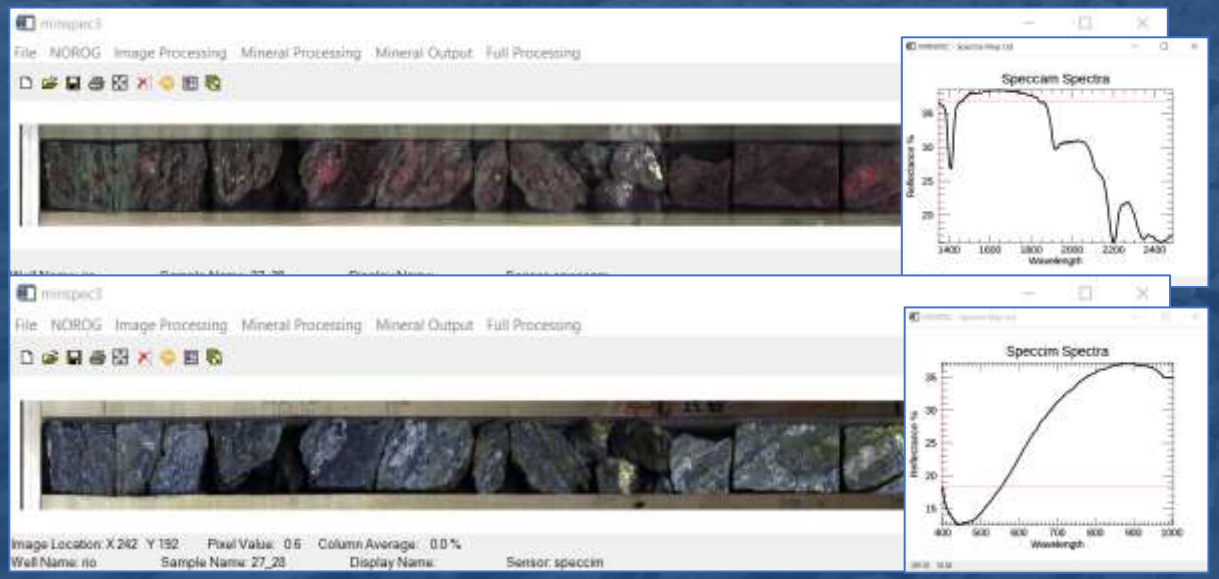
- Using onboard segmentation algorithms to separate the core into lengths that can be measured. Core depth information added to allow for instrument depth to be converted to borehole depth. Perfect to broken or archived cores
- Segmentation of the core enables rock quality parameters and geotechnical metrics to be calculated (RQD, Fracture Freq, Fracture spacing etc)
- Segmentation also identifies fractures and laser returns from the surface of the fractures enables planes to be fitted so that orientation of fractures can be calculated if the orientation of the core is know.

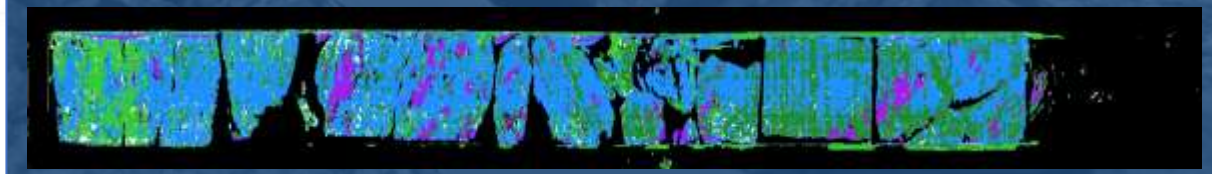




MINSPEC: Onboard Mineralogical Processing Software

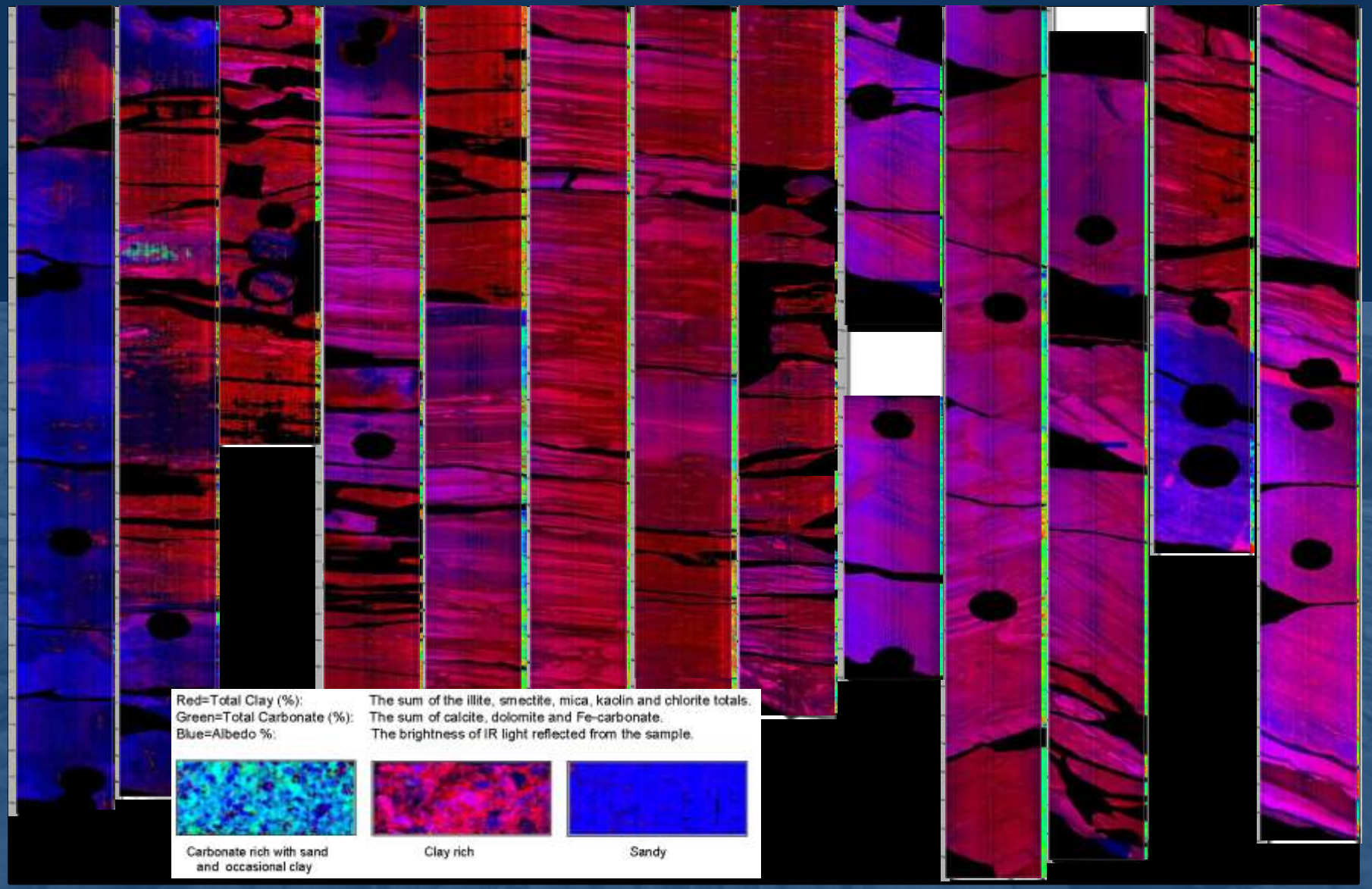
- MINSPEC software to be deployed onto HCIS and BoxScan systems for automated processing of VNIR and SWIR spectra from either SpecCam IV or ASD Labspec/Terraspec instruments
- Data are automatically sent to MINSPEC during acquisition where in near-real time data will be processed into mineral maps, mineral classification maps, false colour images
- Laser scans will automatically create masks to ensure that any erroneous data are removed from the final data deliverable





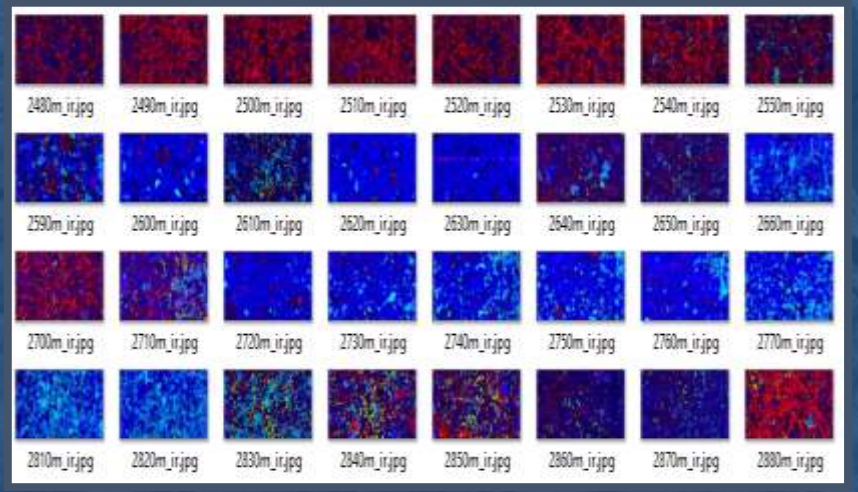
Scanning Outputs – Core Imaging

- High resolution core images in Tiff and JPEG format
- Hyperspectral data outputs: Mineral classification maps, Mineral abundance maps (vol %), model (vol %) data and log profiles
- Laser imaging providing: core curation, RQD, fracture frequency, alpha and beta angles
- Data delivered digitally



