The 2025 Mw7.7 Mandalay, Myanmar, earthquake: extremely long and uniform rupture part of a supercycle

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Abstract

The 2025 Mw7.7 Mandalay earthquake ruptured a seismic gap along the Sagaing fault, producing a ~510 km-long surface rupture overlapping sections of past events. Remote sensing shows uniform slip averaging 3.3 m across the entire 0–13 km depth, without shallow-slip deficit. The slip pattern only partly fits the slip-predictable model and expected segmentation. Moment analysis indicates the quake belongs to a phase of elevated seismicity, with clustering and segmentation. Simulations with a simplified non-planar geometry reproduce variable earthquake sequences, including events like the 2025 rupture. These findings challenge standard hazard models and highlight the potential of assimilating data into simulations for time-dependent hazard assessment.

Remote-sensing observations of the 2025 event

Cross-correlation of Sentinel-2 optical, and Sentinel-1 SAR images reveal:

- highly localized right-lateral deformation along a prominent 510 km-long surface rupture which is remarkably continuous and straight (Fig. 1b,c).
- the rupture follows very closely the known geometry of the primary fault and none of the subsidiary faults were ruptured (Fig. 2a).
- fault-parallel surface slip distribution shows little variability along strike with a mode value of 3.8±0.004 m, an average of 3.3±0.004 m, and a peak value of 5.7±0.1 m in the epicentral area (Fig. 2c, black curve).

