

Research Paper

The 28 March 2025 M_W 7.7 Myanmar earthquake revealed by InSAR and POT observations: A supershear event with no shallow slip deficitZhe Ding^{a,b}, Xin Wang^c, Shuai Wang^{b,d,*}, Caijun Xu^e, Limei Wang^f^a School of Geomatics Science and Technology, Nanjing Tech University, Nanjing 211816, China^b Wuhan Gravitation and Solid Earth Tides National Observation and Research Station, Wuhan 430071, China^c School of Earth and Space Sciences, University of Science and Technology of China, Anhui 230026, China^d School of Environment Science and Spatial Informatics, China University of Mining and Technology, Xuzhou 221116, China^e School of Geodesy and Geomatics, Wuhan University, Wuhan 430072, China^f School of Surveying and Urban Spatial Information, Henan University of Urban Construction, Pingdingshan 467000, China

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ABSTRACT

On 28 March 2025, a shallow devastating strike-slip earthquake with a moment magnitude (M_W) of 7.7 struck Mandalay, the second-largest city in Myanmar, marking the most powerful seismic event in this region over the past century. The event holds significant implications for understanding regional tectonic evolution. In this study, we utilize spaceborne interferometric synthetic aperture radar (InSAR) data and pixel offset observations in both azimuth and range directions to capture the co-seismic surface deformations associated with this earthquake, which depict clear surface ruptures extending approximately 500 km. We develop a three-segment fault slip model to estimate the detailed slip distribution of the 2025 Myanmar event. The inversion results demonstrate that a three-segment fault model with dip angles varying from 70° to 88° can effectively produce the observed coseismic surface deformation. Our analysis reveals that the earthquake is dominated by right-lateral strike-slip motions within the top 12 km of the crust. Notably, the maximum slip of 4.6 m is observed at the ground surface, suggesting no significant shallow slip deficit occurred. Furthermore, the 2025 M_W 7.7 earthquake appears to have filled a previously identified seismic gap along the southern segment of the Sagaing fault. Coulomb stress transfer modeling indicates that coseismic slip on the northern segment has promoted the subsequent failure of the two southern segments. We estimate a recurrence interval of large-magnitude earthquakes ($M_W > 7$) of approximately 104–131 years for the seismogenic fault based on the coseismic and interseismic released seismic moments. The significant scarcity of aftershocks within the supershear rupture zone, coupled with the relatively low moment-scaled radiated energy, provides compelling evidence for supershear rupture propagation along the Sagaing fault during this earthquake.

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1. Introduction

On 28 March 2025, a devastating M_W 7.7 earthquake struck Mandalay, the second-largest city in Myanmar. The shallow hypocenter (approximately 10 km depth) of the earthquake has caused intense ground shaking that was felt throughout Southeast

Asia, including Thailand, Vietnam, and southern China. As the most powerful seismic event in Myanmar since 1912, the earthquake caused devastating consequences: over 5400 fatalities and 11,000 injuries were reported. Widespread destruction affected residential structures, transportation systems, and critical infrastructure in both urban and rural areas, creating significant socio-economic disruptions that will require extensive long-term recovery efforts.

The 2025 Myanmar earthquake ruptured along the Sagaing fault, a major N–S striking, right-lateral strike-slip fault that accommodates the relative motion between the Burma and Sunda plates at a rate of about 18–24 mm/yr [1–5]. This approximately 1200–1400 km-long fault extends from the Andaman Sea

* Corresponding author. School of Environment Science and Spatial Informatics, China University of Mining and Technology, Xuzhou 221116, China.

E-mail address: shwanggeo@cumt.edu.cn (S. Wang).

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spreading center in the south (traversing densely populated regions such as Yangon, Naypyidaw, and Mandalay [4–8]) to the Himalayan collision zone in the north. Geological studies indicate that the Sagaing fault has accommodated approximately 330–450 km of cumulative dextral displacement since the Miocene [9–11], and historical earthquake catalogs indicate that it has generated at least nine earthquakes (Fig. 1) with $M \geq 7.0$ since 1900. These demonstrate its long-lived and active tectonic history. Preliminary finite fault waveform models derived from the USGS for the 2025 event reveal a rupture length exceeding 500 km, with maximum slip of up to about 5 m occurring at shallow depths. Surface displacements exceeded 6 m in several areas, and the rupture propagated at supershear velocity, faster than the local shear velocities, making this event one of the rare and well-documented cases of supershear earthquakes [12].

Despite the long-recognized seismic hazard in this region, the 2025 earthquake revealed significant gaps in our understanding of rupture dynamics, surface deformation patterns, and risk exposure in densely populated zones along the fault. Investigating this earthquake provides a rare opportunity to study one of the world's longest documented strike-slip surface ruptures. In this study, we employ interferometric synthetic aperture radar (InSAR) data and pixel offset tracking (POT) from multiple satellite tracks to quantify the spatial distribution of coseismic surface deformation. We develop two fault slip models to constrain the coseismic fault geometry and kinematics of the 2025 Myanmar earthquake based on the observed surface deformation. The first model assumes a uniform dip angle along the fault strike, while the second employs a three-segment fault configuration to better capture the geometric complexity of the rupture. We also perform Coulomb stress

