

Application and Development Directions of Electrical Imaging Logging

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Abstract: Electrical imaging logging, as a pivotal advancement in modern well logging technology, has revolutionized reservoir characterization by providing high-resolution, visual representations of borehole walls and formation structures. This paper reviews the geological applications of electrical imaging logging, including fracture analysis, sedimentary facies identification, and reservoir heterogeneity evaluation, while addressing current challenges and future development trends. The integration of autonomous equipment upgrades, digital transformation, and enhanced imaging resolution are highlighted as critical pathways for advancing this technology.

Keywords: Electrical Imaging Logging; Geological Applications; Fracture Analysis; Autonomous Technology; Digital Transformation.

1. Introduction

Electrical imaging logging, characterized by its ability to generate two-dimensional resistivity images of borehole walls, has become indispensable in hydrocarbon exploration. Unlike conventional logging methods, it offers unparalleled insights into complex formations such as fractured reservoirs and heterogeneous lithologies. This paper synthesizes recent advancements and identifies emerging trends in electrical imaging logging, drawing on case studies and technological innovations from both domestic and international contexts.

2. Current Applications of Electrical Imaging Logging

2.1. Fracture and Structural Analysis

Electrical imaging logging excels in identifying fractures, faults, and stress orientations. High-resolution images enable quantitative analysis of fracture density, aperture, and connectivity, which are crucial for evaluating reservoir permeability in carbonate and igneous formations. For instance, in the Shengke-1 well (232°C), electrical imaging facilitated fracture characterization in ultra-high-temperature environments, supporting targeted drilling strategies.

2.2. Sedimentary Facies and Stratigraphic Interpretation

The technology aids in reconstructing depositional environments by resolving thin-bedded sand-shale sequences and distinguishing sedimentary structures (e.g., cross-bedding, bioturbation). In the CCSD-1 scientific exploration well, imaging data enabled precise core-to-log integration, enhancing stratigraphic correlation accuracy.

2.3. Reservoir Heterogeneity and Fluid Identification

Electrical imaging logging is instrumental in assessing reservoir heterogeneity, particularly in low-porosity, low-permeability formations. Recent studies demonstrate its utility in identifying high-water-saturation zones and optimizing hydrocarbon recovery in mature fields. For

example, oil-based mud applications in imaging logging have expanded its use in challenging drilling environments.

3. Challenges in Electrical Imaging Logging

3.1. Dependence on Foreign Technology

Despite progress, China's imaging logging systems, such as those used by Sinopec, still rely heavily on imported software (e.g., Schlumberger's Geoframe, Baker Hughes' eXpress) and legacy equipment, limiting operational flexibility.

3.2. Equipment Maintenance and Costs

Rising costs and parts shortages for advanced tools (e.g., dipole acoustic, nuclear magnetic resonance) hinder maintenance, reducing service efficiency.

3.3. Data Interpretation Limitations

Current methodologies often focus on single-well analysis, lacking integration of multi-well datasets for basin-scale geological modeling.

4. Future Development Directions.

4.1. Autonomous Equipment and Standardization

Domestic initiatives, such as CNPC's CPLog systems, have achieved 80.3% market penetration through aggressive upgrades and API-certified manufacturing. Future efforts should prioritize full-spectrum autonomy, including high-temperature (175°C), small-borehole, and rotary-steering tools.

4.2. Digital and Intelligent Transformation

The construction of integrated lifecycle management systems (e.g., EISC) has reduced equipment failure rates by 23.1% through predictive maintenance algorithms. Cloud-based platforms and AI-driven interpretation models are poised to enhance data asset utilization.

4.3. Enhanced Resolution and Deep Detection

Next-generation tools aim to improve lateral detection

depth and resolution for unconventional reservoirs. Innovations in 3D imaging and multi-physics integration (e.g., electromagnetic-acoustic hybrids) will address complex lithological challenges.

4.4. Global Market Expansion

Chinese companies, exemplified by CNPC and Richwell Technology, are commercializing imaging services in Africa (e.g., Niger, Chad) and advancing toward becoming the fourth global leader in imaging logging technology.

5. Conclusion

Electrical imaging logging remains a cornerstone of subsurface evaluation, yet its full potential hinges on overcoming technological dependencies and embracing digital innovation. By fostering autonomous R&D, standardizing equipment, and leveraging big data analytics,

the industry can achieve transformative growth in both conventional and unconventional reservoirs.

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