Extended Abstract

Characterization of Indian Shales under Heated Environment: Implication for Enhance Gas Recovery

Kumar Nilankar
(21PE0008)
Department of Petroleum Engineering and Geoengineering
Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi, Uttar Pradesh, India.

For many decades, conventional fossil fuels have been the primary energy source, effectively meeting the world's energy demands. However, their widespread use has raised concerns about resource depletion and environmental impacts, especially the increase in greenhouse gas emissions. In response, there has been a growing emphasis on the exploration and development of cleaner, unconventional fuel resources. One such promising alternative is shale gas, which offers abundant reserves and serves as a low-carbon energy source, attracting global attention. Shale gas is a natural form of gas generated from organic-rich shale through biogenic or thermogenic processes. Methane, or shale gas, is found within these formations in several states: free gas in pores and fractures, adsorbed gas on and within organic matter and minerals, and dissolved gas in water within the shale formations. This versatile presence enhances its potential as a significant component of future energy approaches, contributing to a more sustainable energy landscape. Shale gas can also be found dissolved in organic matter and water. According to the EIA (2015) report, India's total shale gas resource amounts to 584 trillion cubic feet (tcf), with technically recoverable resources estimated at 96 tcf. Despite the large reserves in the country, extracting shale gas poses significant challenges due to the complex nature of shale formations. These formations exhibit heterogeneity, low permeability (less than nano-Darcy), and intricate

pore systems characterized by diverse pore types and distributions. The numerous nanopores within the shale influence the adsorption behavior of gas, as well as the original gas in place and the flow characteristics of the rock matrix. Understanding and navigating these complexities are crucial for efficient and sustainable shale gas extraction. Over the years, many researchers have proposed using combustion and pyrolysis treatments to extract shale gas. These methods help desorb gas from the pores within the shale, enhancing permeability and providing a potential alternative to hydraulic fracturing (fracking).

The field of high-temperature rock mechanics has gathered increased attention due to its significance in projects like oil and gas storage, coal mining, nuclear waste disposal, and geothermal development. Thermal effects can induce significant alterations in the physical and mechanical characteristics of rocks, potentially leading to mechanical failure. Variations in rock mechanical properties—such as compressive and tensile strength, modulus ratio, elastic constant, thermal expansion coefficient, and fracture toughness—can be attributed to different heating environments. Increasing temperatures with depth (geothermal gradient) significantly affect these properties. Pressure and tectonic stability also influence rock properties and should not be overlooked.

While much research has focused on the impact of heating environments on hard and crystalline rocks (e.g., granite, basalt, sandstone), there has been less attention on soft and anisotropic rocks like shale. Given shale's importance in gas exploration and production, understanding its behavior under various conditions is crucial for assessing its durability and integrity. Shale's inherent anisotropy challenges accurate predictions of its behavior under environmental changes, including temperature.

Existing studies highlight the significant role of thermal conditions in altering shale's physical, mechanical, and chemical properties. Researchers have examined these properties separately under various temperatures to understand variations in hydraulic fracturing, wellbore stability, and enhanced oil/gas recovery. However, comprehensive studies incorporating all these properties under thermal conditions are rare. Different shales exhibit varied behaviors under thermal conditions, influenced by their mineralogical composition and anisotropic properties. Therefore, each type of shale should be studied individually under various conditions to fully understand hydraulic fracturing, wellbore stability, and enhanced oil/gas recovery challenges.

Chapter 1 provides a concise overview of the effects of thermal treatment on shale reservoirs for enhanced shale gas recovery and the potential for CO2 sequestration. It also includes a summary of previous studies conducted both in India and internationally.

Chapter 2 presents an investigation of the physico-mechanical characteristics of thermally treated Raniganj shale at various temperatures and durations. The influence of temperature and time on the physical properties (P-wave and S-wave velocities, density, weight loss, and thermal damage), mechanical properties (tensile strength, point load index, and elastic constants), chemical properties (mineralogical variation), and structural changes are detailed in the subsections of the manuscript.

Chapter 3 presents an investigation of the pore morphology and surface characteristics of Raniganj shale under heating from room temperature to 400°C using advanced techniques. To characterize the chemical and mineralogical changes with increasing temperature, FTIR, XRD, and TGA analyses are performed and combined to examine the overall development and decomposition of mineral phases and organic matter in shale. The effect of thermal treatment on the physicochemical characteristics and shale gas recovery with adsorption capacity is highlighted to understand the efficiency of thermally enhanced gas recovery.

Chapter 4 considers the heterogeneous and anisotropic nature of shales from three distinct locations and investigates their mechanical, physical, and mineralogical characteristics. Additionally, the adsorption behavior of these shales is examined to understand their various pore characteristics.

Chapter 5 provides a comprehensive summary of findings from various investigations and suggests potential avenues for future research to further explore the practical application of thermal treatment in shale for enhanced gas recovery.