Hyperspectral Imaging, XRF and High-Resolution Scanning: The Key to Quick Accurate Core Analysis*

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Abstract

The oil sand deposits of northeast Alberta, Canada, have been evaluated in the past using up to 32 well cores per section. Each core is slabbed, logged and described by a geologist with depth corrected photographs. Destructive analysis follows to determine the bitumen saturation, clay mineralogy, and grain size distribution present. This entails spot sampling for XRD analysis and thin sections made to determine the presence of clays. Also a few samples are collected for Laser Coulter/sieving to resolve the grain size distribution. To complete all these analyses can take months, be costly, and are not repeatable or statistically relevant.

Recent research has found that hyperspectral imaging merged with X ray fluorescence and high-resolution photography significantly speeds up the process, generates statistically relevant and repeatable datasets at resolutions unattainable previously due to the cost and time needed for processing. The technology uses scanners mounted on tracks which image the slabbed core from millimeters a way, generating half millimeter pixel data across the core in the near infrared part of the spectrum (920 to 2520 nm), and XRF measurements (Na to Fe) at 2.5 cm sampling intervals. A digital camera is also used on the same track assembly to photograph down to a resolution of 5 microns, though the normal resolution is 44 microns – below the cut off for the finest sand grain size. A new core scanning XRF system, using Helium atmospherics, can also resolve clay types including the presence of swelling clays containing sodium atoms. Overall for a 10 meter core, about 11 GB of information is produced so that big data techniques have to be utilised during processing.

Generated output curves include bitumen saturation, porosity, grain size, sorting, mineralogy, and net-to-gross. Furthermore, the bitumen in the core can be electronically removed to reveal hidden sedimentary structures and trace fossils in what would previously be described as ‘massive sandstone’. Also, the exact locations of any secondary tests on the A side core, such as bitumen geochemical analysis and ESEM studies, are recorded. The B side of the core can now be submitted to the Alberta Government in pristine condition. If not required for preservation, the core can be destroyed, saving significant storage costs for the operator. This new technology dataflow can fully analyse a core in under a week and is significantly cheaper than previous lab-based analyses.

Reference Cited

Shchepetkina, A., M. Speta, M. Gingras, and G. Pemberton, 2017, Hyperspectral imaging as an aid for facies analysis in massive-appearing sediments: a case study from the middle McMurray Formation: Bulletin of Canadian Petroleum Geology, v. 65/2, p. 262-278.

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Hyperspectral imaging, XRF and high resolution scanning; the key to quick accurate core analysis

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Summary slide

Summary points

- High resolution and hyperspectral imaging creates data of use to geoscientists and engineers
- Optical resolution cameras can now image sand and silt grains (below 20 micron resolution)
- Solvent and Steam technologies are effected by lithology units on the 10cm scale, which is presently not resolved using standard technologies
- Further integration with XRF data and logs produces a step change in analysing core for mineralogy
- Big data and AI technologies can automate many of the core description methods
- The technologies have significant future potential

Mine face in the winter. The porous units are not meters thick. Image 2m high

Outline of talk

1: Discuss the standard work flow for analysing core

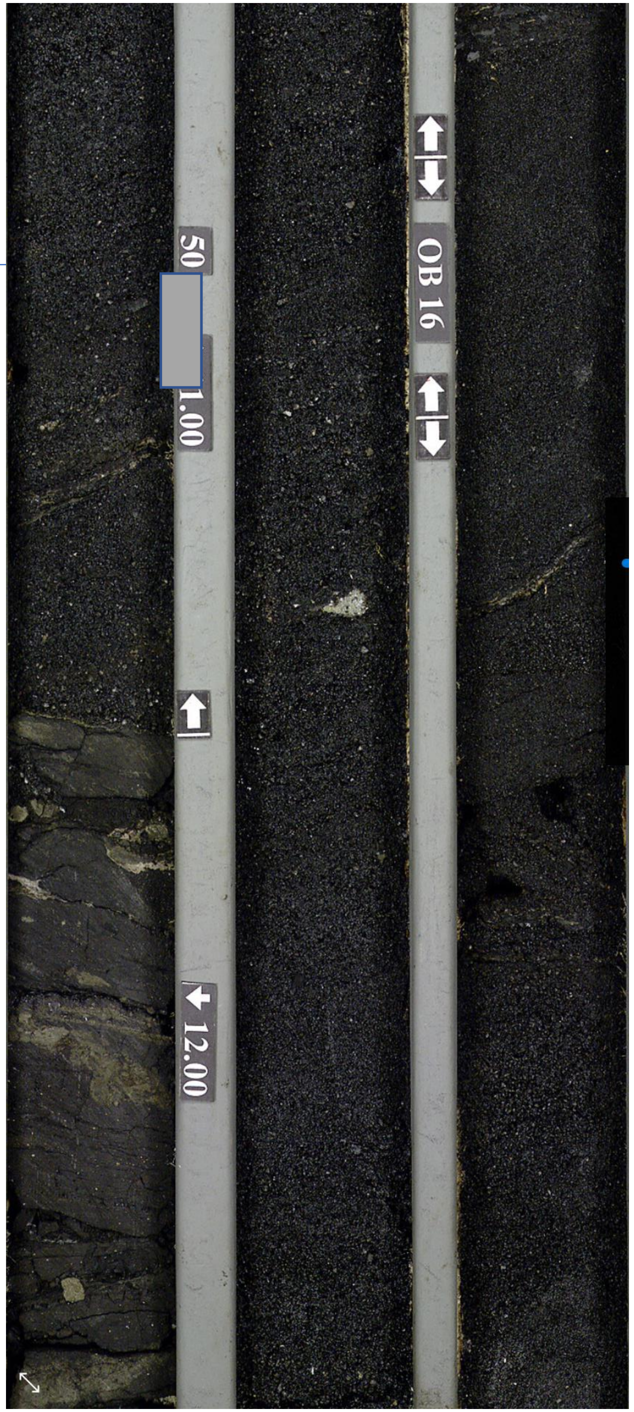
2: New technologies and the technology behind it
- High resolution imaging
- Hyper spectral imaging
- XRF sampling

3: What results can the data fusion provide?

4: New work flow for core analysis

5: Key application outside of oilsands

Standard core photographs 3Meg per image



1: Standard Oil Sands core evaluation workflow

Core the well in January

Ship to Calgary lab

Slab core

Dry and photograph B side

Depth correct core and photographs

V notch A side

'Dean stark' bitumen analysis

Reports to client

Company geologist interprets data and integrates with petrophysics and seismic

Total time: for the outlined program circa April

Standard Oil Sands evaluation workflow pt 2

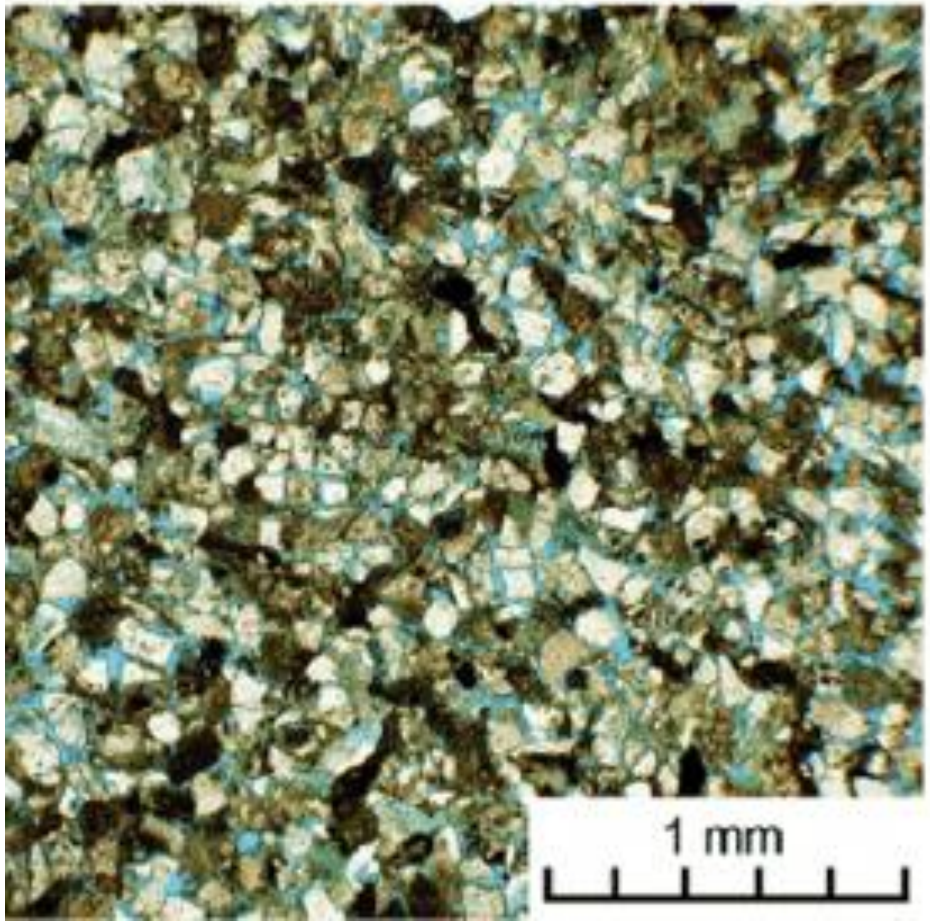
Company geologist interprets data → Core stored/given to AER/disposed of