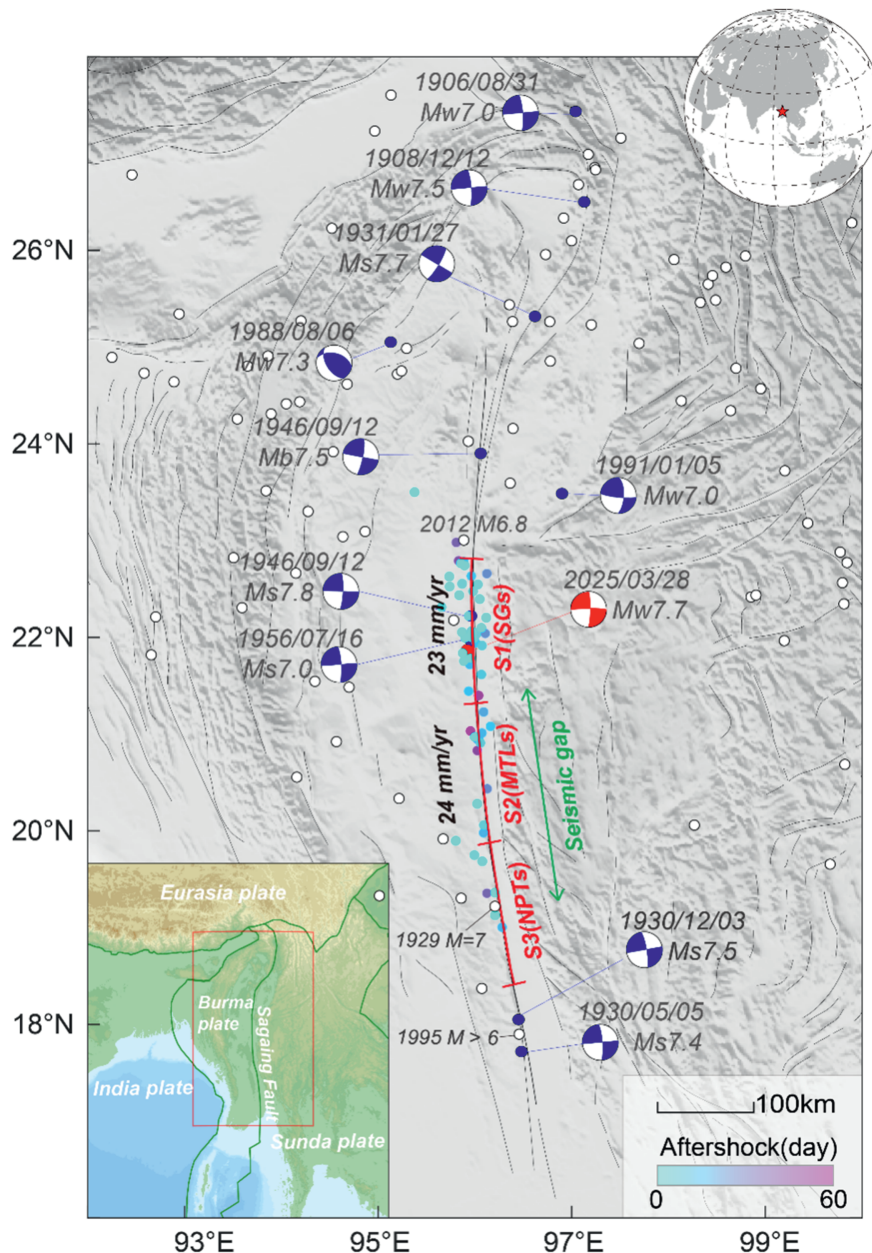


Fig. 1. Tectonic settings of the study area. The red beach ball represents the focal mechanism solution for the 2025 $M_w7.7$ Myanmar earthquake from the United States Geological Survey (USGS), with colored dots indicating aftershocks of this event. The blue beach balls represent $M > 6$ historical earthquakes along the Sagaing fault [6], while the white dots are regional $M > 6$ historical earthquakes from the USGS catalog. The red line marks the surface trace of the seismogenic fault for the 2025 $M_w7.7$ earthquake, which is divided into three segments (S1–S3) according to Wang et al. [7]. SGs: Sagaing segment; MTLs: Meiktila segment; NPTs: Nay Pyi Taw segment.

transfer analysis to investigate intersegment interactions and analyze the differences in rupture slip between this event and several other large earthquakes. We estimate the recurrence interval of the seismic gap by utilizing the coupling relationship between interseismic locking and coseismic slip. Additionally, we examine the distribution of aftershocks and the moment-scaled radiated energy to investigate the rupture velocity characteristics. The findings provide new insights into strike-slip fault mechanics and seismic hazard along the Sagaing fault system.

2. Data and method

2.1. Data

In this study, to characterize the kinematic responses of the Earth's surface to the 2025 Myanmar earthquake, we apply a combination of interferometry and SAR pixel offset tracking methods to Sentinel-1 SAR data from the satellite's ascending (paths 70 and 143) and descending (paths 33 and 106) tracks. The specific InSAR data processing steps are as follows. First, GMTSAR software [13] is used to derive the coseismic surface deformation fields for the event, based on the principle of two-pass differential interferometric synthetic aperture radar (D-InSAR). This involves generating interferograms from pairs of Single Look Complex (SLC) images acquired along the same satellite track and frame (Table S1), captured before and after the event. The topographic phase contributions are removed through precise orbit data from the European Space Agency, combined with the 30-m resolution Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM). A multi-looking process is applied with 16 looks in the range direction and 4 looks in the azimuth direction to balance resolution and phase noise reduction. To reduce phase noise and avoid signal distortion simultaneously, a Gaussian filter with a wavelength of 400 m is used to suppress high-frequency noise. The filtered interferograms are subsequently unwrapped using the SNAPHU algorithm [14]. To mitigate unwrapping errors, the interferograms are divided along both sides of the fault, and each segment is unwrapped separately. The two unwrapped segments are subsequently merged to ensure phase continuity. The unwrapped phase is then geocoded into the WGS84 geographic coordinate system. Finally, to minimize atmospheric phase delays, linear phase ramps are removed using data from regions distant from the coseismic deformation area. Following these processing steps, the final coseismic deformation fields for the 2025 Myanmar event are derived.

The pixel offset displacements of the 2025 Myanmar event are derived using the POT method [15,16] applied to synthetic aperture radar (SAR) images acquired by the Sentinel-1 satellite (Table S1). The matching window is set to 64 pixels in range and 64 pixels in azimuth. The resulting range and azimuth offset displacements are shown in the POT results. The complete datasets used in this study are publicly available through Wang and Xu [17].

2.2. Modeling strategy

According to official reports and satellite optical imagery [18], the rupture of the 2025 Myanmar earthquake had reached the Earth's surface, requiring a dislocation model to extend to the surface. Utilizing the coseismic deformation fields derived from D-InSAR and POT, we estimate the coseismic slip distribution through linear inversion using CosInv software [19–21]. To improve the inversion efficiency, we downsample these observations using the quadtree sampling algorithm [22]. During the

inversion process, each type of observation is weighted based on the variance of its respective dataset.

For coseismic slip distribution modeling, we construct two fault models based on the surface rupture traces identified from the pixel offset displacements. Model I assumes a uniform fault dip along the strike. While Model II incorporates structural segmentation as proposed by Wang et al. [2], dividing the Sagaing fault into three segments: SGs, MTLs, NPTs, represented respectively as segments S1, S2, and S3 in Model II (Fig. 1). Each segment in Model II is assigned a constant dip angle along strike. In both models, the fault plane is uniformly set to a width of 30 km and discretized into rectangular slip patches of about $4 \text{ km} \times 4 \text{ km}$. To determine the optimal dip angle, we predefine a range of 50° – 89° based on USGS-reported focal mechanism solutions. We then apply a grid search method at 1° intervals to identify the optimal dip (Fig. S1). The Green's functions are calculated using the elastic half-space uniform slip model [23]. To avoid non-physical slip discontinuities between adjacent fault patches, we apply a Laplacian smoothing constraint [24] and use the L-curve method to balance data misfit and slip roughness (Fig. S2). The weighting for each downsampled data set (LOS, azimuth offset, and range offset displacements) is assigned based on their respective variances, under the assumption that they are mutually independent [19–21].

