From Nanopore to Seismic Scale: the Role of Organic Matter in Vaca Muerta Shale Oil Productivity and Sweet Spot Prediction in Rincón de Aranda Block*

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Search and Discovery Article #42011 (2017)**
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[3]Now in YPF

Abstract

An increasing number of studies demonstrate the key role of organic matter in the productivity of shale plays. Integrated results from the first shale oil well in Rincón de Aranda (RDA) block confirm this strong relationship, but current understanding of hydrocarbon storage and flow in the matrix and fractures of shales is still insufficient to predict recovery. In order to understand the specific role of organic matter for porosity and oil saturation in a shale oil reservoir, we image shale pore networks at micro- to nanoscale and quantify relative petrophysical properties using an integrated workflow of CT/FIBSEM 3D imaging of core subsamples. From well logs and laboratory data, we observed a strong correlation between TOC and Sonic measurements for a large collection of shale oil wells and calculated a TOC-DT function. Using neuronal network and multiatribute workflow, we applied this function to the Transit Time cube calculated from a trace inversion of the 3D seismic data available for the RDA block and obtained a calibrated TOC cube. If the search for the sweetspot(s) in an area should be multicomponent (TOC, reservoir thickness, overpressure, etc.), the TOC cube should be considered as a key element for productivity prediction not only in Rincón de Aranda but also all over the Vaca Muerta oil window.

Reference Cited

Sommacal S., A. Fogden, B. Young, W. Noel, A. Arena, L. Salazar, T. Gerwig, C. Qianhao, A. Kingston, D. Marchal, A.M. Perez Mazas, C.H. Naides, G. Köhler, and M. Cagnolatti, 2016, 3D multiscale imaging of the distribution of pores, organic matter and oil in place in Vaca Muerta shale samples: Unconventional Resources Technology Conference, San Antonio, Texas, USA, 1-3 August 2016, 2460975-MS-URTeC.

AAPG

Latin America & Caribbean Region

ARGENTINA 2016

Geosciences Technology Workshop

Co-hosted by the Argentine Association of Petroleum Geologists and Geophysicists

Moving toward the Prediction of Unconventional Plays:

Lessons Learned from Tight and Shale Reservoirs in the Neuquén Basin

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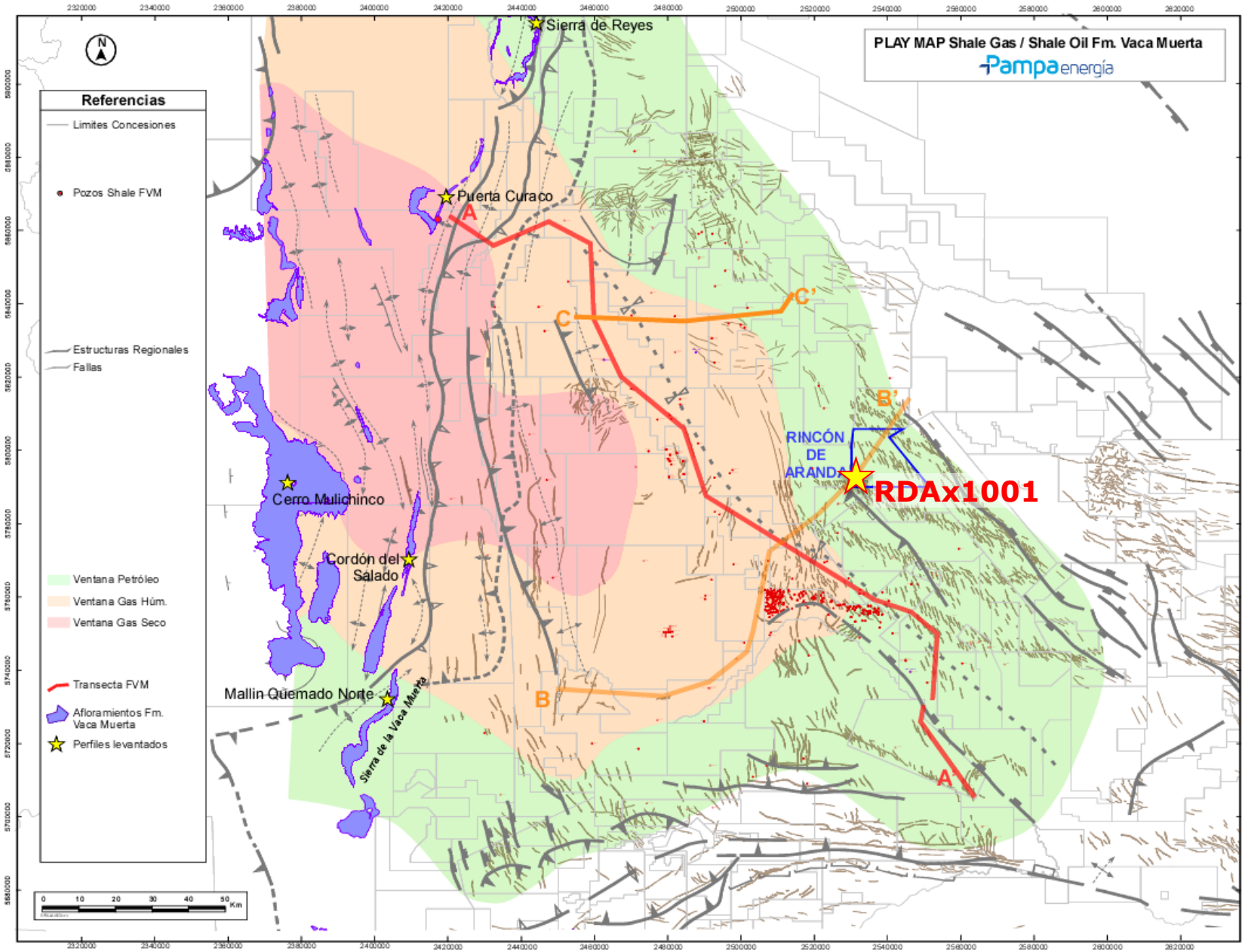
17/11/2016

Denis MARCHAL, Ana PEREZ MAZAS*, Claudio NAIDES, Federico SATTLER, Jorge ERLICHER, Guillermina KÖHLER, Esteban NIGRO (Pampa Energía), Silvano SOMMACAL, Andrew FOGDEN (FEI Oil and Gas)

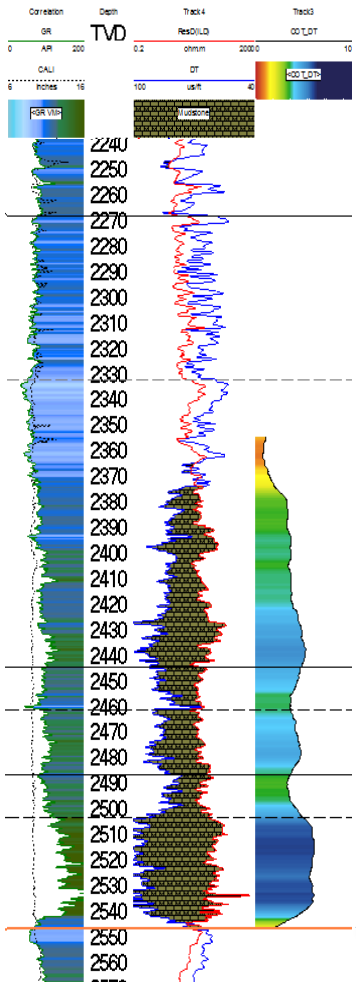
* Now in YPF

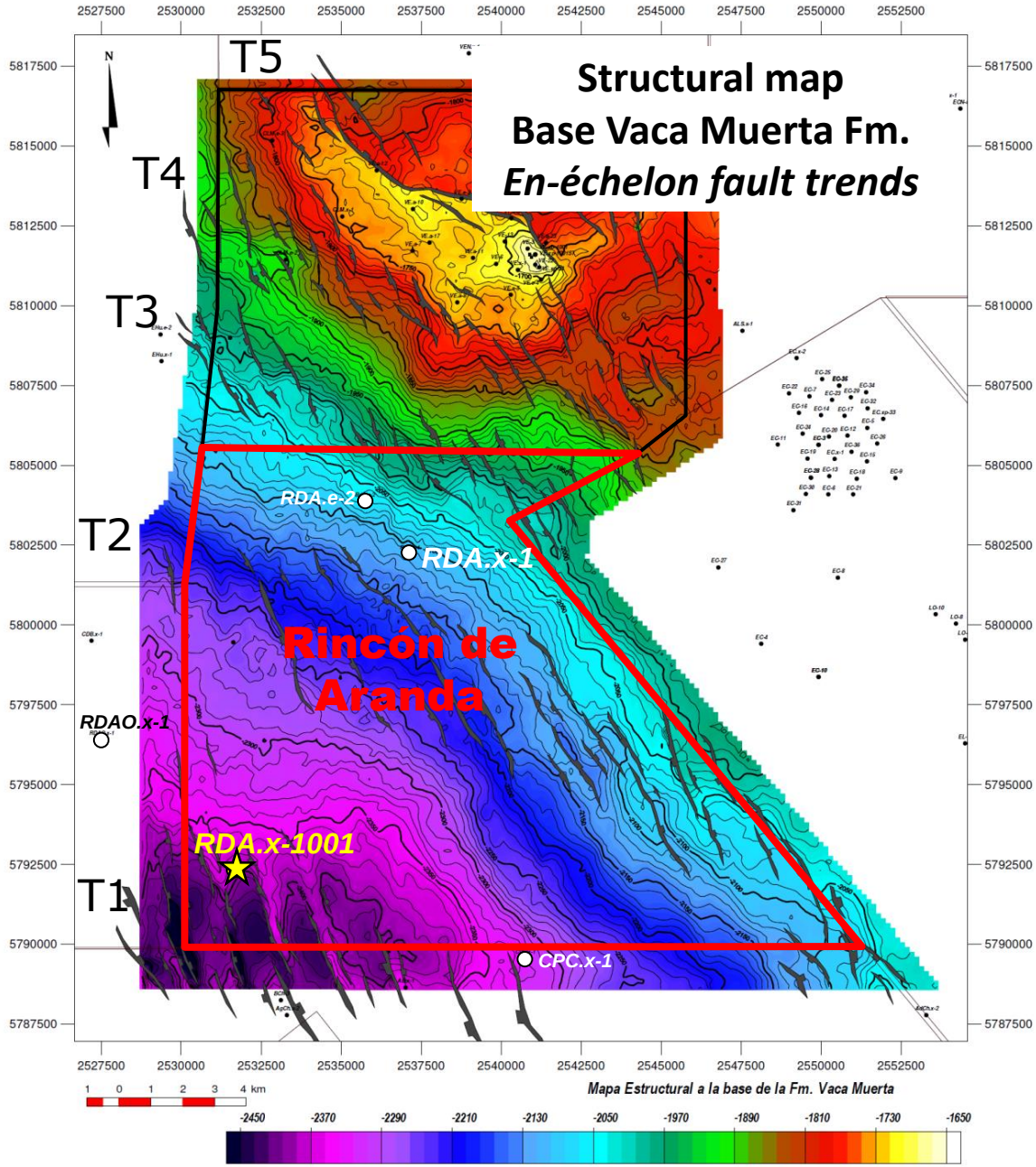
From Nanopore to Seismic Scale - Play Map & Block location



From Nanopore to Seismic Scale - RDA.x-1001 location

RDA.x-1

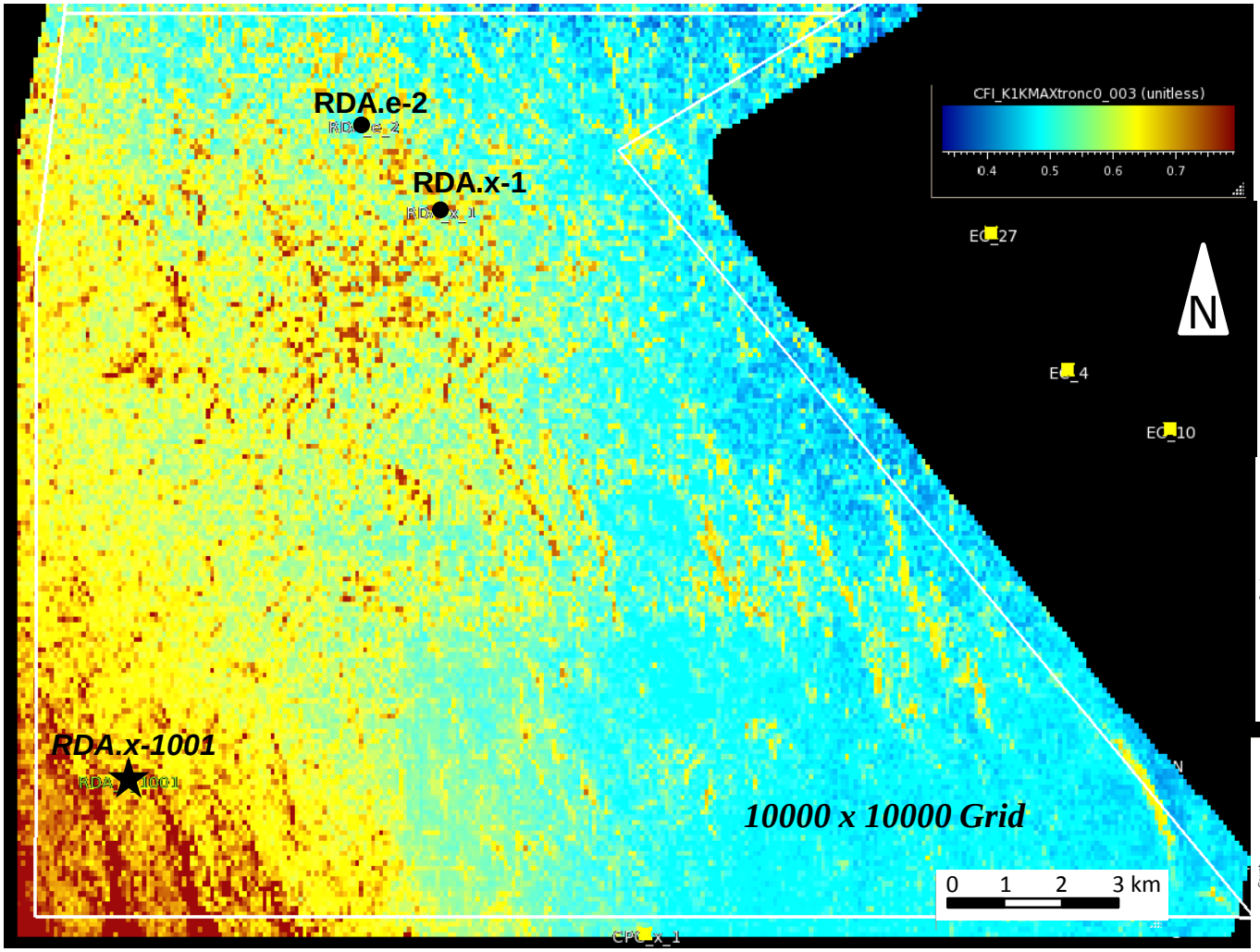


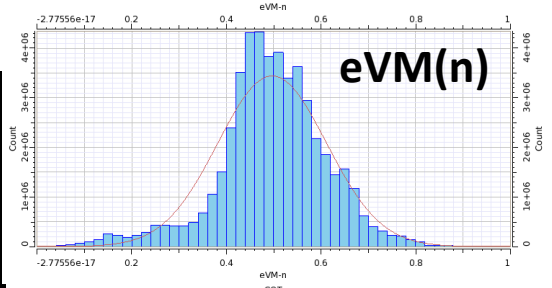


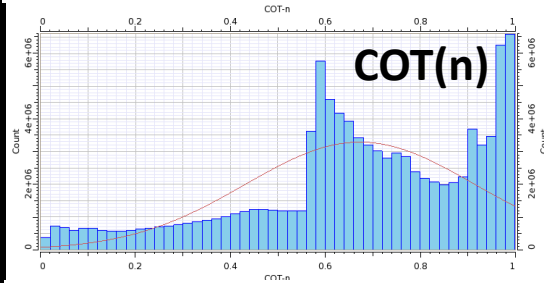
Critical Factor Index with Curvature: CFIc

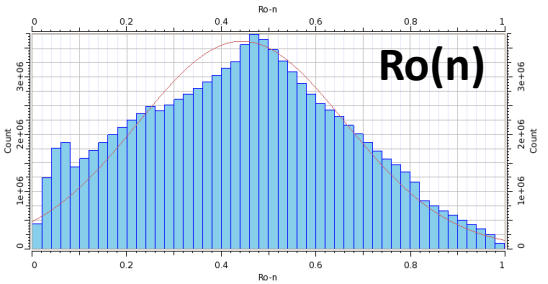
$$CFIc = \frac{c1*eVM(n) + c2*COT(n) + c3*Ro(n) + \mathbf{c4*Curv(n)}}{c1+c2+c3+c4}$$

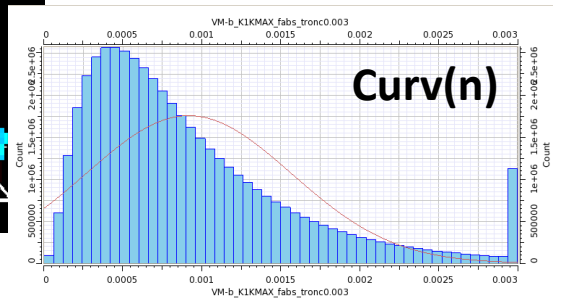
X(n): normalized parameter
c1, c2, c3 y c4: weighting coeficientes
(this run, c1=c2=c3=c4=1)