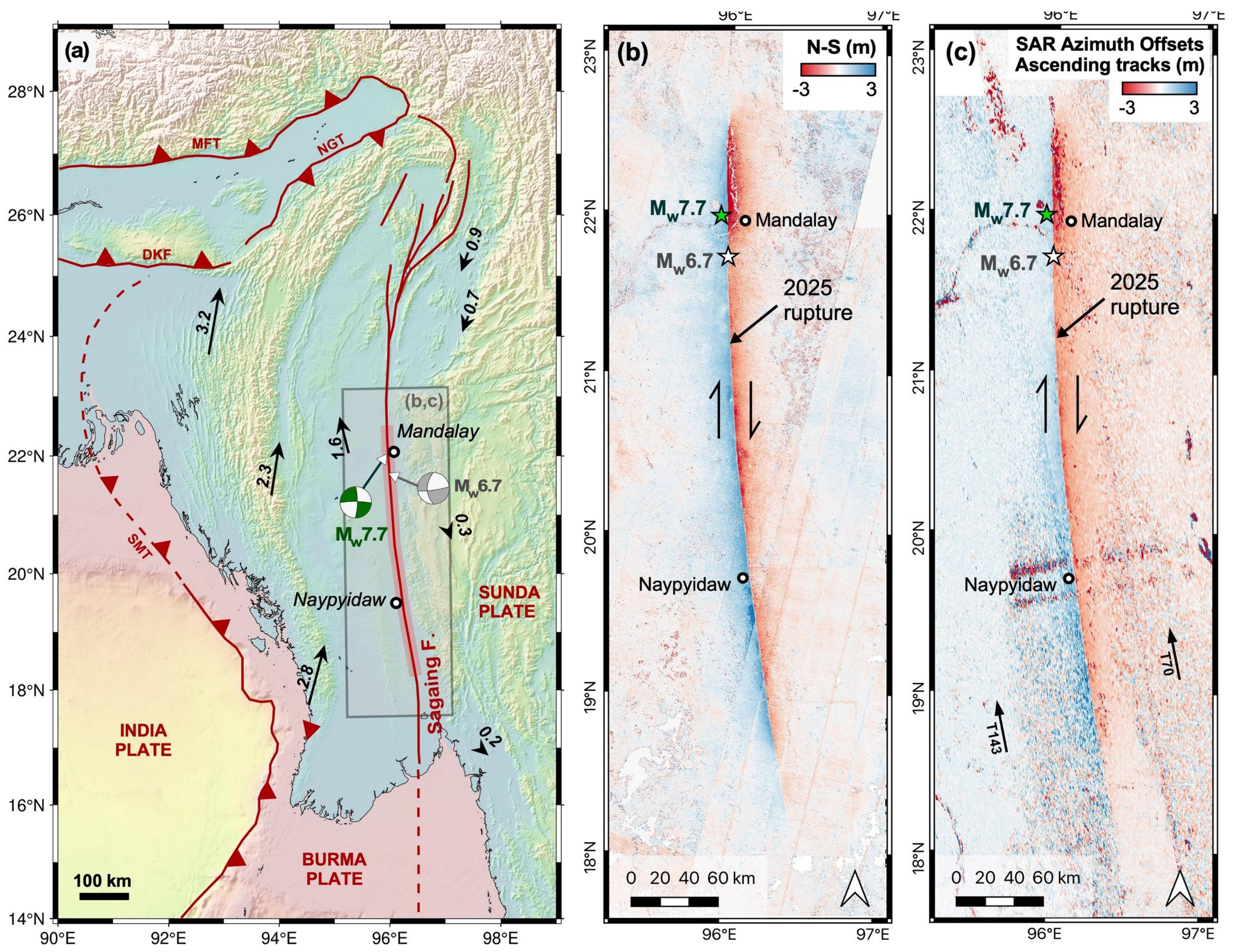


Figure 1: (a) Regional fault trace overlaid on SRTM topography. GNSS vectors and associated velocities (in mm/yr) are relative to a stable Eurasia Plate. (b) North-South surface displacement of the 2025 earthquake from Sentinel-2 image correlation. (c) Sentinel-1 Synthetic Aperture Radar (SAR) pixel offsets, in the azimuth direction.

Slip-predictable? Not exactly…

Does comply with predictions:

- rupture of a known seismicity gap quiescent since 1839 (186 yrs)
- slip of 3-4 m along the ruptured seismicity gap, consistent with the amount of slip accumulated since the last event (dashed grey boxed in Fig. 2c)
- the rupture propagated at supershear speeds, likely favored by the rather linear and smooth geometry of the mature (>300 km total slip) Sagaing Fault
- no shallow slip deficit (at the resolution of our remote sensing observations; field measurements shall reveal more distributed surface deformation)

Does not comply with predictions:

- little impact of the proposed fault segmentation on the slip distribution (expected to have lesser slip at segment boundaries)
- the event ruptured sections that experienced recent moderate to large events, for a total rupture length that exceeds by a factor two the predictions
- largest slip during the 2025 event occurred in a region that already ruptured in the 1946-1956 M_w7.7 and 7.1 sequence.
- little dynamic weakening within the transition zone at 10-15 km, and a uniquely large length/width ratio of ~50.