Cuttings Imaging Output

- **Make more of cuttings with continuous downhole mineralogy**
- **Fast enough to be used in the field to provide valuable information to support field interpretations.**
- **Data Outputs: Mosaiced logs, modal outputs, mineral abundance map per cutting sample**



No sample prep
No sample damage
Fast - **200+** samples/day

Minerals Quantified
Clays, carbonates, sulphates, and iron oxides

Hyperspectral
Imaging **Services**
for **Cuttings**

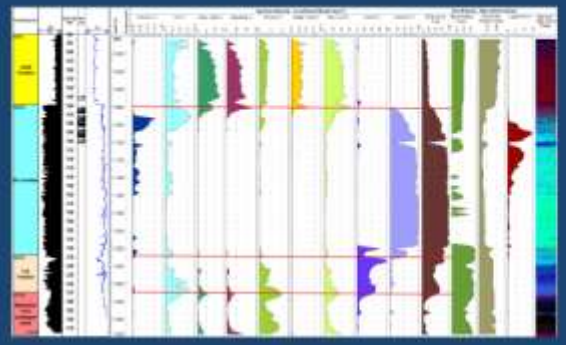
Mineralogical services in the **lab** *Or* at the **wellsite**

Make **informed decisions in** ***real time*** to guide projects

Reveal subtle changes in chemistry

Near **continuous** data

Output
mineralogical logs



Up to
10,000
spectra in
each image
500µm
resolution

Geotek X-ray CT System Product Range For Industry and Academia

ScoutXcan	X-ray CT (XCT)	Vertical X-ray CT (VXCT)	Rotating X-ray CT (RXCT	PlugXcan
2D Radiography and Laminography	Horizontal Rotating Core	Vertical Rotating Core	Horizontal Stationary Core	Core Plug and Sidewall Core Scanning
				

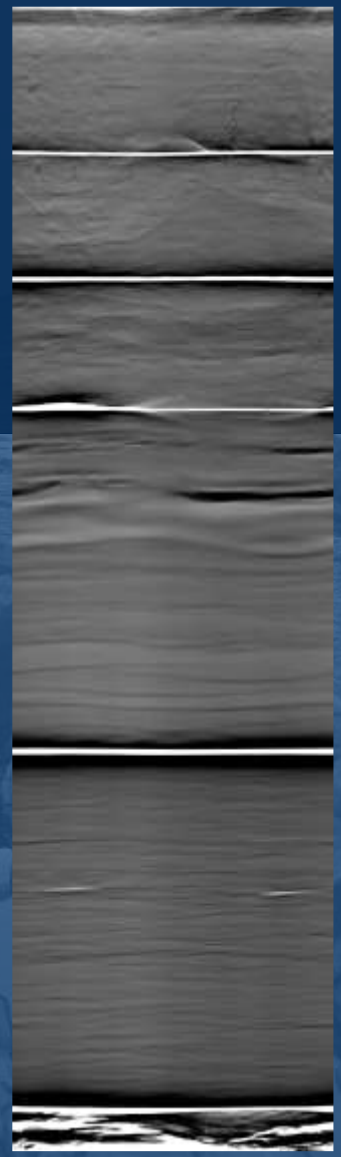
Geotek's versatile X-ray product range provides valuable high resolution **2D and 3D** X-ray images from **whole and split** core samples. The Geotek product range system are **affordable and practical instruments** ideal for geological and Industrial research laboratories.

Scanning Outputs – X-ray CT

- **2D X-ray Radiography**
  - Transmission X-ray imaging to produce an averaged projection
  - Conducted at 3 (0,45, 90) angles to visualize 3D structure
  - Data delivered as Tiffs, Jpegs and with report to ASTM
- **3D X-ray Laminography**
  - Image processing technique using the 2D X-ray radiograph to produce multiple slabs along the core axis
  - Optional unwrapped circumferential images
  - Data delivered as Tiffs, Jpegs and with report to ASTM
- **3D Computed Tomography (CT)**
  - Image processing technique to produce axial slices
  - These slices can be used to create orthogonal slabs and unwrapped images and 3D volumes
  - Data delivered as stacked Tiff seqence, Jpeg orthogonals
  - Optional report