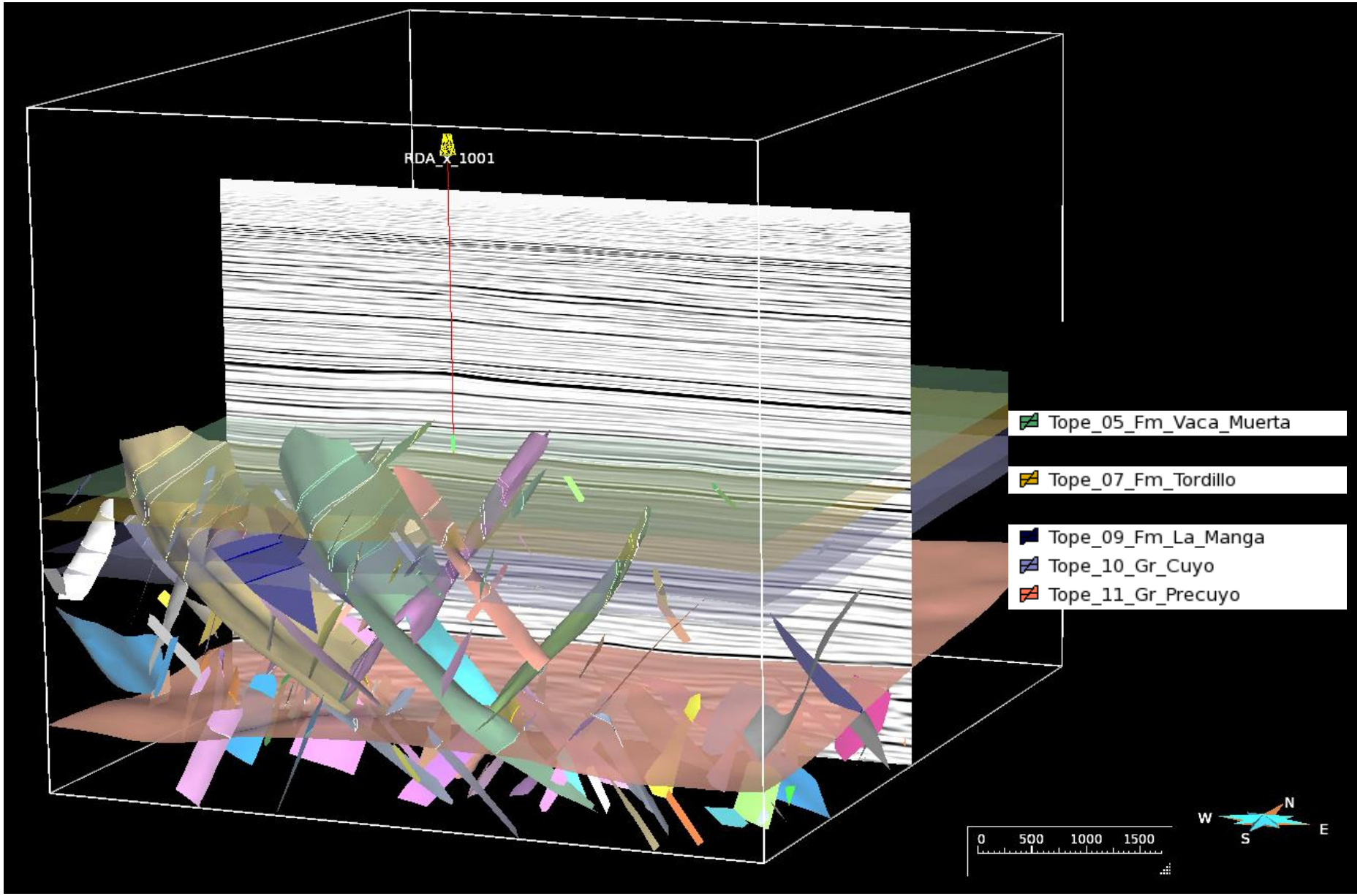




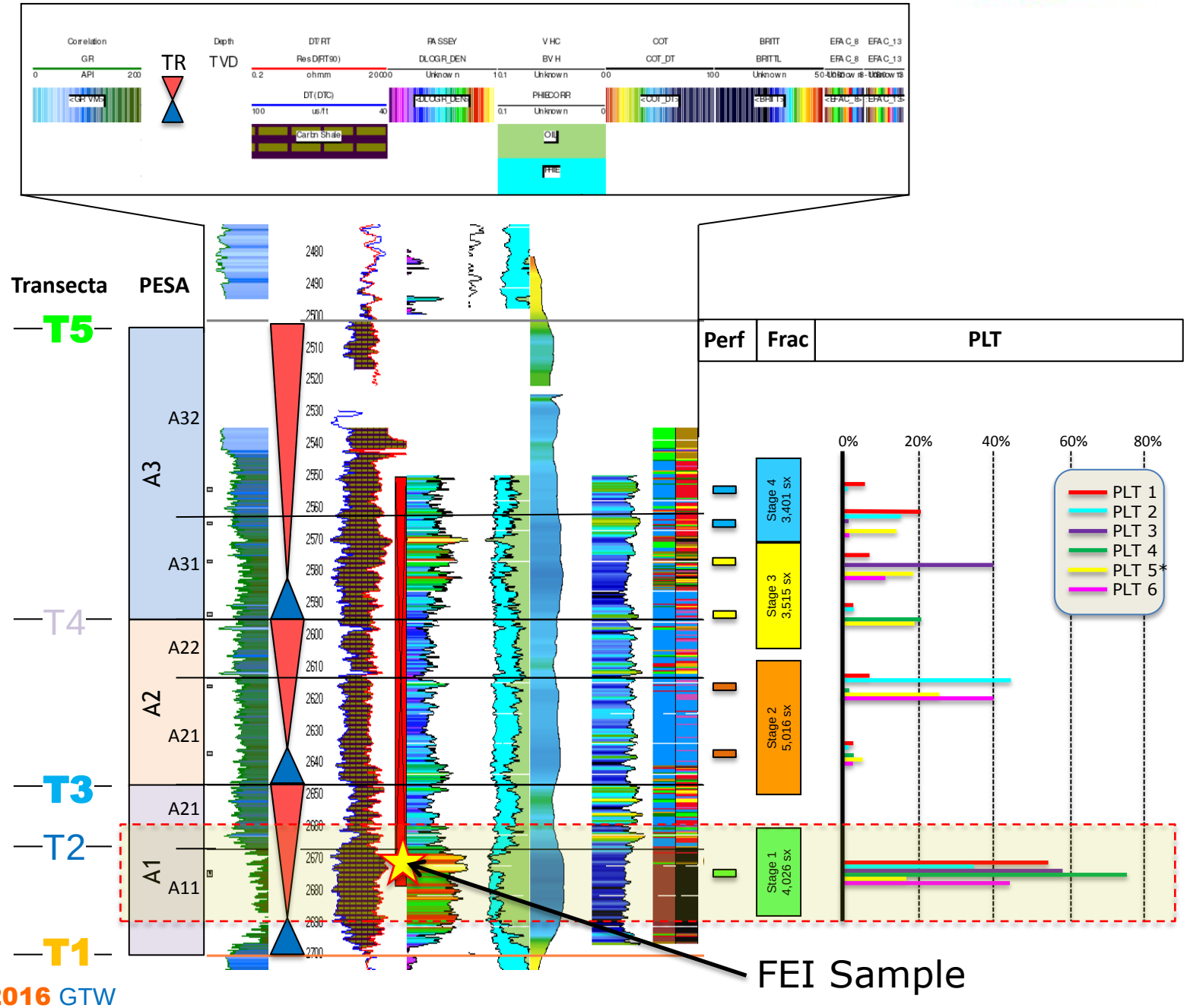




From Nanopore to Seismic Scale - 3D Structural Model & RDA.x-1001

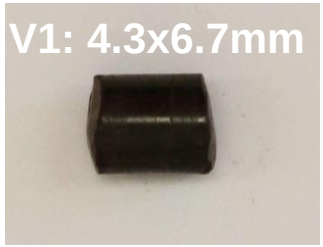


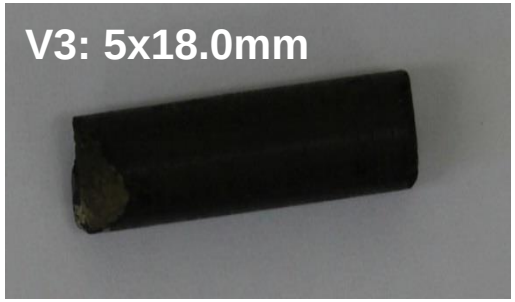
From Nanopore to Seismic Scale - RDA.x-1001 result summary



Original Sample:

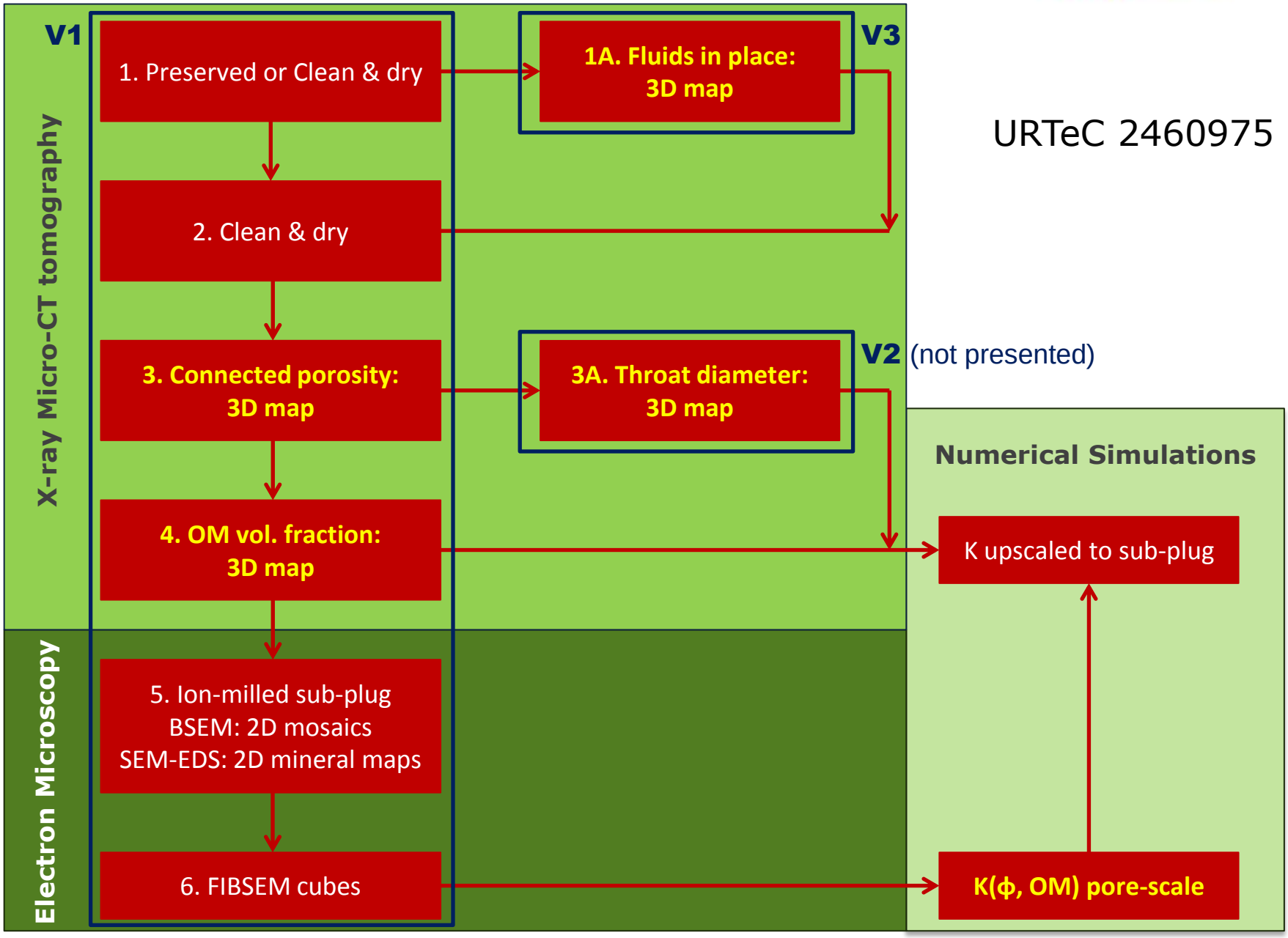
Subsamples:





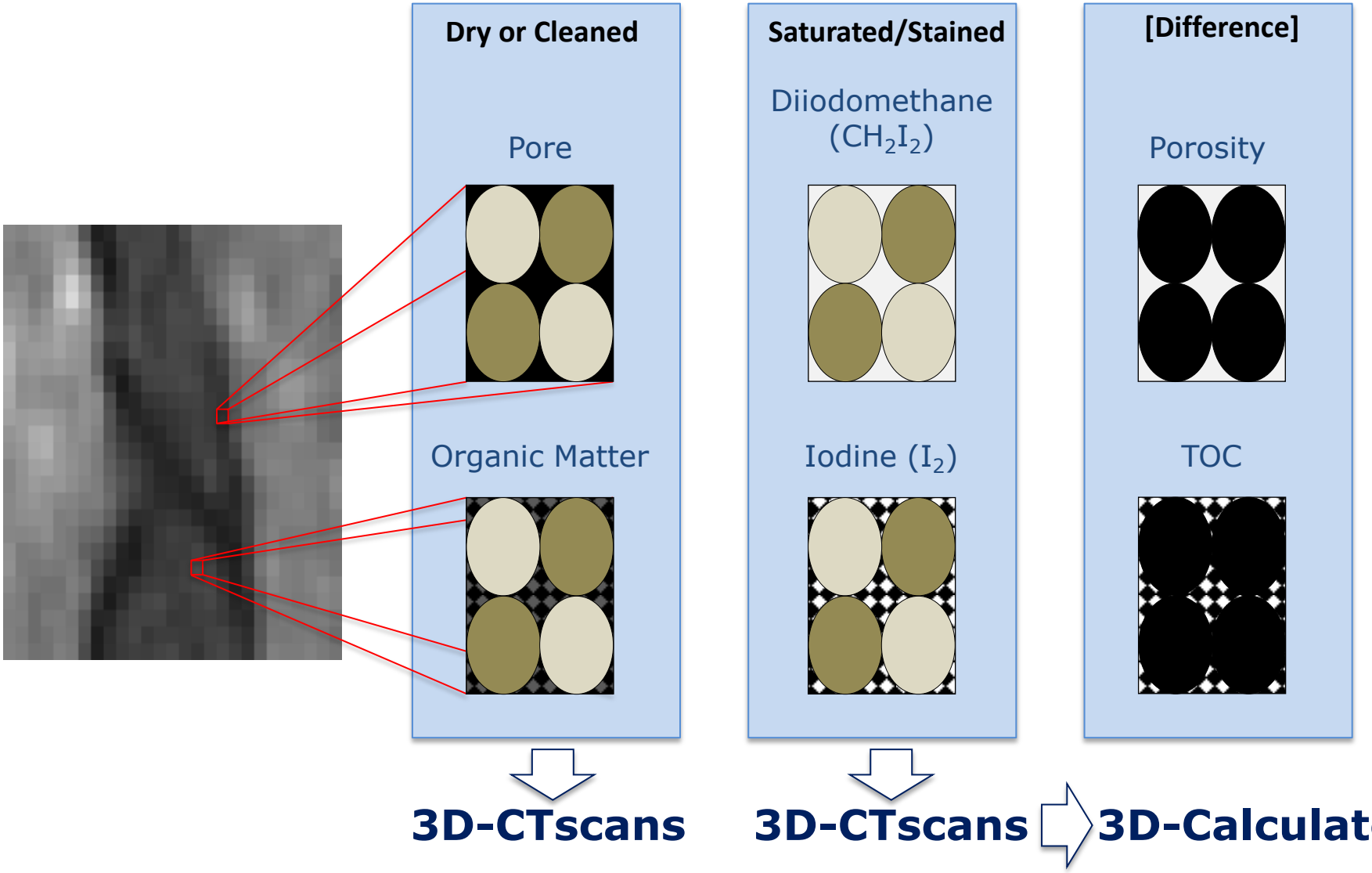
Sample	TOC (wt%)	Porosity (%)	Calcite (wt%)	Dolomite (wt%)	Quartz (wt%)	K-feldspar (wt%)	Plagioclase (wt%)	Illite/ Smectite (wt%)	Illite (wt%)	Kaolinite (wt%)	Pyrite (wt%)
V1-V3	8.1	6.0-9.3	65-11	2-1	17-52	0-1	5-14	6.2-11.9	3.1-4.5	0.7-1.6	1-3

From Nanopore to Seismic Scale - Shale Workflow



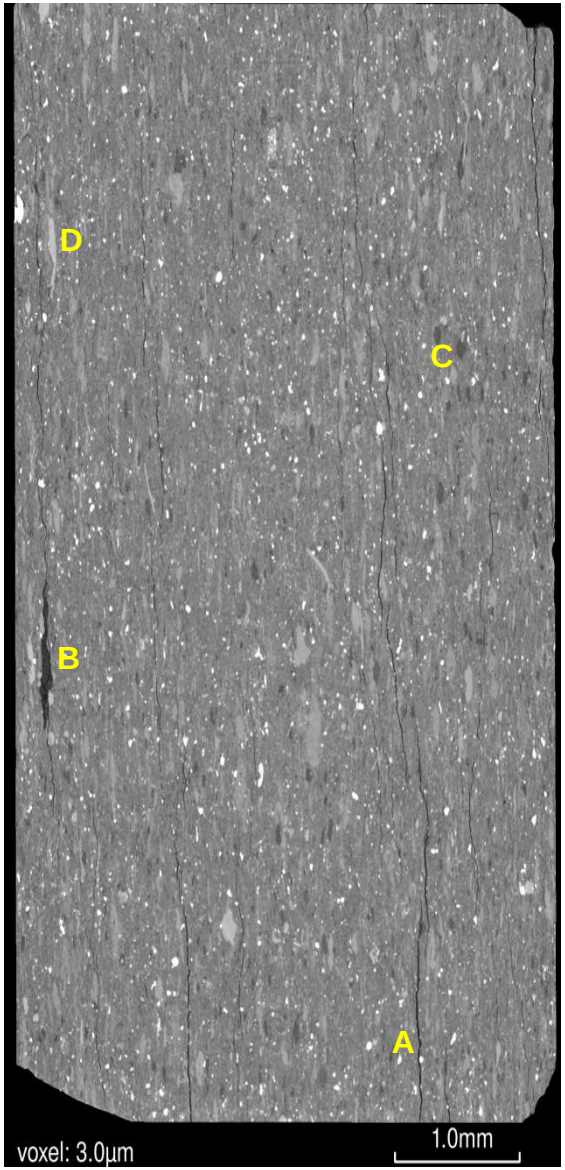
URTeC 2460975

X-ray contrast enhancement strategies for shales

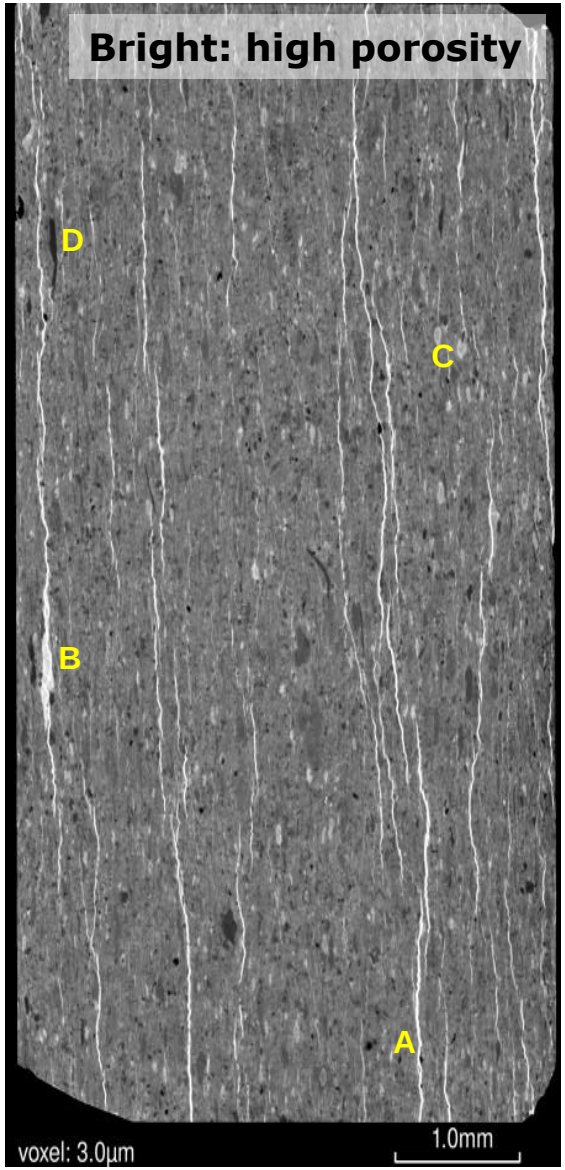


From Nanopore to Seismic Scale - Mapping Porosity & OM (V1)

