Fracture Visualization and Quantification Using Helical CT Scan Technology*

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Abstract

Fracture characteristics—such as orientation, type, fluid storage capability, and permeability—are complex yet essential information for understanding fractured reservoirs. Fractures are often perceived as permeable pathways, although many fractures partially or completely inhibit permeability within a reservoir. For example, opening-mode fractures (joints) may be partially or entirely sealed hindering flow along and/or across the joint plane. Mineral-fill percentage can be modeled using aperture and mineral-fill threshold data obtained from surrounding fractures and matrix, yet this is difficult to model for calcite, a common fracture-fill material.

Fracture data obtained from core and image logs provides a direct test to structural and geomechanical models and reduces prediction errors for fracture orientation, type, and aperture. The ability to visualize fractures and fracture networks on a variety of scales is essential for an interpreter to predict these properties.

Advances in computerized tomography (CT) technology in the medical industry has made 3D core imaging possible, opening up new opportunities for visualizing and quantifying complex fracture systems. Helical CT scanning (HCT) technology allows a user to model fracture attributes while preserving the integrity of valuable core samples. The use of HCT for fracture quantification and visualization greatly improves the understanding of the characteristics and behavior of dominant fracture sets within a fractured reservoir.

Introduction

The data for this study was obtained using a third generation Toshiba 64-slice medical (helical or spiral) CT scanner modified to scan rock samples ranging from plugs to 3-foot sections of whole core. The x-ray source and detectors in the scanner are located on opposite sides of a circular gantry, which rotates around the sample as it moves through the scanner. Each 360° rotation captures 64 slices of CT data, with a slice thickness of 0.5mm. Approximately 3,200 axial slices are obtained for a 3-foot section of core. The data from the scanner provides a 3D distribution of X-ray attenuation values (Hu), with a maximum voxel resolution of .28x.28x.30mm.

The 3D dataset is then imported into Avizo® Fire software package for 3D materials analysis. Fractures within the CT dataset are first isolated from the host rock using the Avizo® software. Voxels are then identified as either mineral-fill (represented by relatively high CT numbers) or pore space (represented by relatively low CT numbers) using a combination of manual and automated selection tools to accurately partition the fracture components.

Once the fracture components have been identified, mineral-fill and pore space volumes are used to calculate a representative porosity percentage within a fracture set to be used in fracture models. These calculations are made using the materials statistics tools in Avizo® Fire. Pore space and mineral-fill can also be displayed within the 3D model of the core to provide a visual representation of the fracture.

Discussion and Results

This method was tested on a highly fractured network of anastomosing, opening-mode, vertical fractures from the Cretaceous Niobrara Formation from the CEMEX Quarry near Lyons, Colorado (Figure 1). Fracture apertures range from 0.05 to 20.00 mm, partially or fully mineralized with euhedral calcite. Volume modeling was conducted on three fractures within the sample with median kinematic apertures ranging from 4.0 to 6.6 mm (Figure 2).

Preliminary results suggest that substantial porosity preservation occurs at or above kinematic apertures of ~1.6 to 2.0 mm. Further analysis measuring kinematic aperture and pore width over 30 slices was conducted to determine the ratio of pore volume to fracture cement and to relate this ratio to kinematic aperture. Preliminary results show a linear relationship between kinematic aperture and pore width. A logarithmic relationship exists between the ratio of fracture porosity and kinematic aperture, with fracture porosity peaking at 70% in a fracture with a 2.6 mm kinematic aperture.

Summary

This preliminary study illustrates the use of HCT scanning technology as an effective way to quantify mineral-fill percentages in fractures in conventional core. This method also provides a way for interpreters to visualize fractures as three-dimensional structures with distinct zones of mineral-fill and porosity. Current research objectives include the use of HCT to map cement bridges and define pore geometry within fractures. Additional potential exists to incorporate data from µCT to image smaller-scale features within large fractures and to image smaller aperture fractures, such as hairline fractures.