Radiography

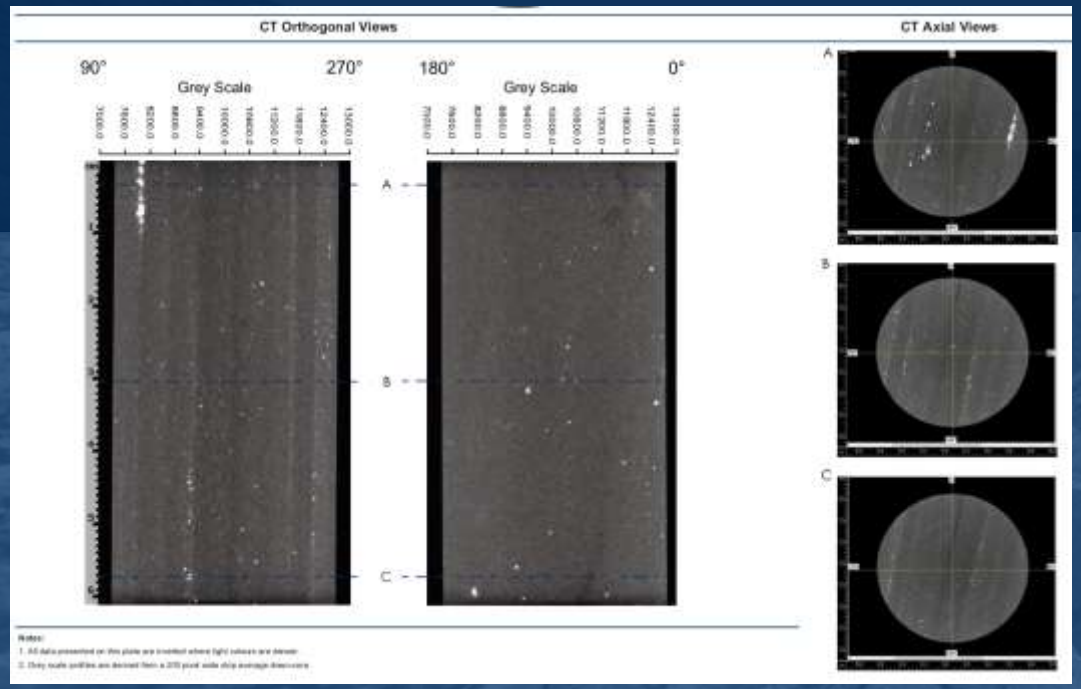
Unwrapped Laminography



Unwrapped CT

plugXcan: CORE PLUG SCREENING SERVICE

Scan up to **100 core plugs per day!**



Outputs: Stacked tiff sequence, orthogonals and summary plates per plug

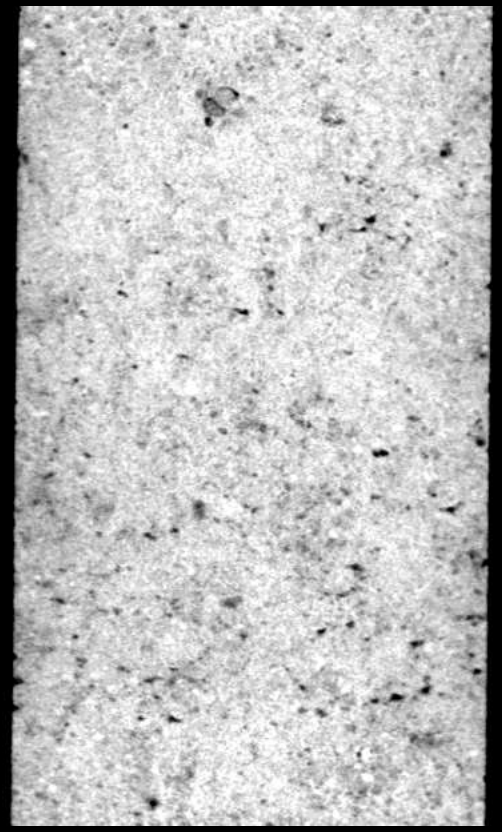
GEO TEK

plugXcan: RESOLVE MORE

Medical CT
300µm x 625µm

plugXcan

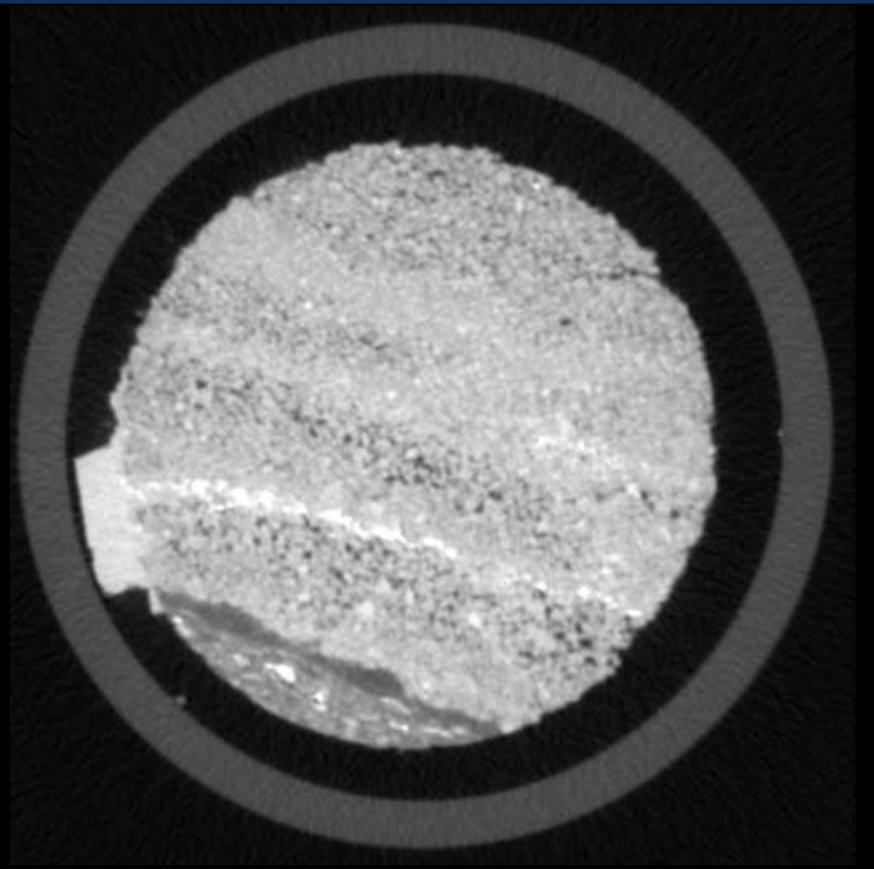
100µm x 100µm



Medical CT
300µm x 625µm

plugXcan

100µm x 100µm



Case Study: British Geological Survey

670 km of core stored within National Geological Repository (NGR) with an estimated replacement cost of £175 billion GBP!

The BGS view “automated core scanning as an essential technique [core analysis], minimising the need for destructive sampling, whilst providing much higher resolution data.

BGS Core Scanning Facility have installed:

RXCT: Rotating X-ray CT

MSCL-S: density, P-wave, magnetic susceptibility, natural gamma

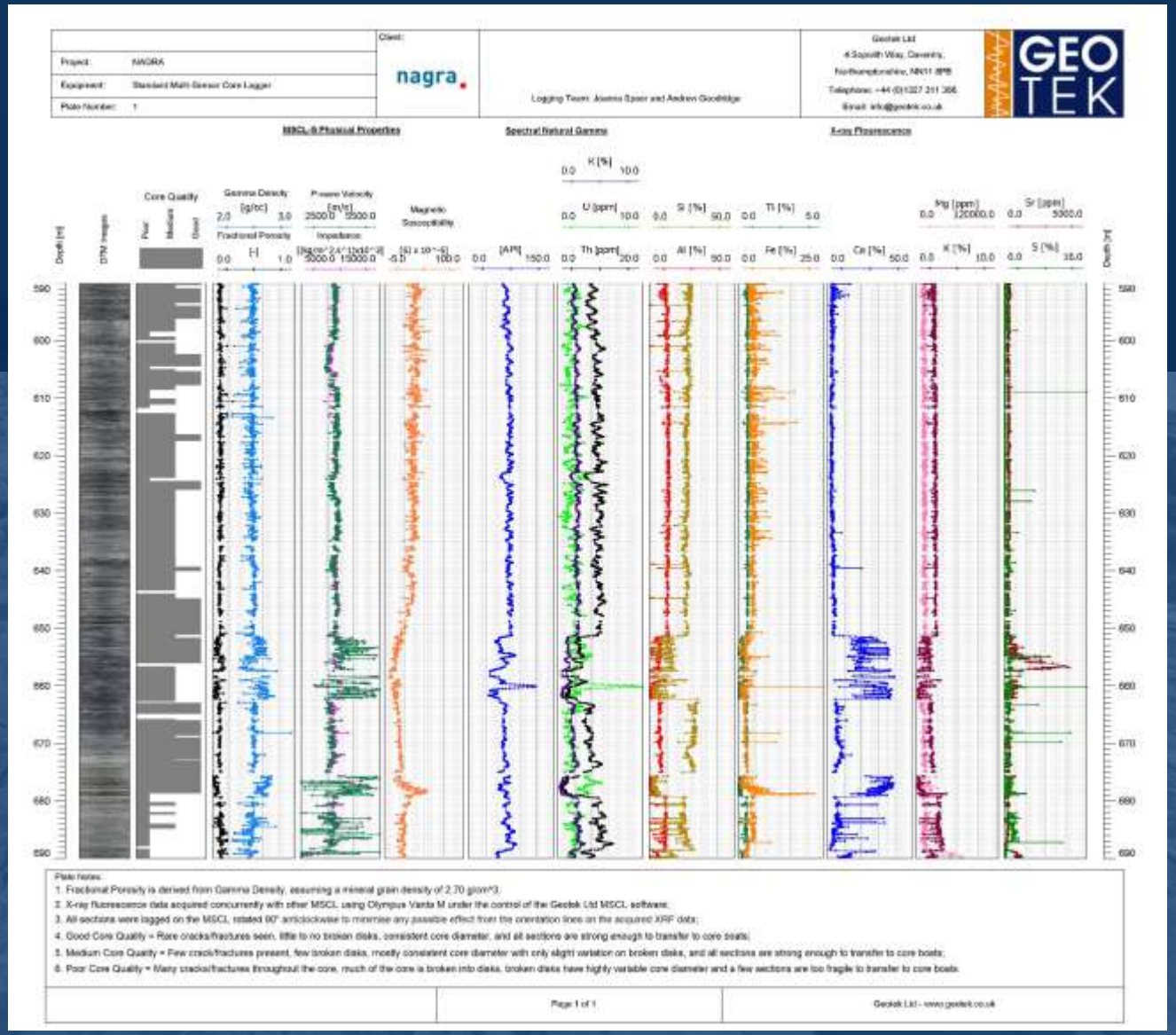
MSCL-XYZ XRF: ASD VNIR/SWIR Spectroscopy, XRF, Imaging

Case Study: Vale, Brazil

- Vale estimated that 230 km are acquired each year and most of this material was hardly investigated
- Geotek provided a 20ft containerised lab to the core repository in Belo Horizonte, Brazil
- Geotek trained in country providers and Vale staff to operate the equipment and then supported remotely
- Iron-ore deposit, using the MSCL to identify new reserves and to help **maximize the resource potential**

NAGRA

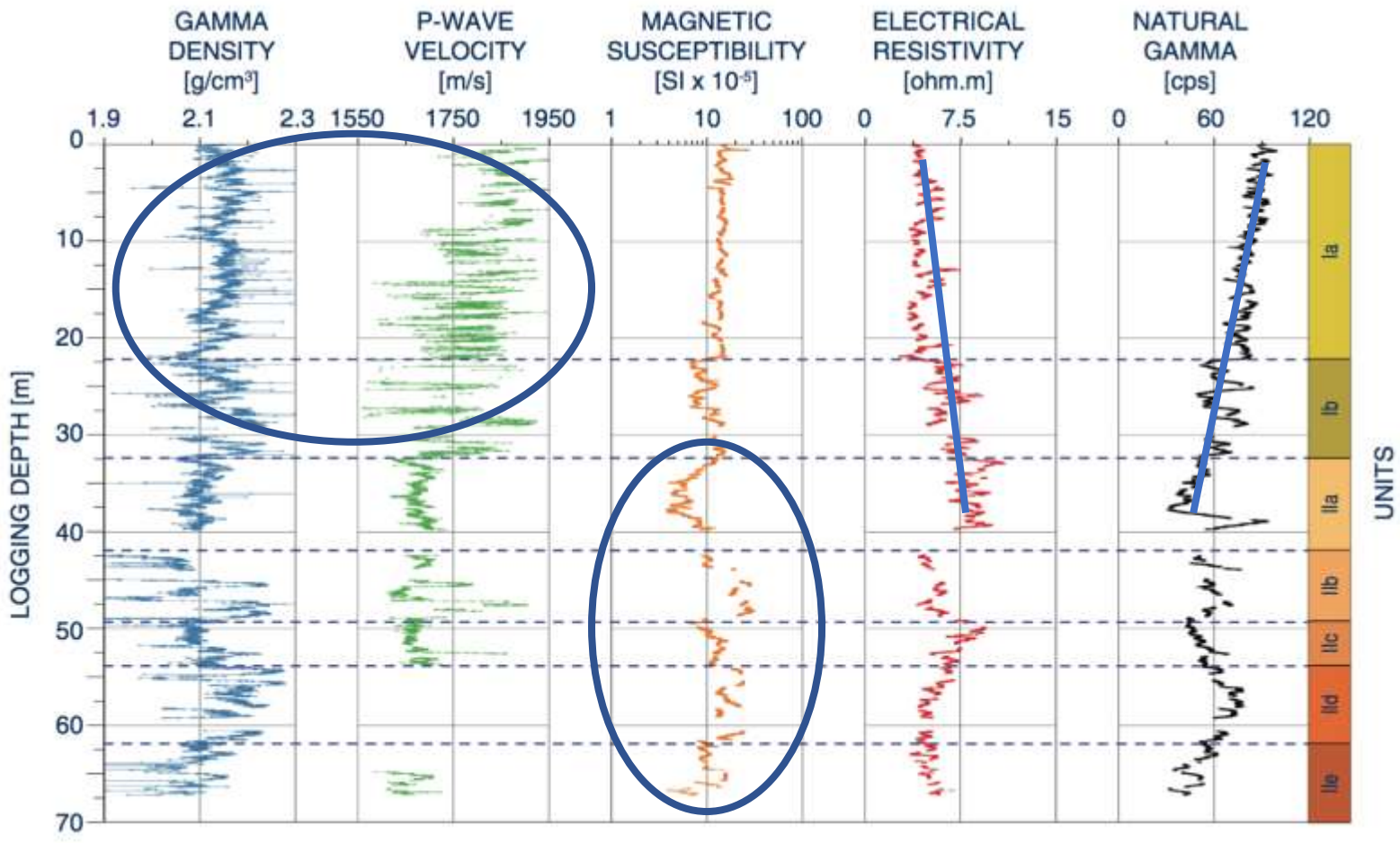
- MSCL-S purchased and Geotek staff conducted all the scanning
- Data depth curated to hole depth
- Data delivered in non-proprietary formats with each parameter depth co-registered
- Data delivered digitally alongside borehole logs showing selected data and factual report
- NAGRA using the data to interpret lithology through ML approach. This was used to complement the wireline data.



