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On the triggering mechanism of fault-slip bursts during deep underground excavation

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To meet the target of net-zero emissions by 2050, six times more mineral inputs are required in 2040 than today. However, with the depletion of mineral resources in the shallow subsurface, mining at great depth is inevitable. Furthermore, the rapid development of urban systems, transport networks, and hydropower plants also impose an increased demand of deep underground excavation. These deep mining or tunneling activities are, however, confronted with the risk of induced earthquakes and rockbursts. For example, during the Gotthard Base Tunnel construction at great depths of up to 2.5 km in the Swiss Alps, extensive regional earthquakes with magnitudes reaching up to M_w 2.4 were recorded. Accompanying some of these earthquake events, intense rockbursts occurred at the Faido Multifunction Station. So far, it remains poorly understood the triggering mechanisms of these rockburst events and their relationship with the induced earthquakes. Here, we develop a novel three-dimensional coupled seimo-mechanical model which can capture the rupture of a seismogenic fault zone, the redistribution of stress field, the propagation of seismic waves, and the occurrence of coseismic rockbursts in a tunnel located a few hundred meters away from the hypocenter (i.e., in the near-field of the earthquake fault). We investigate the competing roles of static and dynamic triggering in generating these fault-slip burst events and find that static stress changes play a much more dominant role than dynamic waves. The results and insights derived from our research have important implications for understanding and predicting catastrophic rockbursts during deep underground excavation for various geoenergy or geoengineering applications, ranging from critical mineral extraction and nuclear waste disposal to underground energy storage and civil infrastructure development.