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Real-Time Detection of H_2, He, and ^{222}Rn while Drilling: A Key Tool for Natural Gas Exploration – Insights from the ICDP DIVE-1 Boreholes

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The identification and real-time monitoring of geofluids during drilling are essential for ensuring safe operations and gaining valuable insights into reservoir properties and fluid migration. While mud gas logging is a well-established technique in oil and gas exploration, the growing interest in natural hydrogen (H_2) and helium (He) exploration has highlighted the need for advanced mud gas logging methods, particularly for continuous wireline coring in crystalline bedrock. Detecting both H_2 and He is particularly valuable not only for exploring these resources but also for identifying deep fluid migration, especially in crystalline formations. This study presents mud gas logging results for O_2, N_2, ^{40}Ar, ^{38}Ar, ^{36}Ar, CO_2, CH_4, H_2, He, and ^{222}Rn from two boreholes (909.5 m and 578.5 m deep) drilled in the Ivrea-Verbano Zone (Northern Italy) as part of the DIVE-ICDP project. Comparison with geophysical logging data revealed that gas peaks correlate strongly with variations in the physical characteristics of well fluids, indicating zones of fluid inflow. Real-time gas monitoring proved valuable for detecting deep gas migration and supporting decision-making, positioning it as a promising tool for targeting He or H_2 in crystalline bedrock—especially in regions with limited surface indicators. However, challenges remain, such as distinguishing between formation-derived and drilling-induced gases. Despite these challenges, the correlations of He and H_2 with other gases, lithology and structural features offer preliminary insights into their potential origins, reinforcing the value of this method for exploring H_2 and He in deep geological formations.