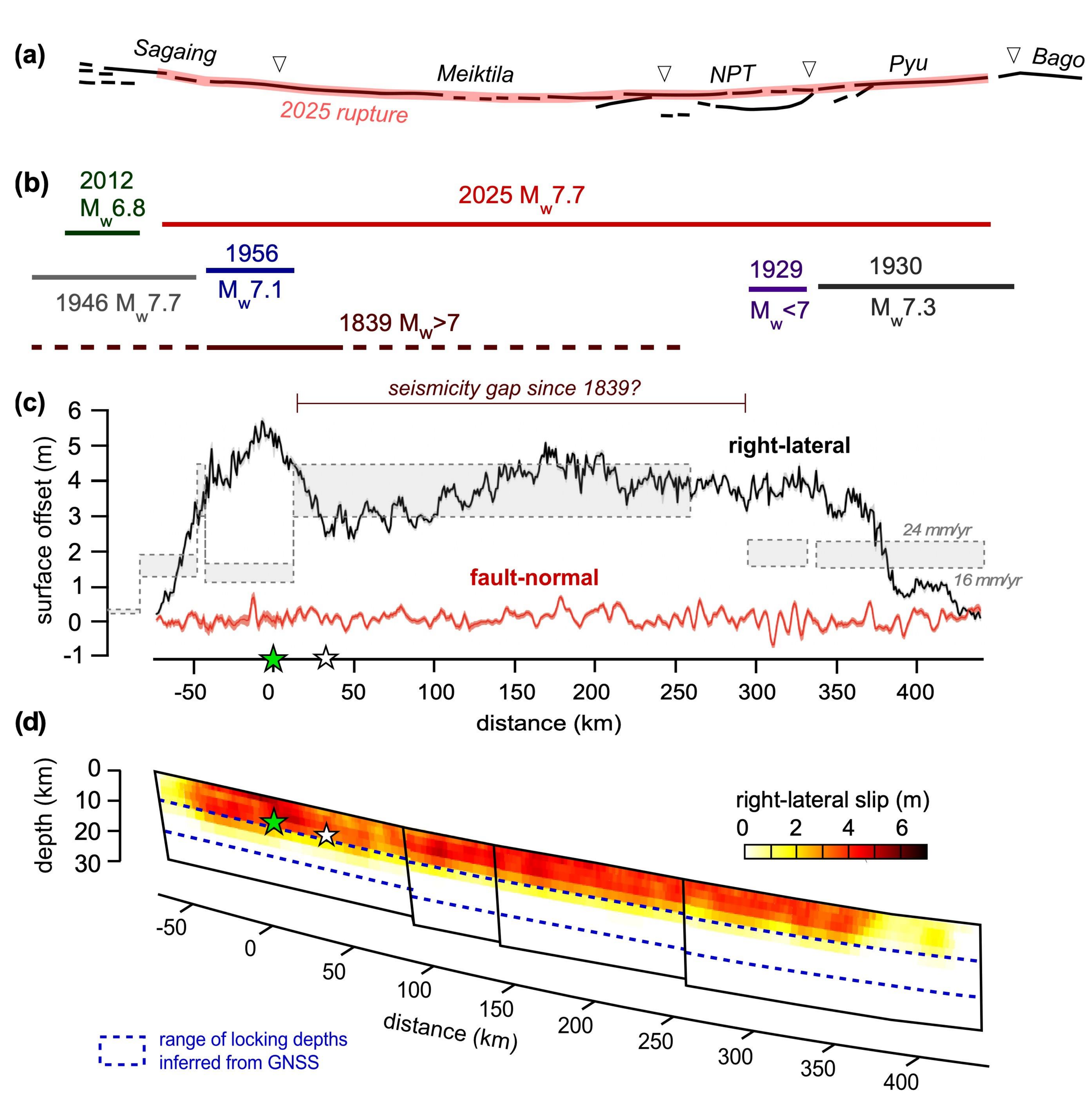


Figure 2: (a) Known geometry of the Sagaing fault along the length that ruptured during the 2025 event. Triangles indicate the fault segment junctions. (b) Horizontal extend of past ruptures and of the 2025 rupture. Vertical distribution of the events reflects their relative chronology. (c) Fault-parallel (black) and fault-perpendicular (red) surface offsets extracted from the Sentinel2 displacement maps. Grey dashed polygons are the expected slip from a slip-predictable model considering the rupture history from (b). (d) Finite slip model for the 2025 Mandalay earthquake, including the M_w6.7 aftershock and the M_w7.7 mainshock.

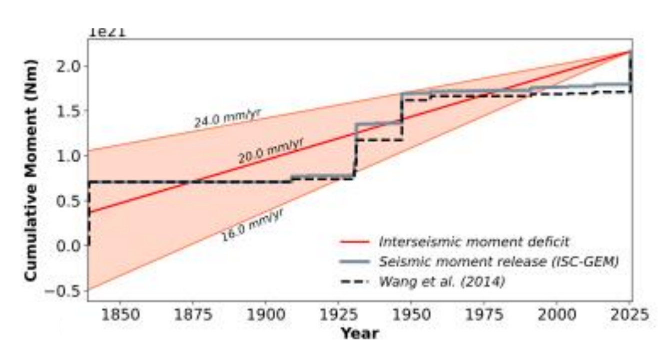
Take home message

- The 2025 M_w7.7 Mandalay earthquake is a unique example of an extremely long supershear rupture with homogeneous slip distribution and velocity.
- This event does not comply with the segmented slip-predictable model as it re-ruptured, with high-slip, sections of the fault that recently ruptured in M_w>7events.
- It is part of a period of elevated seismicity on the Sagaing Fault, likely favored by the simple but curved geometry of the mature Sagaing Fault

Elevated seismicity and supercycle

Moment budget on the Sagaing Fault over the last two decades reveals:

