



Computer Aided Modeling for Reservoir Characteristics Measurement

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Introduction

Reservoir characteristics measurement such as wettability is fundamental for the understanding of multiphase flow in reservoir systems.

Recent growing of high resolution laser micro computed tomography images and development of geometrical algorithms has provided certain tools in Computer Aided Modeling for Reservoir Characteristics Measurements.

We will introduce a new method for measurement of reservoir parameters by developing new algorithms in computational geometry and using accurate and sensitive MCT scanner.

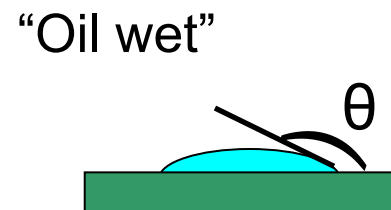
Wettability

- Determination of rocks wettability is fundamental for the understanding of multiphase flow in reservoir systems such as:
 - Oil migration from source rocks
 - Primary production mechanisms
 - Enhanced oil recovery processes

Wettability

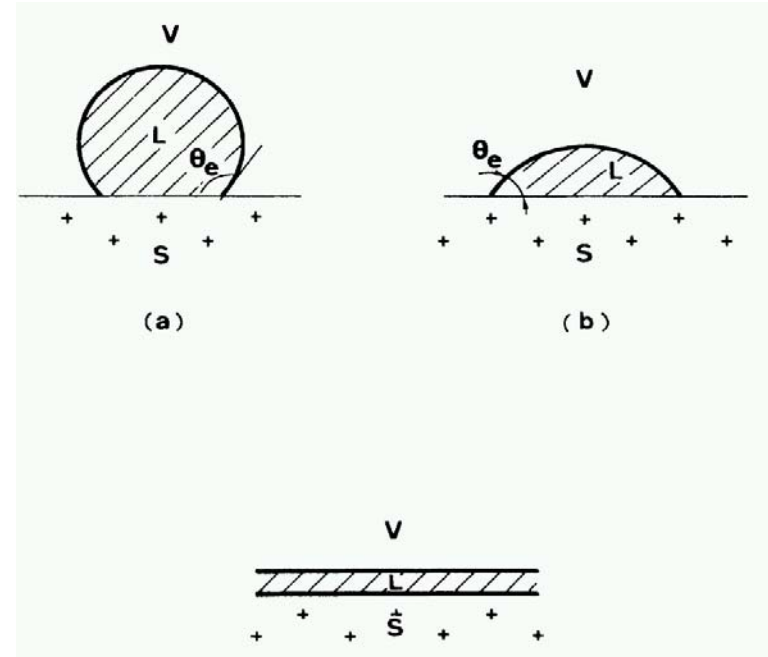
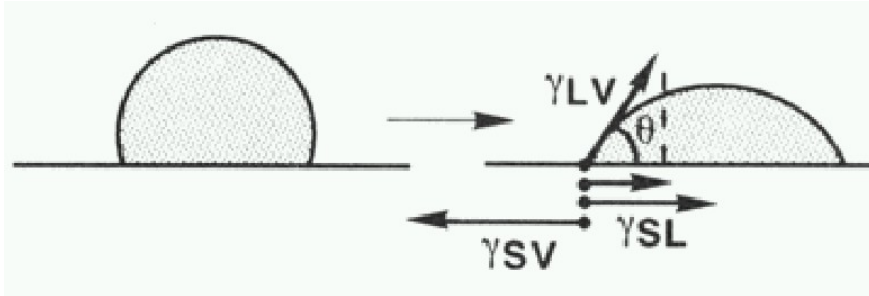
General concepts

The wettability of a liquid is defined as the contact angle between a droplet of the liquid in thermal equilibrium on a horizontal surface. It is a measure of which fluid preferentially adheres to the rock. Depending on the type of surface and liquid the droplet may take a variety of shapes as illustrated below.



The angle θ measured through the water, is called the contact angle. If $\theta < 90^\circ$ the reservoir rock is described as being water wet, whereas if $\theta > 90^\circ$ it is oil wet.

Wetting and Contact Angles



Young equation:

$$\gamma_{SV} - \gamma_{SL} - \gamma_{LV} \cos(\theta_e) = 0$$

$$\theta_e = \cos^{-1} \left(\frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}} \right)$$

partial wetting: $\theta_e > 0$
 complete wetting: $\theta_e = 0$

- Assumes thermodynamic equilibrium
- Surface roughness can effect measurements
- Assumes surface is homogenous and non-reactive

Modeling

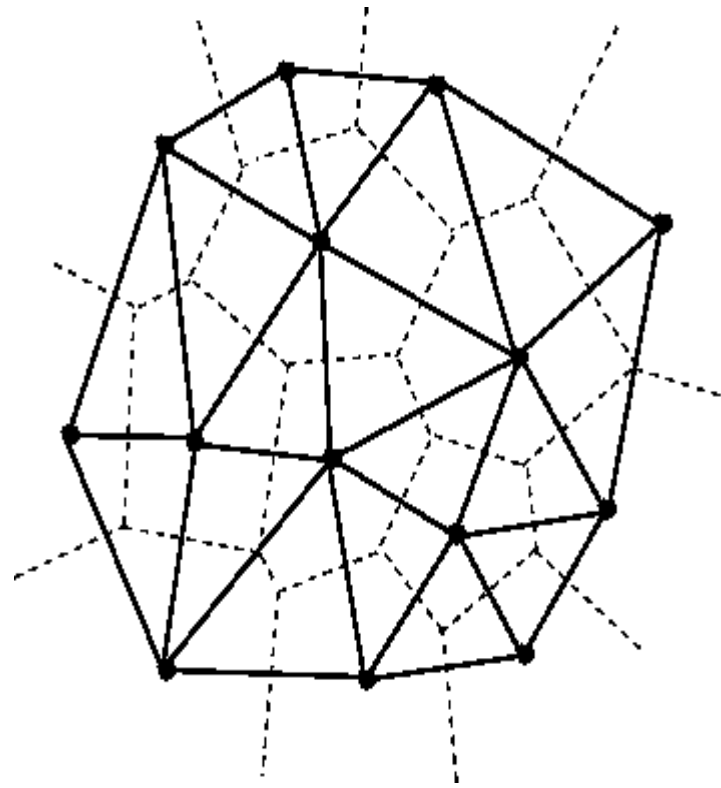
- **Contact Angle Algorithm**

An algorithm to approximate contact angles.

