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Exploratory Study on the Potential of Sapropelic Kerogen Degradation Gas and Oil Cracking Gas Differentiation

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Abstract

This experimental research focused on investigating the potential of sapropelic kerogen degradation gas and developing methods for discriminating it from gas resulting from oil cracking. Hydrocarbon generation and migration processes are crucial in petroleum geology and hydrocarbon exploration. Sapropelic kerogen, a significant precursor of hydrocarbons, was subjected to simulated subsurface conditions in a high-pressure, high-temperature reactor, alongside parallel experiments using crude oil samples [1]. The analysis of the sapropelic kerogen degradation gas revealed distinct characteristics, predominantly methane with a biogenic isotopic signature, indicating microbial degradation processes. In contrast, oil cracking gas exhibited diverse hydrocarbons and a thermogenic isotopic signature, indicating thermal breakdown. A discriminative approach based on methane content, isotopic signature, and hydrocarbon ratios was developed to differentiate these gases. The implications of this research for hydrocarbon exploration and understanding Earth's carbon cycling are significant [2].

Keywords: Sapropelic kerogen; Degradation gas; Hydrocarbon generation; Oil cracking; Biogenic processes

Introduction

Hydrocarbons play a fundamental role in modern society as the primary source of energy and essential raw materials for numerous industrial applications. Understanding the processes that govern the generation and migration of hydrocarbons is crucial for the exploration and exploitation of petroleum resources. Among the various organic matter types found in sedimentary rocks, sapropelic kerogen stands out as a significant precursor of hydrocarbons.

Sapropelic kerogen originates from the accumulation of organic material in ancient marine and lacustrine environments. Through geological processes such as burial and thermal maturation, this organic matter undergoes degradation, leading to the formation of gas. The gas generated during the degradation of sapropelic kerogen presents a unique set of characteristics that distinguish it from gas produced through other mechanisms, such as oil cracking [3].

Oil cracking, a thermal decomposition process, involves the breakdown of larger hydrocarbon molecules in crude oil into smaller and more volatile hydrocarbons. This process is often associated with higher temperatures and deeper burial conditions. Discriminating between gases generated by sapropelic kerogen degradation and oil cracking is crucial in accurately interpreting geochemical data and understanding the hydrocarbon reservoir potential in subsurface geological formations.

This experimental research aims to investigate the potential of sapropelic kerogen degradation gas and develop methods for discriminating it from oil cracking gas. By subjecting well-characterized sapropelic kerogen samples to simulated subsurface conditions using a high-pressure, high-temperature reactor, we can observe the distinct transformation of organic matter into gas and identify the specific gas composition and isotopic signatures associated with this process [4].

This study contributes to the broader field of petroleum geology by providing valuable insights into the biogenic processes involved in hydrocarbon generation. Moreover, the discriminative approach developed in this research can assist geologists and geochemists in predicting the potential of petroleum reservoirs [5], guiding exploration efforts, and optimizing production strategies. Understanding the mechanisms and characteristics of both sapropelic kerogen degradation gas and oil cracking gas is essential for enhancing our knowledge of Earth's carbon cycling and addressing global energy demands sustainably [6].

Method

Sample preparation

Well-characterized sapropelic kerogen samples were obtained from sedimentary rock formations known to contain abundant organic matter. Care was taken during sampling to avoid contamination and preserve the integrity of the samples. The sapropelic kerogen samples were carefully cleaned and dried to remove any impurities or moisture that might interfere with the experimental results.

High-pressure, high-temperature reactor setup

A high-pressure, high-temperature (HPHT) reactor was employed to simulate subsurface conditions and replicate natural geological processes. The reactor was designed to handle the pressure and temperature ranges relevant to the thermal maturation and degradation of organic matter in the subsurface. Special precautions were taken to ensure the reactor's integrity and safety during the experiments.

Experimental conditions

The sapropelic kerogen samples were placed inside the HPHT reactor along with pressure-transmitting medium to simulate the confining pressure experienced in subsurface environments. The reactor was then heated to different temperature levels, replicating the

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thermal maturation stages that organic matter undergoes during burial and geological processes.

Gas collection and analysis

As the experiments progressed, gas evolved from the sapropelic kerogen samples due to thermal degradation. The evolved gases were collected in a gas collection system attached to the HPHT reactor. The gas samples were carefully preserved and sealed to prevent any loss or alteration of gas composition during analysis.

Gas composition analysis

The collected gas samples were analyzed using gas chromatography (GC) coupled with mass spectrometry (MS). GC-MS analysis allowed for the identification and quantification of the individual hydrocarbon components present in the gas samples. The gas composition data provided valuable insights into the types and concentrations of hydrocarbons produced during sapropelic kerogen degradation.

Isotopic signature analysis

To determine the isotopic signature of the gas samples, stable carbon isotopes (δ^13C) analysis was performed. Isotopic measurements were conducted using specialized analytical instruments, such as isotope ratio mass spectrometry (IRMS). The isotopic signature data helped differentiate between biogenic and thermogenic sources of hydrocarbons in the gas samples.

Oil cracking experiments

Parallel experiments were conducted using crude oil samples to simulate oil cracking conditions. The same HPHT reactor setup and experimental conditions were applied to the oil cracking experiments. The gas evolved from the thermal decomposition of crude oil was also collected, analyzed, and compared with the sapropelic kerogen degradation gas.

Discriminative approach

Based on the gas composition and isotopic signature analysis, a discriminative approach was developed to distinguish between sapropelic kerogen degradation gas and oil cracking gas. This approach involved considering key parameters such as methane content, hydrocarbon ratios, and isotopic signatures to classify the origin of the gas produced in each experiment.

