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Evidence for remotely triggered microearthquakes during salt cavern collapse

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Microseismicity 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. We show evidence of triggered microseismicity observed in the vicinity of an underground salt cavern prone to collapse by a remote M $\sim$ 7.2 earthquake, which occurred $\sim$12 000 km away. High-dynamic range broad-band records reveal the strong time-correlation between a dramatic change in the rate of local high-frequency microseismicity and the passage of low-frequency seismic waves, including body, Love and Rayleigh surface waves. Pressure was lowered in the cavern by pumping operations of brine out of the cavern. We demonstrate the near critical state of the cavern before the collapse by means of 2-D axisymmetric elastic finite-element simulations. On this basis, we show that the increment of stress necessary for the failure of the Dolomite layer, which ensures the stability of the whole system, is of the same order of magnitude as the maximum dynamic stress magnitude observed during the passage of the earthquakes waves. This suggests that the stress oscillations due to the seismic waves correlated with the recorded microearthquakes induced damage of the overburden, which eventually led to the collapse of the salt cavern. We show that the contribution of Rayleigh waves is the most efficient to trigger microseismicity at periods close to the natural fundamental frequency of the cavern system found at about 10–20 s by investigating the impulse response of the cavern + overburden + brine system.