3. Results

3.1. Coseismic deformation

Fig. 2 presents the coseismic interferograms for the 2025 Myanmar event from two different tracks, both showing complex coseismic deformations. The maximum observed in the coseismic InSAR displacement map is about 0.4 m along the line of sight (LOS). However, this value underestimates the actual surface displacements, as the phase gradient is too high across the fault trace. The large deformations are predominantly concentrated on both sides of the Sagaing fault, clearly delineating the extensive surface rupture associated with this event. In the ascending T70 (Fig. 2(a)), areas distal to the epicenter exhibit fragmented, discontinuous fringes, with coherence values generally below 0.3 (Fig. S3), reflecting decorrelation. Such coherence loss is likely driven by environmental factors, including dense vegetation, humidity fluctuations, and surface disturbances. In contrast, the near-field zone flanking the fault maintains higher coherence (>0.5 ; Fig. S3), allowing for a more complete and reliable characterization of the coseismic deformation field. In the descending T33 (Fig. 2(b)), the interference fringes are generally more continuous, and the coherence on the eastern side of the fault exceeds 0.6 (Fig. S3), enabling a clearer and more accurate delineation of the earthquake-induced deformation.

Fig. 3 shows the POT results. The descending and ascending azimuth offset maps show different patterns on both sides of the fault. The east side moves away from the ascending satellite, while towards the descending satellite, with maximum offset magnitudes reaching about 4 m (Fig. 3(a)–(d)). The ground displacement discontinuity can be clearly seen in the range offset maps (Fig. 3(e)–(h)), indicating that the slip during the earthquake had reached the Earth's surface. In the range offset results (Fig. 3(e)–(h)), the maximum offset is approximately 1 m, which is significantly smaller than the azimuth offsets. The POT results depict a significant and slightly curved rupture zone, corresponding to the Sagaing fault, with an estimated rupture length of approximately 500 km.

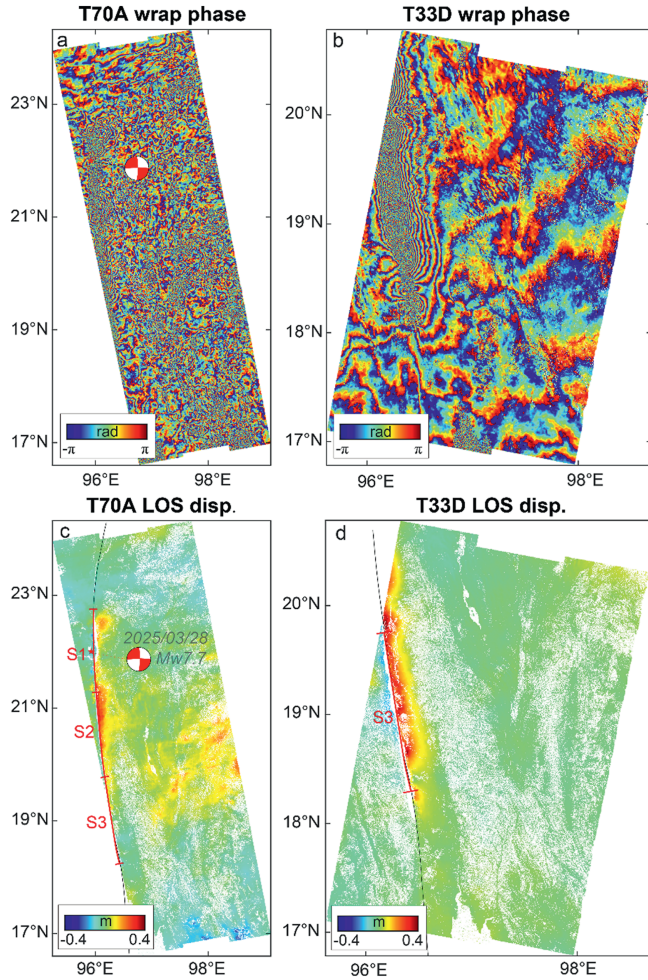


Fig. 2. Coseismic deformation fields of the 2025 Myanmar event. (a) and (b) are the wrapped interferograms from ascending T70 and descending T33. (c) and (d) are the same as (a) and (b) but for the unwrapped LOS displacements. The red star represents the location of the hypocenter.

3.2. Inversion results

Fig. 4 shows observed and simulated results from two models. Although both models effectively reproduce the InSAR observations, Model II exhibits a smaller root mean square (RMS) difference between its simulated results and the InSAR observations (Fig. 4), indicating better fitting performance. In the LOS simulation, the fit for ascending T70 is not as good as that for descending T33. Specifically, the LOS residual of the ascending T70 shows slight deformation near the fault rupture zone (Fig. 4(c) and (e)). This could arise because the ascending T70 data are acquired 3 days later than the descending T33 data (Table S1), potentially capturing post-seismic deformation. Additionally, the poorer coherence in the ascending T70 interferogram compared to the descending T33 interferogram may introduce noise.

The optimal dip angle estimated for Model I is 87° (Fig. S1), resulting in a seismic moment of 5.91×10^{20} N·m, corresponding to an $M_W 7.78$ event, assuming a shear modulus of 30 GPa (Table 1). In comparison, Model II assigns optimal dip angles of 70° , 87° , and 88° to its three segments from north, yielding seismic moments of 2.07×10^{20} , 2.26×10^{20} , and 1.85×10^{20} N·m, respectively. These correspond to $M_W 7.48$, $M_W 7.51$, and $M_W 7.45$ events (Fig. S1 and

Table 1). The total seismic moment for Model II is 6.18×10^{20} N·m, corresponding to an $M_W 7.80$ event. Each segment in Model II exhibits distinct surface slip characteristics, with maximum slips of 4.6 m (S1), 4.5 m (S2), and 1 m (S3), respectively (Fig. 5). Both Models I and II consistently indicate that the 2025 Myanmar event was dominated by right-lateral strike-slip motion, with the majority of the coseismic slip concentrated in the upper 12 km of the crust. The maximum slip is located at shallow depths of 0–4 km. Comparisons of the surface rupture amplitudes derived from Model II with those observed in optical imagery [18], Fig. S4 show general agreement, despite minor discrepancies, which remain within acceptable error margins. Overall, the optical image analysis supports the reliability of Model II and further confirms that the rupture reached the Earth's surface, with near-surface slip potentially exceeding that at greater depths.

4. Discussion

4.1. Coulomb stress changes and the rupture propagation of the 2025 Myanmar earthquake

Our coseismic slip distribution model indicates that the rupture extended approximately three to four times farther south of the hypocenter than to the north (Fig. 5(b)), suggesting a predominantly southward rupture propagation. This finding is supported by rupture velocity data, which show that the $M_W 7.7$ earthquake primarily ruptured southward along the Sagaing Fault over a duration of about 70–90 s [25]. The observed rupture pattern may be closely linked to the existence of a seismic gap in the region [26,27].

Notably, the northern portion of the 2025 $M_W 7.7$ rupture partially overlapped with the southern segment of the 2012 $M 6.8$ earthquake (Fig. 1), while the southern end appears to coincide with the rupture area of the 1930 $M 5.75$ earthquake [25] (Fig. 1). This indicates that the fault segment for the 2025 $M_W 7.7$ earthquake has remained largely inactive for nearly a century, potentially allowing substantial strain accumulation that ultimately resulted in this large-scale rupture. Moreover, Xiong et al. [1] demonstrated that the Coulomb stress from previous earthquakes along the Sagaing fault contributed to a positive stress buildup within the gap area, implying that a major event, such as the 2025 $M_W 7.7$ earthquake, was becoming increasingly likely inevitable.