ONDRAF/NIRAS

Case Study: Sediment Core, ONDRAF/NIRAS, Belgium
10 mm Multi-Parameter Stratigraphy Acquired using a MSCL-S

- Whole plastic lined unconsolidated sediment cores
- Sediments are a **clay transitionir to a underlying sand/silt/clay** sequence
- Natural gamma and electrical resistivity show **fining upwards sequence** from 0 m to 40 m
- Erratic gamma density and P-wav velocity profiles from 0 m to 32 m from **authigenic precipitates**
- Magnetic susceptibility and densit highlight changes in **sediment lithologies** below 40 m



Enhanced characterisation of radiologically contaminated sediments at Sellafield by MSCL core logging and X-ray imaging

Oliver Kuras[1], James Shreeve[2], Nick Smith[3], James Graham[3], Nick Atherton[4]

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

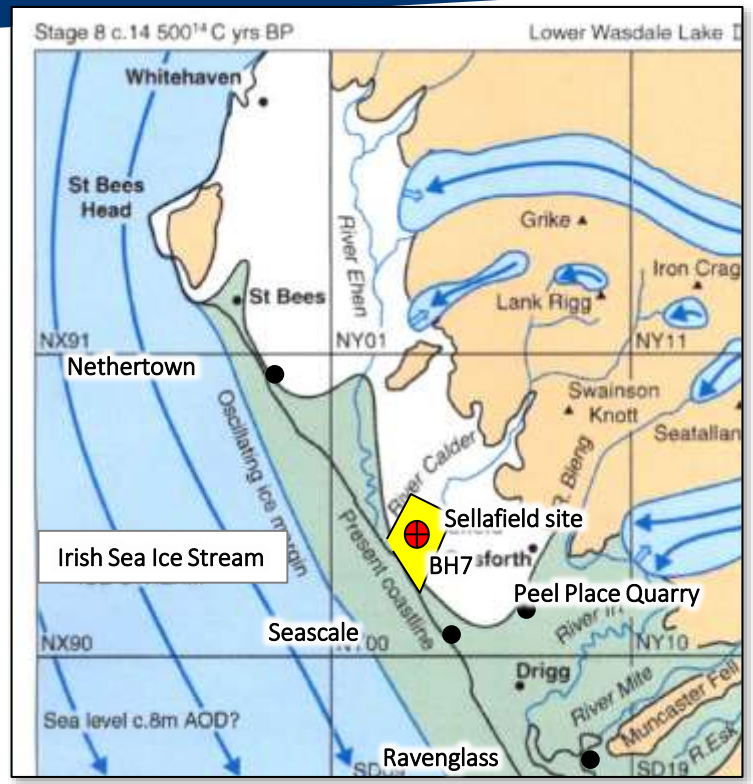
[1]

