CULLEN
COLLEGE OF ENGINEERING
UNIVERSITY of HOUSTON

DOCTORAL DISSERTATION DEFENSE ANNOUNCEMENT

AT THE CULLEN COLLEGE OF ENGINEERING

Interpreting Nanoindentation
USING MACHINE LEARNING AND MODELING CAPILLARY PRESSURE IN SHALE

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Location: Bld9 Room 124

Zoom: TBA

Committee Chair:
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Abstract

As an organic-rich sedimentary formation, shale has a fine-grained structure with complex mineralogy and ultra-narrow pores. Its nano-size pores change the physical properties and fluid behavior of the formation. This dissertation addresses three major challenges of characterizing shale pertaining to fracture toughness, capillary pressure, and the Young–Laplace equation (YL). It proposes a machine-learning approach and a conceptual model for analyzing images and determining fracture length from nanoindentation. The imaged fractures of nanoindentations form complex patterns. This dissertation analyzes over 1,500 images to characterize fractures based on color intensity using K-means clustering, showing that creation of fracture is plausible when the applied load varies between 400 mN and 700 mN. The determined fracture toughness was found to be between 0.5 MPa.m$^{0.5}$ and 0.7 MPa.m$^{0.5}$, which is validated against the energy method for the studied shale.This dissertation also addresses the challenge of capturing capillary pressure in

shale using the Brooks–Corey and van Genuchten models. It analyzes the mercury injection capillary pressure measurements (MICPs) of US shales and demonstrates how the conventional models fail to capture the entry pressure and its trend. It then proposes an empirical double-log model to overcome the limitations of existing models. The proposed model not only honors non-zero entry pressure but also captures the trend more accurately, providing a simple yet significant advancement in the field. Moreover, this dissertation underscores the crucial effects of size-dependent (actual) contact angle and interfacial tension on interpreting capillary pressure measurements in shale using YL. It applies the actual properties to the MICPs of Bakken and Eagle Ford shale samples. It also shows that the actual properties are particularly significant when the throat radius is less than 10 nm. The conventional approach with fixed properties overestimates the pore–throat size from 5% to 18%, leading to a decrease in the interpreted throat radius from 10 nm to 2.5 nm. These findings highlight the necessity of considering actual properties in future studies.