How much longer will the Muswellbrook earthquake swarm last

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The ongoing Muswellbrook earthquake swarm (Risk Frontiers, 2024, Briefing Note 503) has now continued for over a month with a magnitude 3.1 earthquake occurring on September 23, stimulating interest in the incidence and causes of earthquake swarms. Although earthquake swarms usually generate small to moderate magnitude earthquakes, the persistence of felt earthquakes can be disruptive and cause distress to the population. Earthquake swarms are problematic for public safety because the end of seismic activity cannot be predicted, and because it is uncertain whether another earthquake with a magnitude larger than those of previous events in the sequence will occur.

Mainshock – Aftershock Sequences and Swarms

Most shallow crustal earthquakes consist of a mainshock followed by a sequence of aftershocks whose magnitudes are typically one magnitude unit smaller than the mainshock. In contrast, an earthquake swarm is a sequence of earthquakes occurring in a local area within a relatively short period of time in which no single earthquake in the sequence is obviously the main shock. It is unusual for a large event to emerge from an earthquake swarm. Individual earthquake swarm events tend to generate their own earthquake sequences, suggesting that they occur independently in response to local conditions, not to a broad-scale regional condition.

Earthquake "Hotspots"

The occurrence of a magnitude 3.2 earthquake west of Gunning on September 26, 2024 serves as a reminder that some locations in Australia experience earthquakes much more frequently than others (McCue et al., 1989). These regions were termed "hotspots" in the Geoscience Australia 2012 National Seismic Hazard Map (Burbidge et al., 2012), and another prominent one is located near Morwell, Victoria, but Geoscience Australia has since discontinued usage of that term in its two most recent updates of the National Seismic Hazard Assessments (Allen et al., 2018; Allen et al., 2023). "Hotspots" are places where earthquake mainshocks occur frequently, each with its own aftershock sequence, unlike the earthquake swarms described next.

Incidence of Earthquake Swarms

Earthquake swarms are common in volcanic regions, where they occur before and during eruptions. They also occur in zones of Quaternary volcanism or of hydrothermal circulation. They also occur frequently far from tectonic plate boundaries in locations including many regions in Western Australia; Korumburra, Victoria (Risk Frontiers, 2019); and now the Muswellbrook region. None of these swarms are known to be associated with fluid injection activities. Earthquake swarms also occur frequently in places where energy developers inject fluids as part of oil, gas or geothermal projects in places such as, Oklahoma, the Netherlands, and Scotland. In all of these cases, high-pressure fluid migration in the Earth's crust seems to be the trigger mechanism and the driving process that governs the evolution of the swarm in space and time.

Influence of Fluids on Fault Strength

While much of the advanced earthquake modelling of the last twenty years has focused on the role of friction in unlocking faults, new research (Zhu et al., (2020) has examined the interactions between fluid and pressure in the fault zone, and found that changes in fluid pressure around a fault may play as large a role as friction in controlling its strength.

Faults in the Earth's crust are always saturated with fluids, mostly water. Some of these fluids originate deep in the Earth and migrate upwards. Others come from above when rainfall seeps into the ground or energy developers inject fluids as part of oil, gas or geothermal projects. Increases in the pressure of the fluid can push the walls of the fault apart, making it easier for the fault to slide. Conversely, decreases in pressure creates a suction that pulls the walls together and inhibits sliding.

Rocks unearthed from fault zones have revealed cracks and mineral-filled veins and other signs that pressure has fluctuated strongly during and between large earthquakes, suggesting that water and other fluids play an important role in triggering earthquakes and influencing when the largest earthquakes occur.

Faults as Valves, with Intermittent Fluid Migration Triggering Earthquake Swarms

Zhu et al. (2020) suggest that fluids ascend along faults intermittently, even if those fluids are being released or injected at a constant rate. In the decades to thousands of years between large earthquakes, mineral deposition and other chemical processes seal the fault zone. With the fault valve closed, fluid accumulates and pressure builds, weakening the fault and forcing it to slip. Sometimes this movement is too slight to generate noticeable ground shaking, but it can fracture the rock and open the valve, allowing fluids to resume their ascent. Zhu et al. (2020) showed that when these pulses of fluids travel upward along the fault, they can open the valve and create earthquake swarms.

Implications for Public Safety

Most earthquake swarms last for only a few days or weeks, but some earthquake swarms in Australia have lasted for months or years, and our current understanding of them makes it difficult to forecast the end of the current Muswellbrook earthquake swarm. Earthquake swarms raise several public safety issues, because the end of seismic activity cannot be predicted, and because it is uncertain whether another earthquake with a magnitude larger than those of previous earthquakes in the sequence will occur. The 2009 L'Aquila, Italy earthquake is an example of this, with an Mw 6.3 mainshock shock emerging from a swarm of activity with magnitudes in the range of 1 and 3 (Risk Frontiers Briefing Notes 172, 285). Although swarms usually generate small to moderate magnitude earthquakes, the persistence of felt earthquakes can be disruptive and cause distress to the affected population.

REFERENCES

Allen, T., J. Griffin, D. Clark, P. Cummins, H. Ghasemi and R. Ebrahimi (2023). The 2023 National Seismic Hazard Assessment for Australia: Model overview. Record 2023/53. Geoscience Australia, Canberra.

Burbidge, D. R., Ed. (2012). The 2012 Australian Earthquake Hazard Map, Geoscience Australia Record 2012/71.

McCue, K., B.L.N. Kennett, B.A. Gaul, M.O. Michael-Leiba, J. Weekes, and C. Krayshek (1989). A century of earthquakes in the Dalton-Gunning region of New South Wales. BMR Journal of Australian Geology & Geophysics, II, 1-9.

Risk Frontiers (2024). The 24 August 2024 Muswellbrook Earthquake Sequence and Implications for Future Events. Risk Frontiers Briefing Note 503.

Risk Frontiers (2009). Did technician Giampaolo Giuliani predict the L'Aquila, Italy earthquake of 6 April 2009. Risk Frontiers Briefing Note 172.

Risk Frontiers (2009) The Korumburra Earthquake Sequence – What Next? Risk Frontiers Newsletter Article, March 30, 2009.

Risk Frontiers (2015). L'Aquila Aquittal. Risk Frontiers Briefing Note 285.

Zhu, W., Allison, K.L., Dunham, E.M. *et al.* (2020). Fault valving and pore pressure evolution in simulations of earthquake sequences and aseismic slip. *Nat Commun* **11**, 4833 (2020). https://doi.org/10.1038/s41467-020-18598-z

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