- **Triangulated Surface Algorithm**

A geometric algorithm to approximate surface by triangular interpolation mesh to use Computer-Aided Geometric Design.

Triangulated Surface Algorithm



- An algorithm of $O(n \lg n)$ developed
- New methods for accuracy considered

Software Development

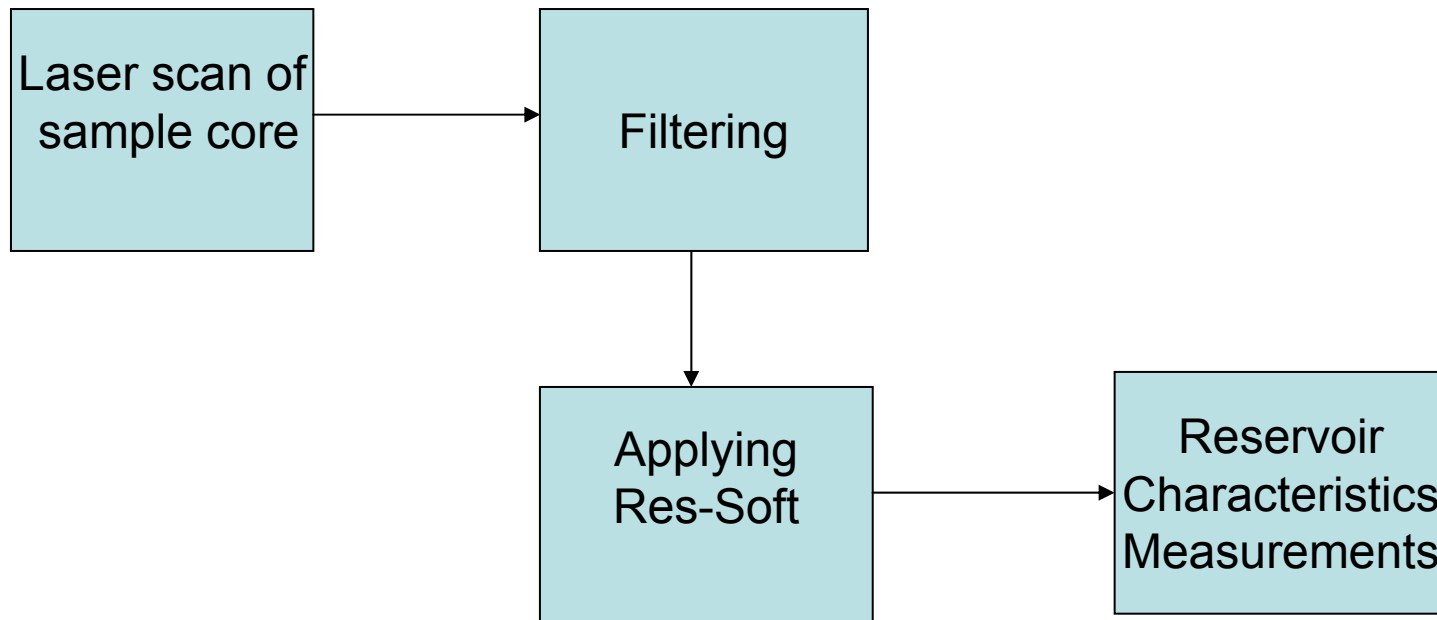
Software development through Open Source tools such as:

- GTS Library
- ITK tool kit

Using surface representations based on triangular grids to develop the **Res-Soft** software.

Wettability measurement of the core by using density measurement.

Methodology



Pilot Project

- A core sample was provided by NIOC. The core sample was used for the analysis in details.
- The major line of the study was to review and evaluate the following:
 - **DISTRIBUTION OF PORES**
 - **DISTRIBUTION OF OIL AND PORES**
 - **PORE RAY DISTRIBUTION CURVE**
 - **PORE VALUE CALCULATION**
 - **WETTABILITY OF THE CORE**