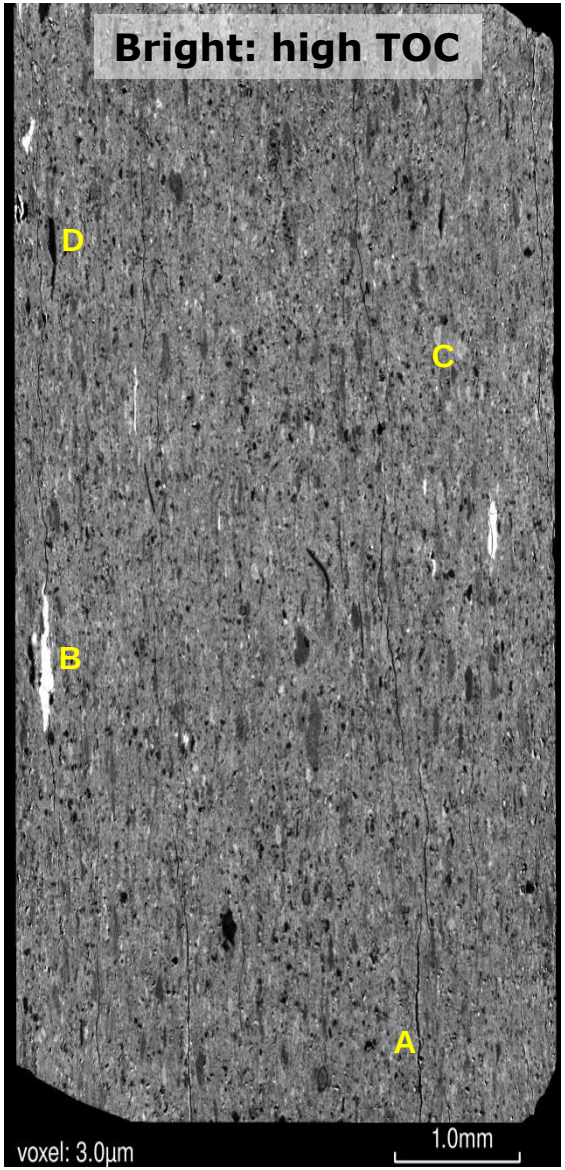
DRY TOMOGRAM



DIFFERENCE "POROSITY"
[CH_2I_2-SATURATED – DRY]

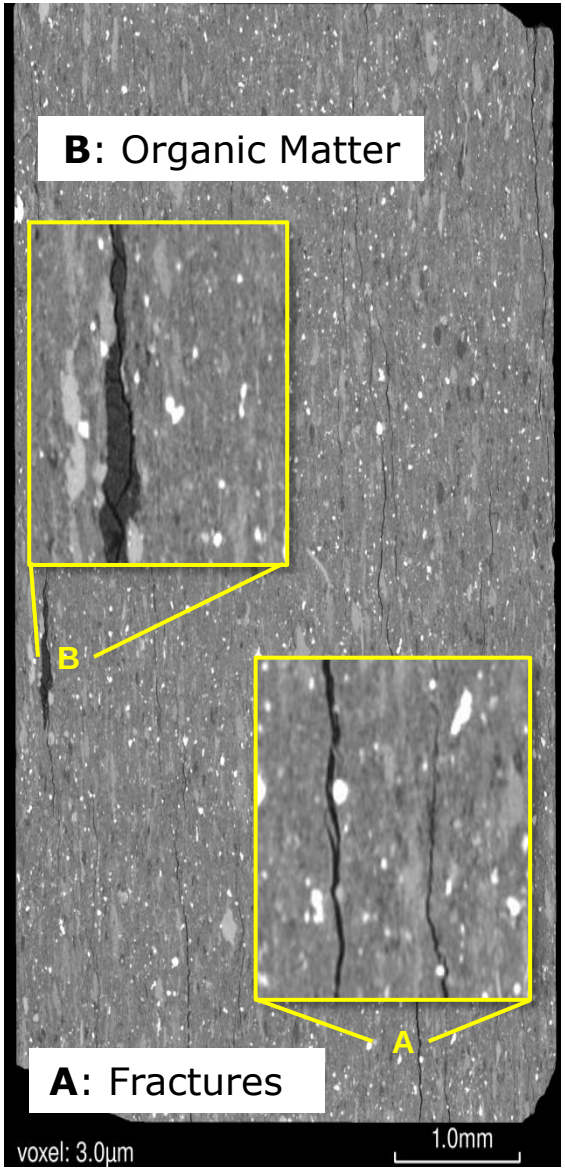


DIFFERENCE "TOC"
[I_2-STAINED – DRY]

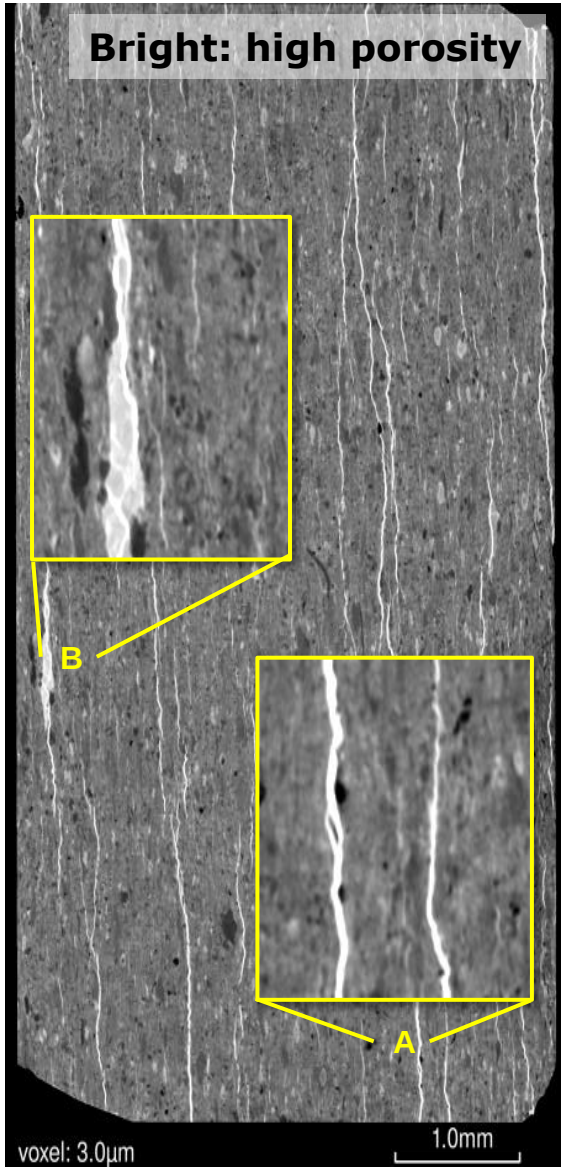


From Nanopore to Seismic Scale - Mapping Porosity & OM (V1)

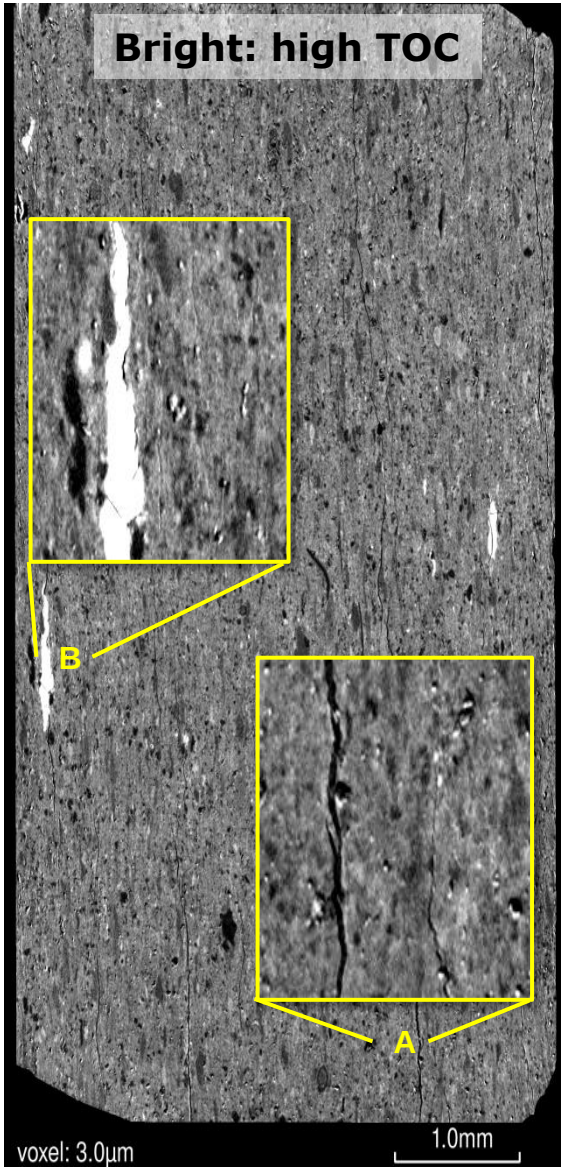
DRY TOMOGRAM



DIFFERENCE "POROSITY"
[CH_2I_2-SATURATED – DRY]

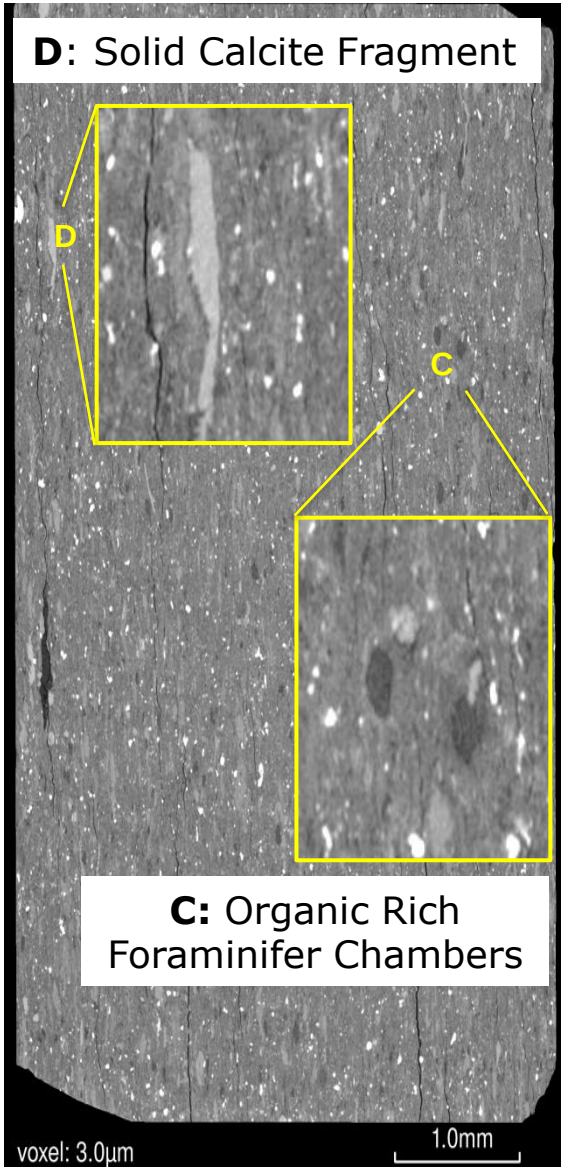


DIFFERENCE "TOC"
[I_2-STAINED – DRY]

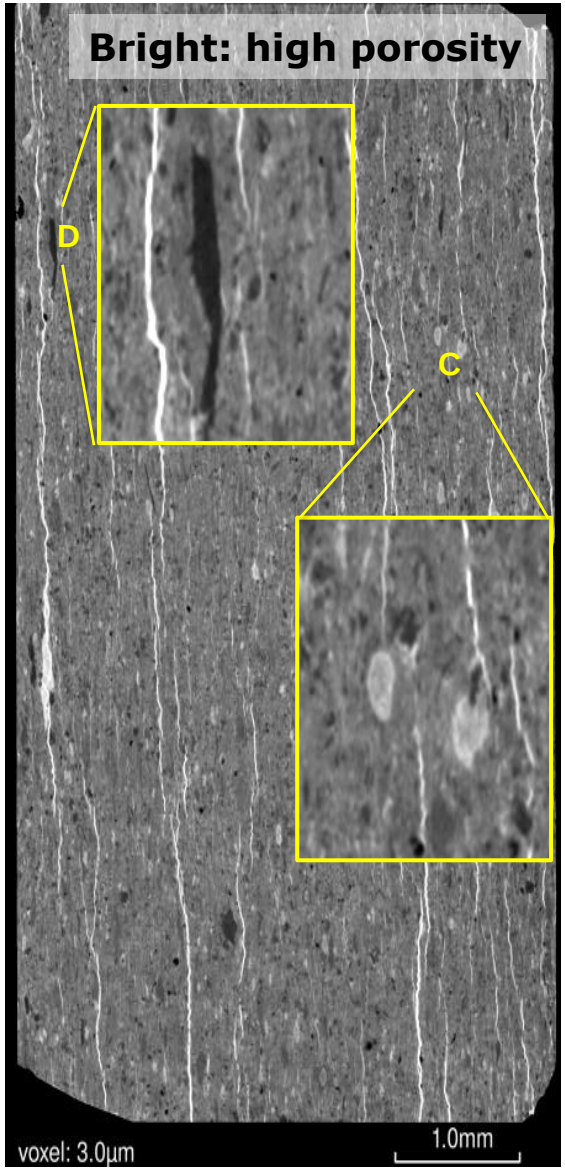


From Nanopore to Seismic Scale - Mapping Porosity & OM (V1)

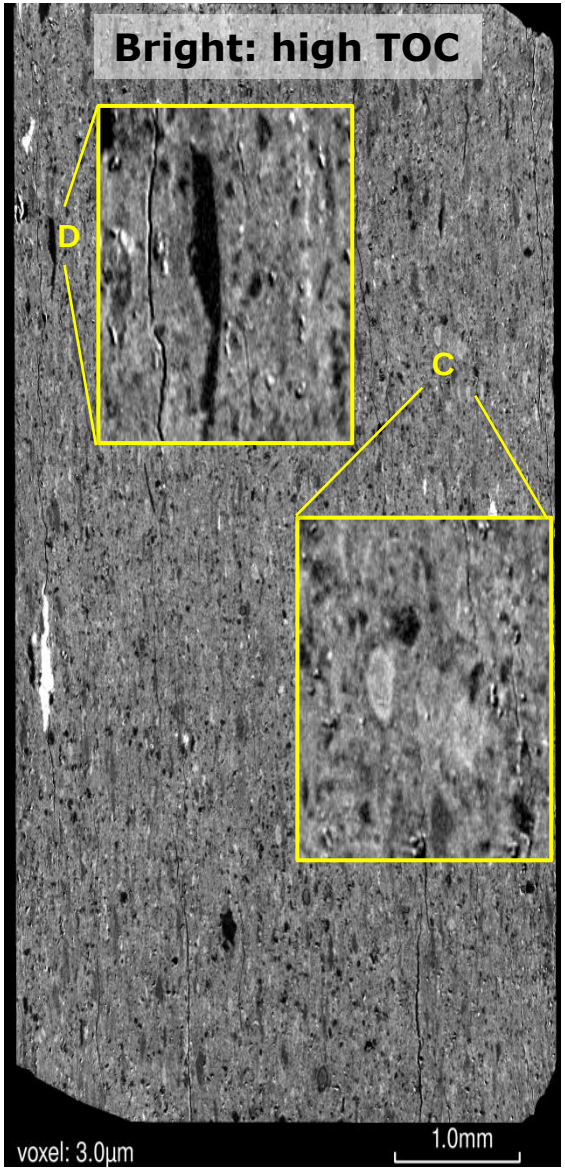
DRY TOMOGRAM



DIFFERENCE "POROSITY"
[CH_2I_2-SATURATED – DRY]

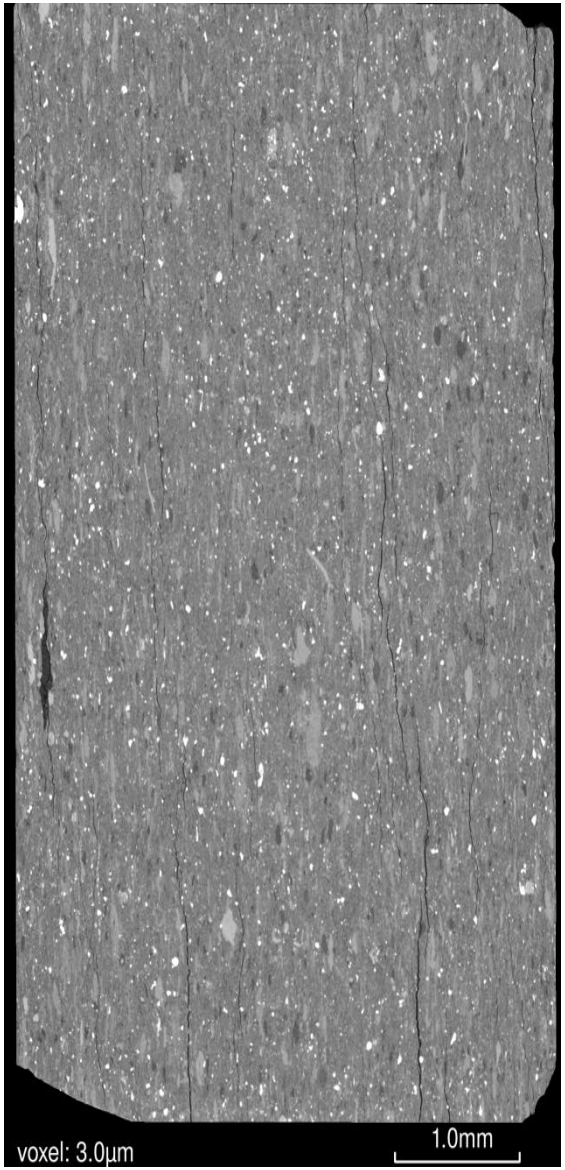


DIFFERENCE "TOC"
[I_2-STAINED – DRY]