To further elucidate the physical mechanism of the rupture process, we calculate the static Coulomb failure stress change (CFS) on subsequent fault segments caused by the initial rupture segment, based on the Coulomb failure criterion [28] (Eq. (1)).

$$\Delta CFS = \Delta \tau + \mu \Delta \sigma \quad (1)$$

where $\Delta \tau$ represents the change of shear stress on the fault plane, which usually takes a positive value when it increases in the slip direction; $\Delta \sigma$ is the change of normal stress, and the tensile stress direction is generally positive. μ is the effective friction coefficient, typically between 0.2 and 0.4 [29]. Previous studies have shown that different μ within this range have little effect on ΔCFS [30]. We then adopt a value of 0.4 for our calculations. A positive ΔCFS can enhance tectonic loading on faults, promoting them closer to failure, whereas a negative ΔCFS inhibits seismicity.

Our results show that the Myanmar earthquake rupture initially nucleates at the S1 (SGs) and then propagates both southward and northward (Fig. 6). A significant stress increase conducive to rupture nucleation is observed near the northern end of S2 (MTLs). Subsequently, the rupture continues along S3, with a static Coulomb stress change reaching up to about 2 bars within

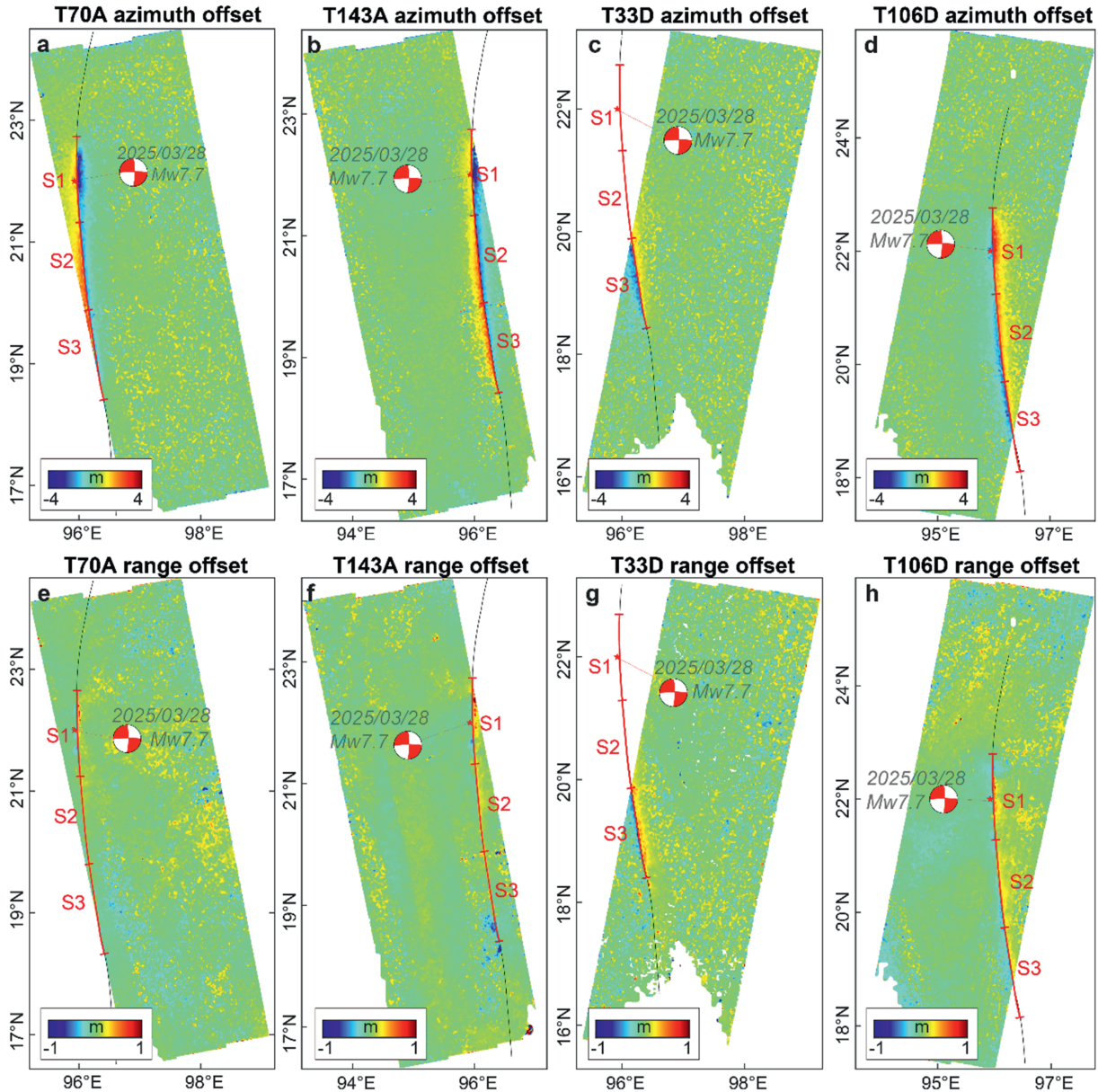


Fig. 3. Pixel offset maps of the 2025 Myanmar event. (a) and (b) are the azimuth offset displacements from ascending T70 and T143. (b) and (c) are the azimuth offset displacements from descending T33 and T106. (e)–(h) are similar to (a)–(d) but for range offset displacements. The red star represents the location of the hypocenter.

approximately 100 km at the northern end of S3 (Fig. 6), ultimately triggering slip on S3. Although the rupture process associated with this event is less complex than that of other seismogenic faults (e. g. the 2018 $M_W7.5$ Papua [31]), the long-distance rupture nucleation phenomenon observed in this study area is relatively rare, and its rupture length far exceeds the upper limit of approximately 250 km predicted by empirical relationships [32] for an $M_W7.7$ earthquake.

Given the extensive rupture of the 2025 earthquake, it is critical to understand how the resulting stress changes affected nearby fault structures and possibly contributed to the distribution of aftershocks. Peng et al. [12] conducted a detailed analysis of the aftershock clustering, revealing that the right-lateral strike-slip faults with a strike of 330° may represent one of the key seismogenic structures responsible for the observed aftershocks. Additionally, they identify a series of left-lateral strike-slip faults with a strike of 70° , primarily located north of the mainshock.

To investigate the relationship between the mainshock and these potential seismogenic faults, we assume both are pure strike-slip faults with a dip angle of 90° , assigning rake angles of 180° and 0° for the right-lateral and left-lateral faults, respectively. Using Model II as the source fault, we calculate the CFS changes at a depth of 10 km on both receiver fault orientations. The results show that, for the receiver fault striking 330° , areas of increased stress are present on both sides of the fault trace (Fig. 7(a)), indicating a potential promotion of slip along these structures. In contrast, for the receiver fault striking 70° , the mainshock only induces positive CFS changes on two ends of the seismogenic fault, indicating the potential triggering of aftershocks in that region. These findings are aligned with the stress changes calculated by Peng et al. [12] based on the USGS-reported coseismic slip model. Overall, our results highlight the critical role of fault geometry in shaping the spatial distribution of stress changes and potential aftershock activity.