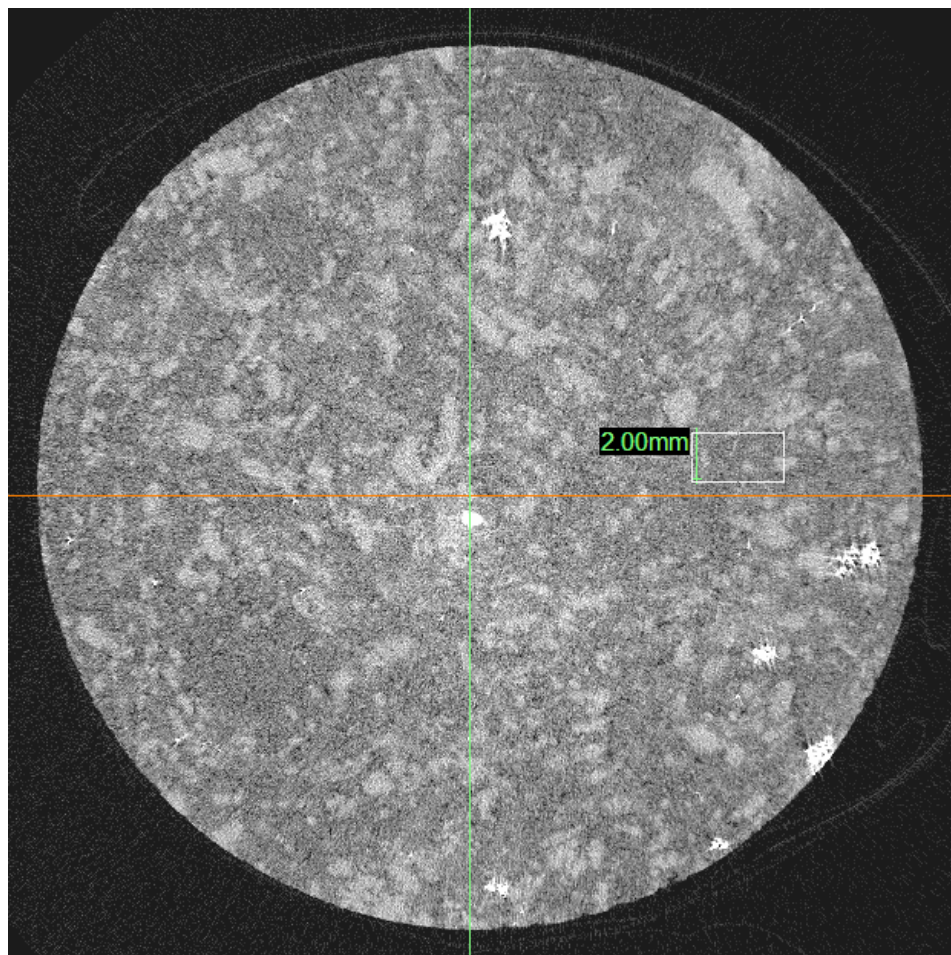
Overview

- A micro computerized tomography (MCT) imaging method is used with accuracy of 4 to 5 μm . (Micron) to detect very fine and accurate images of the core provided by NIOC. The software is used to configure and assemble the images very accurately and to derive 3D images of the layers of the pore to analyze exact position of the available samples, fractures, fillings and impurities within the core, and overall potential of the core.
- The core sample provided was 5cm long and 4cm diameter, the CT scanning was carried out to provide a Matrix of
4000 x 4000 (= 160,000 Pixels).
Each layer includes 160,000 Pixels

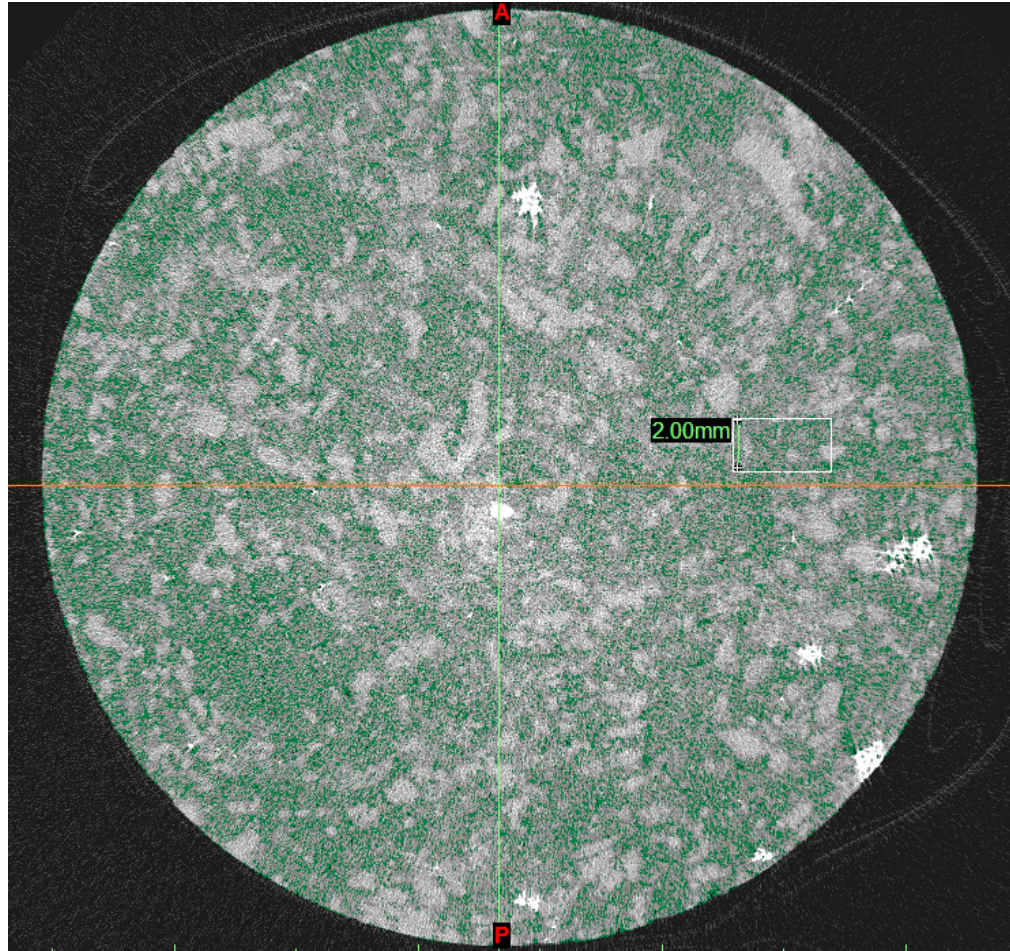
Results

- Import MCT Scan data to software and define different masks for different materials based on different thresholds.