Core logged

Sampled for:
- Thin sections
- XRD
- Cap rock geomechanics
- Particle Size Distribution

Well reinterpreted

Total time: circa summer



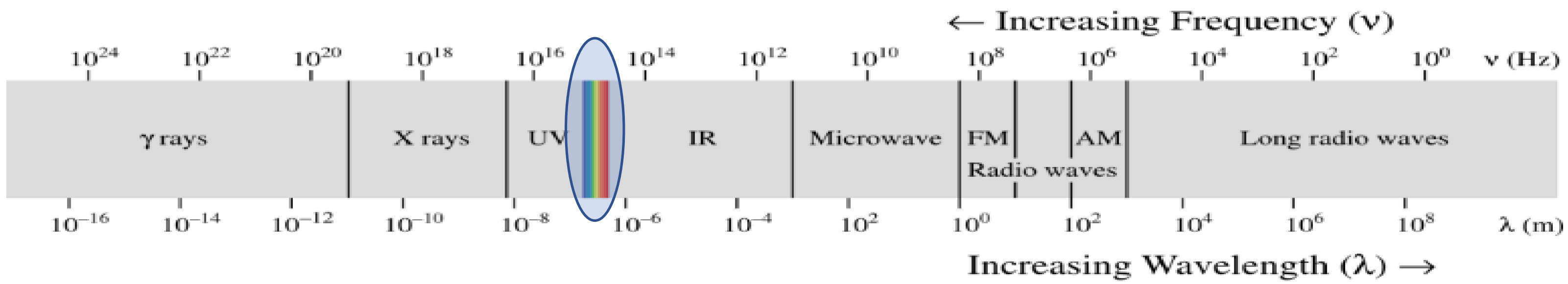
Gate 1 for next years drilling program is during the Spring

New Technologies- High resolution digital imaging

Past technology:
Old wet film cameras, manually operated and getting everything in focus was tough. The location of the zoomed in photograph had to be recorded by hand.

Improvements in:
Lenses: high quality lenses are now significantly cheaper
Scanning technology: use a 50 meg camera with charged couple device technology
Automation: the camera is auto focus and will take a stack of photographs over the same spot to produce a sharp image using computation. The location of the image is automatically recorded so that images can be stitched together seamlessly.

Results:
Standard images of core: now resolve grains down to 25 microns (less than sand/silt boundary.
Enhanced images of core: the limit is below the 2 micron level, though this takes time and is more difficult to produce.

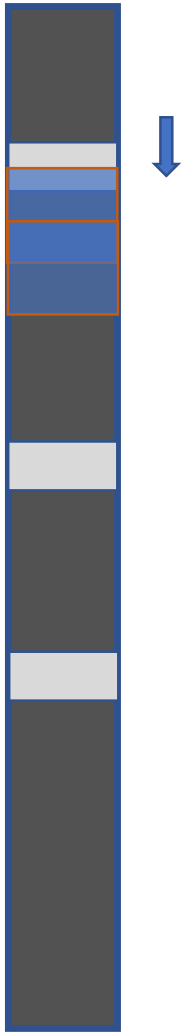


High resolution core imaging

Core cartoon with bitumen saturated sand in black and mud laminae in grey

8,688 by 5,792 pixels
Aspect ratio 3x2

9cm across

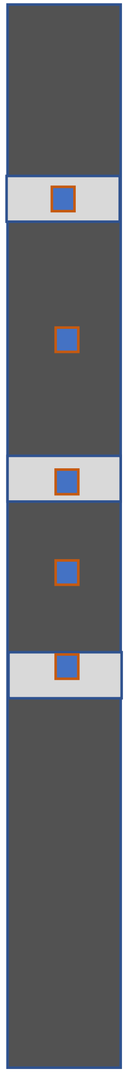


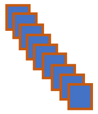
Each image moves down 3 cm

For a 0.75 meter core about 25 images are collected
Each image is 50 megapixels
Image captures all the visible features of the core including apparent dips, structures, trace fossils and visual bitumen saturation

Uses a high powered lens to image core.
Can image grains to below 2 microns in size
Each stack image 50 megabytes, so data compression is needed to create one final image

9 cm across



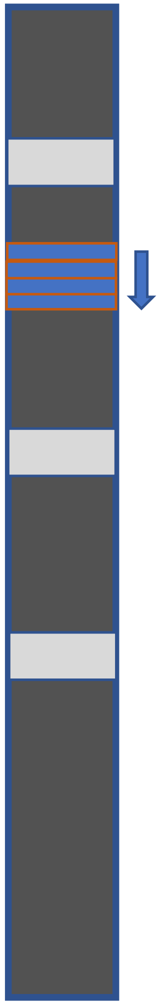


Each stack image is repeated 10's of times at different depths of focus to produce one image in focus

