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Going Deeper: The Importance of Understanding Brittle Fracture Mechanisms in Deep Mining and Tunnelling

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The past 50 years have seen considerable advances in both our fundamental understanding of brittle rock fracture and its application in assessing and safely managing highly stressed rock. This has been essential for meeting the global demand for natural resources, energy, and improved civil infrastructure, which have pushed related projects to unprecedented depths. Deep mines in South Africa and eastern Canada are approaching 3000 m depth, with the latter facing high horizontal stresses that are more than twice the vertical overburden stress. Similarly, transportation tunnels in Europe and hydroelectric tunnels in South America and Asia are reaching unprecedented depths as infrastructure development increasingly expands into mountainous regions. The Olmos Trans-Andean Tunnel in Peru experienced overburdens of up to 1930 m. The Gotthard Base Tunnel in Switzerland was constructed with overburdens of up to 2300 m. The tunnels of the Jinping II in China reached maximum overburdens of 2525 m.

These projects have pushed geoscientists and engineers to the limits of current knowledge and design practice. It has become clear that with increasing depth, the influence of geology and in-situ stresses on rock mass response becomes more pronounced. This requires that both geological uncertainty and model uncertainty (related to the applicability of current empirical and numerical design tools developed for lower stress conditions) be fully accounted for and managed. Critical is a need for deeper understanding of pre- and post-peak rock behaviour, including brittle fracture, dilation, and strength mobilization, in order to properly evaluate the potential for stress-induced failure (e.g., spalling, rockbursting, etc.). A review of our understanding of brittle failure will be presented, examining crack initiation and damage processes and the important role confinement plays in suppressing these. Lessons learned from several recent case histories will be presented together with new research developments. These involve the development of improved predictive tools for assessing brittle failure around deep underground excavations together with improved rock support strategies to safely manage these processes for the construction of the next generation of deep underground mines and tunnels.

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