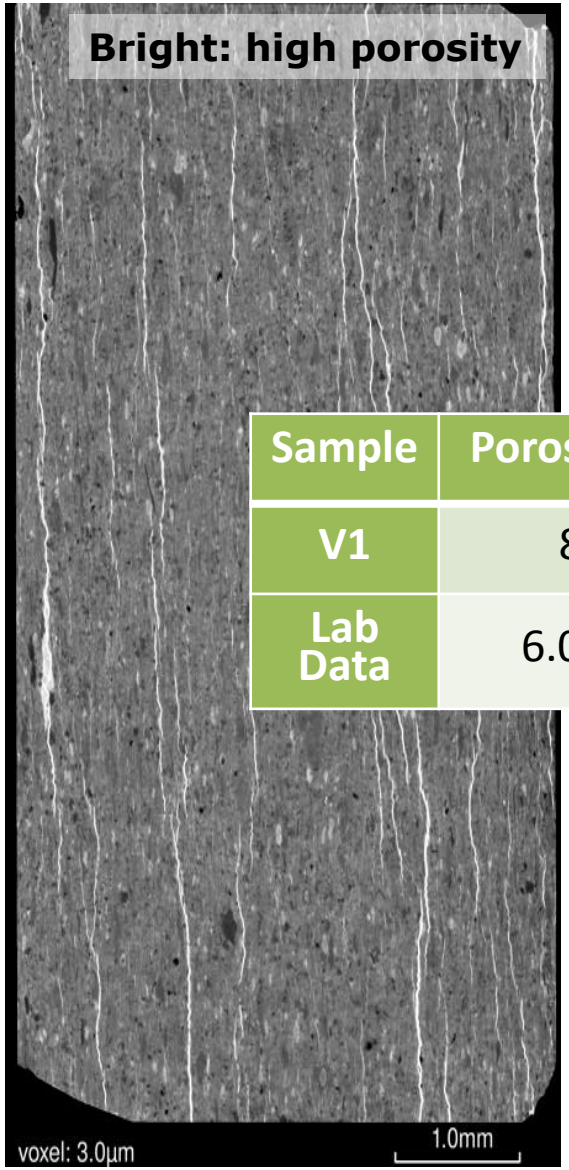


From Nanopore to Seismic Scale - Mapping Porosity & OM (V1)

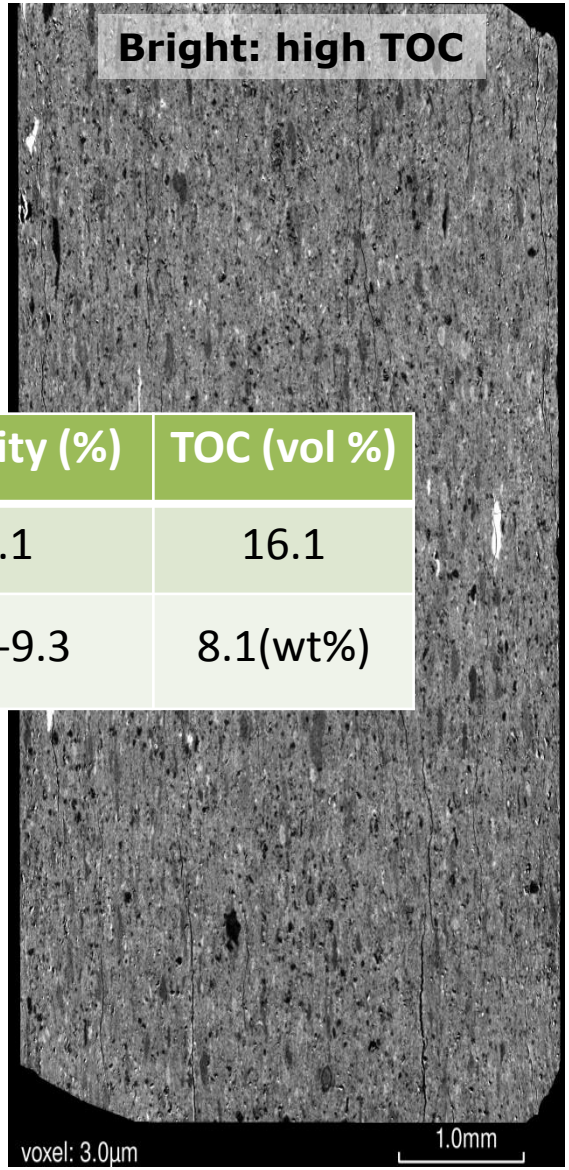
DRY TOMOGRAM



DIFFERENCE "POROSITY"
[CH_2I_2-SATURATED – DRY]



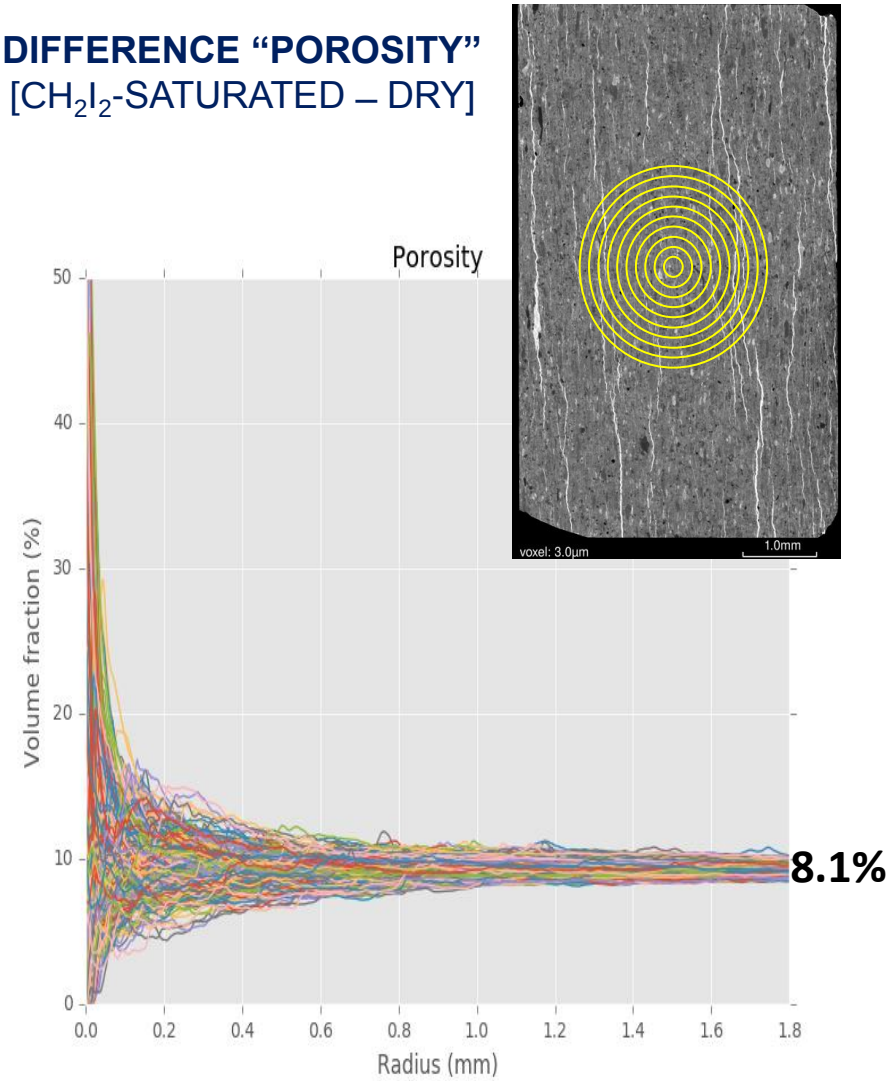
DIFFERENCE "TOC"
[I_2-STAINED – DRY]



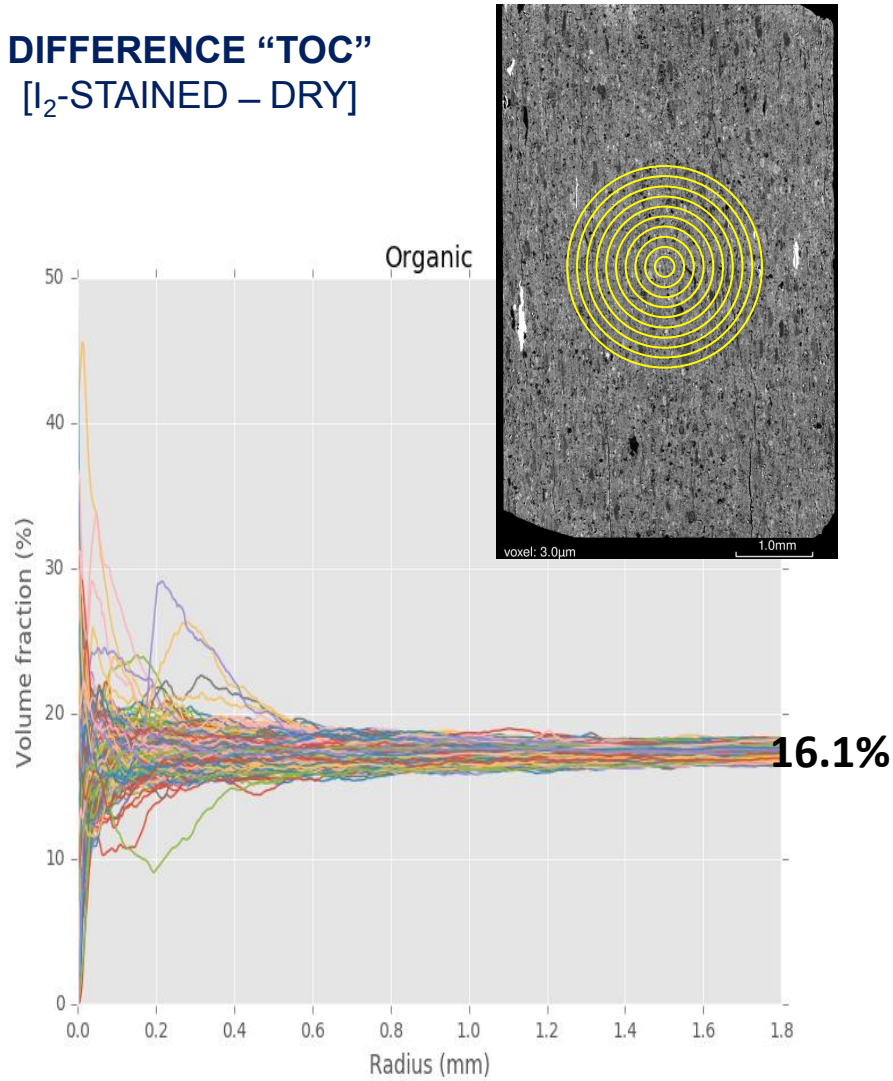
Sample	Porosity (%)	TOC (vol %)
V1	8.1	16.1
Lab Data	6.0-9.3	8.1(wt%)

From Nanopore to Seismic Scale - Porosity – TOC REV's (V1)

DIFFERENCE "POROSITY"
[CH_2I_2-SATURATED – DRY]

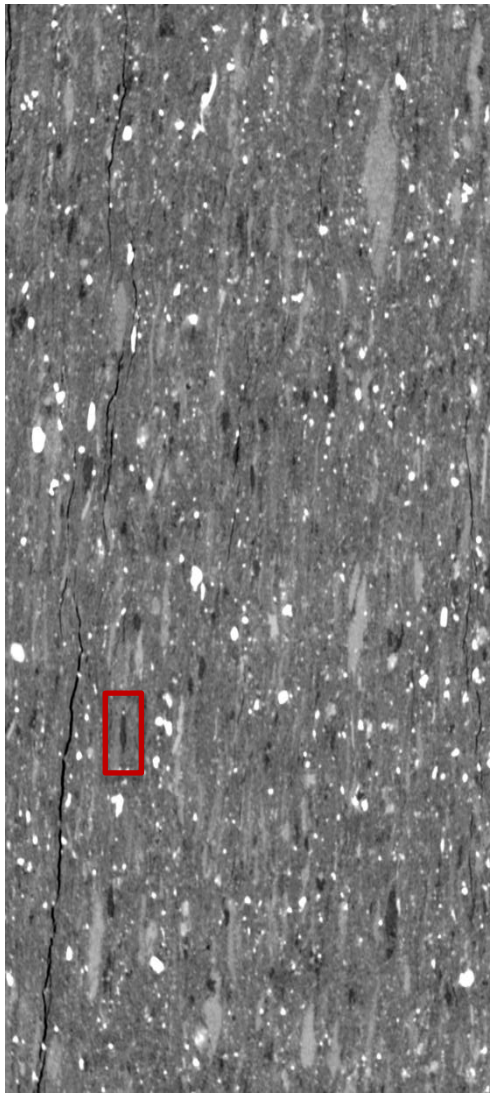


DIFFERENCE "TOC"
[I_2-STAINED – DRY]

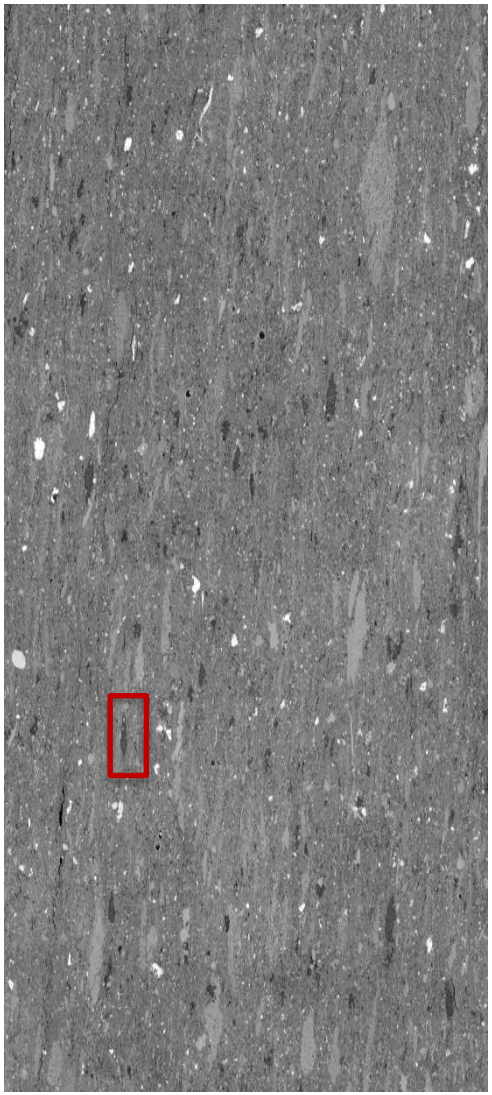


From Nanopore to Seismic Scale - mCT / BSEM / EDS Overlay (V1)