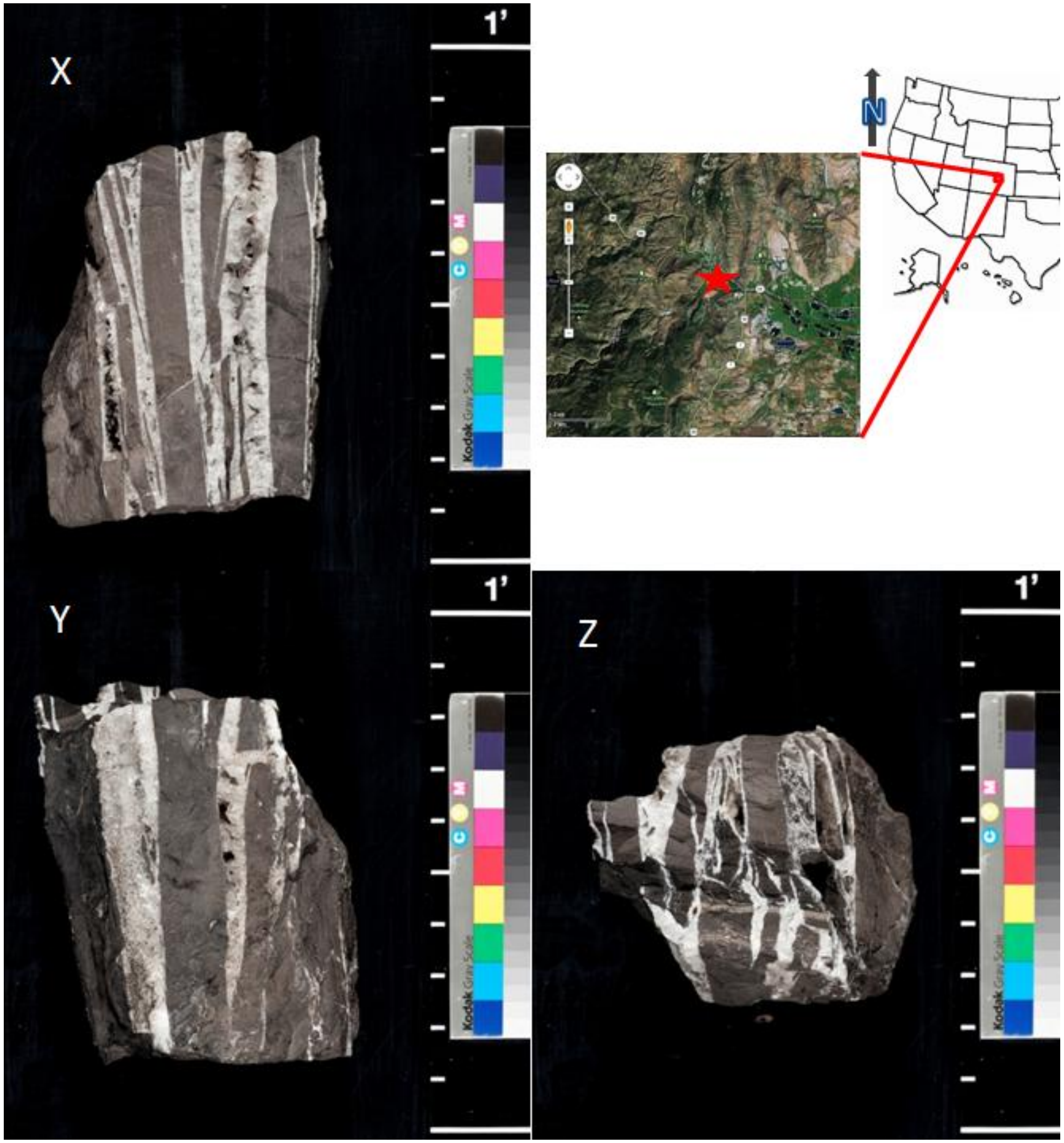

Figure 1. Sample area in the CEMEX quarry near Lyons, Colorado and three perspectives (X-axis, Y-axis, and Z-axis) of the fractured Cretaceous Niobrara Formation sample used in this study.