[3]National Nuclear Laboratory

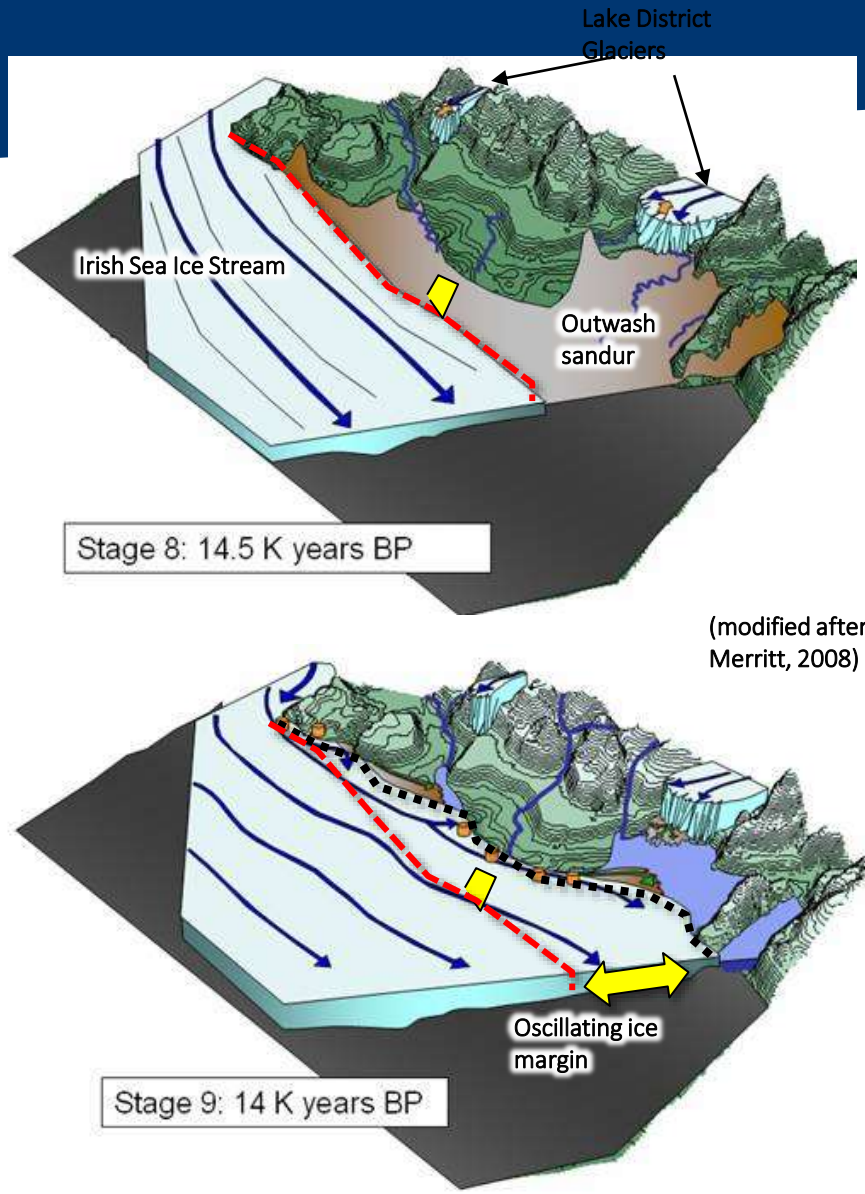
Sellafield Ltd

Geological Setting

Quaternary geological setting of Sellafield site, showing field locations

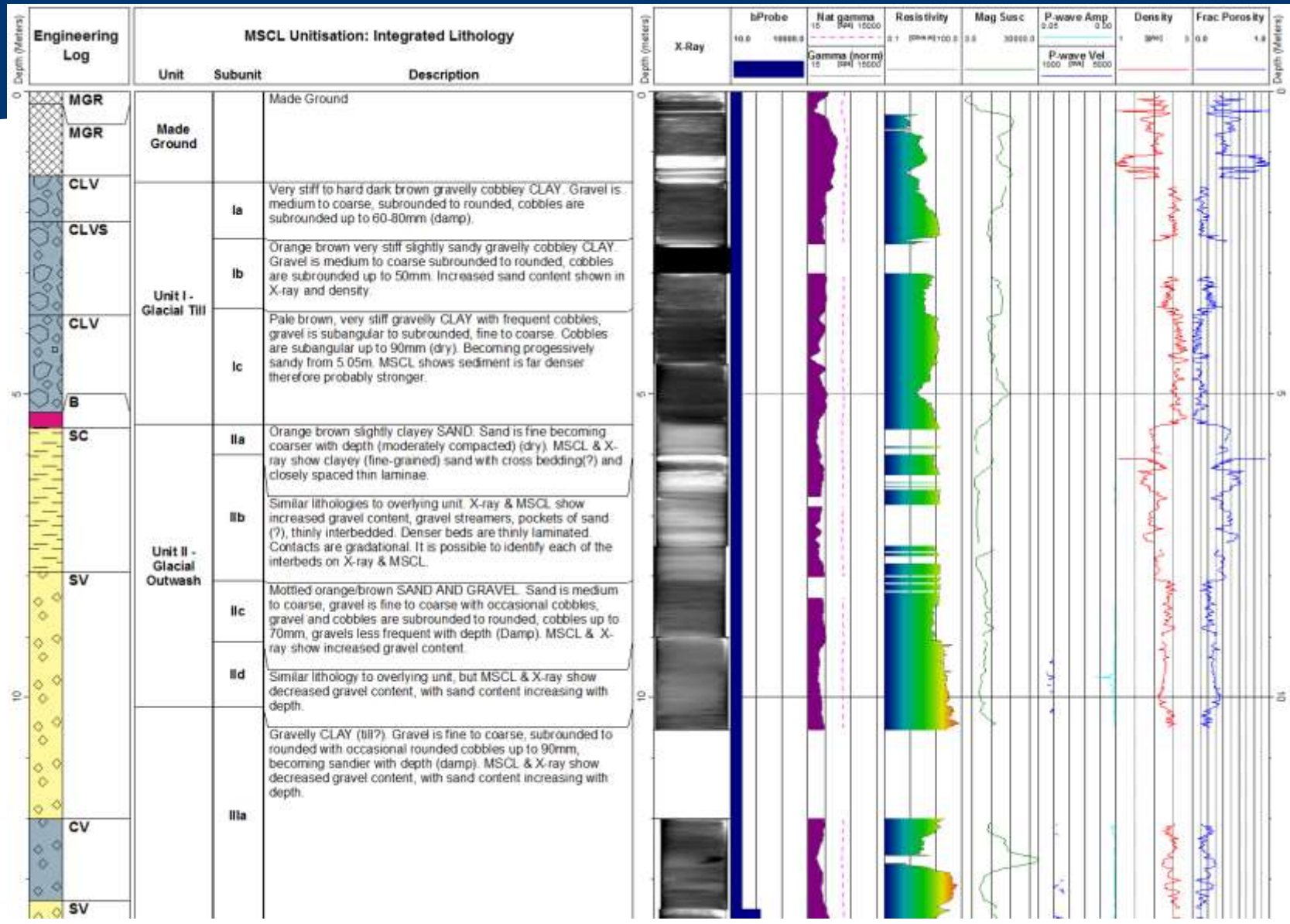


(modified after Merritt & Auton, 2000)

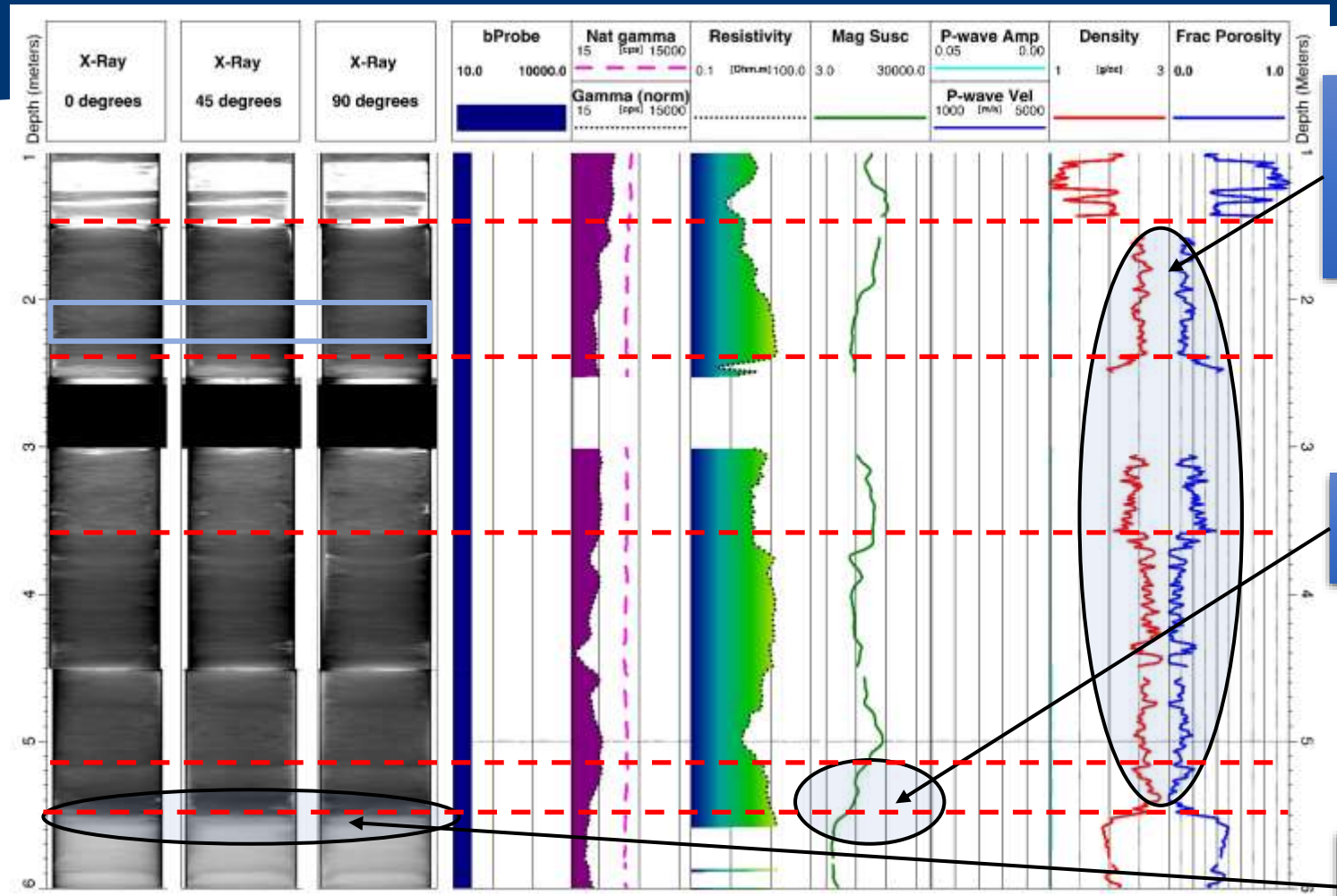


(modified after Smith and Merritt, 2008)

