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A swarm of outer-rise normal earthquakes more energetic than the Mw6.8 thrust event that triggered it

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Outer-rise normal-faulting earthquakes are shallow events occurring on steep faults near subduction zones in response to tensile flexural stresses induced by the subducting plate bending processes. This normal-faulting activity is closely linked to the seismic cycle on the slab interface. Large thrust earthquakes produce additional tensional stresses in the outer rise, enhancing the normal-faulting activity, especially when the rupture of large thrust earthquakes reaches the surface. Seismicity in the outer rise does not usually develop into a seismic swarm, but is rather observed as isolated mainshock-aftershocks sequences or a cluster of "aftershocks" triggered by the preceding large thrust event on the slab interface. In addition, the seismic moment released by the tensional earthquakes in the outer rise is generally much smaller than the one released by the slab interface mainshock. In this work we analyzed a strong sequence of outer-rise normal-faulting events that occurred on a ∼100-km-long segment of the New Hebrides subduction zone close to Loyalty Islands. The tensional earthquake activity showed spatial and temporal evolution of swarm-like seismicity and started after a Mw6.8 tsunami-genic earthquake occurred on the slab interface on 31 October 2017. Together, the outer rise swarm earthquakes had a moment release that was five times larger than that of the preceding thrust mainshock. We used broadband stations at regional distances to estimate moment tensors for 82 events (Mw>4.7) and found only 4 thrust events compatible with the slab interface geometry (i.e. one mainshock and three aftershocks) while 78 earthquakes were normal-faulting events (seven with Mw between 6 and 7). The swarm of tensional earthquakes started with moderate Mw<5.5 events in the first several hours after the slab interface mainshock and then developed with increasing magnitude and eventually leading to a Mw6.7 earthquake on 1 November 2017. The outer-rise seismicity showed a marked northward migration for about 60 km that ended on 19 November 2017 when the largest normal-faulting earthquake (Mw7) and three Mw>6 events struck in the same area. The Mw6.7 (1 November) and the Mw7 (19 November) normal earthquakes generated small tsunamis. We estimated a relatively fast migration speed of 3 km/day, which rules out diffusive processes of high pore-pressure as possible triggering mechanism of the swarm. A GPS station located 100 km West of the swarm recorded ∼2 cm cumulative displacement during the earthquake sequence, which can be explained using finite fault modeling of the swarm earthquakes. This means that major afterslip or a large slow-slip event on the slab interface probably did not take place and can thus also be excluded as a possible triggering mechanism behind the swarm. Therefore, the swarm likely occurred due to a combination of large accumulated tensile tectonic stresses and earthquake-earthquake interaction via static stress transfer. In conclusion, the outer-rise activity at Loyalty Islands subduction zone shows: i) swarm-like characteristics unusual for outer-rise tensional events, ii) cumulative seismic moment release five times larger than that of the slab interface mainshock, and iii) that large tensional stresses must have accumulated for long time prior to this earthquake sequence.