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Original article

Influence of Depositional Environment, Microfacies, and Diagenesis on Electrical Resistivity Changes: Permian-Triassic Sequence, Central Persian Gulf

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Abstract

Understanding the variations in electrical conductivity in porous media is relevant in various fields, including geology, petroleum engineering, and chemistry. Changes in rock electrical resistivity can indicate alterations in their geomechanical properties. Electrical conductivity in rocks reflects the geometric relationships of pores within rock samples, which are influenced by the depositional environment, microfacies, and diagenetic processes. Thus, a thorough study of geological and petrophysical characteristics and their connection to changes in electrical resistivity is crucial for identifying and developing hydrocarbon fields. This research, for the first time, explores the impact of the depositional environment, microfacies, diagenetic processes, and petrophysical factors on the variations in the electrical resistivity of rocks. The dataset for this study comprises 293 meters of core samples, 720 porosity and permeability data points, 921 thin section images, and 251 meters of various well log data, collected from an exploratory well in the central Persian Gulf. The study involved identifying and determining microfacies and depositional environments, examining diagenetic processes through microscopic and macroscopic analysis, and evaluating electrical conductivity in these environments and microfacies using the formation's deep electrical resistivity log. Results show that samples from lagoon environments have lower electrical resistivity and higher permeability, while those from open marine environments exhibit higher electrical resistivity and lower permeability. The sabkha environment, due to extensive anhydrite cementation, has the highest electrical resistivity. Diagenetic processes like dolomitization and isopachous calcite cementation reduce electrical resistivity by improving pore connectivity and preserving primary porosity. Conversely, anhydrite cement and blocky calcite cement increase electrical resistivity by blocking pores and pore throats.

1. Introduction

Measurement and understanding of changes in the electrical conductivity of porous media are applicable in various fields of science and technology, including geology, petroleum engineering, chemistry, hydrology, geophysics, and soil science [1,2]. Studying the electrical properties of hydrocarbon reservoirs is crucial for the effective identification, monitoring, and management of these reservoirs, ultimately leading to improved efficiency and productivity in the oil and gas sector [3]. Variations in electrical resistance can reflect changes in geomechanical properties such as rock strength, stiffness, and stress distribution. By analyzing resistance data alongside geomechanical models, engineers can assess reservoir stability. A reservoir rock sample can be considered a volume containing a combination of an electrically conductive phase and one or more electrically non-conductive phases. The electrically conductive phase is distributed throughout the rock volume in a complex network of pores and pore throats. The distribution of reservoir characteristics is primarily controlled by the distribution and extent of sedimentary microfacies, which are themselves governed by the depositional environment [4]. Electrical conductivity in rock can be seen as an indicator of the geometric relationships of pores among rock samples, which are controlled by the depositional environment, microfacies, and diagenetic processes. Therefore, a comprehensive and precise study of geological and petrophysical characteristics, including microfacies, depositional environment, and changes in electrical resistance, plays a vital role in the identification and development of hydrocarbon fields [5]. By studying geological features such as microfacies, depositional environment, and diagenesis, as well as petrophysical features like porosity and permeability, and examining their impact and relationship with the electrical conductivity of rocks, we can gain a comprehensive understanding of the controlling factors of the reservoir. One of the most important applications of measuring electrical conductivity in the oil and gas industry is calculating hydrocarbon reservoir reserves [6,7]. The impact of geological parameters such as microfacies, depositional environment, and diagenetic processes as the primary controlling factors of reservoir quality on electrical conductivity remains unclear. The aim of this paper is to investigate, study, and comprehensively analyze the impact of the depositional environment, microfacies, and the most important diagenetic processes on the electrical conductivity of rocks.

2. Methodology

The selected dataset for achieving the objectives of this study includes 293 core samples, 720 porosity and permeability data points, 921 thin sections, and 251 meters of well logs comprising gamma, neutron, density, resistivity, and sonic logs. These data were obtained from an exploratory well in a gas field located in the central Persian Gulf. Thin sections were used as reliable data for lithological characterization, various types of porosity, microfacies, and depositional environments determination. Deep formation resistivity log data were utilized to investigate the impact of geological parameters on the electrical conductivity of rocks.

3. Results and Conclusions

Based on the studies conducted on the Dalan and Kangan formations, 12 different microfacies have been identified within four microfacies belts in these sequences. These microfacies have been classified based on lithological characteristics, texture, particle size, and other features. Analysis and examination of the microfacies present in the study area reveal considerable differences in lithological characteristics, texture, and diagenesis among these microfacies. These differences are not only the result of the different depositional environments in which each microfacies formed but also of different diagenetic processes. Results show that samples from lagoon environments have lower electrical resistivity and higher permeability, while those from open marine environments exhibit higher electrical resistivity and lower permeability. The sabkha environment, due to extensive anhydrite cementation, has the highest electrical resistivity. Diagenetic processes like dolomitization and isopachous calcite cementation reduce electrical resistivity by improving pore connectivity and preserving primary porosity. Conversely, anhydrite cement and blocky calcite cement increase electrical resistivity by blocking pores and pore throats.

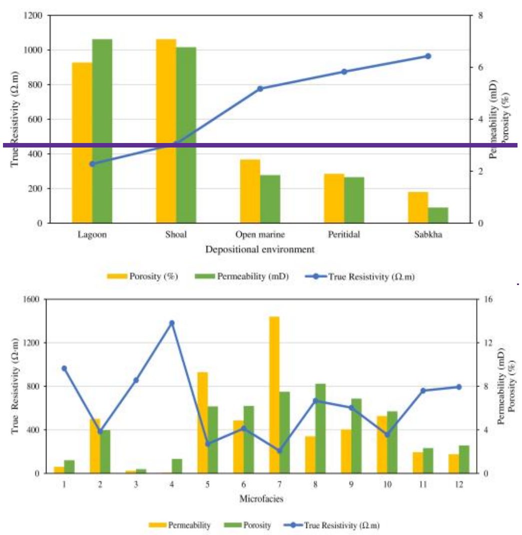

Fig. 1. Chart illustrating alterations in formation resistivity, porosity, and permeability across across different microfacies shows that microfacies F7 has the highest permeability and the lowest electrical resistivity compared to the other microfacies.

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