Image used to spot sample areas of interest

Hyperspectral imaging data collection from core

9 cm across



0.5 mm line scan

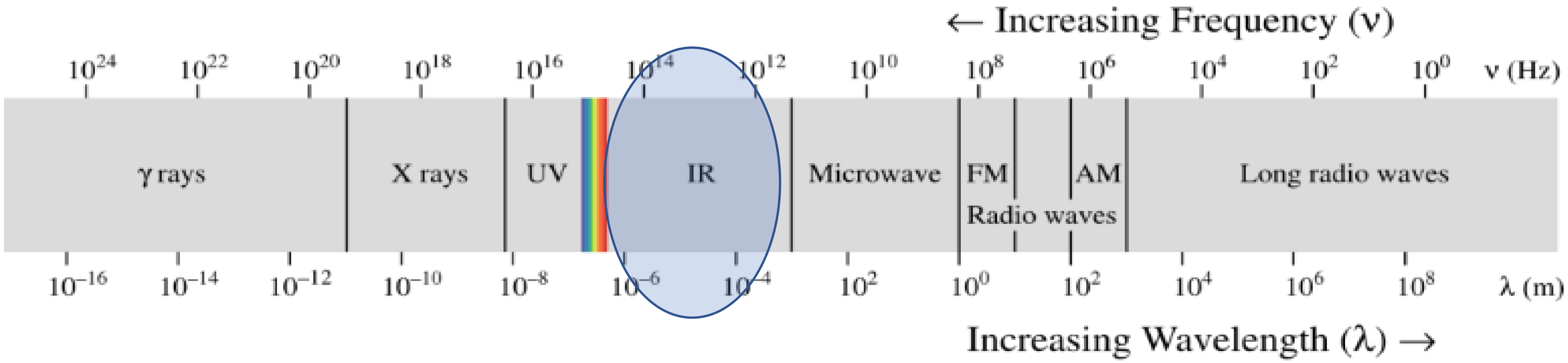
320 pixels per scan

Each image located 0.5mm down the core

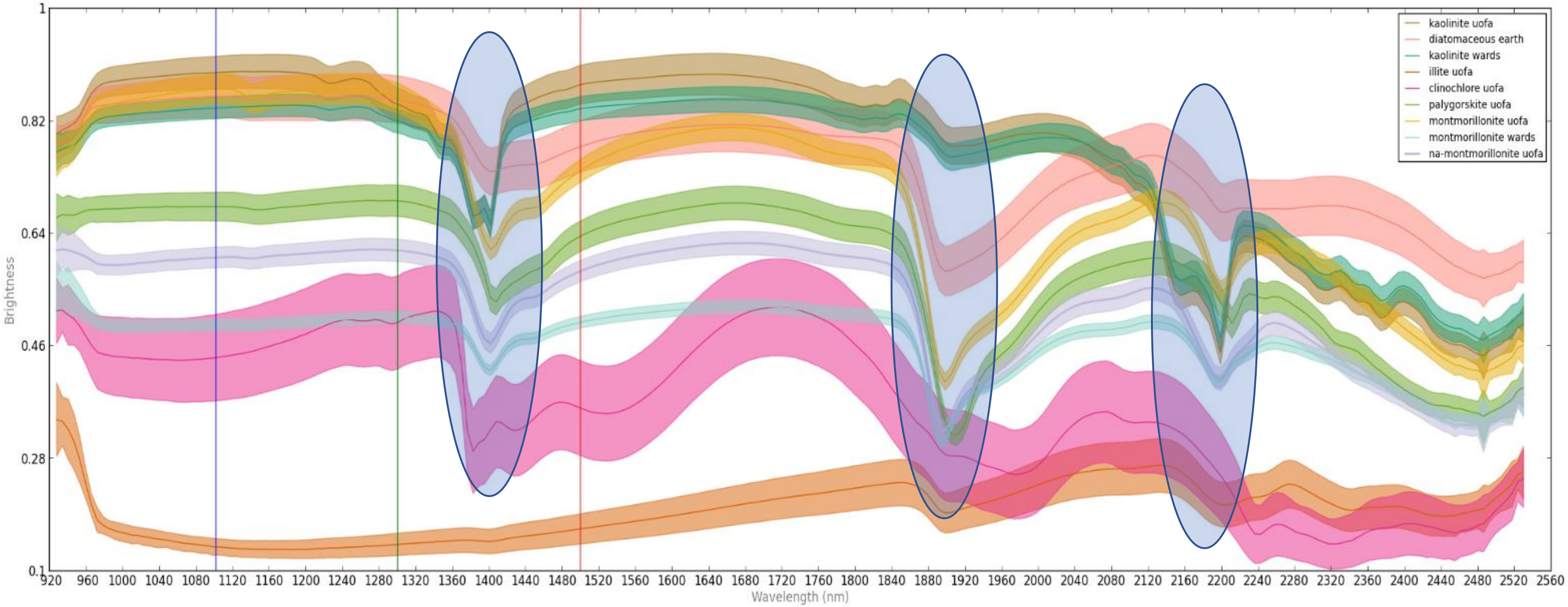
Each scan collects pixels at <10 nanometer intervals.
From 900-2500 nm

NIR: near infra red: 750-1400nm
SWIR: short wave infra red: 1400-3000nm

The line scan sample determines the minerals present and their relative abundances



Spectral signatures of clays in the infra red



- Water and clay absorption increases significantly at 1400, 1900, 2200 nanometres
  This is highlighted in the blue ellipses

- Bitumen absorption occurs at 1710, 1754, 2268, 2342 nanometers

New Technologies – Hyperspectral imaging

Old technologies:

- multispectral imaging had narrow wavelength bands over say 10 intervals, often from visible to longwave infra red. Landsat uses this format
- The cameras were not solid state and often needed cooling

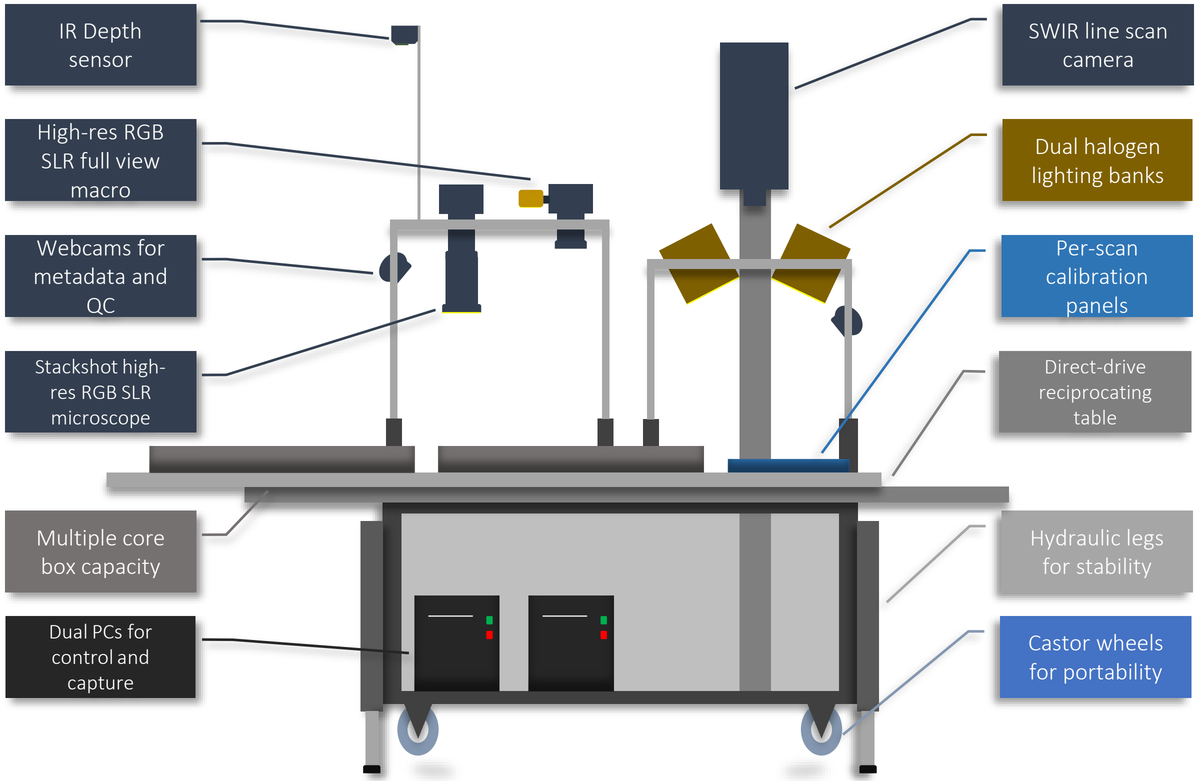
Improvements in scanners, wavelengths, data:

- Hyperspectral imaging can have 250 plus bands over a continuous interval. We use a range from 920-2510 nm with bands less than every 10 nm
- Solid state cameras and charged coupled devises collect data at sub micron pixel size
- Computer big data algorithms and faster cheaper hardware make manipulation of the data much easier

Results:

- Scans can be routinely made, analysed and results presented quickly and cheaply
- Technology is non destructive and repeatable

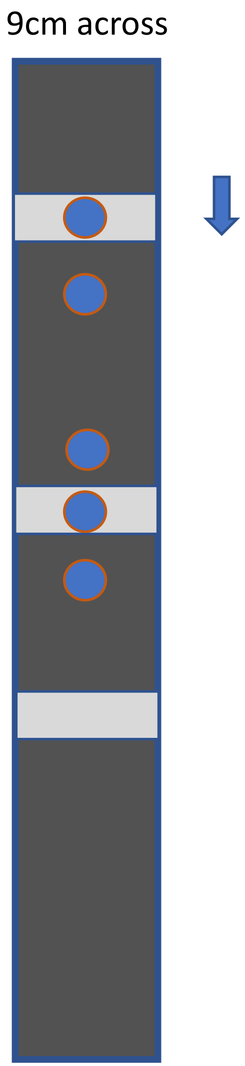
Mobile scanning table for imaging



- A portable hyperspectral/multi-sensor scanner designed to meet the unique needs of commercial core scanning.
- Scanner can process a core box in less than one minute at 0.5 mm per pixel resolution.