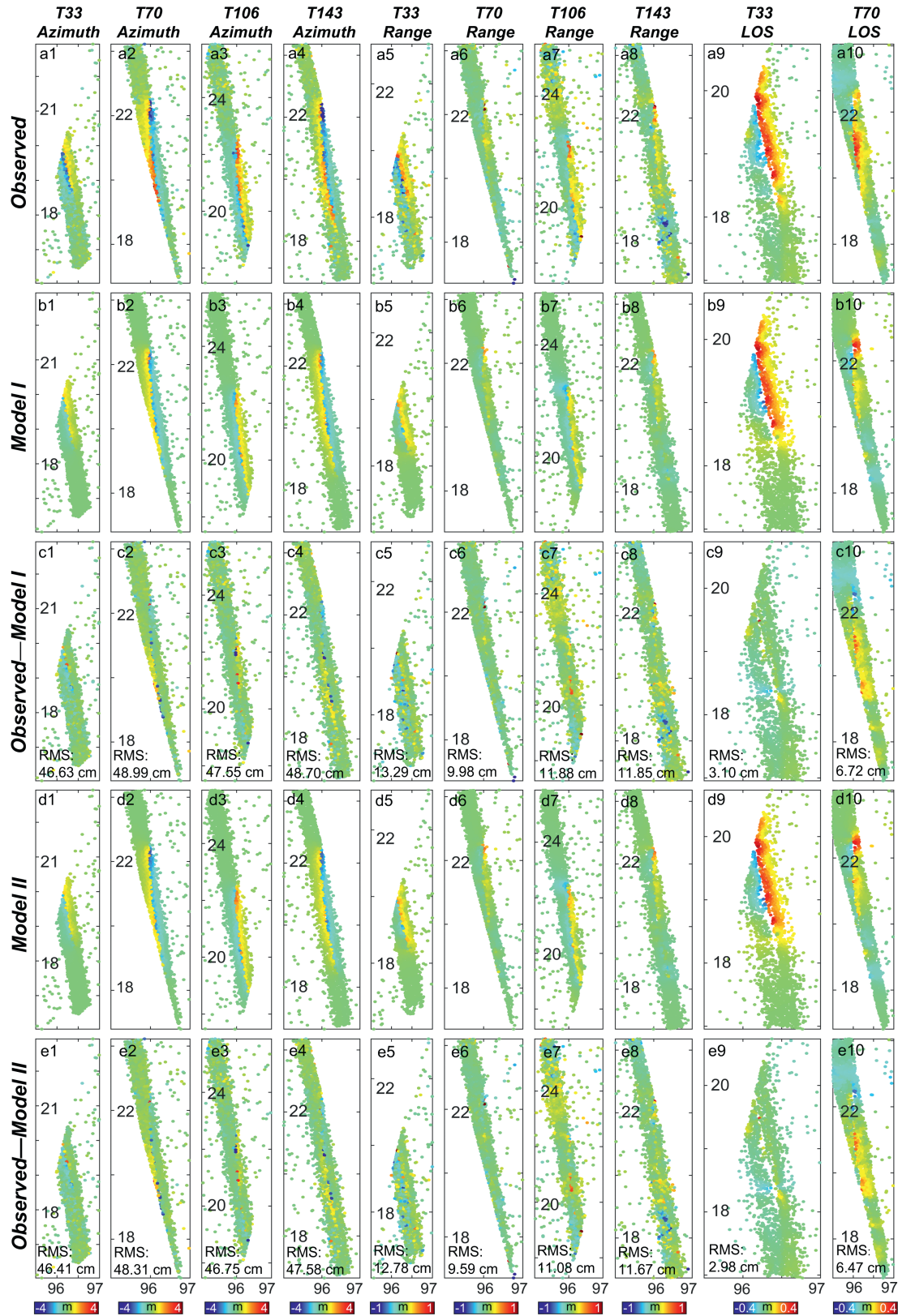


Fig. 4. Comparisons of observed and simulated coseismic deformation from Models I and II. (a1)–(a10) show the observed azimuth offset, range offset, and LOS displacements, respectively. (b1)–(b10) show simulated results from Model I. (c1)–(c10) show fitting residual between (a1)–(a10) and (b1)–(b10). (d1)–(d10) and (e1)–(e10) are the same as (b1)–(b10) and (c1)–(c10) respectively, but from Model II.

Table 1
Geodetic-determined seismic moment for the 2025 Myanmar event.

Model	Segment	Strike (°)	Dip (°)	Length (km)	Width (km)	M_0 ($\times 10^{20}$ N·m)	M_W
I	-	355.7	87	480	30	5.91	7.78
II	S1	358.9	70	156	30	2.07	7.48
II	S2	354.8	87	160	30	2.26	7.51
II	S3	351.3	88	164	30	1.85	7.45
II	S1–S3	-	-	480	30	6.18	7.80