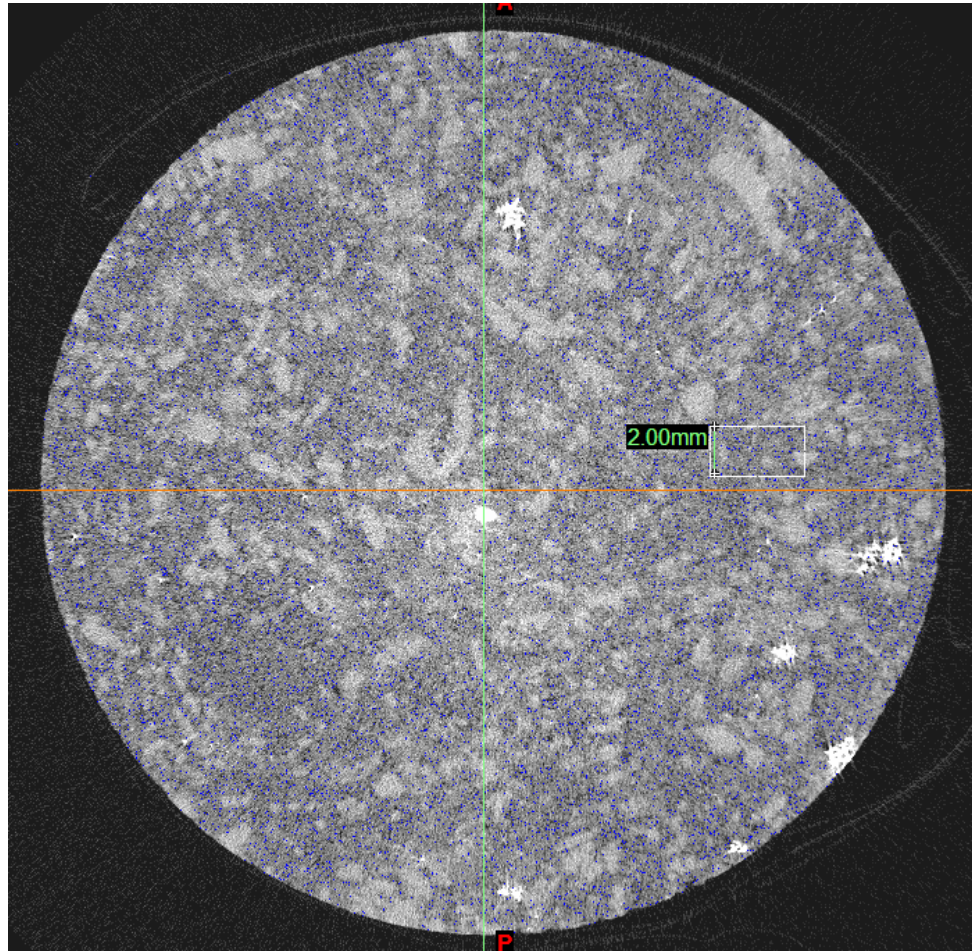
Results



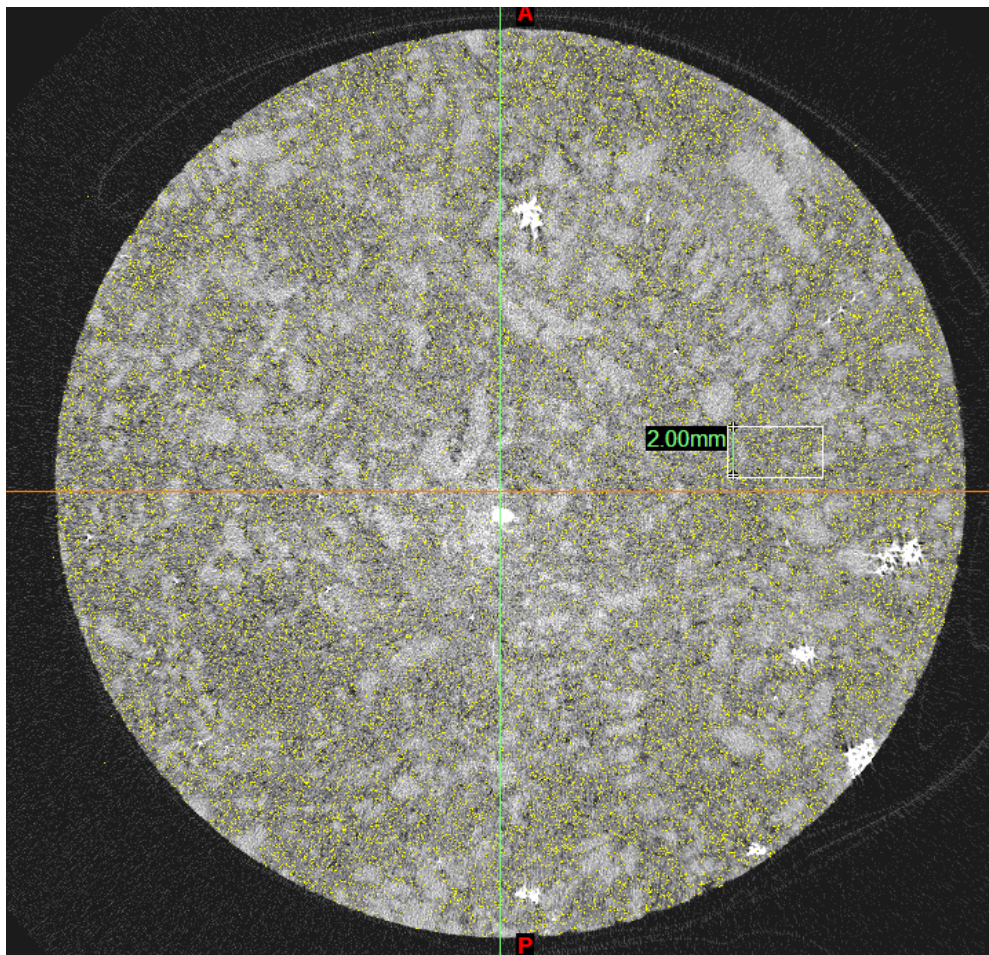
Light Oil Mask



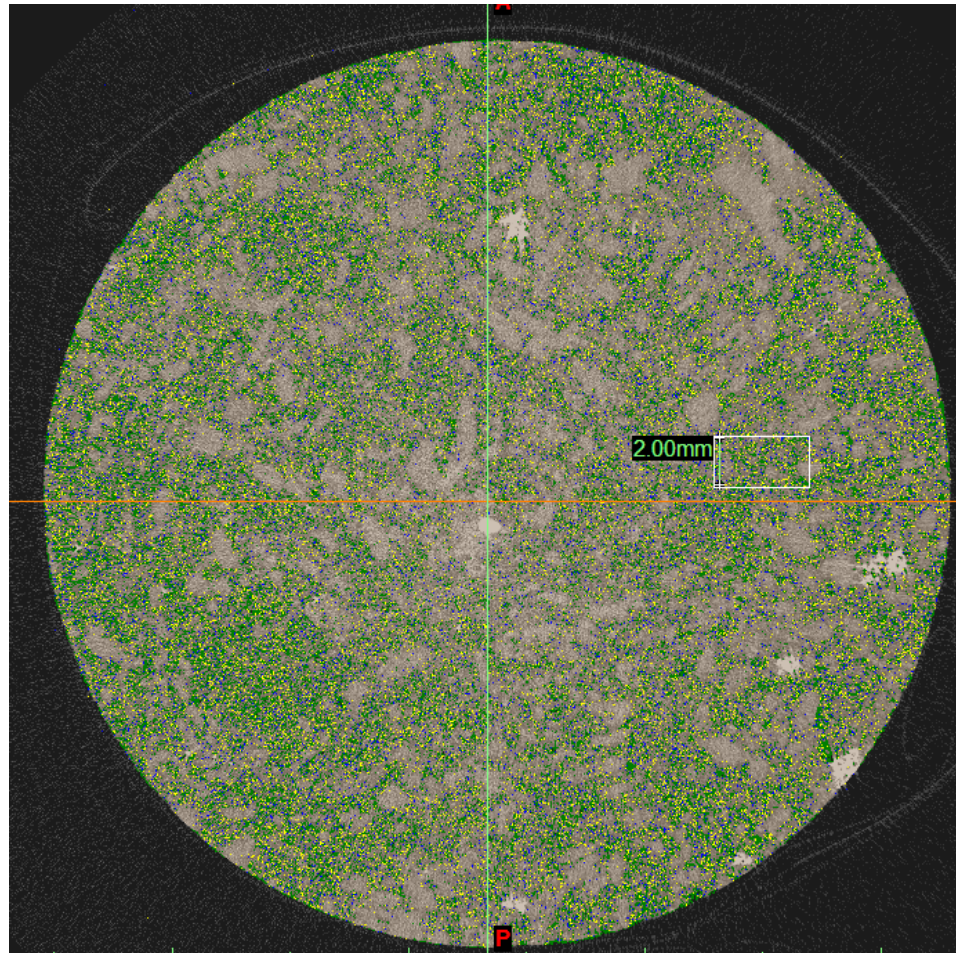
Water Mask



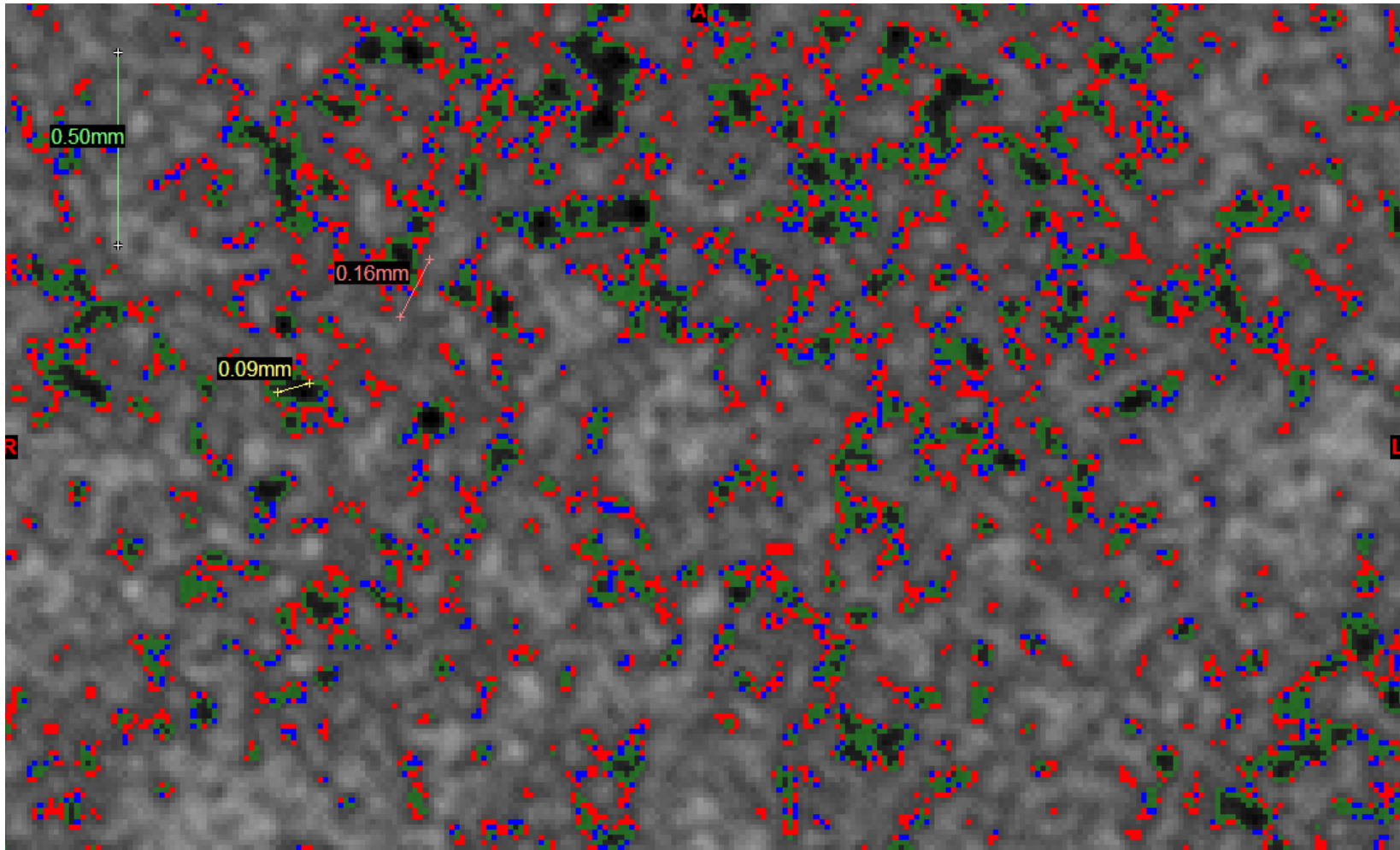
Oil Mask



Stone + Light Oil + Heavy Oil + Water Masks

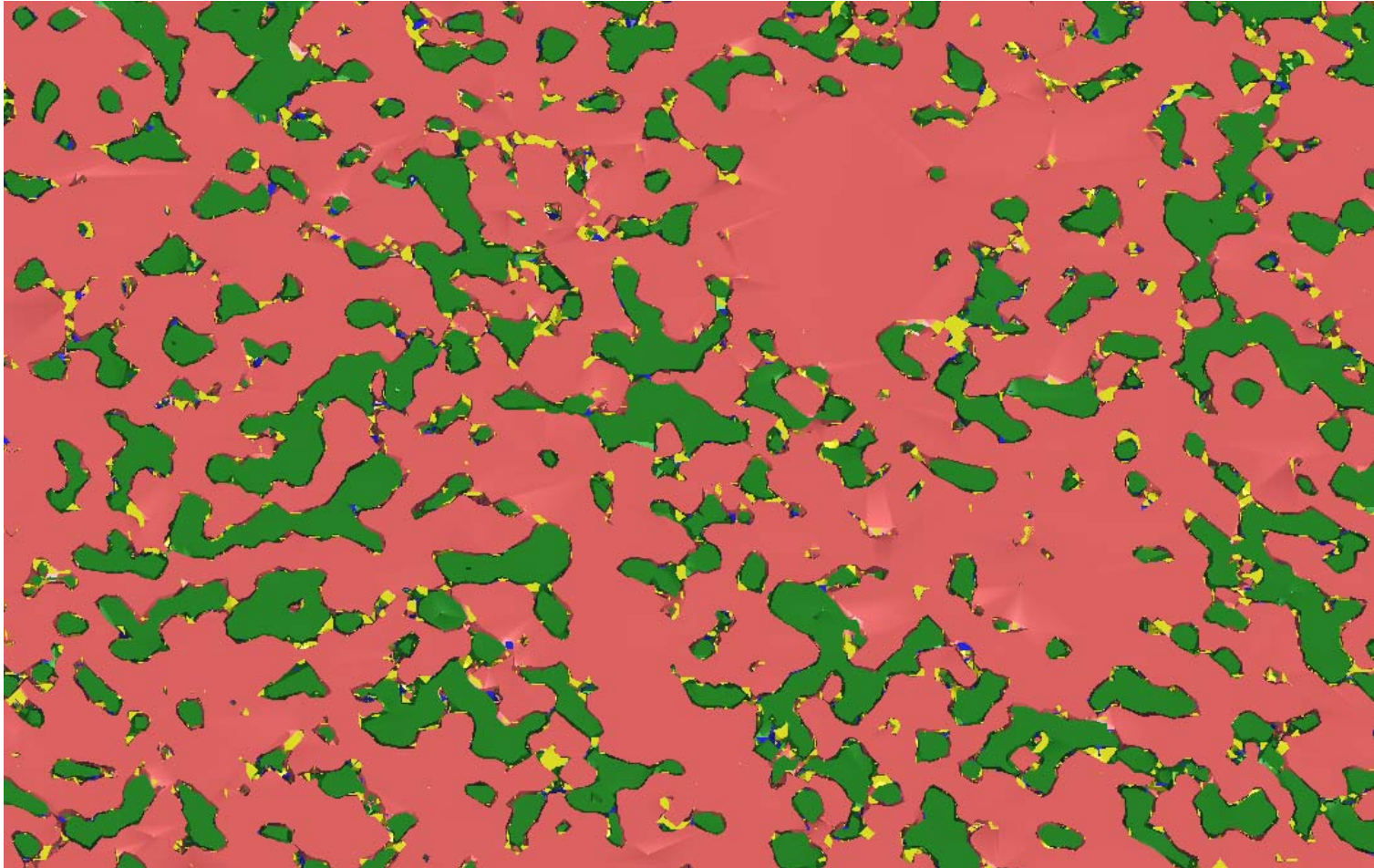


Stone + Light Oil + Heavy Oil + Water + Gas



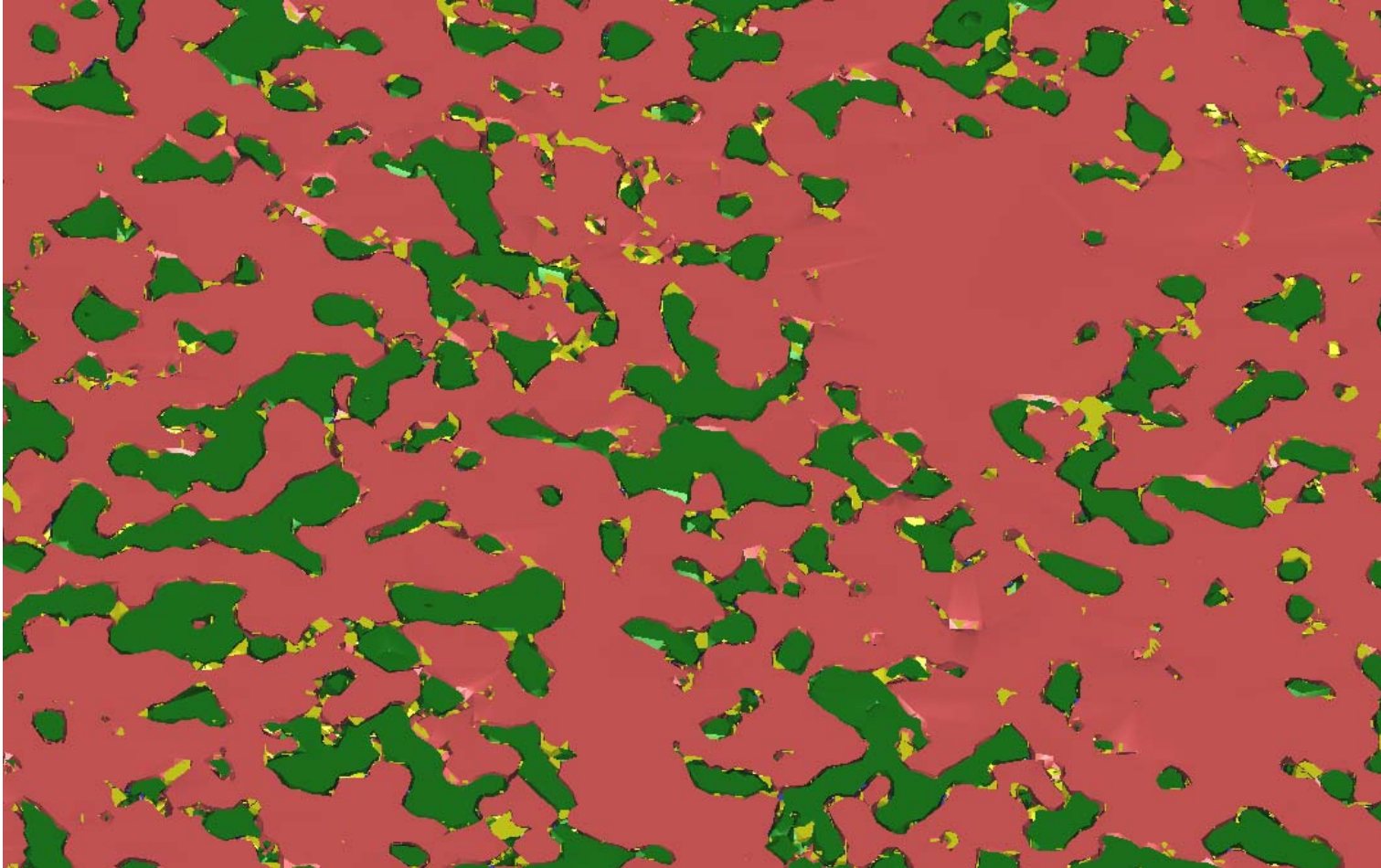
3D Model

Stone + Light Oil + Heavy Oil + Water