XRF data collection from core

2cm diameter area of investigation



Each image located to investigate different lithologies

Sample selection can be automatically chosen or by a geologist using photographs

The spot sample determines the elements present and their relative abundances

New Technologies – X Ray Fluorescence

Old technologies:

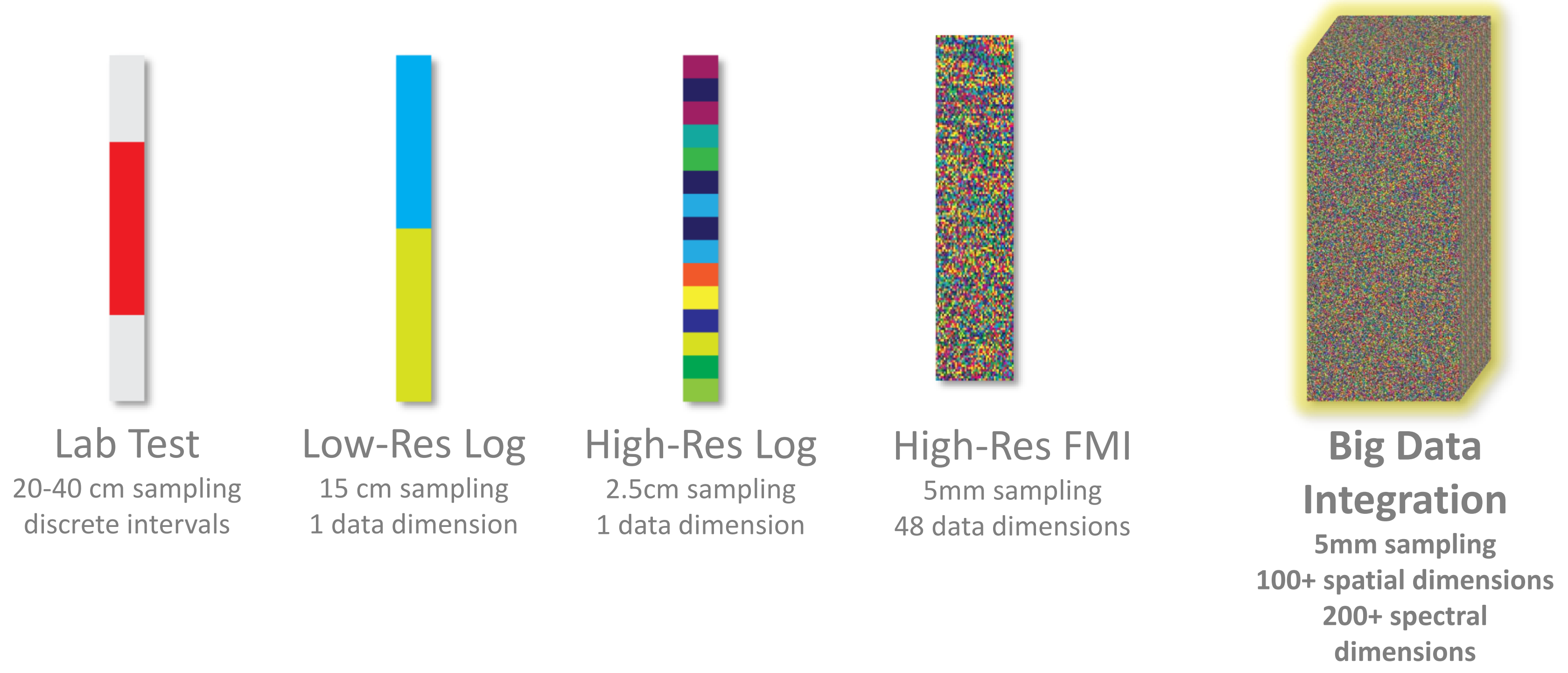
- Hand Held guns placed on the core
- Guns cannot detect Sodium atoms, as too light, so swelling clays cannot be resolved
- Takes time to get the data --- 90 seconds per shot, or hours for a 25 meter core

Improvements in scanners, wavelengths, data:

- Immerse the head in helium (flow detector) and can then resolve swelling clays with Sodium – smectites and montmorillonites
- Improvements in XRF detector heads speed acquisition times to less than 10 seconds
- Automate the data collection and use multiple heads to collect the data speeding up scanning as well

Picture of the new scanner

High-Res Multidimensional Big Data to Solve Big Problems ---- A.I. next

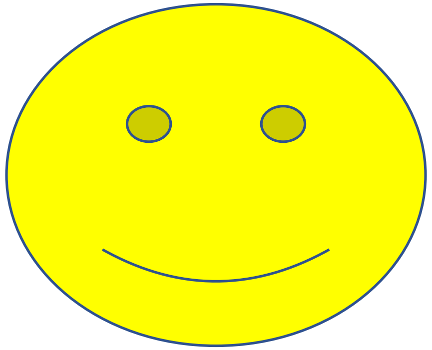


- High-resolution multidimensional spectral data cubes are the key to applying Big Data methodologies to solving the resource industry's increasingly technically challenging problems.

3: So what can you get with data fusion???

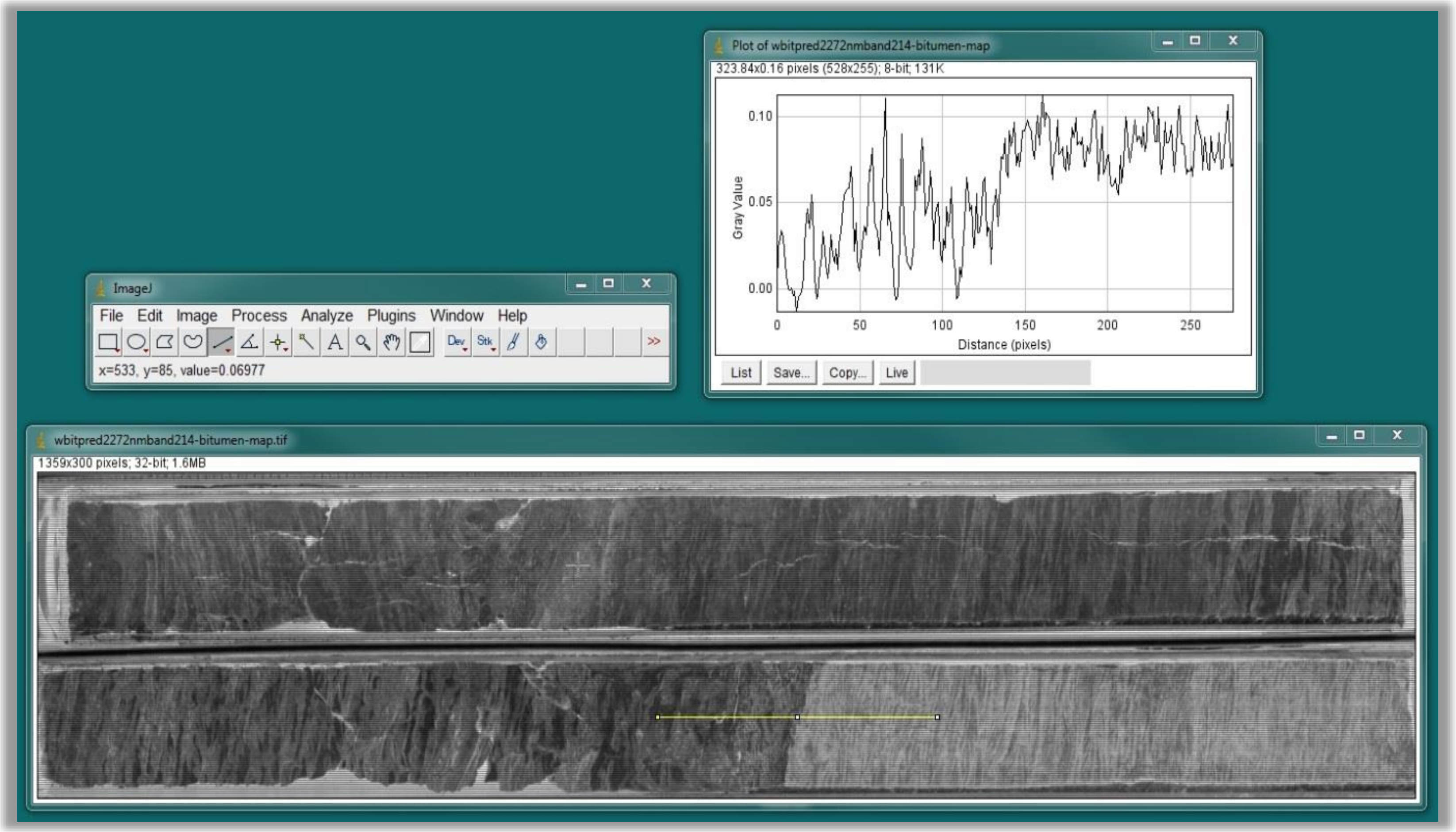
- High resolution datasets
- Quick, cheap and repeatable data
- Non destructive testing
- Happy manager who can save costs (is there a raise in your future?)
- Data before locking down the next year's drilling program