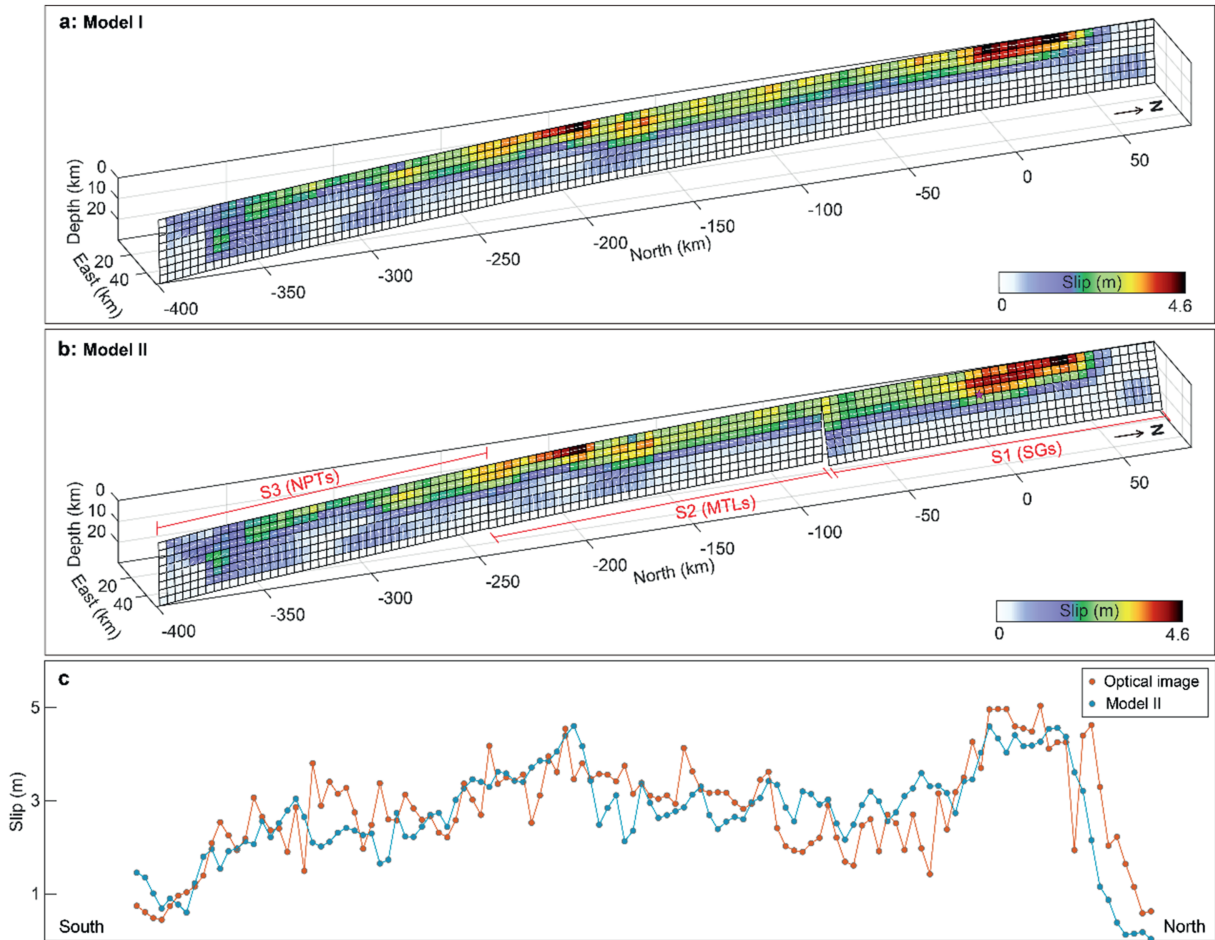


Fig. 5. (a) Coseismic slip distribution inverted for Model I. (b) is the same as (a), but for Model II. (c) Comparison of the amplitude of the surface ruptures estimated in Model II and those derived from optical images. SGs: Sagaing segment; MTLs: Meiktila segment; NPTs: Nay Pyi Taw segment.

4.2. Characteristics of shallow slip deficits

In this study, based on our coseismic slip model, we calculate the cumulative strike-slip of the 2025 event at different depth layers and normalized the results by the maximum cumulative value (Fig. 8(c)). Notably, our results reveal that slip at shallow depths of 0–2 km exceeds that at depths of 4–6 km, indicating the absence of a shallow slip deficit (SSD) in the slip distribution. Considering the potential impact of model discretization, we additionally performed inversions with a finer fault-patch size of 2 km $\times$ 2 km (Fig. S5). The resulting slip distribution is consistent with the 4 km $\times$ 4 km model and similarly shows no evidence of SSD (Fig. S6), confirming the robustness of our conclusions. This conclusion is further supported by the N–S displacement derived from optical imagery, exhibiting surface displacements of up to about 5 m (Fig. S4). It is important to recognize that if the shallow crust were dominated by inelastic deformation, the observed

coseismic slip would likely be reduced, with seismic energy instead released through distributed deformation mechanisms—such as minor surface ruptures, landslides, liquefaction, or lateral spreading [33]—which could result in an SSD pattern. However, our models, particularly Model II, show no substantial reduction in slip at depths shallower than 6 km (Fig. 8(c)), suggesting that the upper crust in this case predominantly underwent elastic deformation. The slip distribution observed in this event closely resembles that of the 2018 M_W 7.5 Palu earthquake, where the maximum slip occurred in the topmost patch of the slip model, and no SSD was observed; the latter event also occurred on a mature strike-slip fault (Palu-Koro fault) [34].

It is worth emphasizing that the Sagaing fault is a highly active strike-slip fault, with a relatively high earthquake recurrence rate and a rapid slip rate (about 20 mm/yr [35]). This maturity likely contributes to the absence of SSD in our case. In contrast, SSD has frequently been documented on immature strike-slip faults [36],

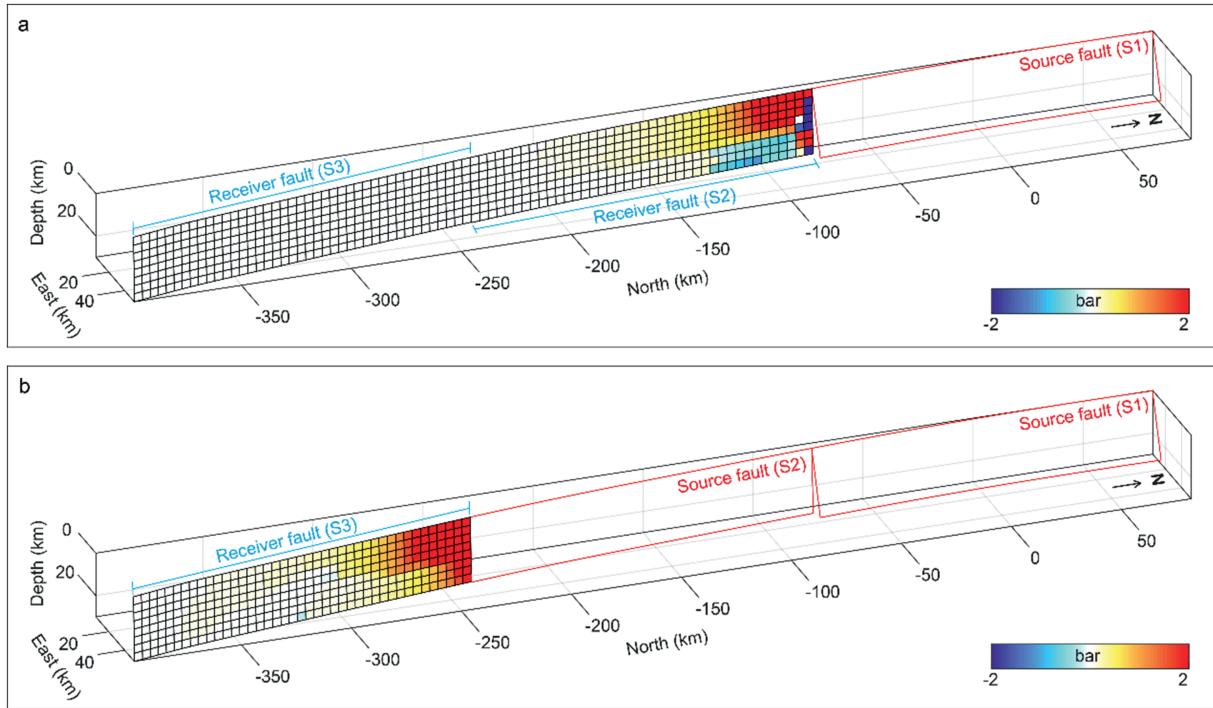


Fig. 6. Static Coulomb failure stress change (ΔCFS) induced by rupture slip. (a) Static Coulomb failure stress change on receiver faults S2 and S3 induced by source fault S1. (b) is the same as (a), but receiver fault is S3 and source faults are S1 and S2.