MSCL and X-ray results
ERT BH 7



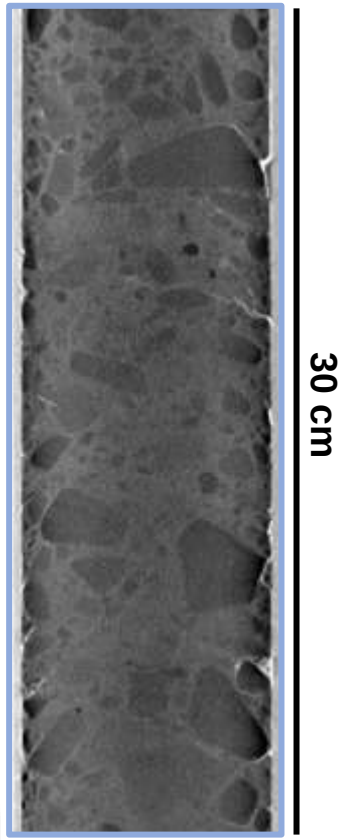
Glacial Till Facies



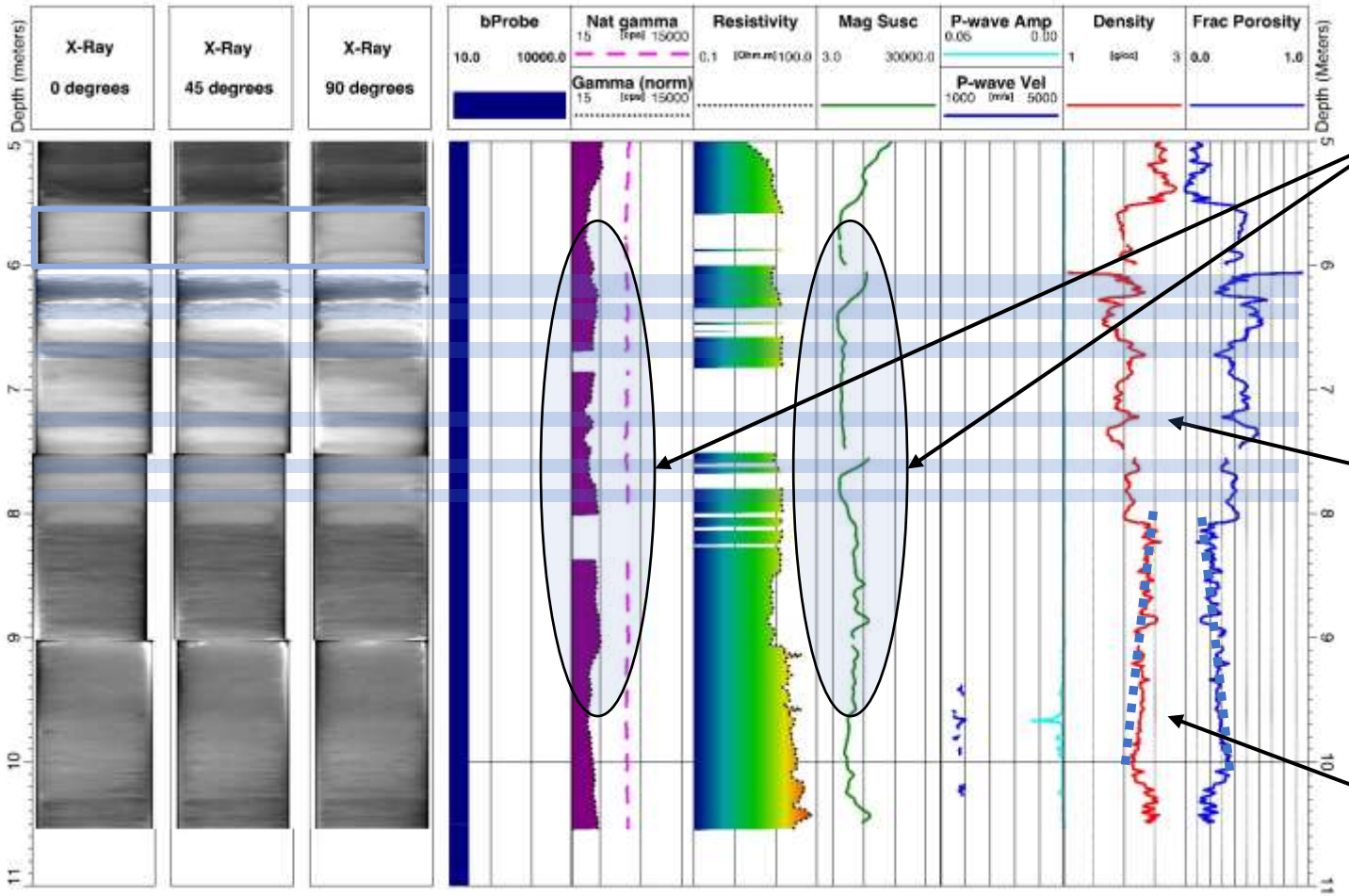
Spikey and non-uniform density signature typical of gravelly sediments

Elevated magnetic susceptibility

Sharp top and bottom contacts



Glacial Outwash Facies

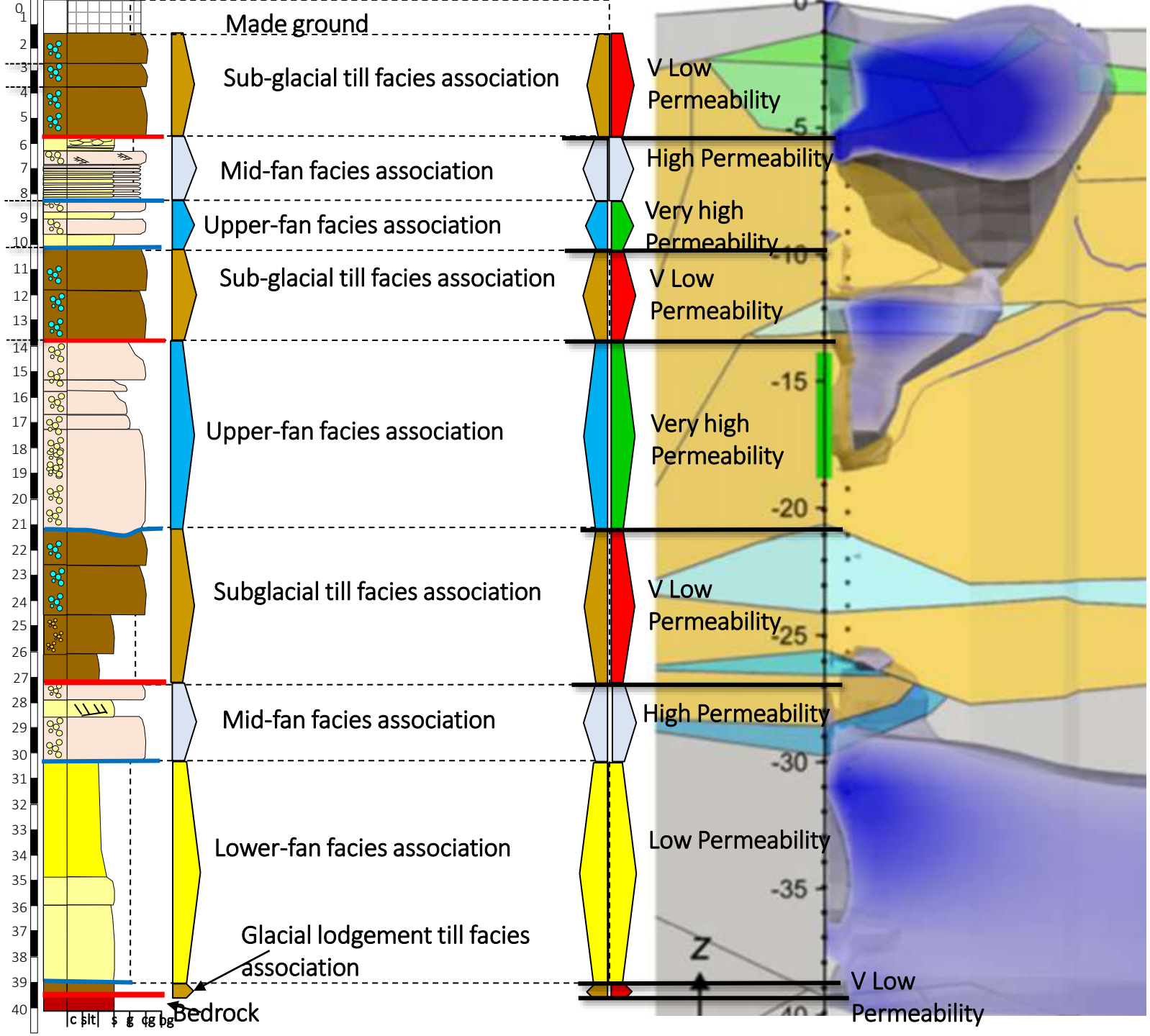


Low natural gamma activity and Mag. Susc.

Variable density profile reflecting thick interlaminated sediments

Decreasing density, and becoming increasingly uniform

Borehole log to hydro-3D model



Cornish Lithium BoxScan and Physical Properties

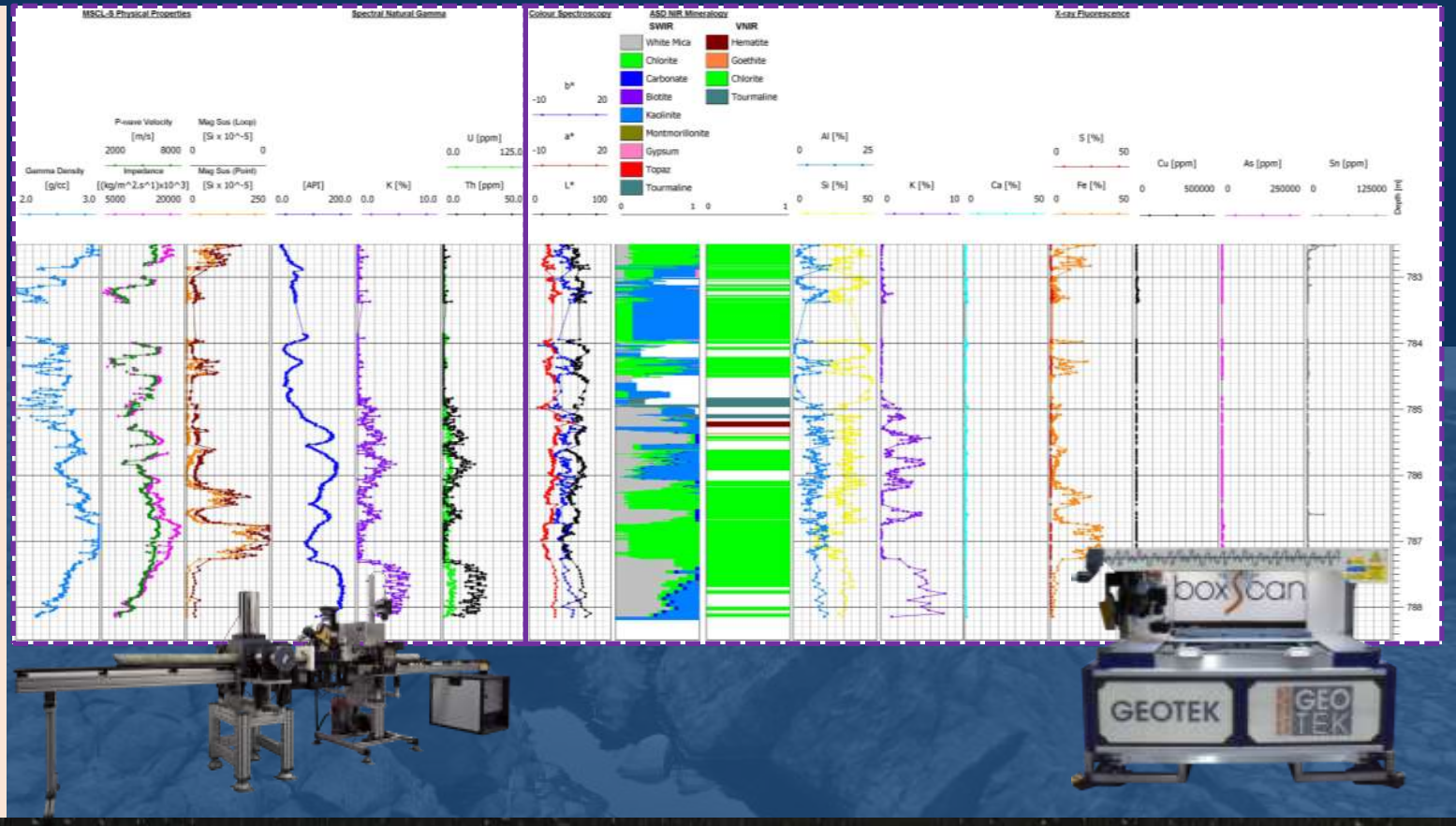
What: 2 boreholes, 76 m of Core samples covering a two base metal-rich and vuggy intervals of core

