

AI-based NG-LFCS: a physics-informed hybrid deep learning framework for high-accuracy lithofacies classification

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Abstract:

Lithofacies classification in heterogeneous carbonate reservoirs remains constrained: raw one-dimensional logs under-represent multi-scale, non-stationary behaviour; well-wise validation is often absent—inviting cross-well leakage and over-optimism; facies-specific interpretability is rarely demonstrated; and deployment cost is seldom profiled. We address this gap with NG-LFCS, a physics-informed hybrid that projects multi-channel log segments (gamma ray, bulk density, neutron porosity, resistivity) into Morlet Continuous Wavelet Transform (CWT) scalograms, enriching representation without increasing statistically independent samples. Local spectral textures are extracted by a Deep Convolutional Neural Network (DCNN); long-range cross-channel dependencies are captured by a Vision Transformer (ViT); and stratigraphic continuity along depth is enforced by a Bidirectional Recurrent Neural Network (BRNN). Training and selection use five-fold well-wise cross-validation with train-only normalisation and in-fold class-imbalance handling. Facies-specific DeepSHAP attribution (illustrated for F8) reveals petrophysically coherent drivers—higher core porosity and lower density, with complementary gamma-ray and deep-resistivity cues—while a logs-only variant (no core measurements) demonstrates deployability and mitigates leakage concerns. Runtime profiling on mid-range GPUs indicates near-real-time inference; a compact ‘Lite’ model further reduces parameters and memory with minor loss in accuracy. NG-LFCS thus couples geological and petrophysical realism with modern deep learning to deliver transparent, validated, and operationally practical lithofacies classification.

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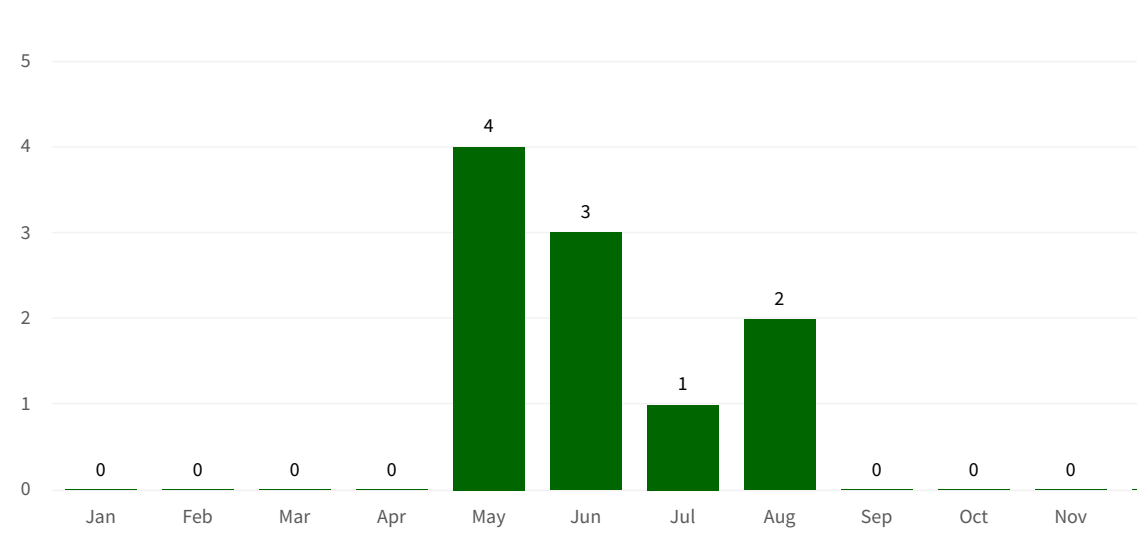
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