From Rock To Digital: Unveiling Unconventional Reservoir Heterogeneity Through High-resolution Core Analysis And Machine Learning

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Objectives/Scope: The future of the oil and gas industry increasingly depends on digital transformation, which can revolutionize operations and enhance value. This study highlights digitization's critical role in improving core analysis workflows in Unconventional Mudstone Reservoir core by deriving high-resolution petrophysical properties, elemental compositions, and mineralogical maps. This advanced digital approach strengthens core-to-log correlation, accelerates analysis through automation, and ensures consistency while minimizing losses, reducing costs, and boosting workforce productivity.

Methods, Procedures, Process: We employed non-destructive core logging devices featuring advanced sensors such as natural and spectral gamma-ray, density, P-wave velocity, magnetic susceptibility, X-ray fluorescence, and hyperspectral imaging. Using both unsupervised and supervised machine learning algorithms, we classified rock types, enhanced log resolution, guided sample selection, and predicted various properties.

Results, Observations, Conclusions: Our high-resolution core logging results provide centimeter-scale resolution of petrophysical properties, elemental compositions, and mineralogical maps, allowing for precise classification of rock types and definition of stratigraphic zones. The results are then calibrated to the logs, revealing vertical variations with distinct properties, such as mineralogical differences (e.g., quartz-rich, carbonate-rich, and clay-rich zones), organic content (organic-rich versus organic-lean zones), porosity (high versus low), saturations (oil, gas, water), and mechanical behavior (brittle versus ductile zones). High-resolution core logging generates robust datasets across multiple wells, facilitating consistent geological analysis and comprehensive insights into reservoir characterization. Furthermore, various machine learning techniques and generative AI have been employed to enhance well log resolution, producing high-resolution properties from discrete measurements such as mineralogy, total organic carbon (TOC), porosity, permeability, and saturations with higher accuracy.

Novel/Additive Information: The use of high-resolution core logging and machine learning has transformed core analysis by significantly enhancing accuracy and efficiency. Hundreds of feet of core can be scanned weekly, with data processing completed in minutes, preserving valuable samples while providing essential physical insights. This workflow optimizes decision-making processes, representing a significant advancement in core analysis.