Happy geologist



Weight Percent Bitumen Mapping (and TOC)

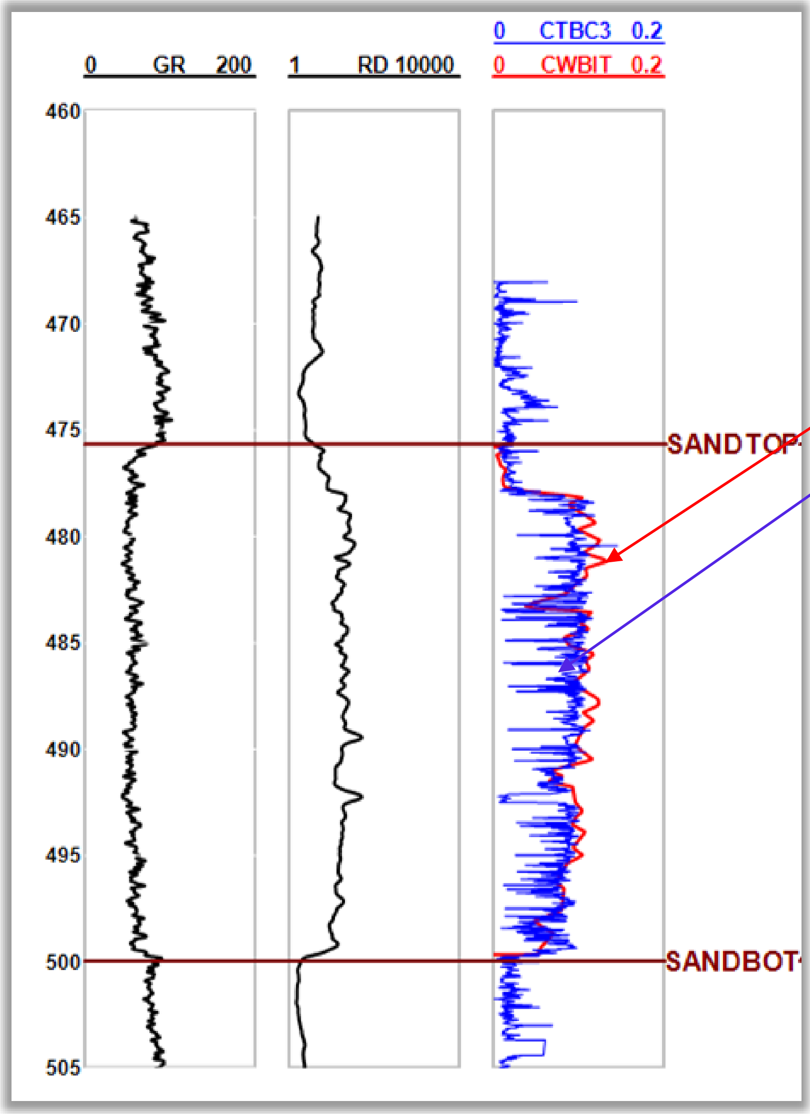
Calculated per-pixel (0.25mm^2 or less) weight percent bitumen mosaic with available interrogation and analysis tool. Hyper spectral imaging is the best for this data collection though XRF can be used at a lower resolution



Mosaic of non-bitumen distribution over a pay interval

Horizontal mud laminae in black, sand packages have variations in clay content illustrated here with the grey scale.
The black spots are mud clasts

Bitumen saturation – Dean Stark vs Hyperspectral imaging



Weight Percent Bitumen Model

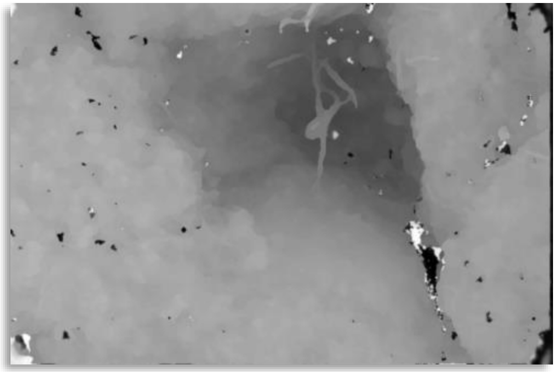
Low-Res Dean Stark Samples

High-Res Spectralog Model

Dean Stark data is subject to sample bias, is destructive, non repeatable, low density data, lab generated and not statistically structured

SWIR data is non destructive, repeatable, cheap, statistically relevant, high density data and quick to generate

Super-zoom Red Green Blue photo



- Integrated macro multi-shot focus stacking rail and super zoom macro lens enable
  micron-per-pixel imagery suitable for particle size analysis

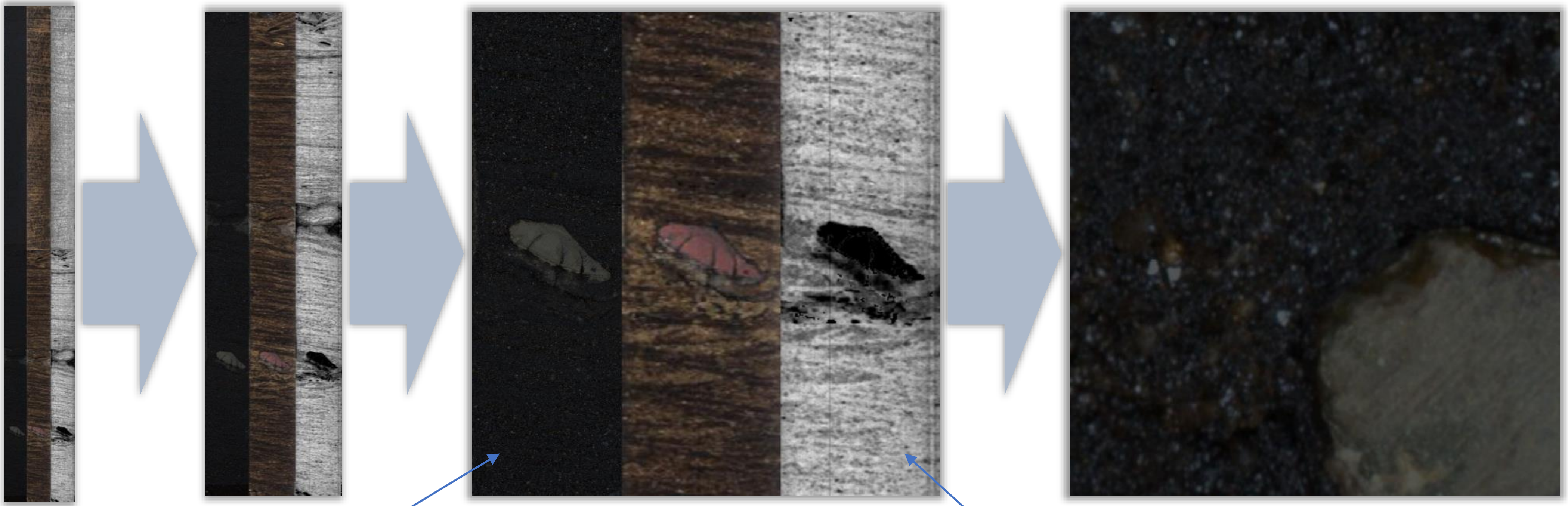
- Texture maps and 3D models can be constructed based on sharpness analysis of the vertical image stack

