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Evidence for remotely triggered micro-earthquakes during salt cavern collapse

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Micro-seismicity is a good indicator of spatio-temporal evolution of physical properties of rocks prior to catastrophic events like volcanic eruptions or landslides and may be triggered by a number of causes including dynamic characteristics of processes in play or/and external forces. Micro-earthquake triggering has been in the recent years the subject of intense research and our work contribute to showing further evidence of possible triggering of micro-earthquakes by remote large earthquakes. We show evidence of triggered micro-seismicity in the vicinity of an underground salt cavern prone to collapse by a remote M$\sim$7.2 earthquake, which occurred $\sim$12000 kilometres away. We demonstrate the near critical state of the cavern before the collapse by means of 2D axisymmetric elastic finite-element simulations. Pressure was lowered in the cavern by pumping operations of brine out of the cavern. We demonstrate that a very small stress increase would be sufficient to break the overburden. High-dynamic broadband records reveal a remarkable time-correlation between a dramatic increase of the local high-frequency micro-seismicity rate associated with the break of the stiffest layer stabilizing the overburden and the passage of low-frequency remote seismic waves, including body, Love and Rayleigh surface waves. Stress oscillations due to the seismic waves exceeded the strength required for the rupture of the complex media made of brine and rock triggering micro-earthquakes and leading to damage of the overburden and eventually collapse of the salt cavern. The increment of stress necessary for the failure of a Dolomite layer is of the same order or magnitude as the maximum dynamic stress magnitude observed during the passage of the earthquakes waves. On this basis, we discuss the possible contribution of the Love and Rayleigh low-frequency surfaces waves.