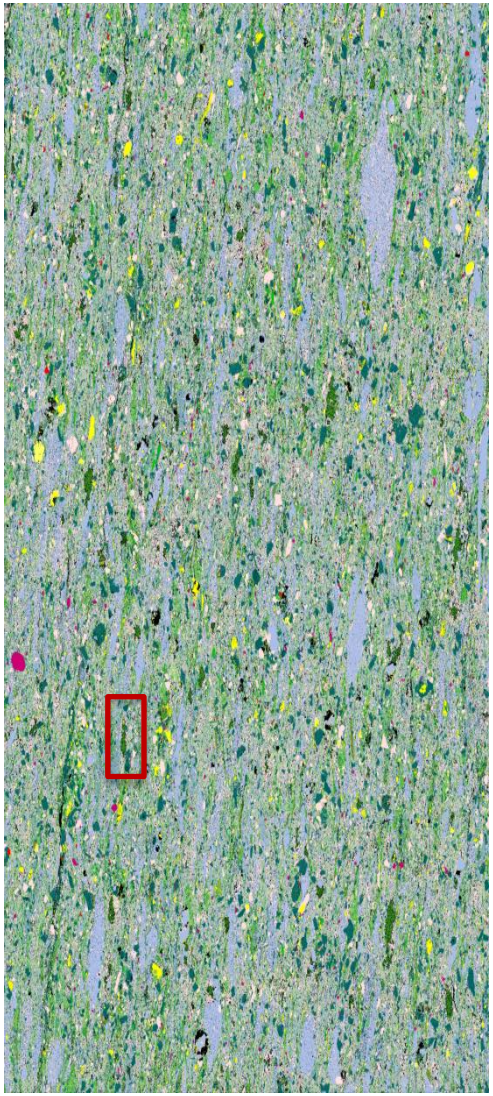
DRY TOMOGRAM

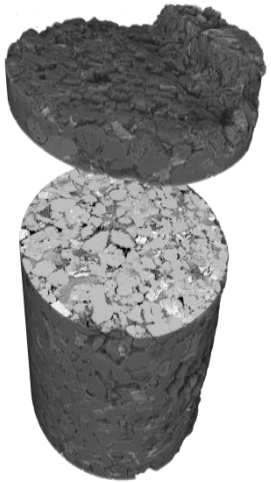


BSEM



SEM-EDS





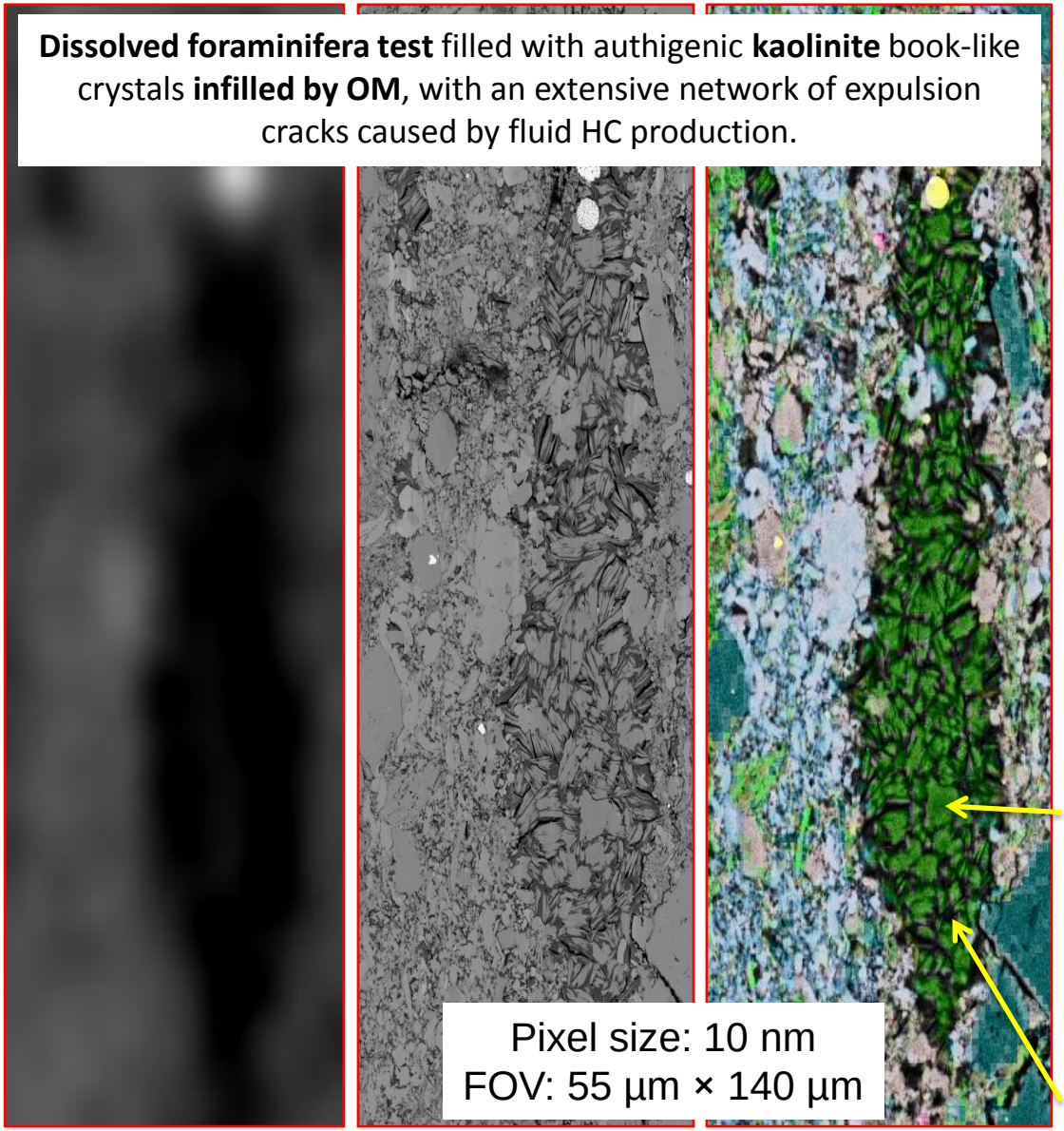
Legend	Mineral	Area%
	Quartz (Silica)	33.68
	K-Na Feldspar	13.71
	Ca-Plagioclase	2.34
	Biotite	0.26
	Muscovite	0.76
	Kaolinite	0.65
	Illite	9.21
	Chlorite	0.14
	I/S Interstratified	6.43
	Calcite (Aragonite)	28.70
	Apatite	0.79
	Pyrite	2.14
	Rutile	0.13
	Unclassified / Organic	1.06

FOV: 3.3 mm × 1.9 mm

From Nanopore to Seismic Scale - mCT / BSEM / EDS Overlay (V1)

DRY TOMOGRAM | BSEM | SEM-EDS

Dissolved foraminifera test filled with authigenic **kaolinite** book-like crystals **infilled by OM**, with an extensive network of expulsion cracks caused by fluid HC production.

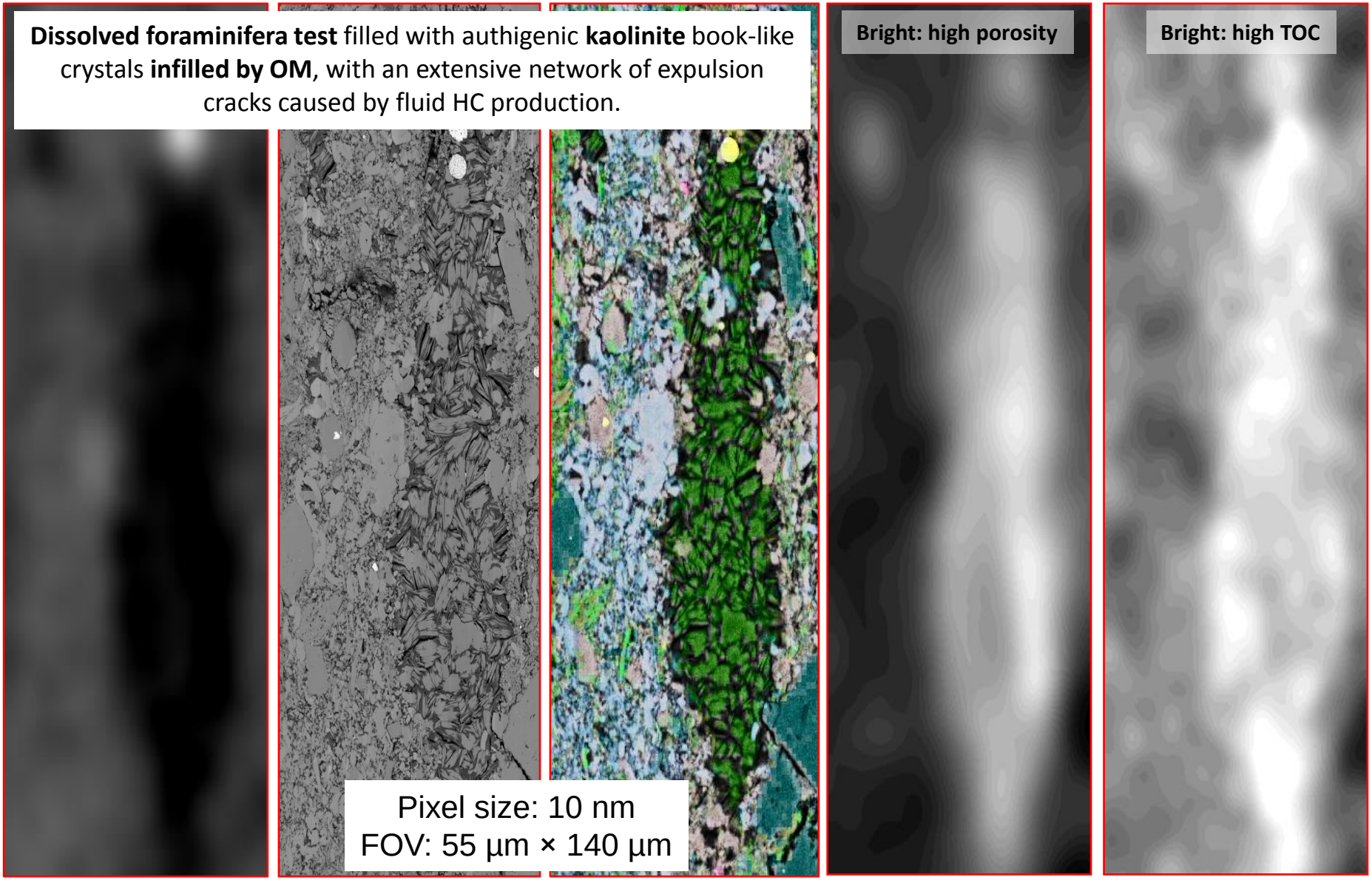


Legend	Mineral
	Quartz (Silica)
	K-Na Feldspar
	Ca-Plagioclase
	Biotite
	Muscovite
	Kaolinite
	Illite
	Chlorite
	I/S Interstratified
	Calcite (Aragonite)
	Apatite
	Pyrite
	Rutile
	Unclassified / Organic

From Nanopore to Seismic Scale - mCT / BSEM / EDS Overlay (V1)

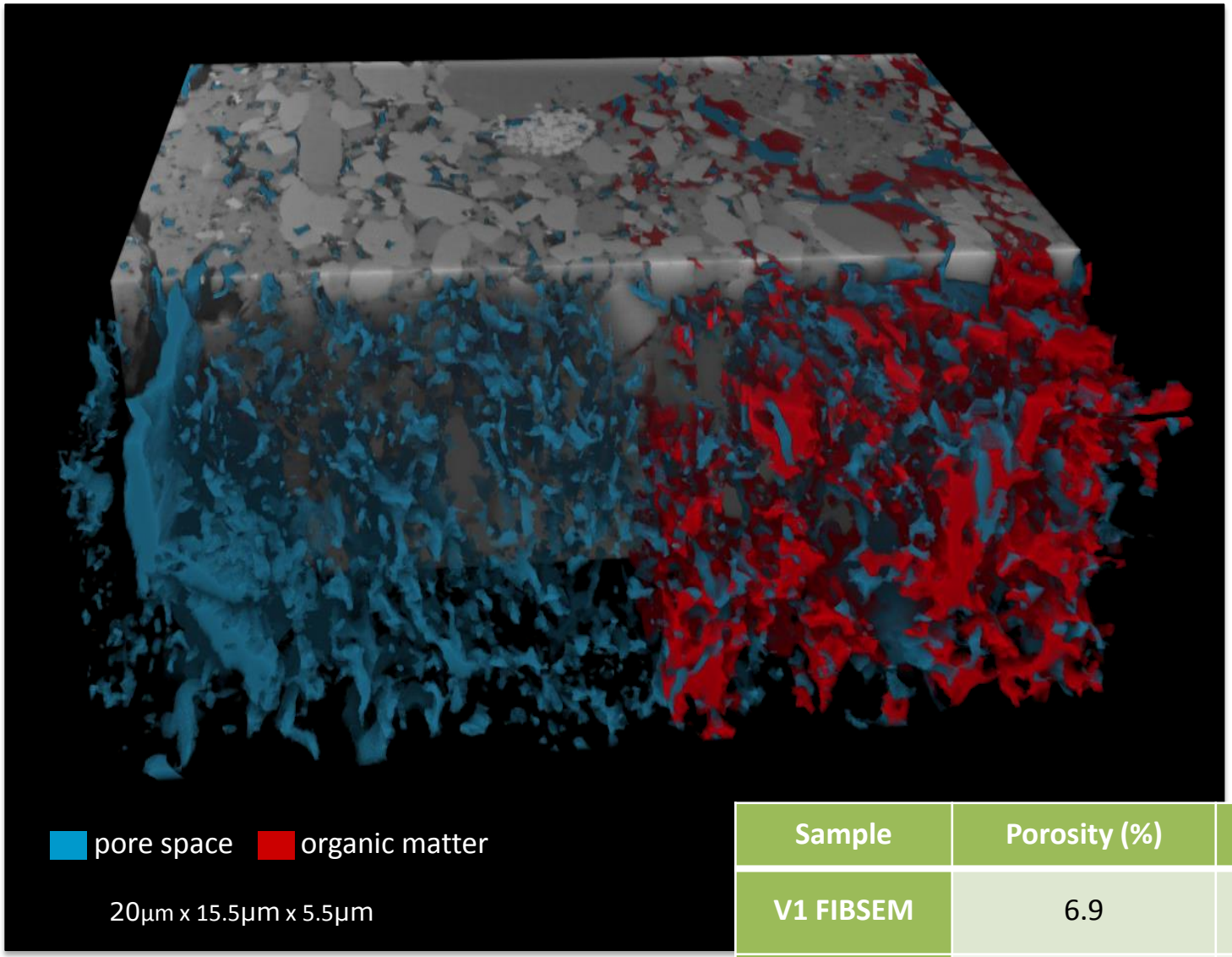
DRY TOMOGRAM | BSEM | SEM-EDS | POROSITY MAP | TOC MAP

Dissolved foraminifera test filled with authigenic **kaolinite** book-like crystals **infilled by OM**, with an extensive network of expulsion cracks caused by fluid HC production.



Pixel size: 10 nm
FOV: 55 µm × 140 µm

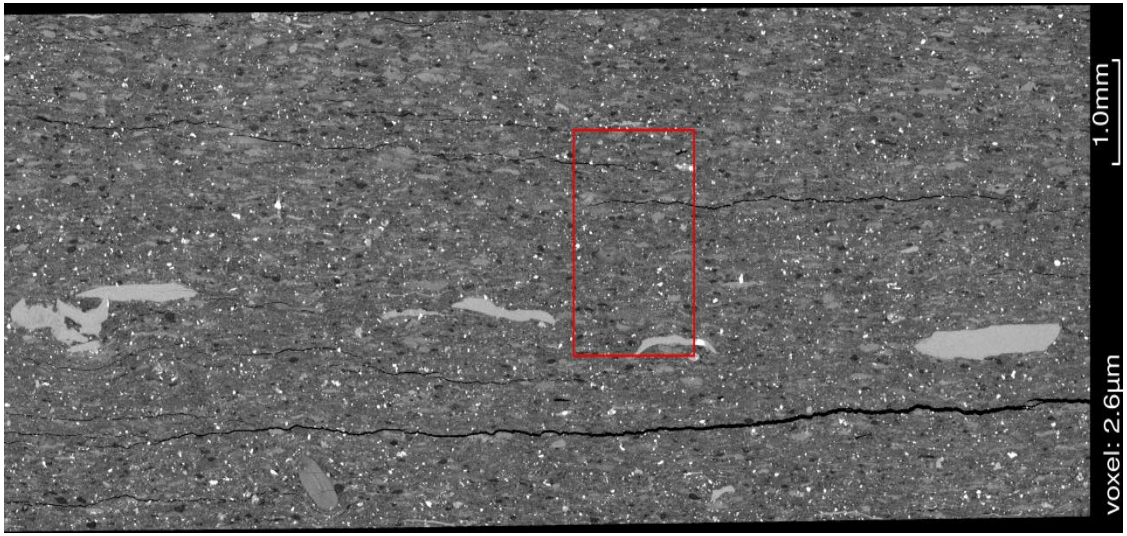
From Nanopore to Seismic Scale - FIBSEM (V1)



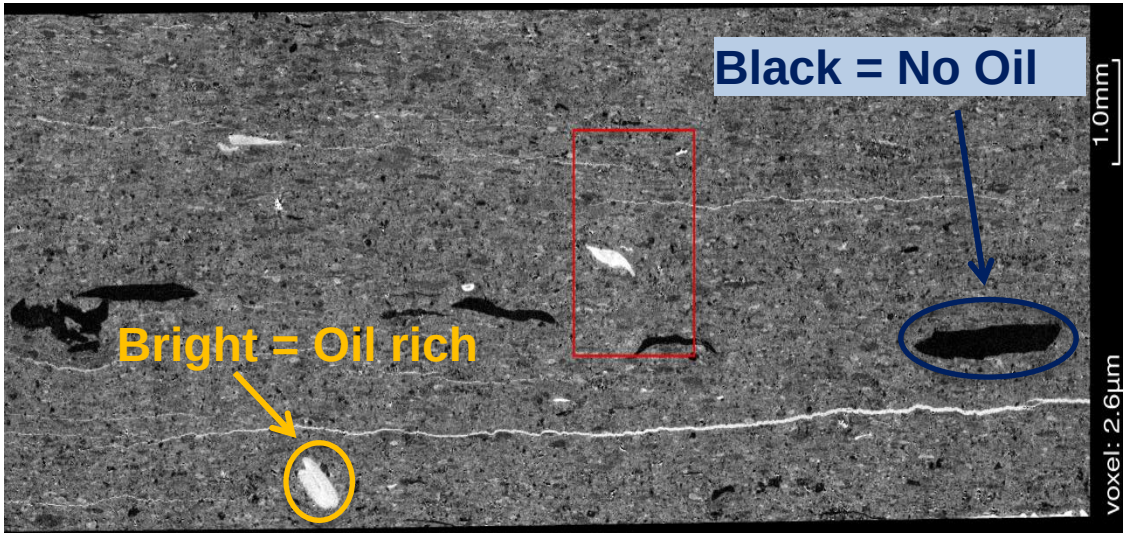
Sample	Porosity (%)	TOC (vol %)
V1 FIBSEM	6.9	14.1
V1 mCT	8.1	16.1
Lab Data	6.0-9.3	8.1(Wt%)

From Nanopore to Seismic Scale - Mapping Oil in Place (V3)

UNCLEANED TOMOGRAM

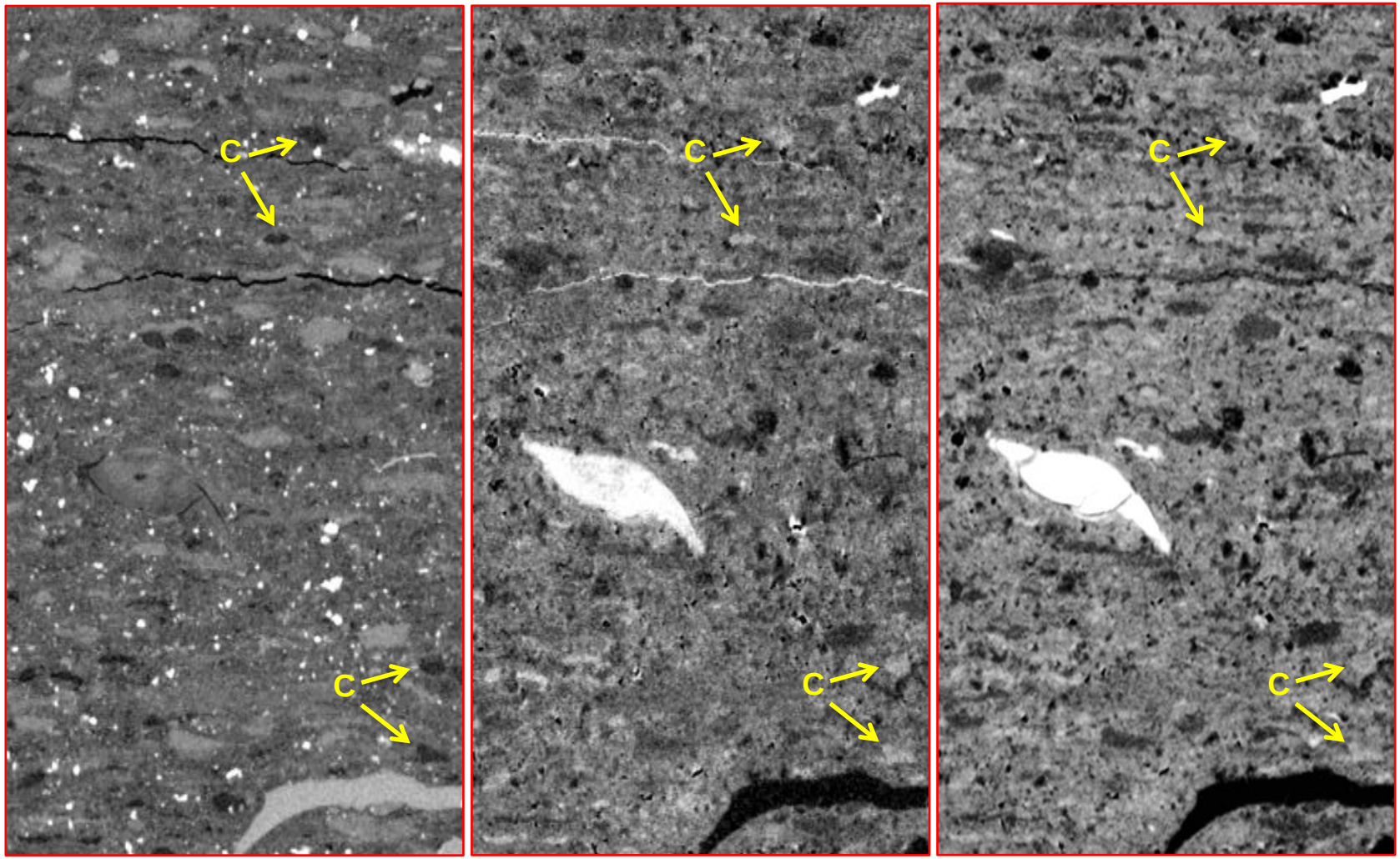


DIFFERENCE [OIL-CONTRASTED – DRY]