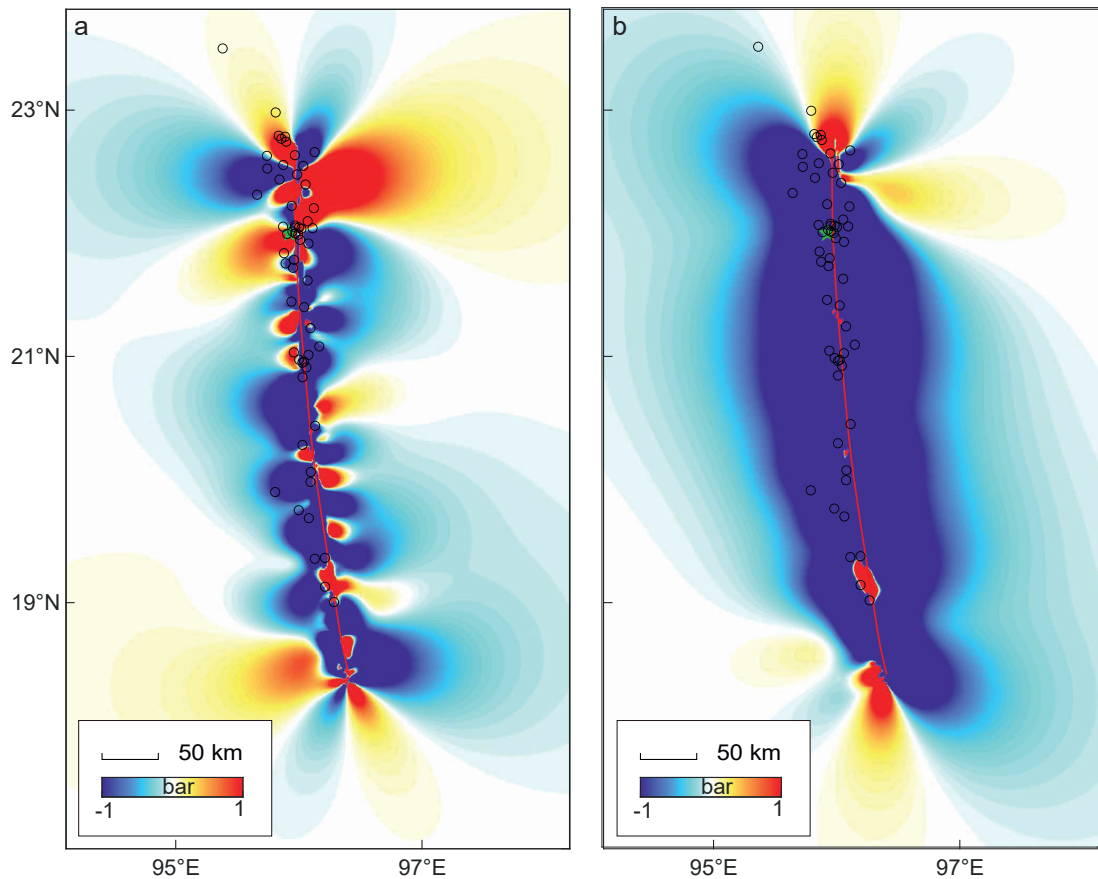


Fig. 7. (a) Static Coulomb failure stress changes at a depth of 10 km induced by the 2025 Myanmar earthquake, with receiver fault parameters of strike = 330°, dip = 90°, and rake = 180°. (b) is the same as (a), but using receiver fault parameters of strike = 70°, dip = 90°, and rake = 0°. The green star represents the epicenter.

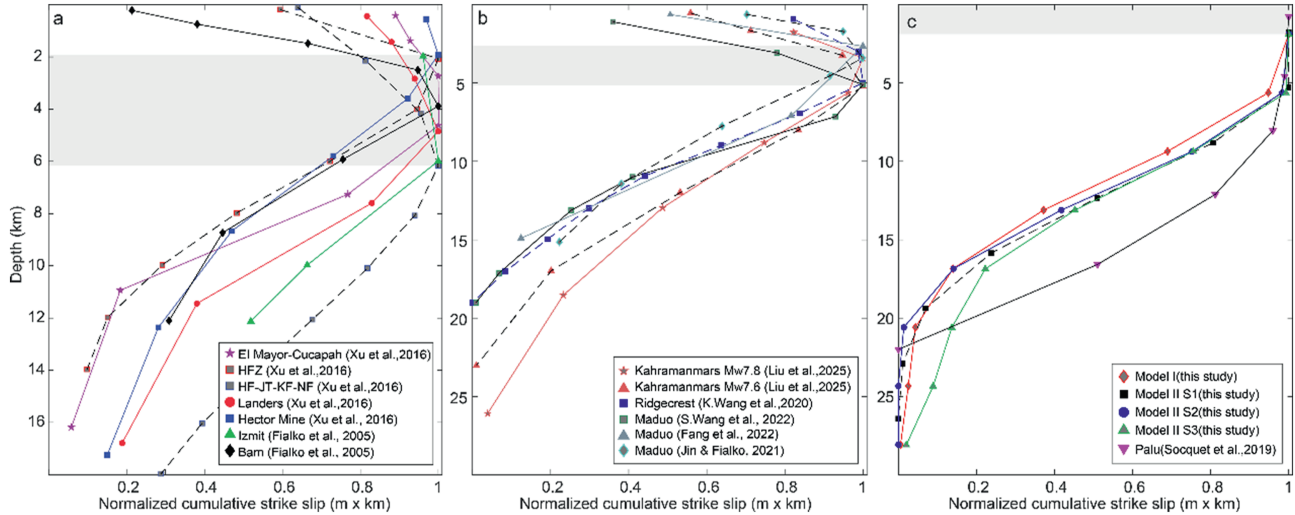


Fig. 8. (a) Normalized cumulative strike-slip versus depth for large strike-slip earthquakes (modified from Fialko et al. [39]). (b) is the same as (a), but for the 2023 Kahramanmaraş, 2019 Ridgecrest, and 2021 Maduo events. (c) is the same as (a) and (b), but for the 2025 Myanmar and 2018 Palu events.

highlighting the significant influence of fault maturity on the spatial distribution of coseismic slip. Generally, mature faults tend to evolve toward a simpler geometry over long-term activity, with smoother fault surfaces and reduced structural complexity. Conversely, immature faults often contain larger and more complex structural zones [37], which frequently exhibit pronounced off-fault distributed deformation [38]. Therefore, earthquakes occurring on mature strike-slip faults do not necessarily exhibit SSD.

In contrast, SSD has been clearly documented in several large-magnitude strike-slip earthquakes, including the 1992 Landers, the 1999 Hector Mine, the 1999 Izmit, the 2003 Bam, the 2023 Kahramanmaraş, the 2019 Ridgecrest, and the 2021 Maduo earthquakes. In these cases, maximum slip is typically concentrated at depths of 2–6 km (Fig. 8(a) and (b); [39–43]). Mechanisms proposed to explain the geodetically inferred SSD include: (1) interseismic creep and postseismic afterslip as a result of velocity strengthening rock friction in the shallow crust [44], (2) inadequacies in fault slip inversions due to the neglect of damaged or compliant fault zones [39], and (3) off-fault inelastic deformation involving elastoplastic processes [45].