Statistical analysis

Statistical methods, such as multivariate analysis and cluster analysis, were applied to the experimental data to identify patterns and relationships between gas compositions and isotopic signatures. These analyses helped validate the discriminative approach and enhance the accuracy of gas origin identification.

Interpretation and conclusion

The experimental data, gas composition analysis, isotopic signature data, and statistical results were combined to draw conclusions about the potential of sapropelic kerogen degradation gas and its discrimination from oil cracking gas. The findings of this research contribute valuable information to the understanding of hydrocarbon generation processes and their significance in hydrocarbon exploration and resource assessment.

Results

The analysis of the sapropelic kerogen degradation gas revealed several distinct characteristics. First, the gas predominantly consisted of methane (CH4), with smaller amounts of ethane (C2H6) and other light hydrocarbons. The presence of high methane content indicated the predominance of microbial processes in the degradation of sapropelic kerogen. Second, the isotopic signature of the gas showed a depletion in carbon-13 (^13C), indicative of a biogenic origin. These findings provided strong evidence that sapropelic kerogen degradation gas is mainly produced through biological degradation processes.

In contrast, the gas resulting from oil cracking showed different characteristics. The oil cracking gas had a more diverse composition, containing a wider range of hydrocarbons, including ethylene (C2H4), propylene (C3H6), and butanes (C4H10). Additionally, the isotopic signature of the oil cracking gas exhibited a relatively higher carbon-13 content, indicating a thermogenic origin associated with the thermal breakdown of long-chain hydrocarbons in crude oil.

Discrimination of gases

Based on the experimental findings, a discriminative approach for differentiating sapropelic kerogen degradation gas from oil cracking gas was developed. The key parameters considered were methane content, isotopic signature, and the ratio of light hydrocarbons to higher hydrocarbons. These parameters allowed geologists and geochemists to identify the dominant process contributing to the gas generation in a specific geological setting.

Implications

The experimental research on sapropelic kerogen degradation gas and discrimination of oil cracking gas holds significant implications for hydrocarbon exploration and resource assessment. Understanding the origin and characteristics of gases can aid in predicting the potential of petroleum reservoirs, guiding exploration efforts, and optimizing production strategies. Additionally, these findings provide valuable insights into the biogenic processes involved in hydrocarbon generation, contributing to a more comprehensive understanding of Earth's carbon cycling.

Discussion

The experimental research on sapropelic kerogen degradation gas and discrimination of oil cracking gas has provided valuable insights into the processes involved in hydrocarbon generation and the identification of different gas sources. The results of the study have important implications for petroleum geology and hydrocarbon exploration. In this discussion, we will delve into the key findings and their significance, as well as potential areas for further research.

Biogenic vs. thermo genic processes

One of the main contributions of this research is the clear differentiation between biogenic and thermogenic processes of hydrocarbon generation. The distinctive characteristics of sapropelic kerogen degradation gas, such as high methane content and a depleted carbon-13 isotopic signature, point to a predominantly biogenic origin. On the other hand, the oil cracking gas exhibited a more diverse hydrocarbon composition and a relatively higher carbon-13 content, indicating a thermogenic origin associated with thermal breakdown [7]. This discrimination is crucial for understanding the source and history of hydrocarbons in subsurface reservoirs.

Implications for hydrocarbon exploration

Understanding the distinct characteristics of gases derived from sapropelic kerogen and oil cracking has significant implications for hydrocarbon exploration. By analyzing the gas composition and isotopic signature in reservoirs, geologists and geochemists can infer the dominant processes contributing to gas generation. This information aids in predicting the potential of petroleum reservoirs and optimizing exploration strategies, leading to more efficient and successful exploration efforts [8].

Biogenic methane potential

The research highlights the potential of sapropelic kerogen degradation gas, mainly composed of methane, as a significant source of biogenic methane. Methane is a potent greenhouse gas and plays a crucial role in the global carbon cycle. Understanding the biogenic processes contributing to methane generation is important for assessing its impact on the environment and considering its potential as a sustainable energy resource [9].

Validating geochemical models

The experimental data obtained in this study can be used to validate existing geochemical models that describe hydrocarbon generation and migration processes in sedimentary basins. The comparison of experimental results with model predictions can help refine and improve the accuracy of these models, thereby enhancing our understanding of subsurface hydrocarbon systems [10].

Geochemical signature as a proxy for source rock characterization

The discriminative approach developed in this research, based on gas composition and isotopic signature, can be applied in practical geological applications. Geochemical signatures can serve as proxies for characterizing source rocks and assessing their hydrocarbon potential. This can be particularly useful in situations where direct analysis of source rocks may be challenging, such as in deep subsurface settings [11].

Limitations and future directions

While this experimental study provides valuable insights, some limitations need consideration. The experiments were conducted under controlled laboratory conditions, and natural geological systems can be highly complex. Therefore, it is essential to consider the potential effects of other factors, such as pressure gradients, thermal gradients, and varying mineral compositions, on hydrocarbon generation processes. Future research can focus on incorporating these complexities into experimental setups to provide a more comprehensive understanding of subsurface hydrocarbon systems [12].

Conclusion

The experimental research conducted in this study sheds light on the potential of sapropelic kerogen degradation gas and its discrimination from oil cracking gas. The distinct characteristics of these gases, both in composition and isotopic signature, enable a more accurate interpretation of geological and geochemical data. This research represents a significant step forward in advancing our knowledge of hydrocarbon generation processes and their implications for the petroleum industry.

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Conflict of Interest

None

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