- Substitute for thin section work

Ability to zoom in quickly

- Composite of all image products aligned and stitched with full RGB zoom capability
- Can access these images at your desktop and in the field using the cloud

Sand grains circa 250 microns



Core photo with pyrite clast

Clays within the bitumen saturated sands

Structures within bitumen saturated sands

Clay discrimination and distribution
Using hyperspectral imaging

- Hyperspectral imaging shows the presence of mineral alteration
- Green is chlorite, orange is kaolinite, gray is illite and black is background unaltered rock
- Able to reconstruct the diagenesis of this whole core without cutting thin sections and XRD

This technology has applications not just in the oilsands but also in conventional E&P, hydrogeology, Quaternary stratigraphy and mining

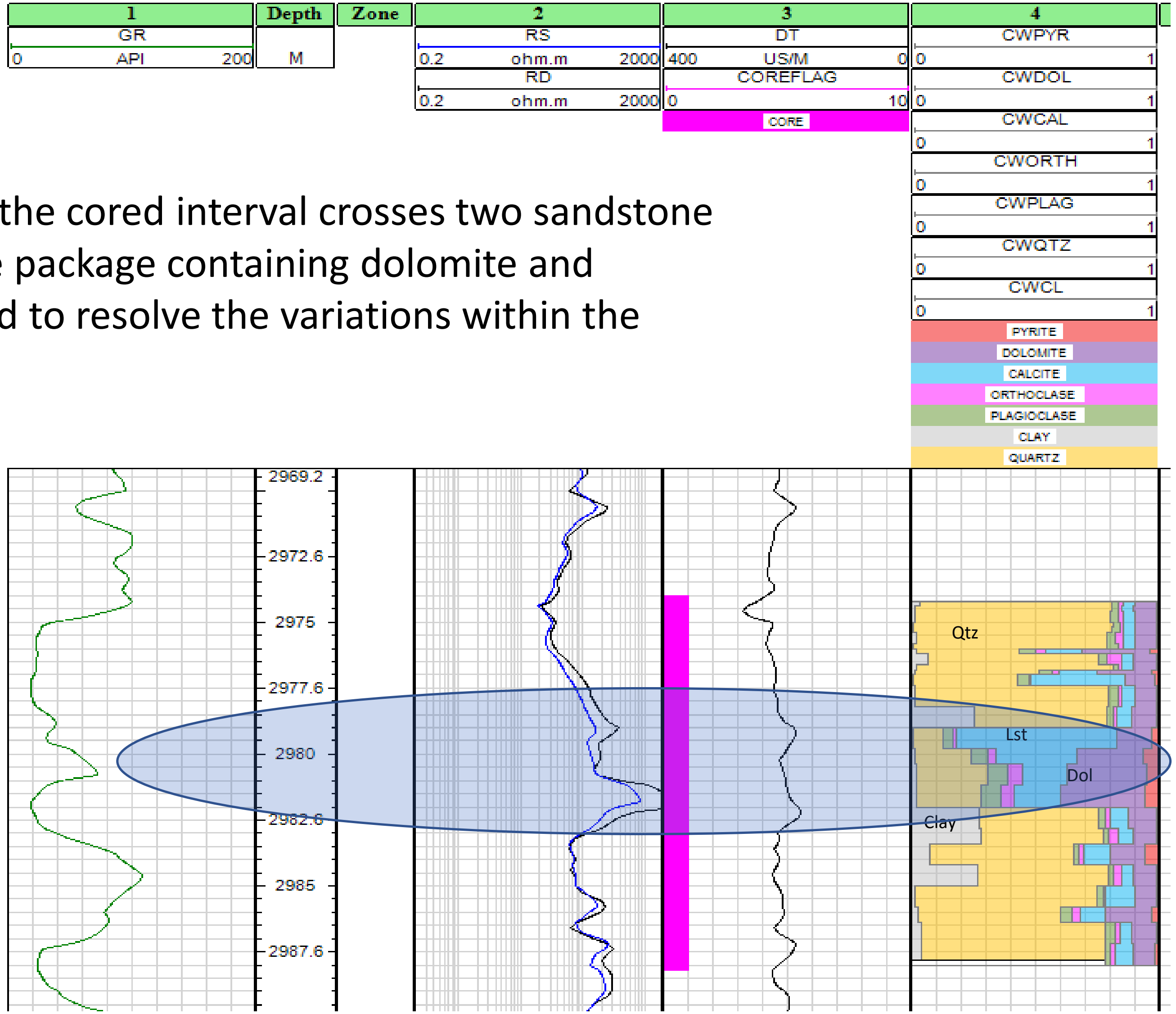
Illite

Kaolinite

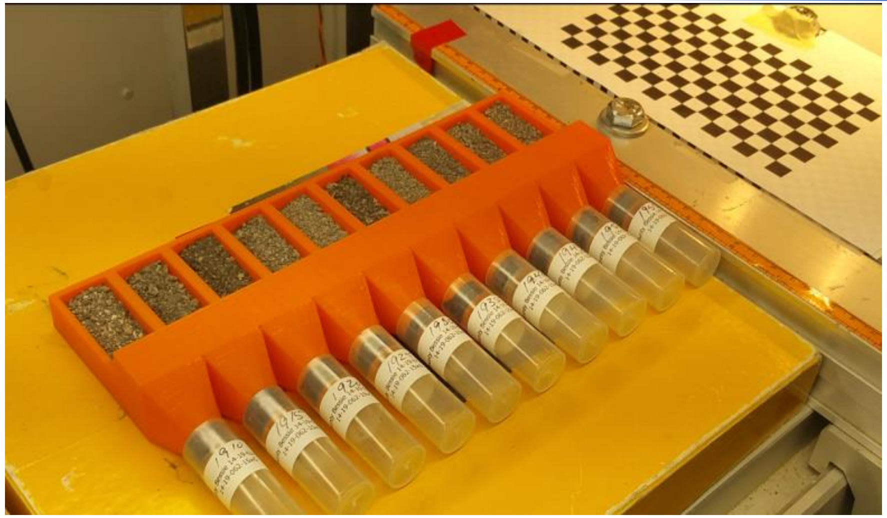
Chlorite

Limestone, Dolomite and Anhydrite distribution in core using XRF

A log and XRF data image showing that the cored interval crosses two sandstone packages with an intervening carbonate package containing dolomite and limestone. Thin sections are not needed to resolve the variations within the packages.

