

Mechanical degradation in granite induced by long-term exposure to deep in situ coupling environments

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Abstract: Deep in situ coupling environments, characterized by high-geostress, geotemperature, and water pressure, play an important role in rock degradation through two potential means: (1) Short-term coupling effects can accelerate the damage evolution during rock failure; (2) Long-term exposure to in situ coupling environments may degrade the physical and mechanical properties of rocks. While extensive research has been devoted to the former, the latter remains completely unexplored. Aiming at this, this study proposes an experimental method and apparatus to characterize how long-term exposure to in situ coupling environments influences the mechanical properties of a typical granite. The long-term effects of various in situ coupling environments, typically at depths of 800, 1200, 1600, 2000, and 2400 meters in the study area, on rock mechanics are quantitatively investigated through a series of long-term in situ environmental retention tests and subsequent uniaxial compression experiments. A reduction in uniaxial compression strength of about 3.7%-13.5% is observed in granite due to the long-term exposure to the coupling environments at depths of 800-2400 meters compared to its natural state; and long-term exposure to the coupling environments at greater depths generally degrades both the strength and stiffness of the studied granite more severely, along with more plasticity. Prolonged exposure to in situ coupling environments also significantly influences the microcracking and failure patterns. It amplifies the tendency for tensile microcracking within granite, leading to a more uniform failure pattern with reduced microfractures. Deeper insights unveil the mechanisms driving the mechanical deterioration in granite, primarily induced by feldspar dissolution, microcrack propagation, and physical erosion facilitated by high-temperature and high-pressure water. Furthermore, this mechanical degradation exacerbates the failure depths of tunnel rock masses, with a more pronounced effect as tunnel depth and radius increase.

Keywords: Deep in situ environment; Long-term effect; Mechanical degradation; Failure behavior.