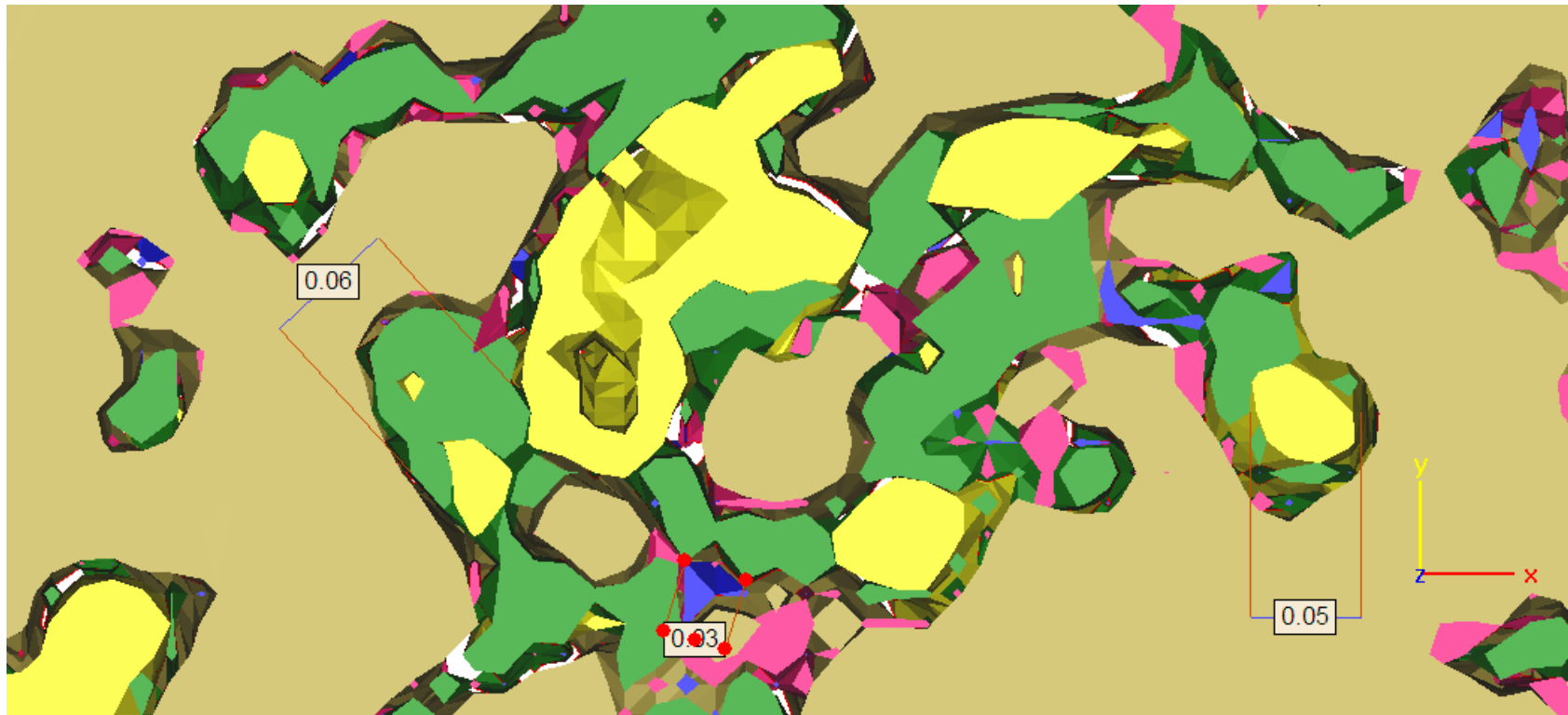
3D Model

Stone + Light Oil + Heavy Oil



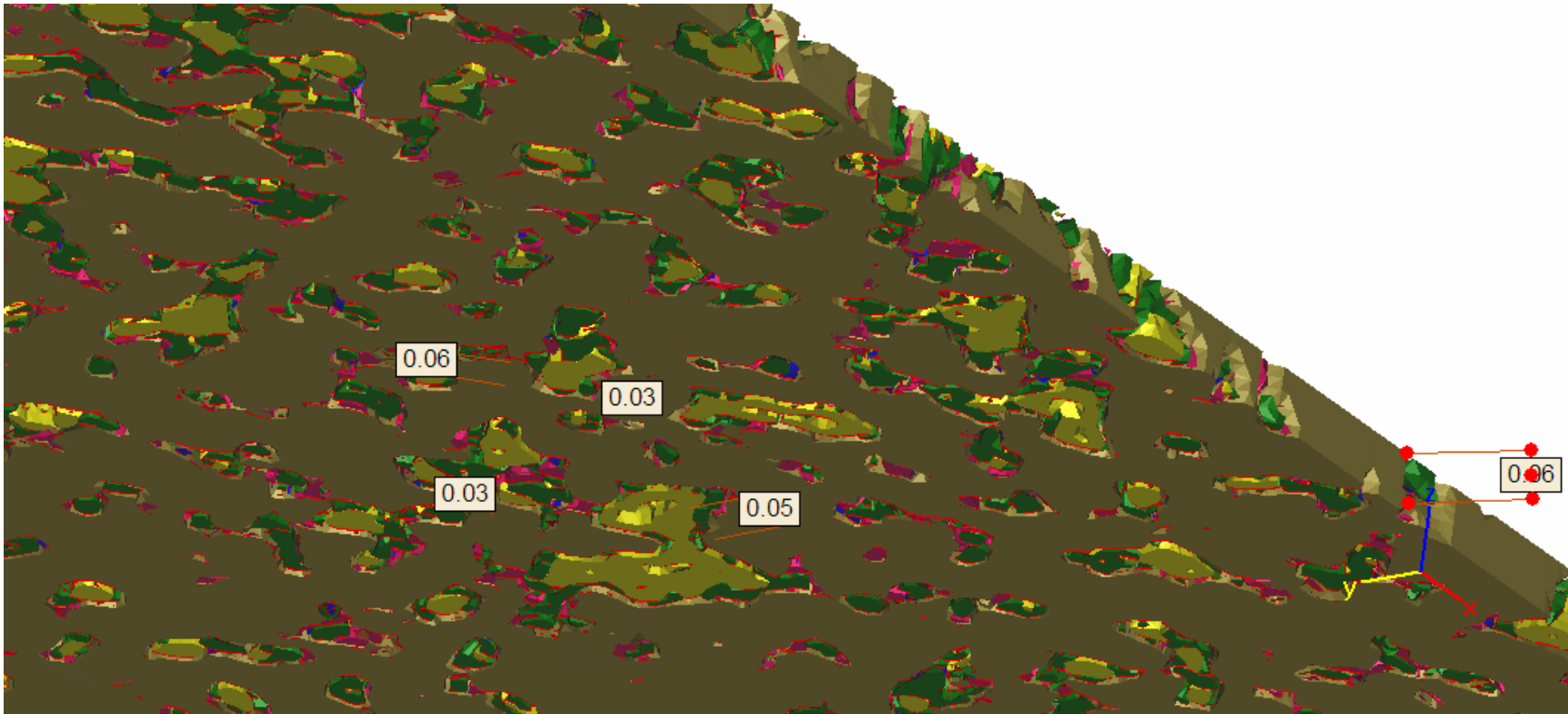
3D Model

Stone + Light Oil + Heavy Oil+ Gas

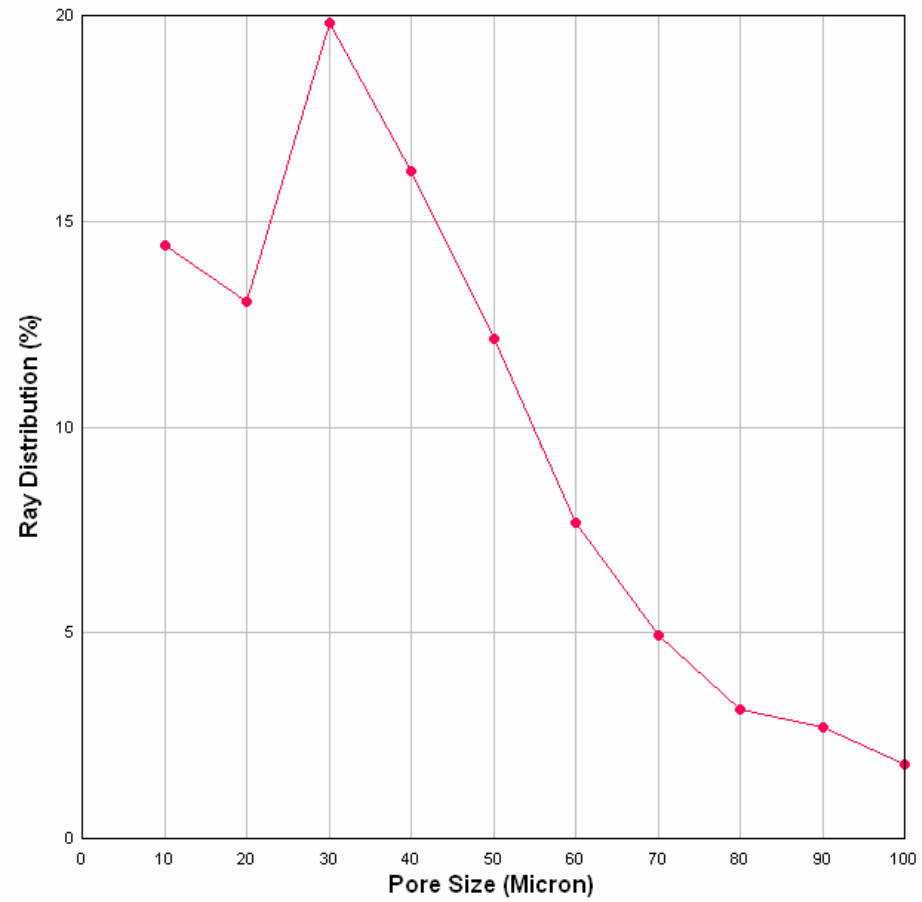


3D Model

Stone + Light Oil + Heavy Oil+ Gas



Distribution Curve



Distribution of pores

Pore Size Volume (Micron ³)	Percentage (%)
0 -10	14.40
10 – 20	13.05
15 -20	8.1
20 – 30	19.81
30 – 40	16.21
40 – 50	12.16
50 – 60	7.66
60 – 70	4.95
70 – 80	3.15
80 – 90	2.7