From Nanopore to Seismic Scale - Mapping Oil in Place (V3)

UNCLEANED TOMOGRAM | **OIL-CONTRASTED – DRY** | **TOC MAP**



C: Organic Rich Foraminifer Chambers

FOV: 2.2 mm × 1.6 mm

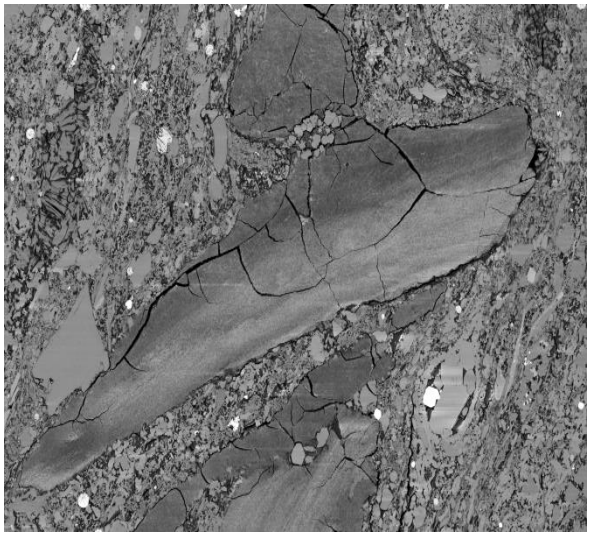
Bright = Oil rich
Black = No Oil

Bright = OM rich
Black = OM poor

From Nanopore to Seismic Scale - mCT / BEM / EDS Overlay (V3)

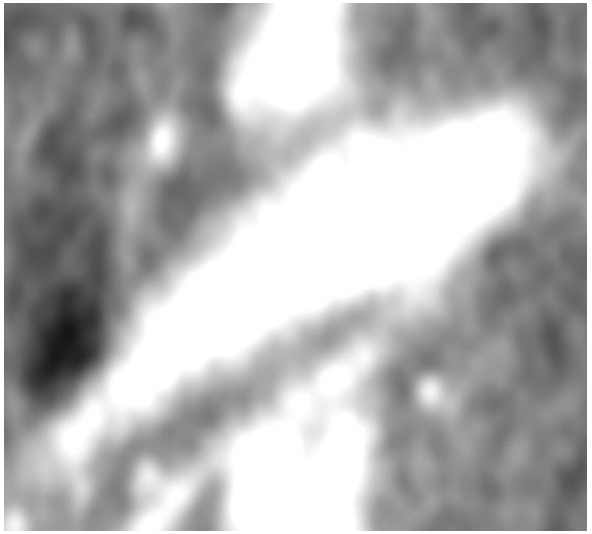
FOV:
255 µm × 173 µm

BSEM

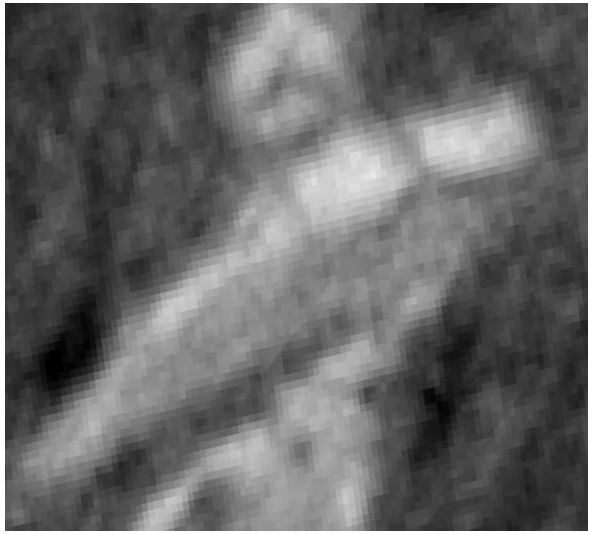


SEM-EDS

Legend	Mineral
	Quartz (Silica)
	K-Na Feldspar
	Ca-Plagioclase
	Biotite
	Muscovite
	Kaolinite
	Illite
	Chlorite
	I/S Interstratified
	Calcite (Aragonite)
	Apatite
	Pyrite
	Rutile
	Unclassified / Organic

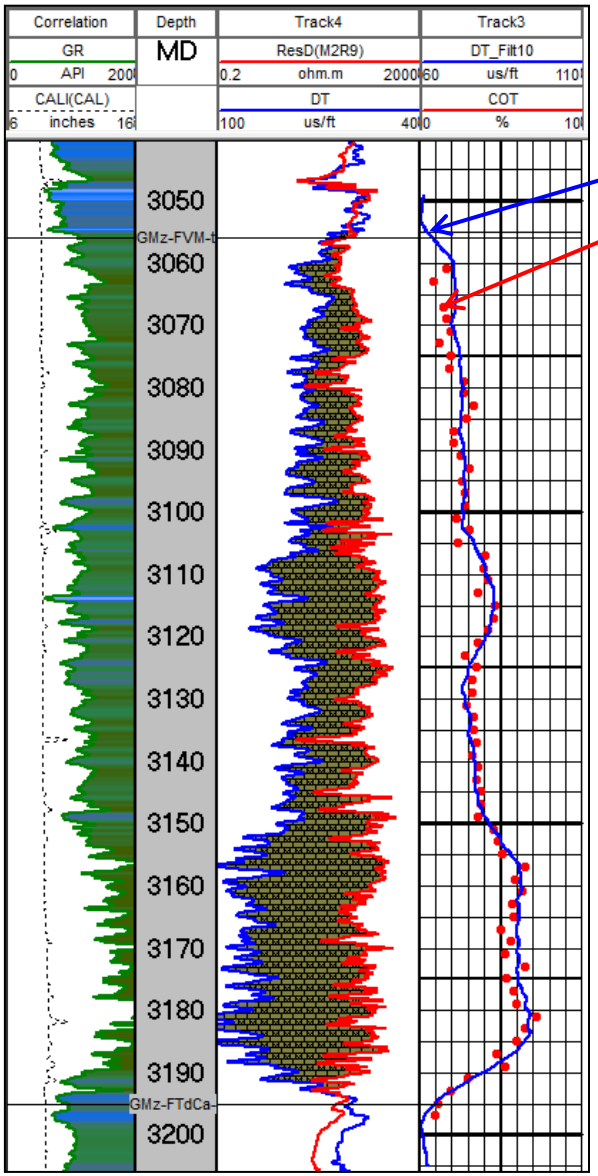


OIL-CONTRASTED – DRY



TOC MAP

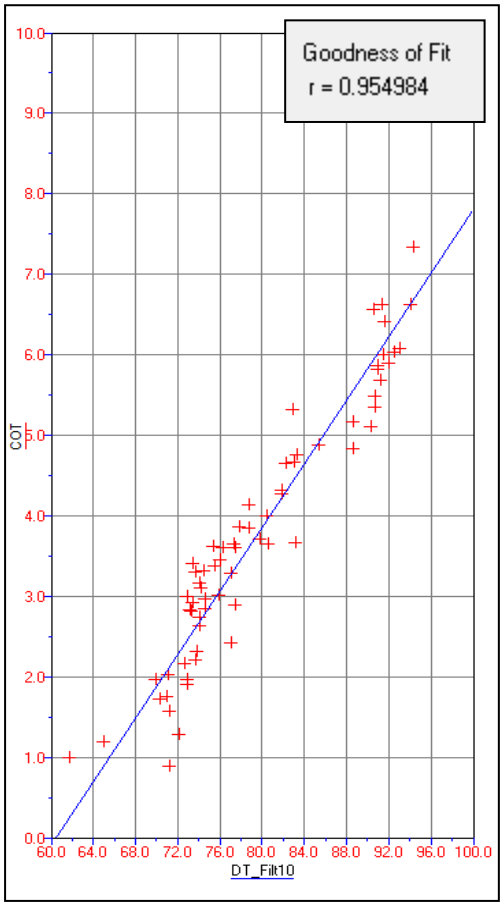
From Nanopore to Seismic Scale - DT/TOC correlation



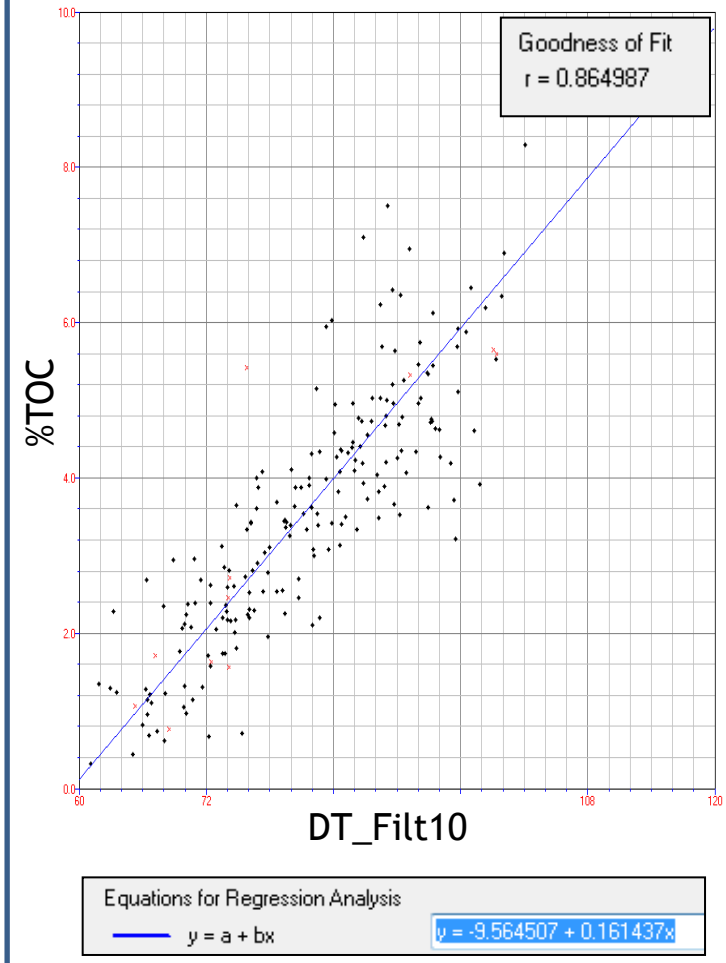
CAS.x-1

Filtered DT curve (/10 samples)

% TOC - From lab. (cutting)

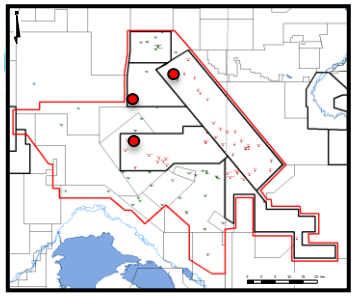


Multiwell (20 wells)

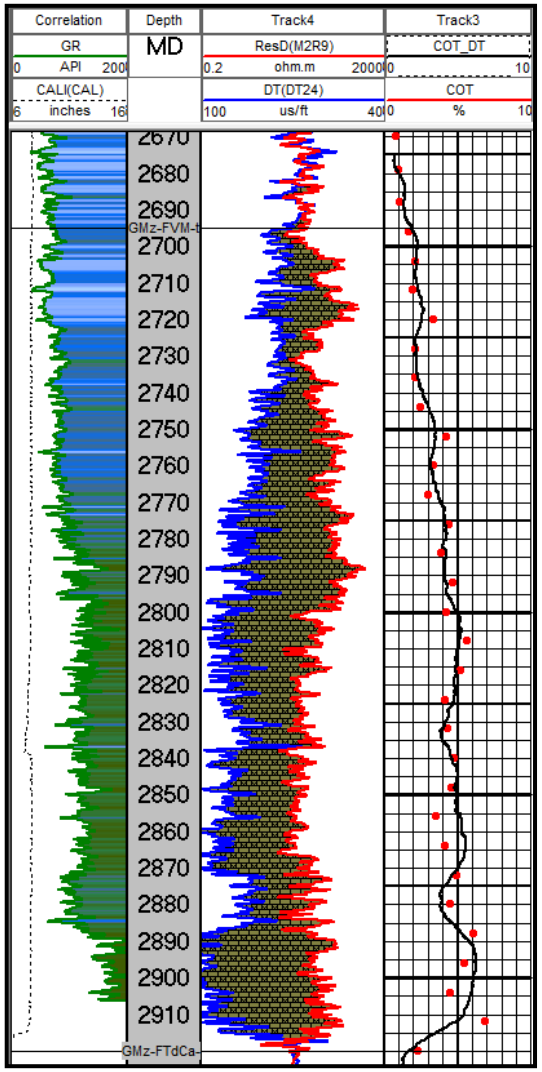


%TOC= -9,56 + (0,16*DT_Filt10)

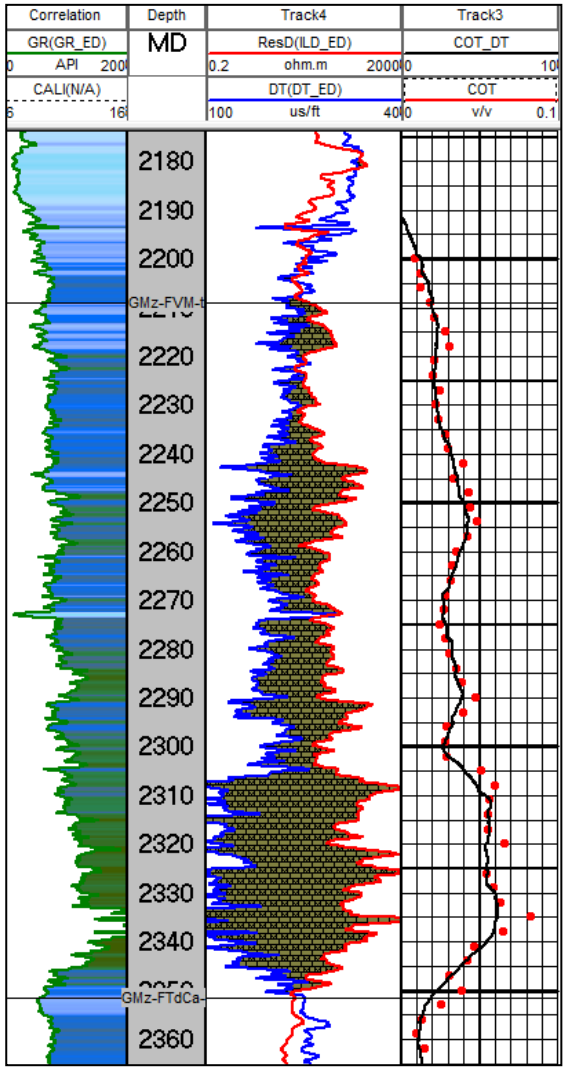
From Nanopore to Seismic Scale - DT/TOC correlation