- no residual moment deficit on the Sagaing Fault following the 2025 event
- elevated seismicity with higher density of M_w>6.5 events than the most likely long-term Magnitude-Frequency Distribution (MFD) over the period of observation
- marginal probability density function of the maximum magnitude peaks at M_w7.9, corresponding to a recurrence interval of ~250 years
- the 2025 event corresponds to the most-likely "maximum earthquake" scenario, with reduced probability of larger events



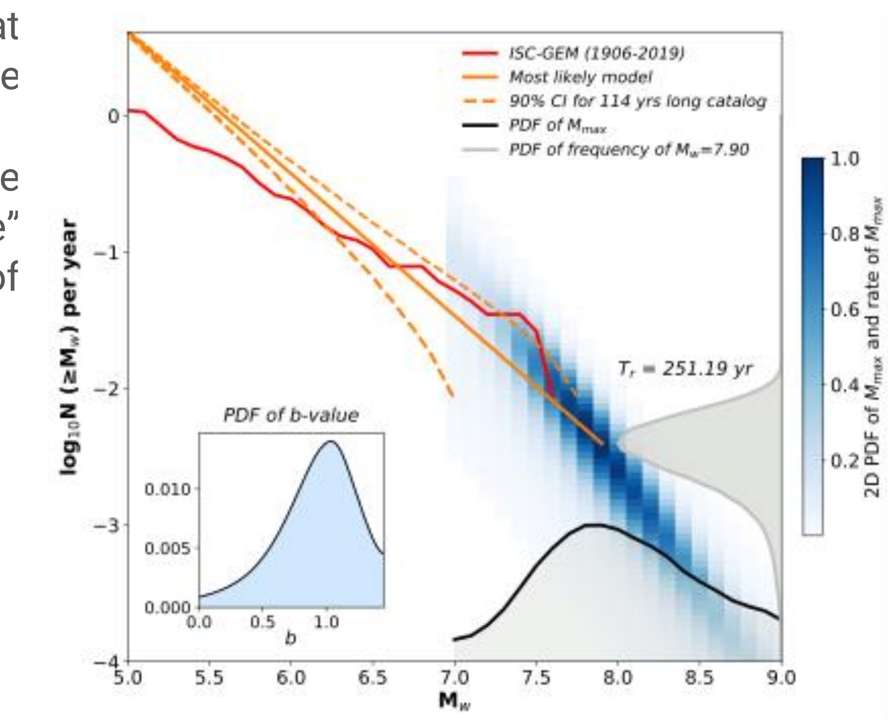
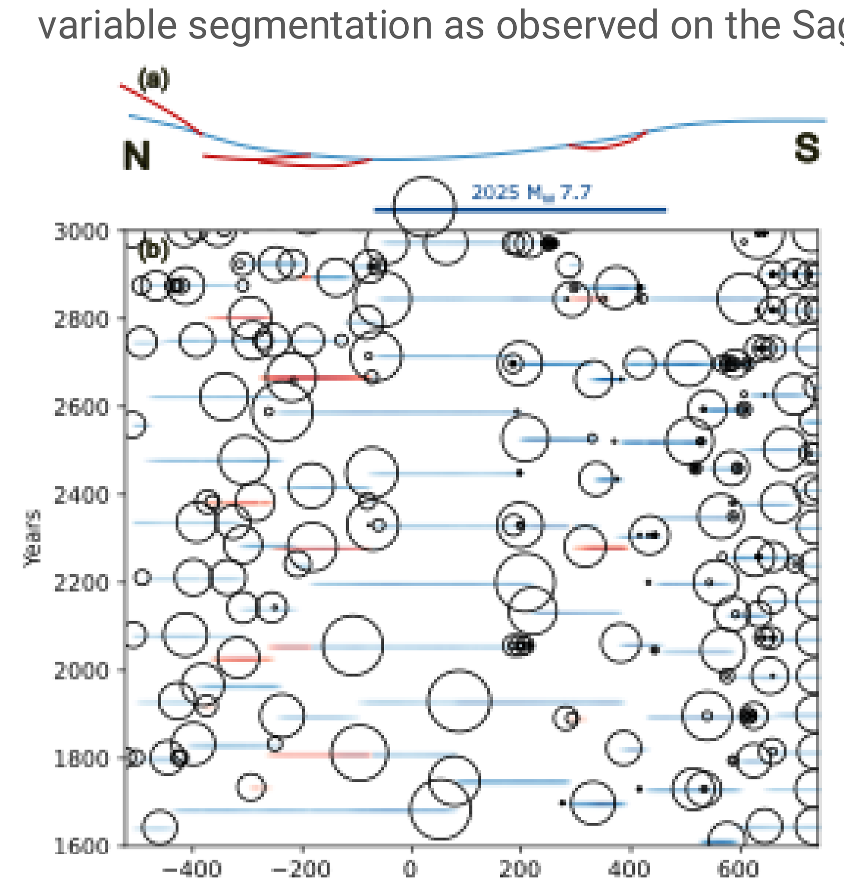