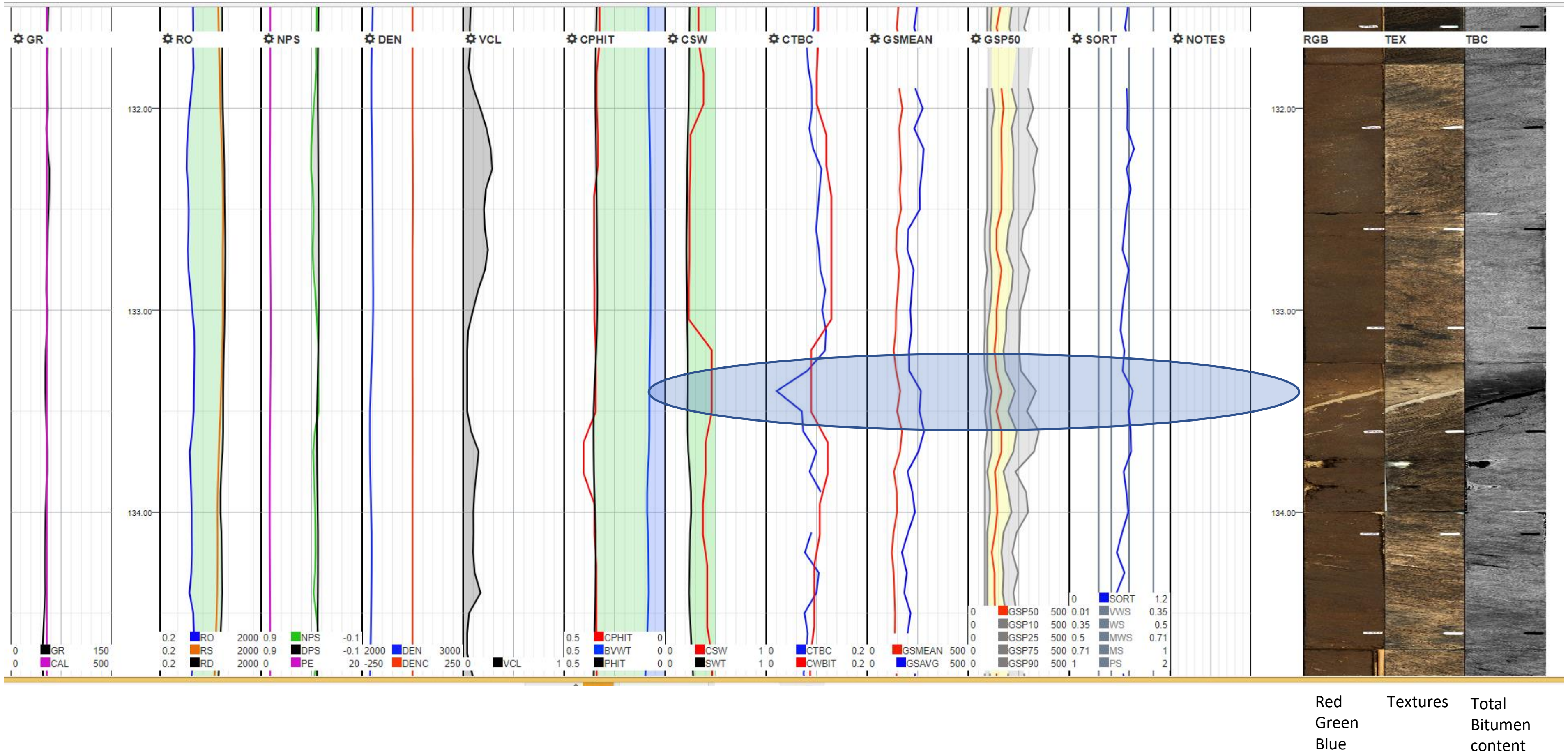


Scanning Chips: Hyperspectral and XRF



- Chips are an underutilised data source, rarely studied by oilsands geologists
- Often collected above the cored bitumen pay interval
- Great way to distinguish the Quaternary sedimentology
- Scanning can determine clay content and alterations with depth
- Chips stored by government can be scanned as the technology is non destructive
- Scan chips whilst drilling (especially horizontal wells) to determine if the well is on depth and following prognosis in almost real time
- What else could we do --- ideas?
- Outside of oilsands, scanning chips has great potential to resolve clays, mineralogy, TOC, grain size etc. within a well

Fused data presentation



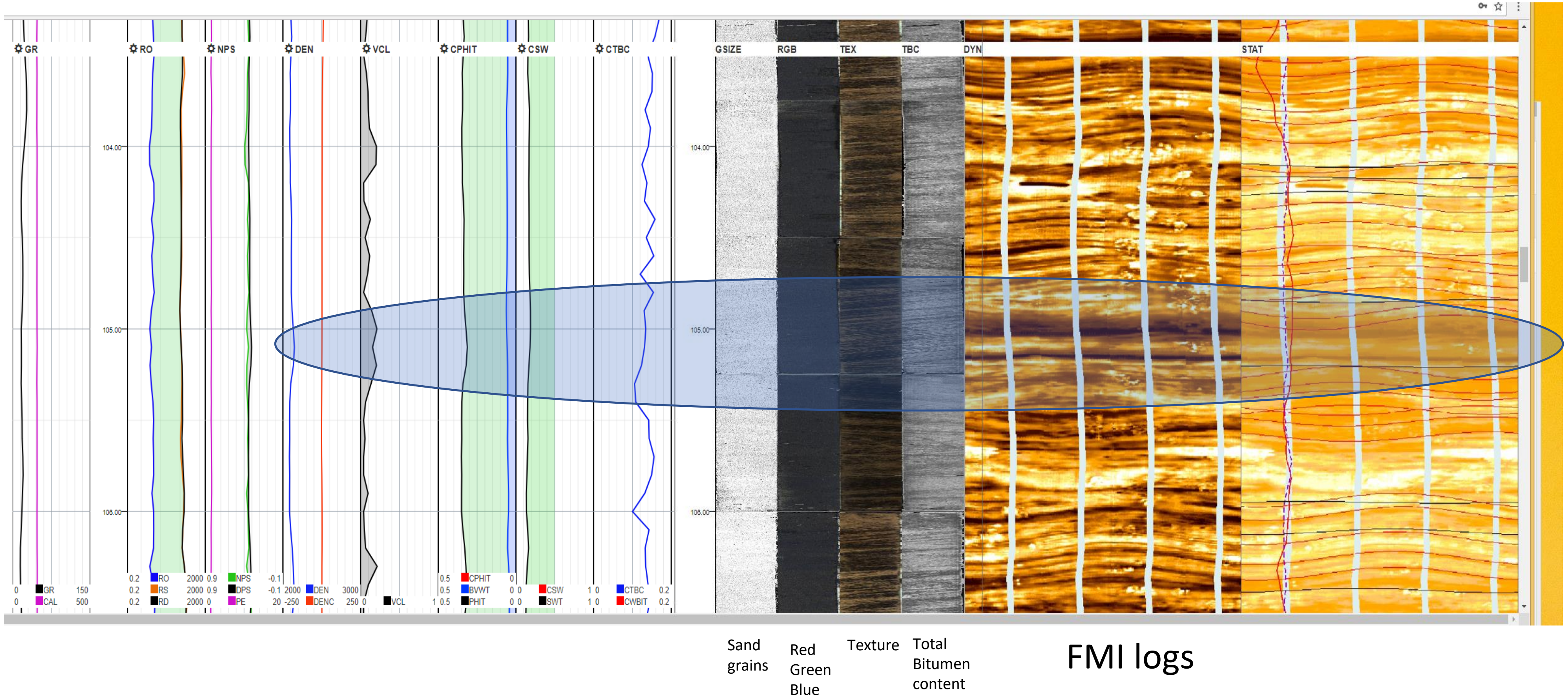
Geophysical logs plotted in 1 meter intervals with the associated grain size curves and core imaging

Logs do not resolve mud laminae or gain size package boundary

The highest bitumen content is light grey

Blue is Enersoft data

Fused data presentation



Correlation of the petrophysical logs with core images and FMI logs.
Dark FMI is clay, CTBC is total bitumen content
No grain size or bit. sat. change in sand package