Aim: Understand how Geotek core scanning technology can be deployed

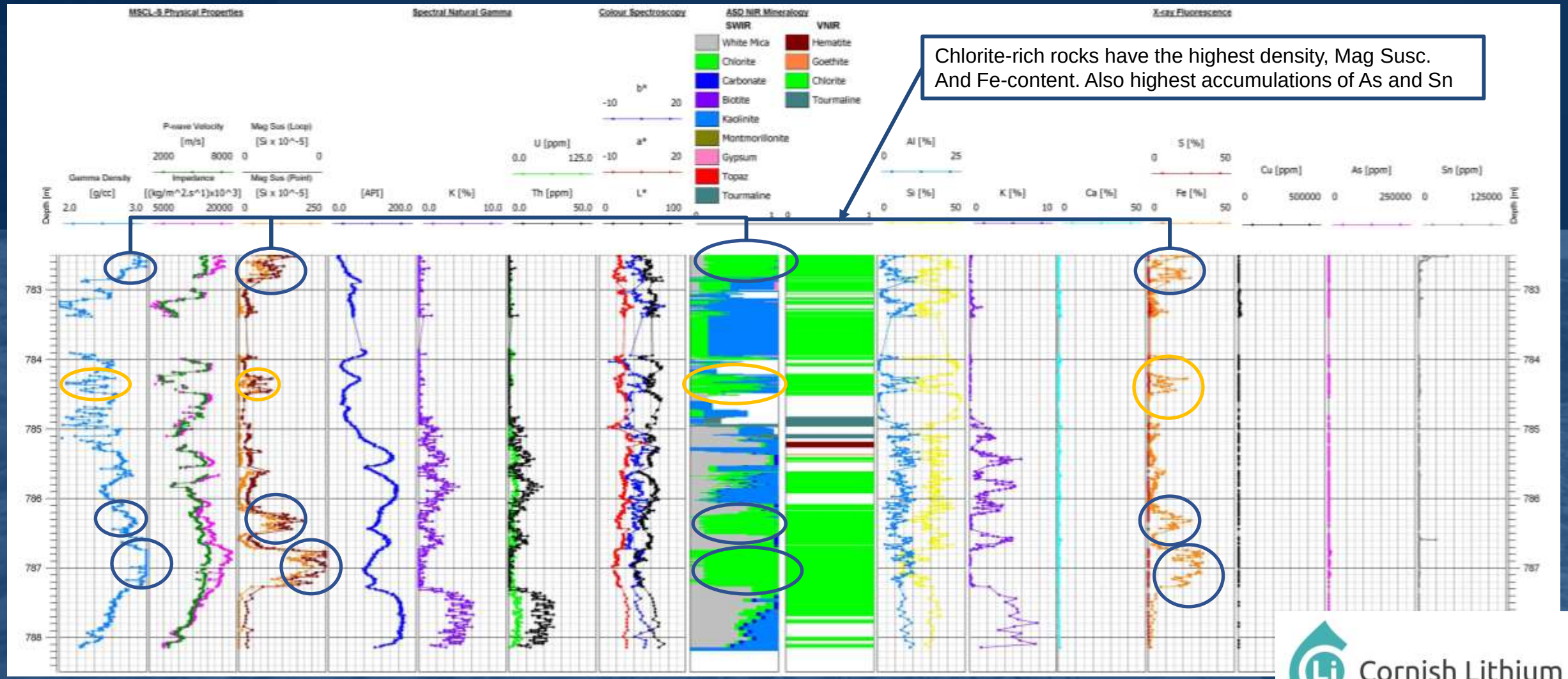
Aim: Can BoxScan provide information on granite alteration and base metal deposits?

Aim: Can we use CT or X-ray imaging to determine if vugs are interconnected to promote lithium-brine permeability

How: Core scanning using multiple sensor technologies and different logging platforms. Therefore, Geotek demonstrated our new BoxScan system and hyperspectral camera technology alongside existing MSCL scanning systems.