Figure 3: (left) Moment release, moment deficit and their uncertainties cumulated going back in time. Cumulative moment considers events from 1839 to present within a 60 km-distance of the Sagaing fault. (right) Preferred long term magnitude-frequency distribution of earthquakes within the domain considered for the moment budget analysis. Inset shows the posterior pdf of b-value.

Quasi-dynamic modeling of earthquake super-cycles on the Sagaing fault:

- no permanent geometrical nor stress barriers inhibiting slip or rupture propagation
- largest-magnitude events re-occur quasi-periodically along the Meiktila segment
- smaller events re-occur more frequently on other segments that present higher geometrical complexity (bends, secondary fault junctions, etc.)
- The model reproduces earthquake supercycles, with clustered seismicity and variable segmentation as observed on the Sagaing Fault
- curved fault geometry is sufficient to create stress heterogeneities and create self-complexity in the system



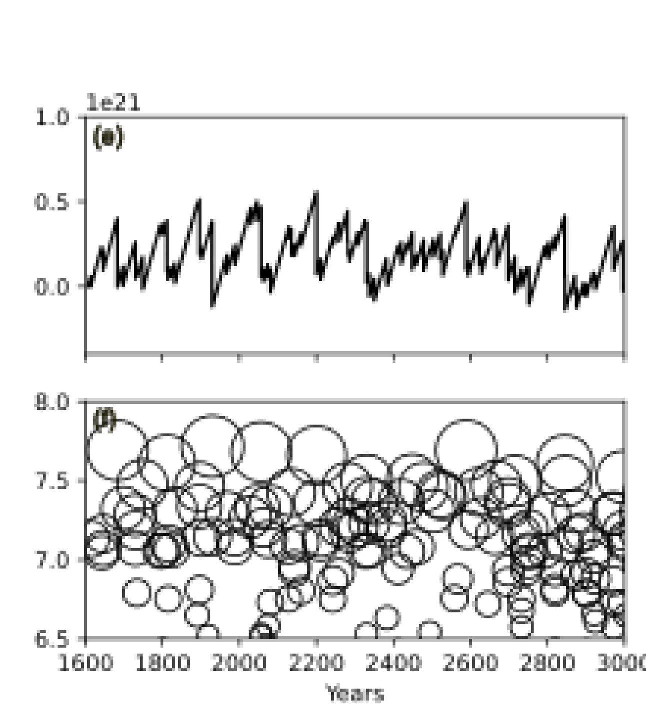


Figure 4: Quasi-dynamic seismic cycle simulations of the Sagaing fault using Quake-DFN. (a) Simplified Sagaing fault geometry (main fault in blue and secondary faults in red). (b) Time series of ruptures once a steady-regime is reached. Ruptures of the main fault are in blue and on secondary faults in red. Circles show epicentral locations with a size proportional to magnitude. (e) Simulated moment deficit and (f) earthquake magnitudes from Quake-DFN.

Reference of the study

Antoine, S. L., Shrestha, R., Milliner, C., Im, K., Rollins, C., Wang, K., Chen, K., & Avouac, J. (2025). The 2025 Mw7.7 Mandalay, Myanmar, earthquake reveals complex earthquake cycle with clustering and variable segmentation on Sagaing fault. *PNAS* https://doi.org/10.1073/pnas.2514378122.

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