PSD from imagery: plotted many ways

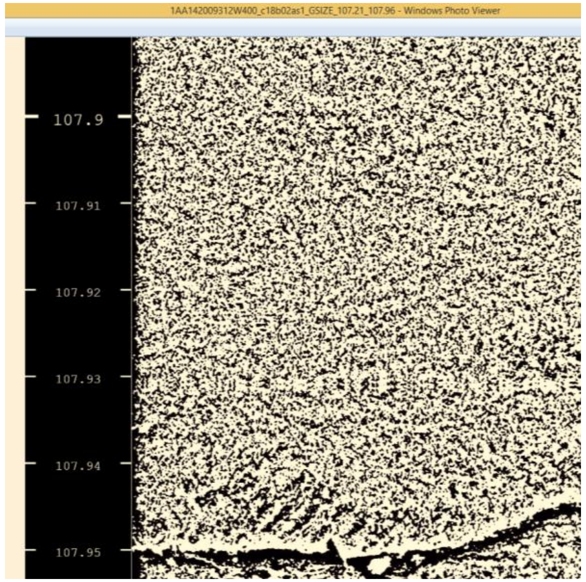
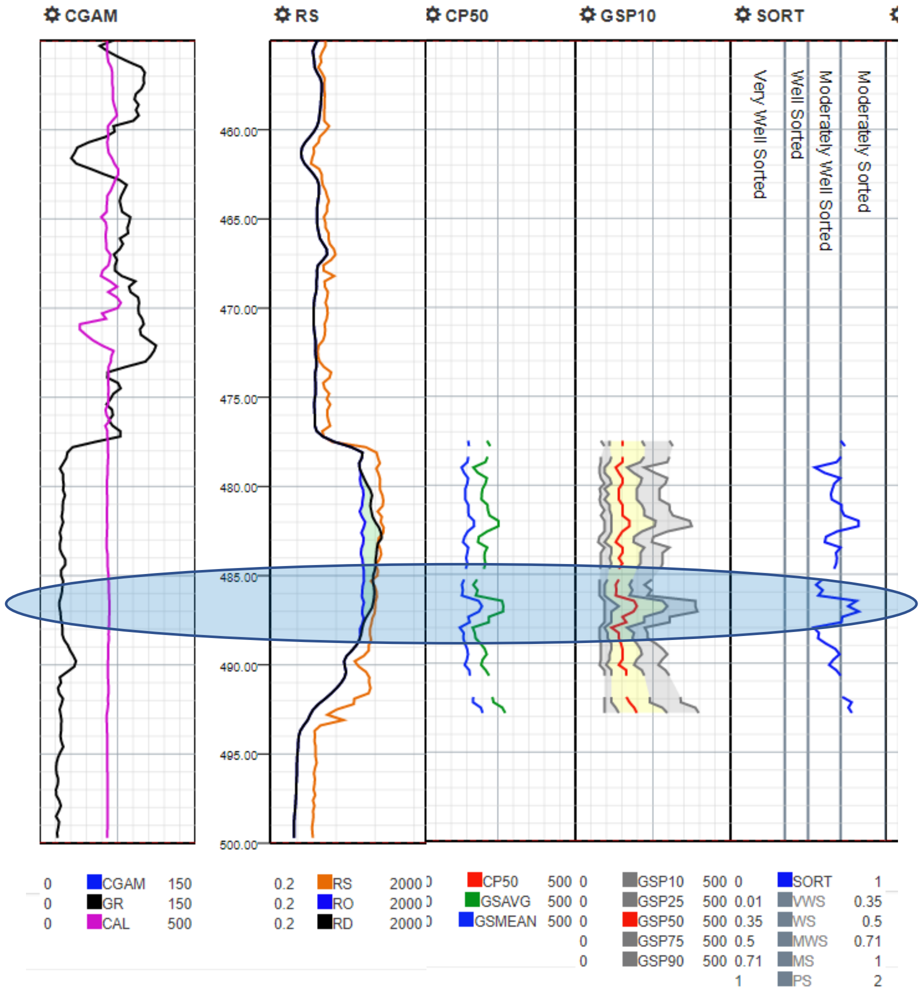
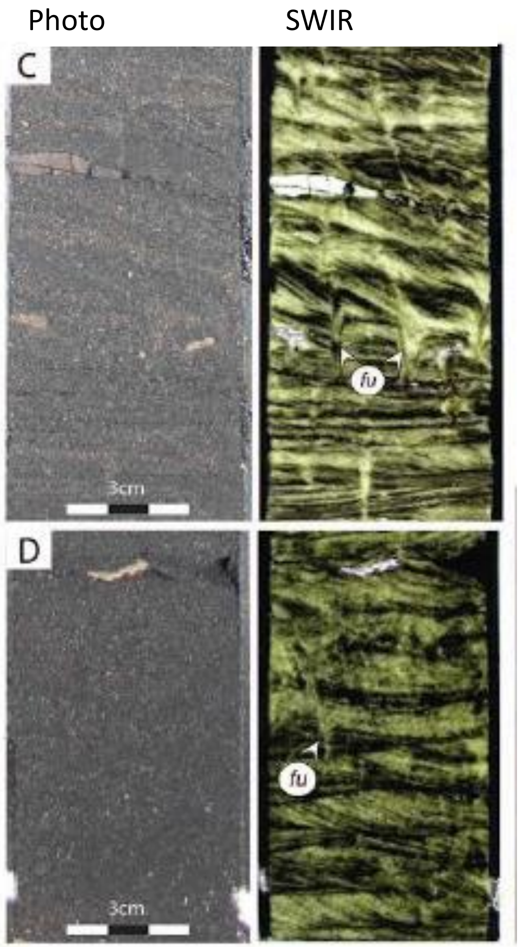


Image of sand grains and porosity.
Resolution is 20 microns



Are there packages of sands within the pay zone based on grain size?
Is the oil/water contact related to grain size variation, not charge?

Trace fossil resolution, and storage degradation within bitumen saturated sands



RGB and SWIR images showing the presence of trace fossils and structures

Image modified from: Shchepetkina, A., et al., 2017

Poorly stored old core showing that fungi have attacked the rock

4: New work flow

Cut core and slab

Scan the core slabs using RGB, hyperspectral and XRF imaging

Depth correct core with logs

Process the data collected to produce fused data including
bitumen saturation, PSD, clays, mineralogy and core images

Select exact locations for further sampling
permeability studies, geomechanical studies

Select a few cores for storage, send AER requested cores

Destroy remaining cores saving storage costs

Turn around time in the order of weeks

5: Key applications outside of oilsands

Tight oil and gas

- Mineralogy of the core and chips recovered: the latter in near real time
- Location of siliceous and calcareous zone variation
- Resolution of faults and fractures within the cored section

High value wells

- Location of variations in clay mineralogy
- PSD datasets for delineating sand on sand contacts
- Determination of siliceous and calcareous cements
- Non destructive analysis of old core and chips from near bye wells
- Creation of statistically relevant datasets for geomodel development

Summary slide

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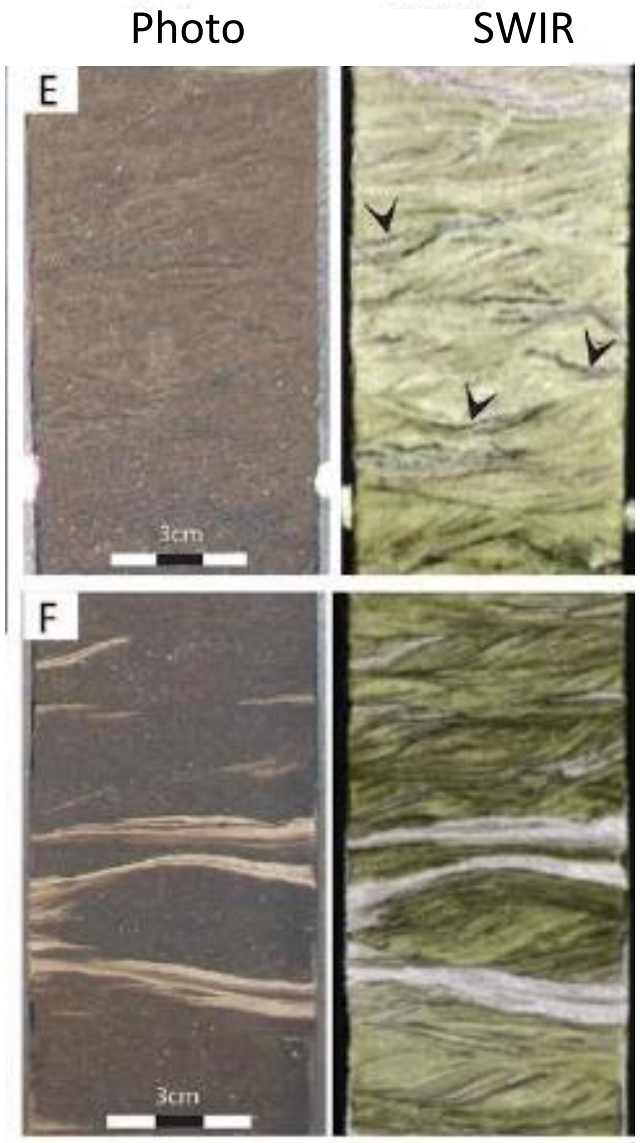

Image modified from: Shchepetkina, A., et al., 2017

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(Still needs some miniaturization though)

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