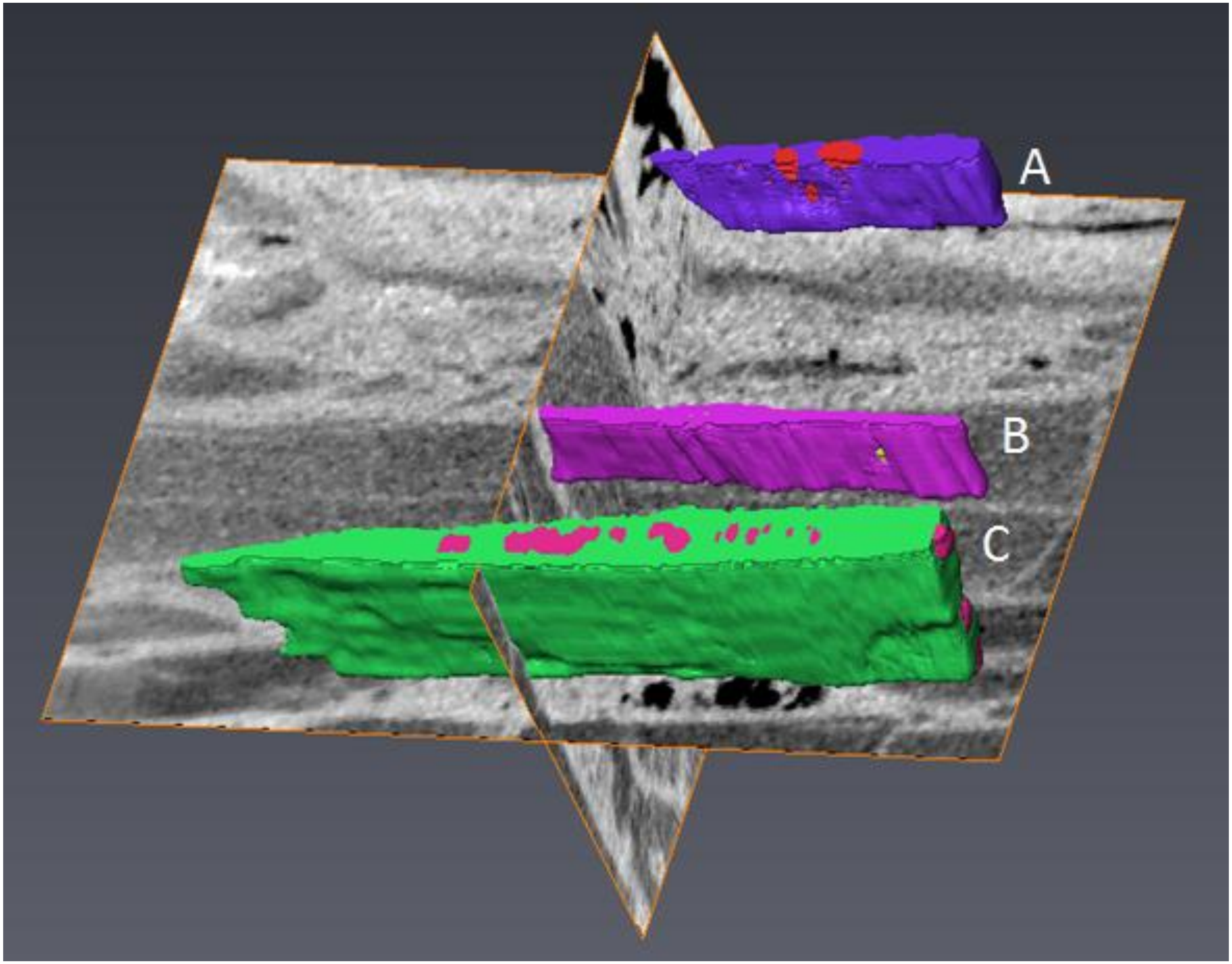

Figure 2. Three fractures in Avizo® Fire, volume modeled for porosity and calcite mineral-fill. A) Purple mineral-fill and red porosity, B) Pink mineral-fill and green porosity, and C) Green mineral-fill and pink porosity.