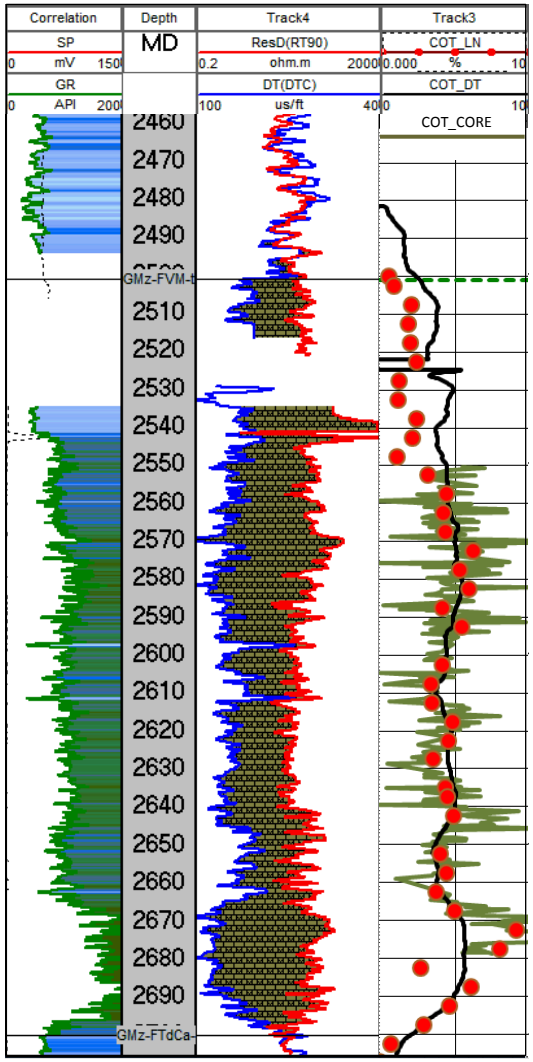
APo.x-1001

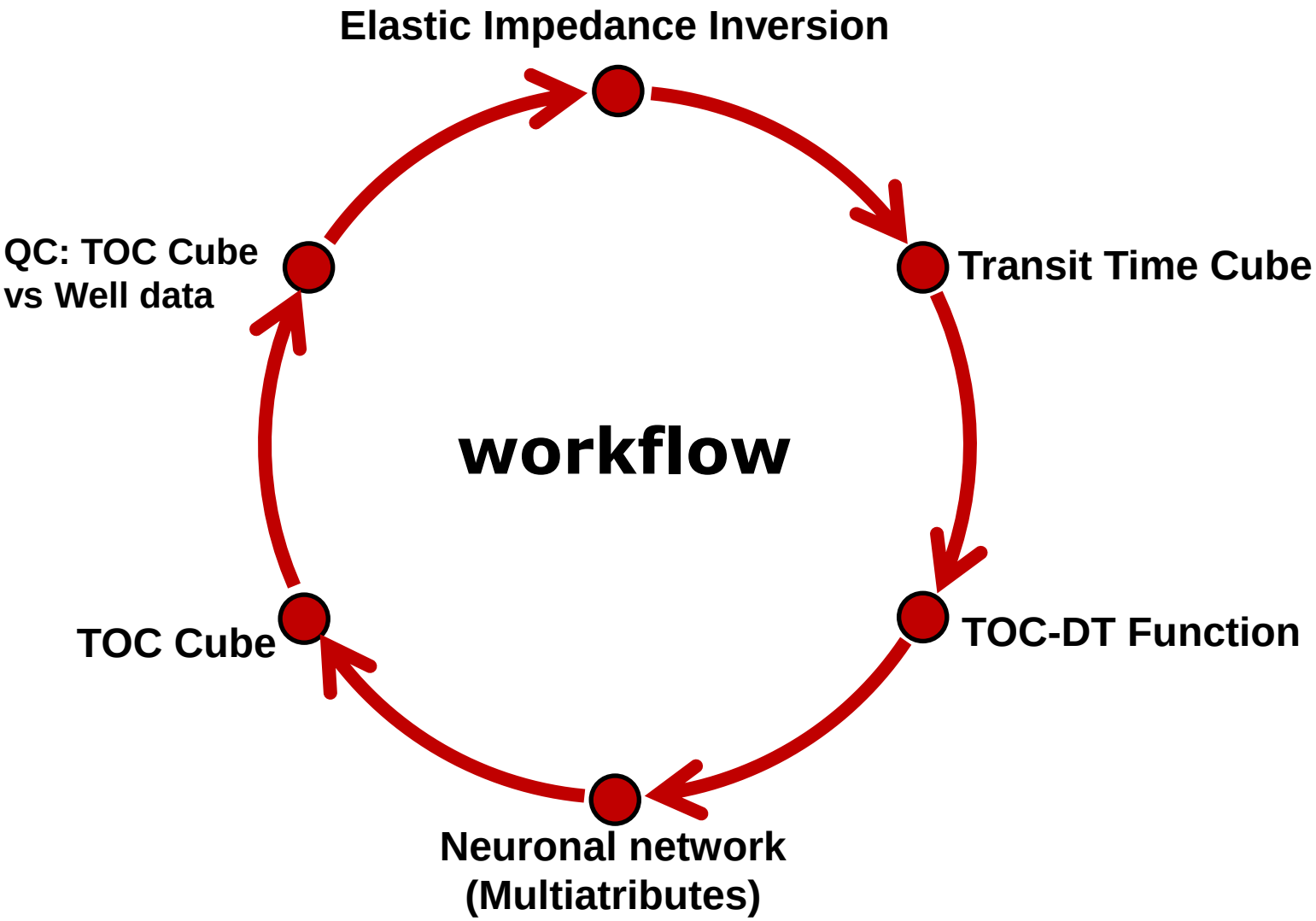


EC-27

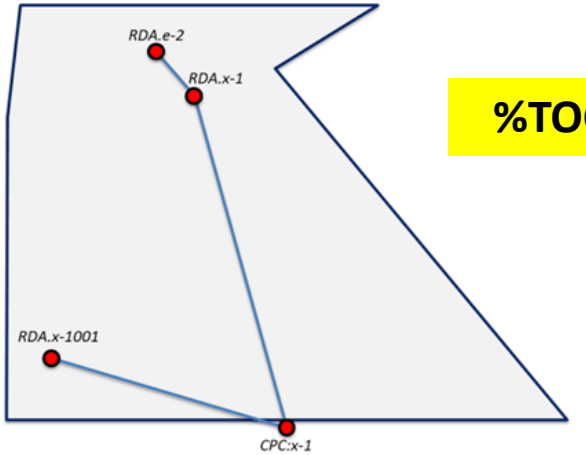


RDA.X-1001

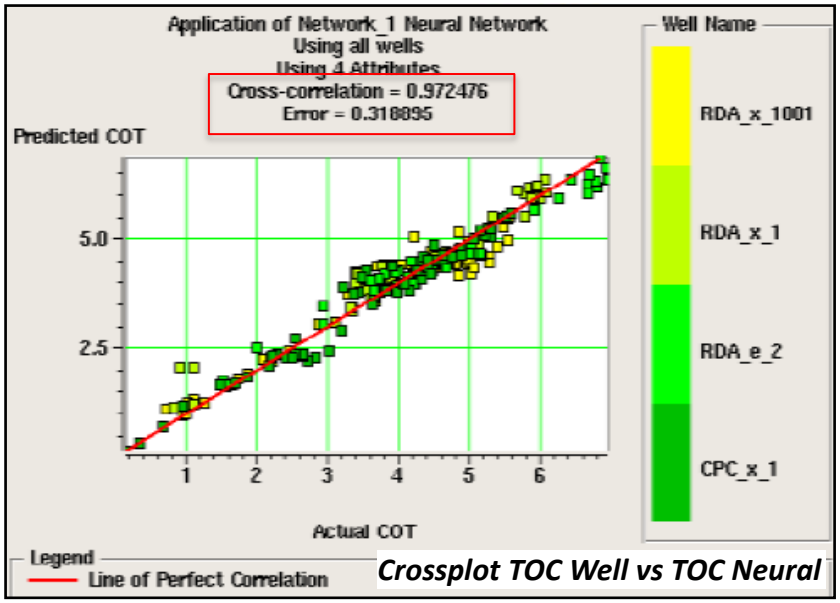



Elastic Impedance Inversion
Transit Time Cube
TOC-DT Function
Neuronal network
(Multiatributes)
TOC Cube
QC: TOC Cube
vs Well data
workflow

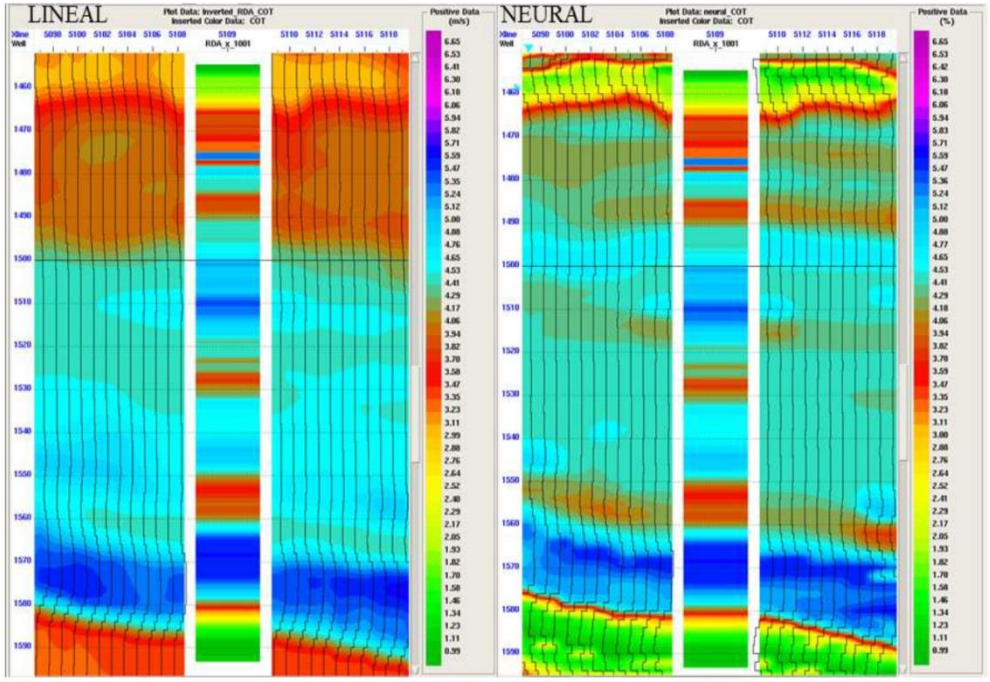
From Nanopore to Seismic Scale - TOC Cube