90 – 100	1.8

Distribution of oil pores

Oil Pore Size Volume (Micron ³)	Percentage (%)
0 -10	14.90
10 – 20	22.8
20 – 30	25.5
30 – 40	12.6
40 – 50	7.3
50 – 60	5.0
60 – 70	3.3
70 – 80	2.6
80 – 90	2.0
90 – 100	1.3

Conclusion

- The ultimate aim of this study was to find out the wettability pore spaces of the rock core sample provided.
- Our study is to provide strength and feasibility of new computer aided innovation procedure using micro CT scan services to point out exact properties of gas, water, and oil present within core sample.
- It is important to note that our study is not based on calculating the porosity of core sample to find out wettability as a variable parameter of porosity, but what our research results show that it is possible to calculate directly the exact amount and the exact location of each of the constituents and inclusions within the reservoir rock including gas, water and oil.

Advantage

Computer Aided Modeling of Reservoir Characteristics implicates the following:

- Reliability
- High-Speed
- Precision
- Cost Effective
- 3D Visualization Efficiency
- Cross Section Visualization

Future Plan

- Reservoir Characteristics Lab:
Based on Computer Aided Modeling for reservoir parameters measurement
 - Developing Model
 - Developing Software
 - Providing Infra Structure
 - Linux Cluster, and Network
 - Advanced Laser Micro Scanner
 - Developing Business Model