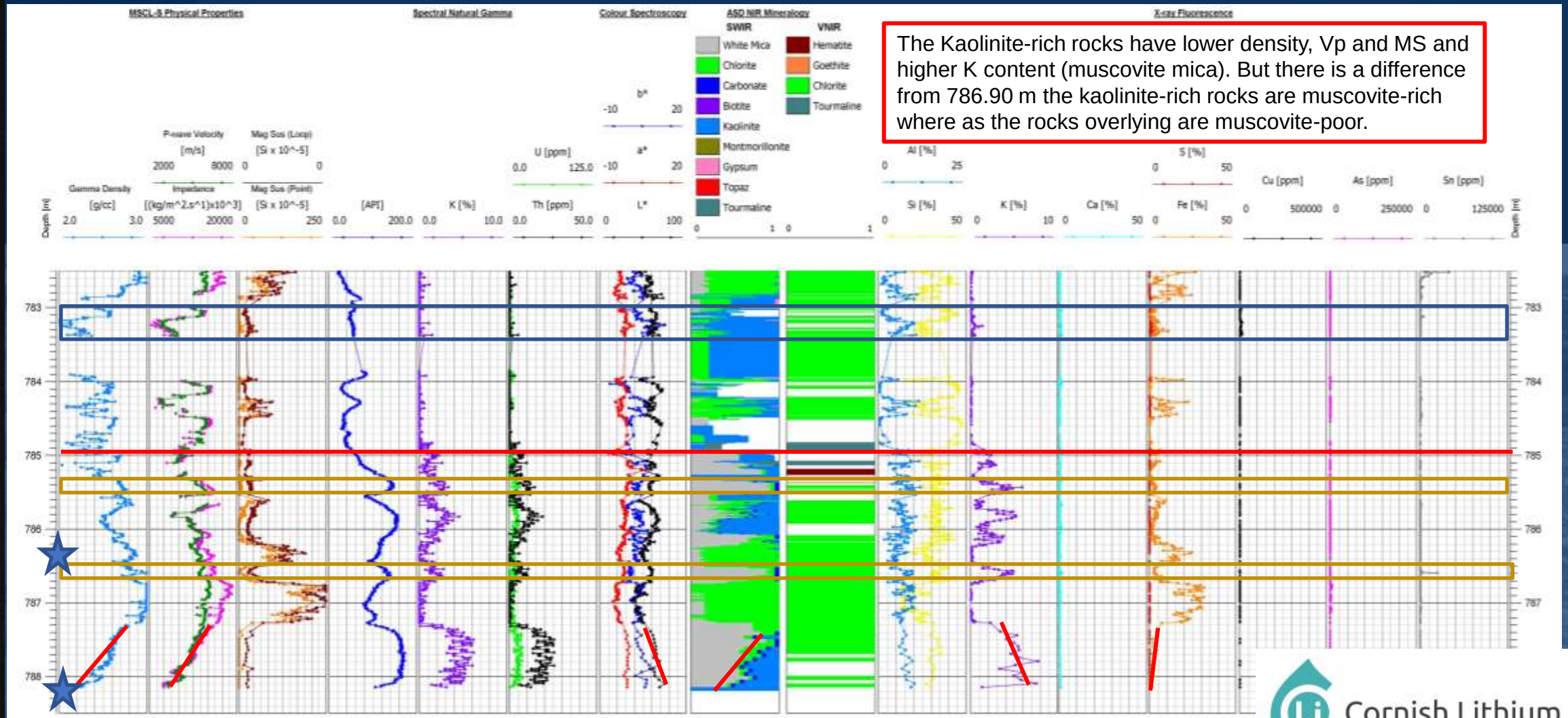


BoxScan and MSCL-S: Depth co-registered data for a combined stratigraphy



Cornish Lithium

BoxScan and MSCL-S: Depth co-registered data for a combined stratigraphy



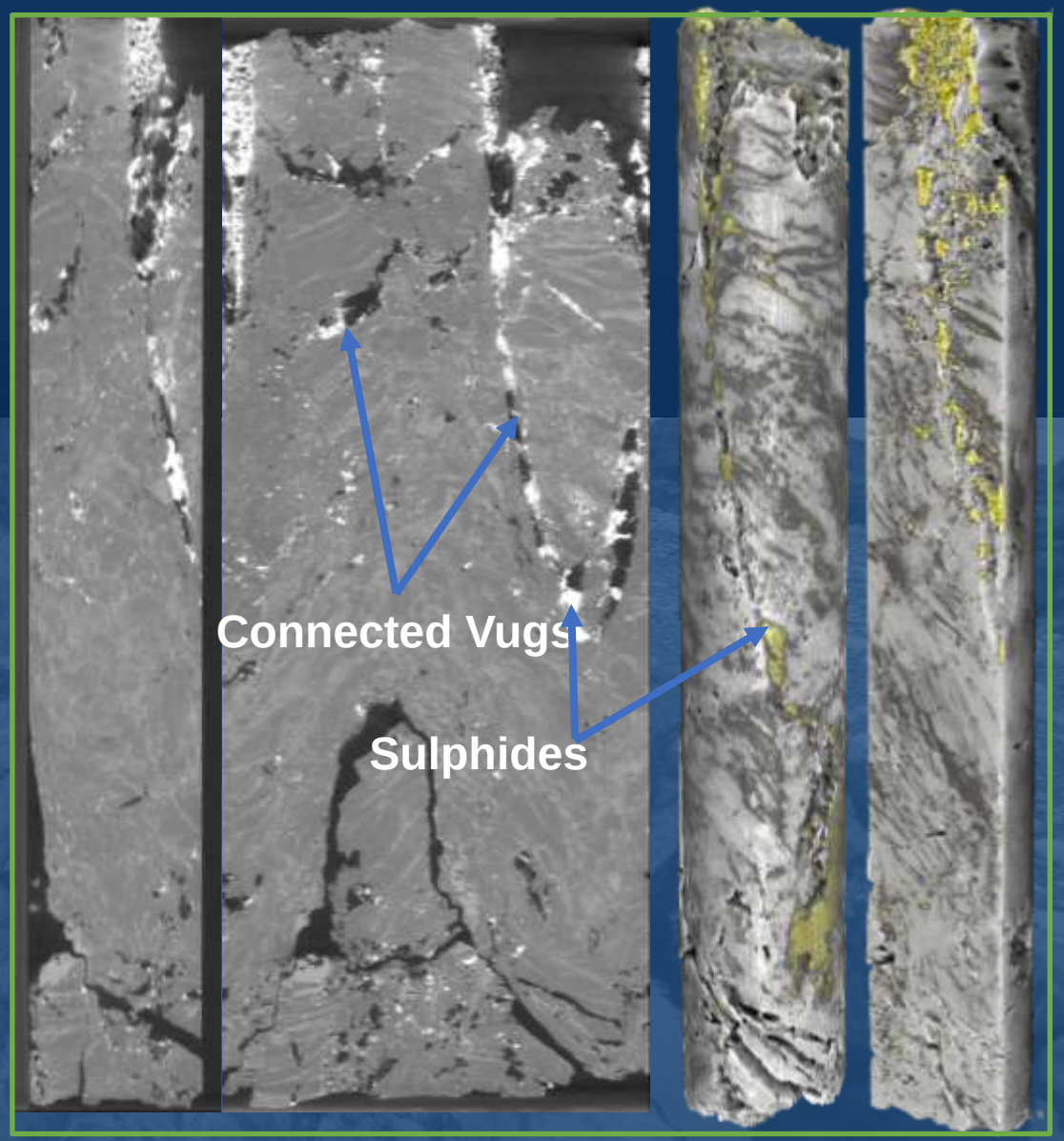
The Kaolinite-rich rocks have lower density, Vp and MS and higher K content (muscovite mica). But there is a difference from 786.90 m the kaolinite-rich rocks are muscovite-rich where as the rocks overlying are muscovite-poor.

Cornish Lithium

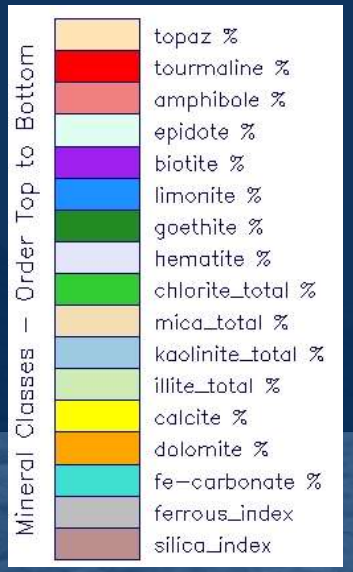
DRY AND WET LINESCAN IMAGES

PHYSICAL PROPERTIES, GEOCHEMISTRY AND MINERALOGY

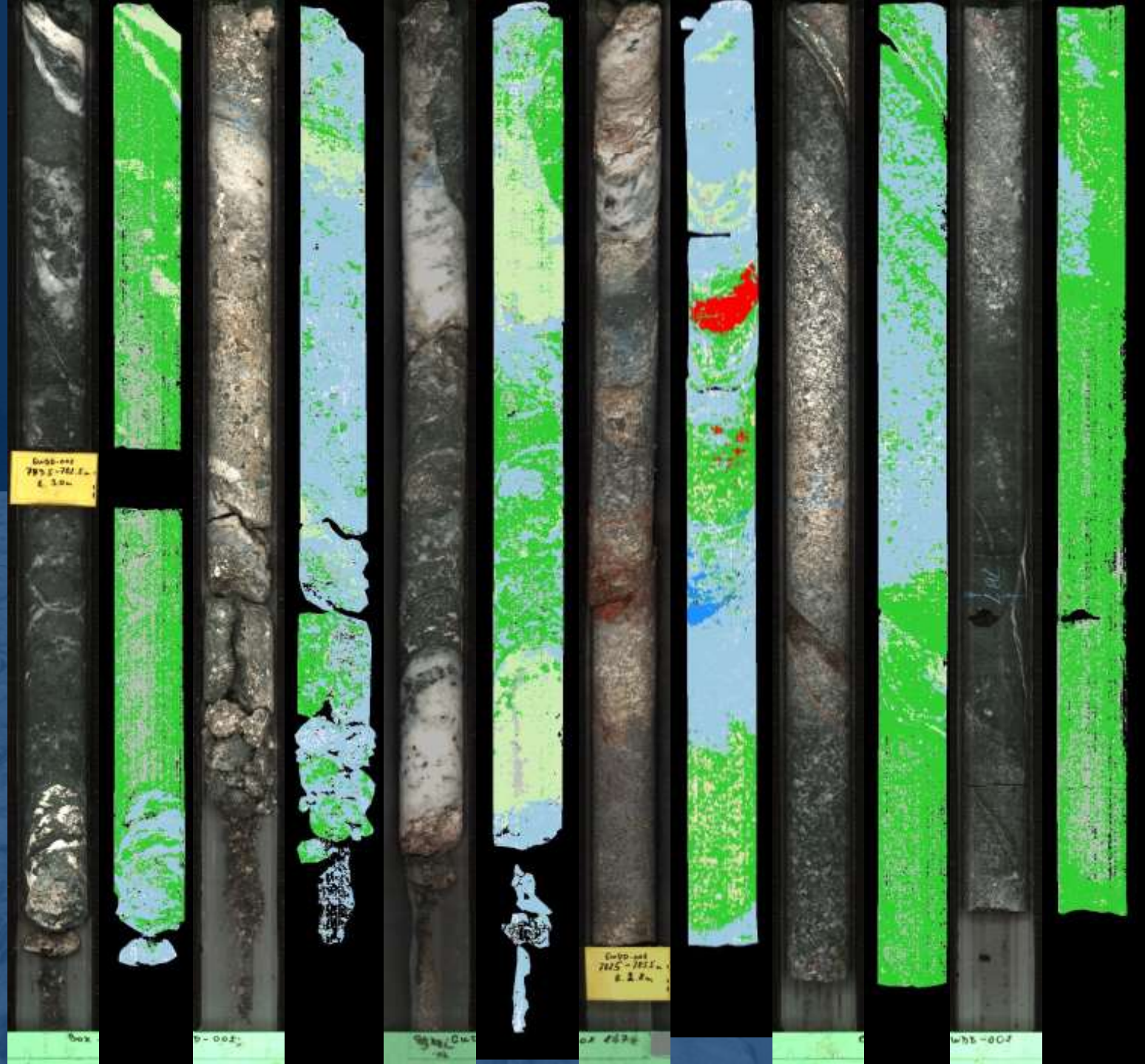
X-RAY CT ORTHOGONAL, CIRCUMFERENTIAL AND RENDERED IMAGES



Hyperspectral Imaging



- Spectral range offered 400 nm to 1000 nm and 1300 to 2500 nm
- Electronically controlled wavelength separation (down to 2nm) for superior spectral resolution
- Continuous coverage high image resolution is (0.5 mm x 0.5 mm)
- Accurate % data derived for the minerals



Hyperspectral – Mapping mineralogy and quantifying