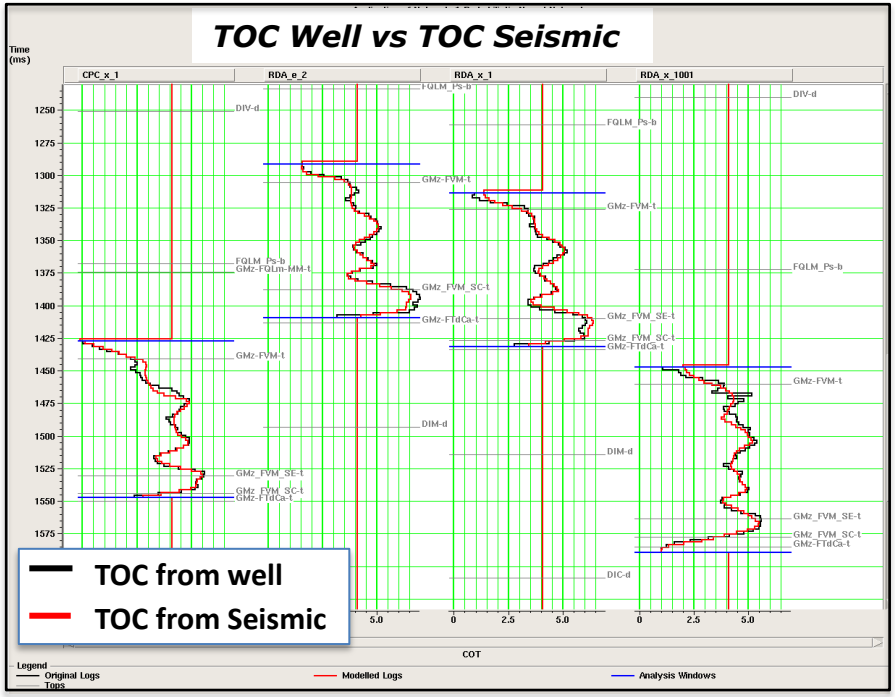
%TOC = (0,16*TT) - 9,6



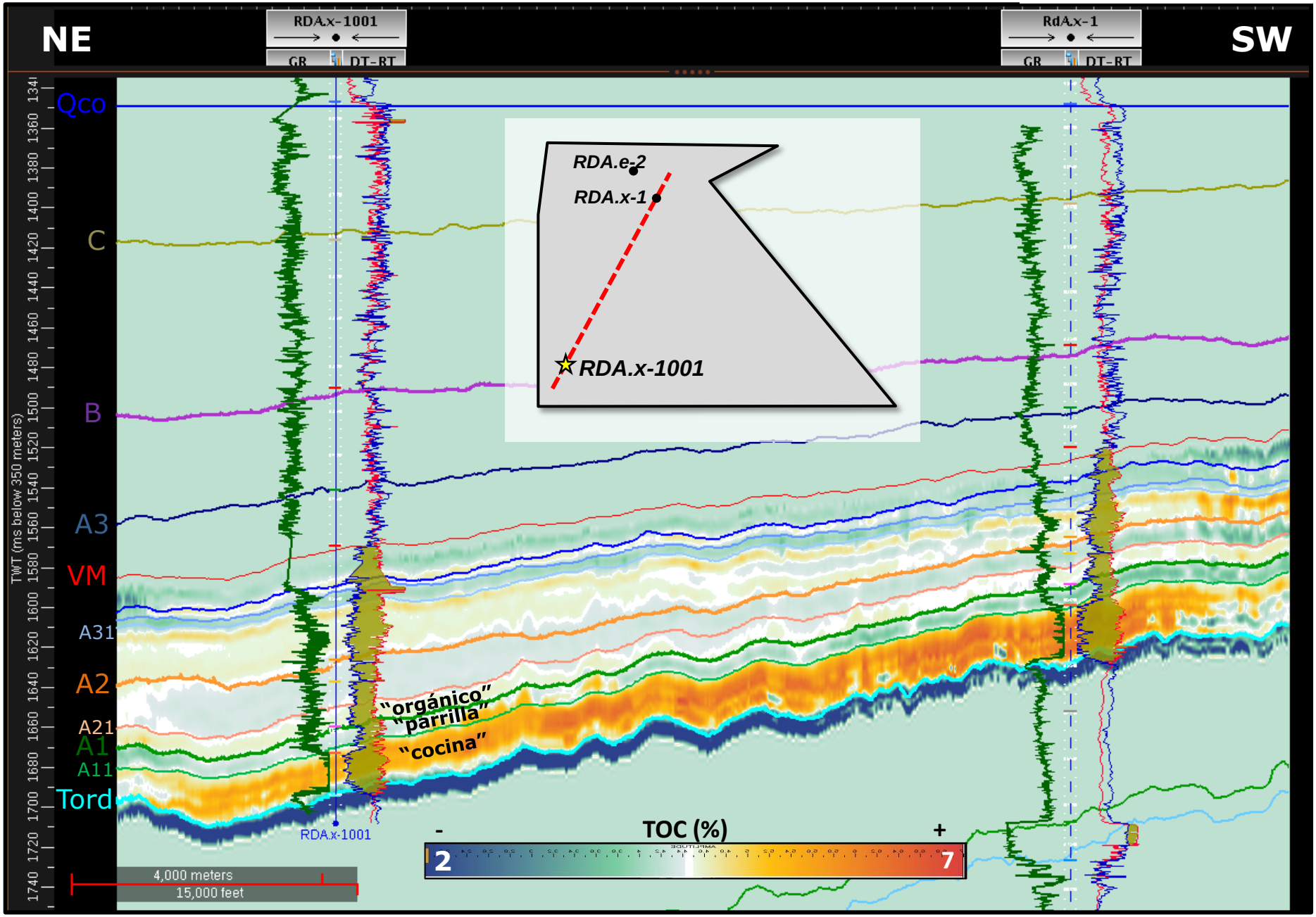
Crossplot TOC Well vs TOC Neural



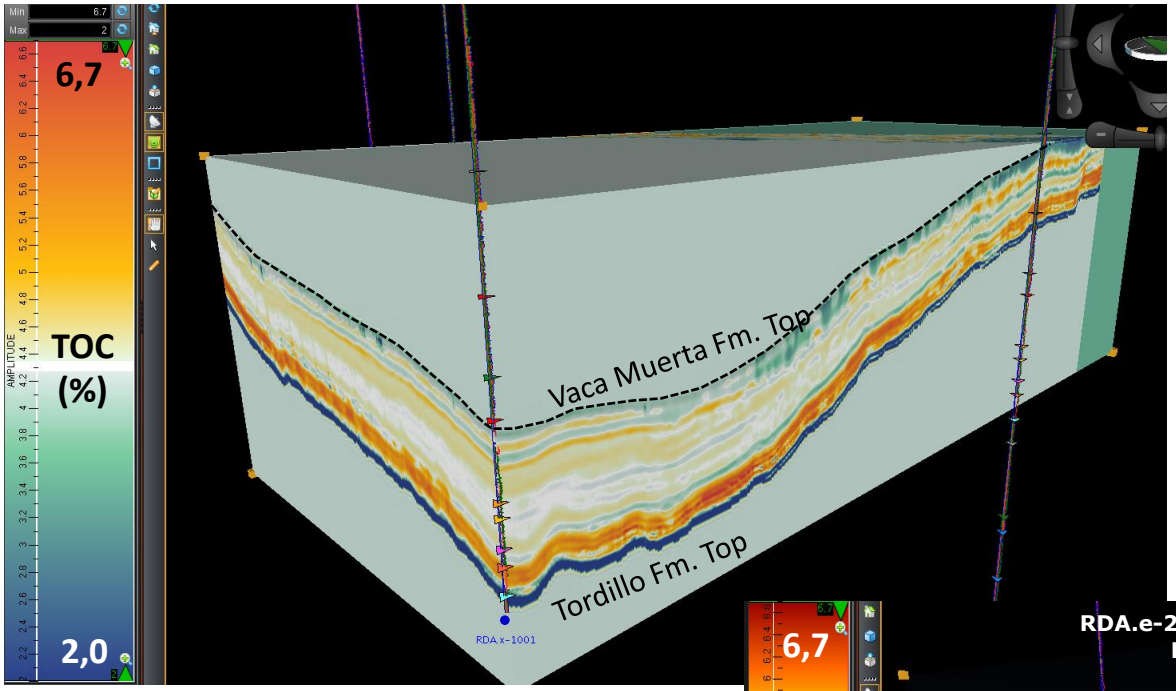
TOC Cube: Lineal vs Neural

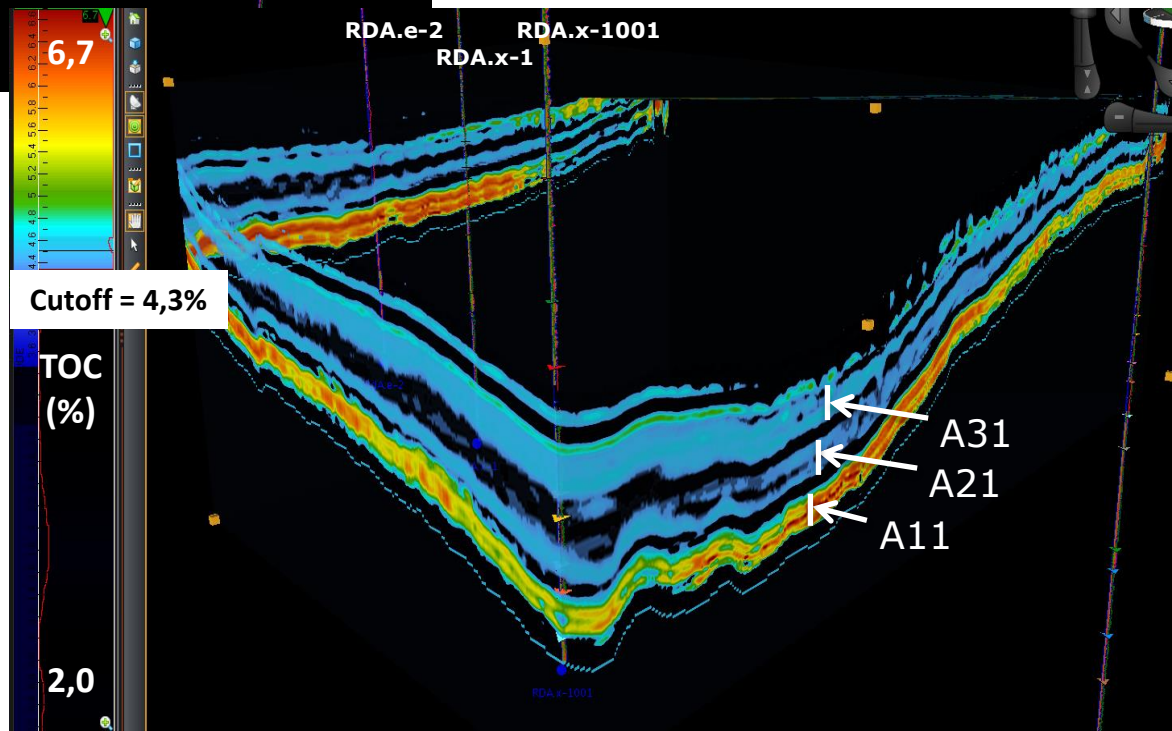


From Nanopore to Seismic Scale - TOC Cube

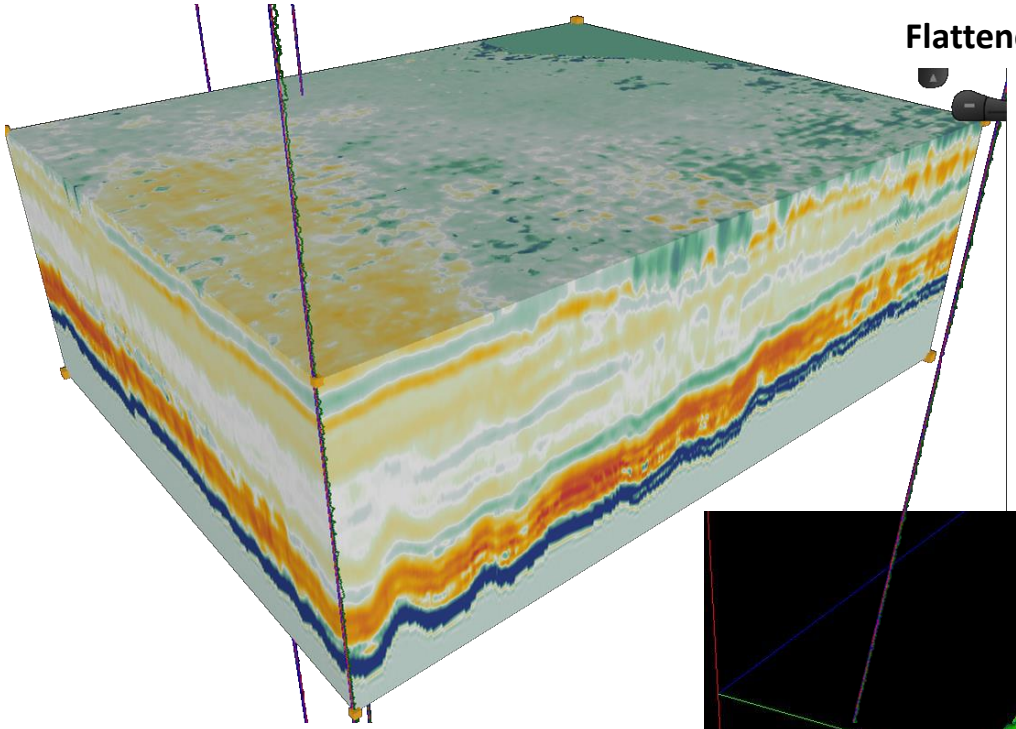


From Nanopore to Seismic Scale - TOC Cube



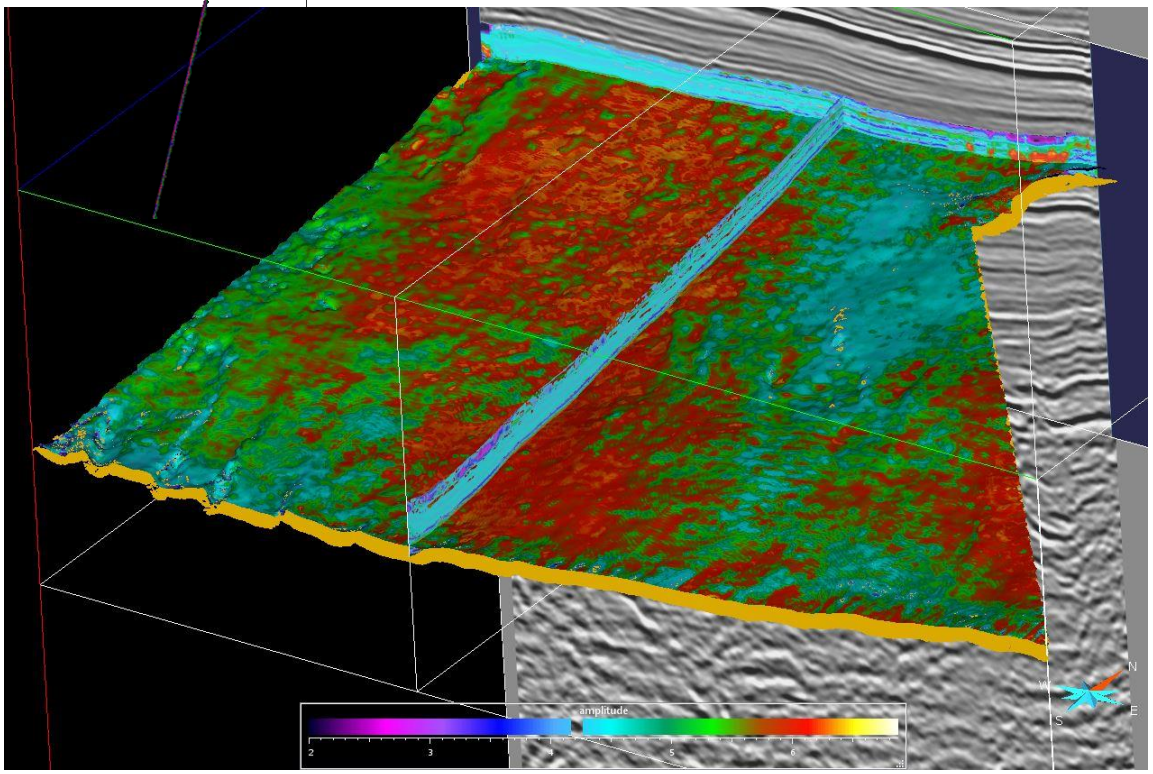


From Nanopore to Seismic Scale - TOC Cube

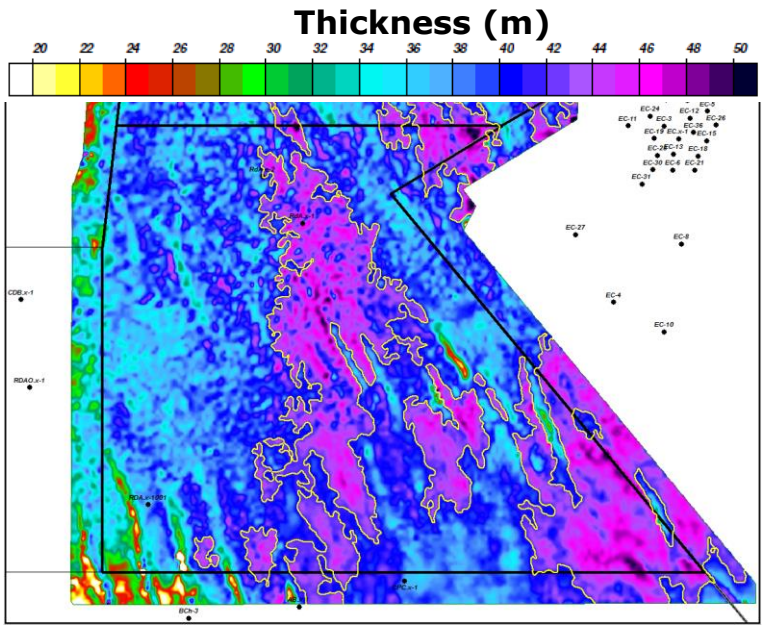


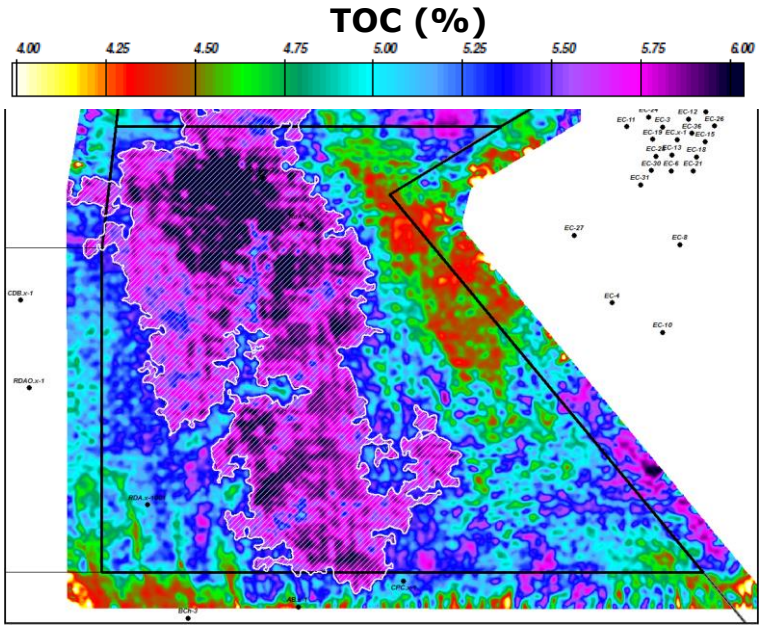
Flattened to Vaca Muerta Fm. Top

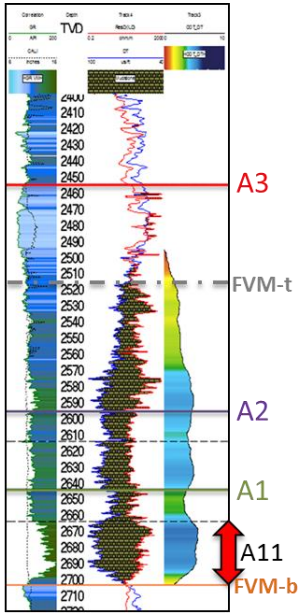
Horizon slice at top A11

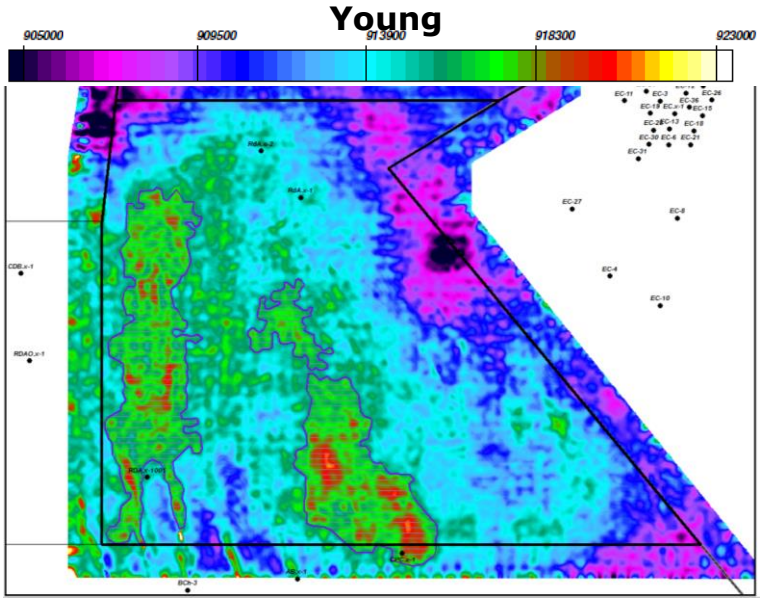


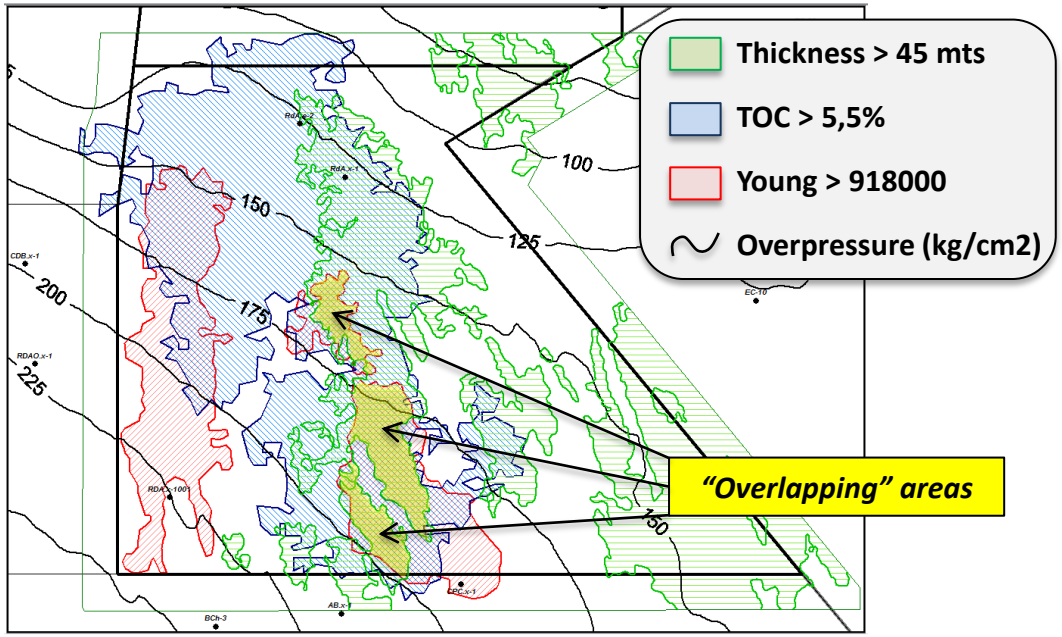
From Nanopore to Seismic Scale - Sweet Spot by Secuence: A11 ("La Cocina")











- Production
  - **Linked to high TOC zones**

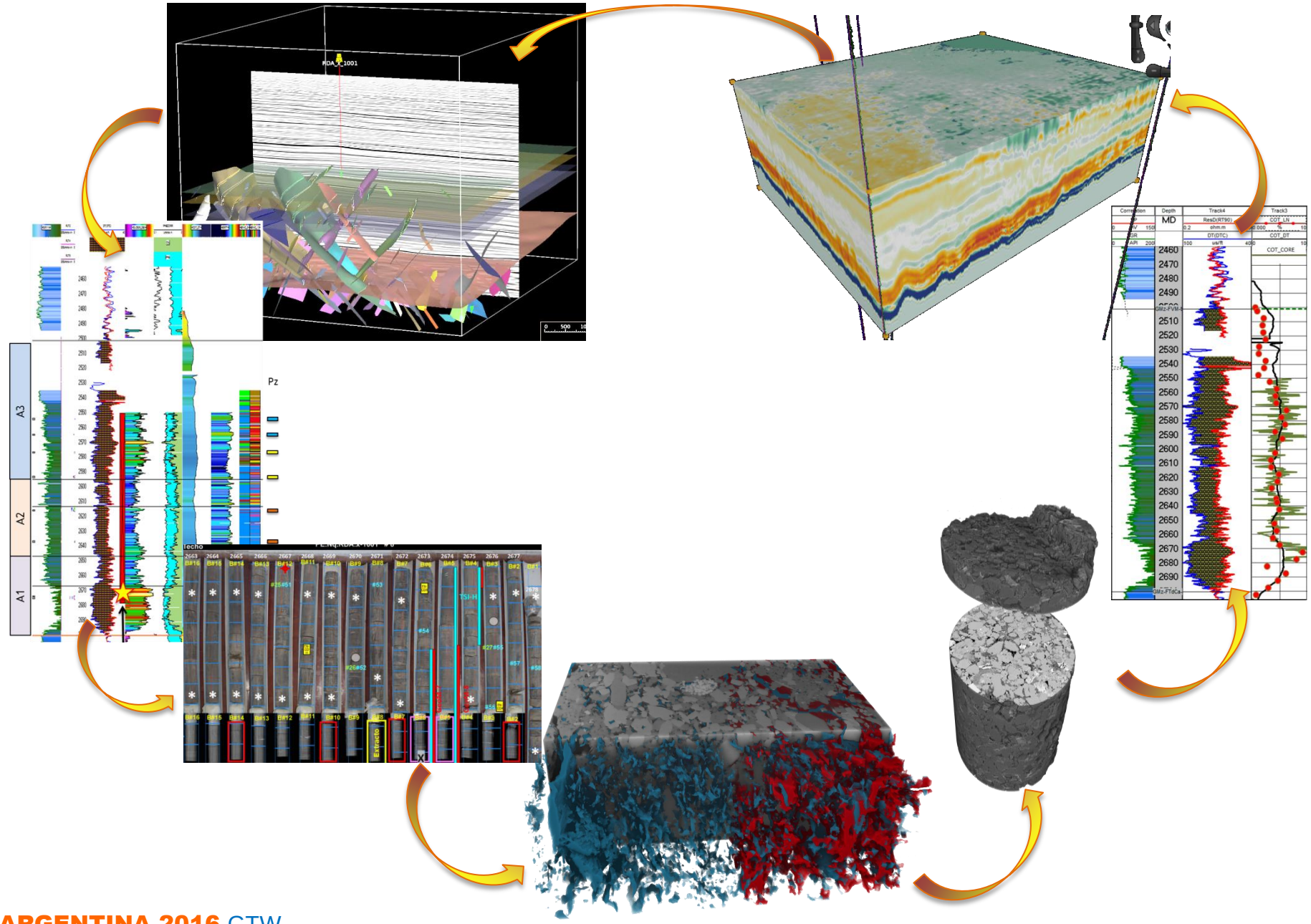
- 3D mapping of porosity and OM
  - **Porosity mainly associated with expulsion cracks in the OM**

- 3D map of Oil in place
  - **Oil strongly associated with OM**

- Upscaling
  - **Properties obtained from FIBSEM upscaled to sub-plug**
  - **Driver upscaled from core/well to seismic: TOC Cube**

- G&G Sweet Spot:
  - **Defining/Refining objectives based on OM distribution**

From Nanopore to Seismic Scale - Conclusions



Thanks to Pampa Energía y Total Austral for permiting publishing these results