4.3. The interplay between the interseismic and coseismic kinematics

Interestingly, we observe a strong consistency between the locking depth (10–15 km [35]) and the coseismic rupture depth (0–12 km) for both S1 and S2, which are about 160 km long. In addition, the ratio of the maximum coseismic slip (4.6 m vs. 4.5 m) between S1 and S2 is approximately consistent with the ratio of the interseismic slip rates (23 mm/yr vs. 24 mm/yr [35]). This consistency indicates that the interseismic kinematics of the 2025 Myanmar event are closely related to its coseismic slip behavior. Therefore, we estimate the interseismic deficit rate using Eq. (2) [46].

$$M_r = S_m L_f (V_s D_s - V_c D_c) \quad (2)$$

where s_m denotes the shear modulus, taken as 30 GPa. L_f represents the fault length. V_s and D_s are the strike-slip rate and locking depth, respectively. V_c and D_c represent the shallow creep rate and the bottom depth of the shallow creep, respectively. We neglect V_c and D_c since there is no evidence for the shallow creep motion on the Sagaing fault. The recurrence interval between two high-

magnitude earthquakes is denoted as T , and the cumulative seismic moment released between earthquakes is $M_r T$.

For the S1 involved in the 2025 Myanmar event, GNSS data analyzed by Tin et al. [35] indicate a slip rate of 23 mm/yr and a locking depth of 10 km. Since the last major event on this segment (the 1956 $M_{\text{W}}7.0$ earthquake), S1 has accumulated an estimated slip deficit of about 1.6 m, corresponding to a moment deficit of 7.43×10^{19} N·m, which is equivalent to an $M_{\text{W}}7.22$ event. This value is generally consistent with the geodetic-determined seismic moment released by S1 during the 2025 event in Model II (1.85×10^{20} N·m, Table 1). The discrepancy between these estimates may not have fully locked since the previous rupture.

In contrast, S2 and S3 are located within a known seismic gap and lack records of recent large earthquakes. Therefore, we assume they are fully locked during the interseismic period and the entire accumulated slip deficit is released during the 2025 Myanmar earthquake. Previous studies indicated that S2 has a locking depth of about 15 km and a slip rate of about 24 mm/yr [35]. During the 2025 earthquake, S2 released a cumulative seismic moment of 2.26×10^{20} N·m (Table 1), corresponding to an estimated recurrence interval of large-magnitude events ($M_{\text{W}} > 7$) of approximately 131 years. Although the specific locking depth and slip rate of S3 remain unknown, we assume them to be the same as those of S2 for estimation purposes. Based on this assumption, the recurrence interval of large-magnitude events ($M_{\text{W}} > 7$) for S3 is about 104 years.

4.4. The evidence of supershear rupture

Preliminary analyses suggest that the 2025 Myanmar main-shock initially ruptured northward along the Sagaing fault for about 100 km from the epicenter at a subshear velocity (about 4 km/s). Concurrently, a southward rupture also began at a subshear velocity, extending about 100 km before transitioning to a supershear velocity (about 4.5 km/s), continuing for an additional 300 km [12]. Notably, the rupture predominantly propagated southward, and upon reaching a distance of approximately 150–250 km from the epicenter, it appears to have transitioned to supershear velocity within the shallow crust. This transition led to widespread surface rupture and was accompanied by the highest energy release, which corresponds to the zones of maximum slip observed in the southern fault segments (Fig. 9). The portion of the Sagaing fault is characterized by a nearly N–S strike, a linear and simple fault geometry, and minimal structural complexity. The

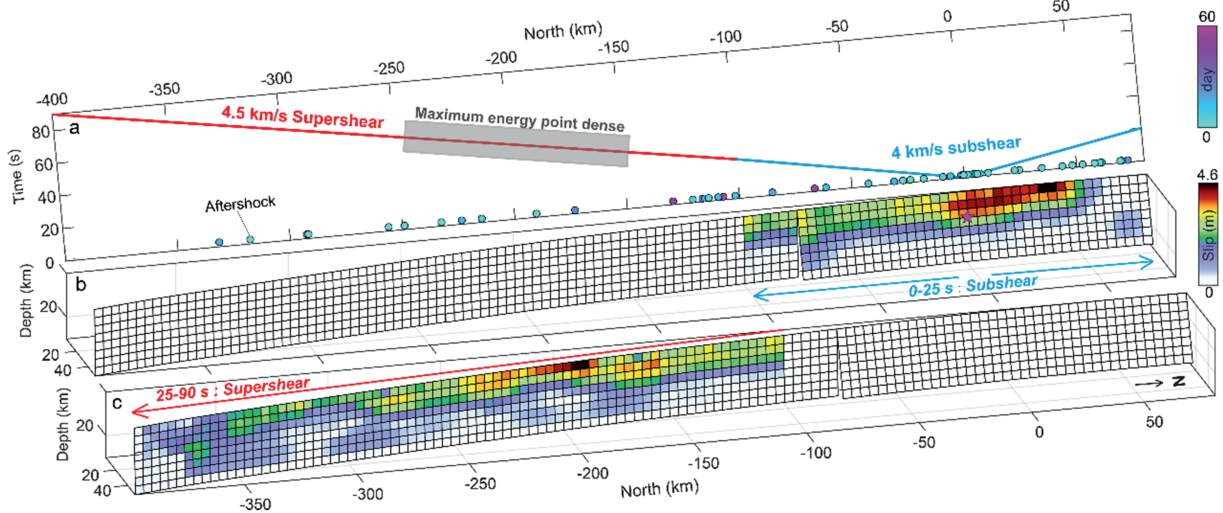


Fig. 9. Temporal evolution of the slip during the 2025 Myanmar event. (a) Distance-time relationship of subshear and supershear propagation. The colored dots are aftershocks recorded within two months following the mainshock, as reported in the USGS catalog. The gray-shaded region marks the area where energy release was most concentrated during the supershear phase. (b) Slip distribution model corresponding to the subshear rupture, which occurred within the first 0–25 s after the mainshock. (c) is the same as (b), but showing slip distribution associated with the supershear rupture phase.

coseismic slip is characterized by right-lateral strike-slip motion that reaches the surface. These slip geometric and kinematic features closely resemble those observed in the 1988 supershear Palu earthquake in Indonesia, which also occurred along a mature, linear strike-slip fault [34]. Collectively, these studies provide preliminary evidence of a southward-propagating supershear rupture during the 2025 Myanmar event.

Additional evidence supporting supershear rupture comes from the spatial distribution of aftershocks. We analyze the aftershock distribution within 2 months following the mainshock from the USGS catalog (Figs. 1 and 9(a)). Results reveal a dense cluster of aftershocks in the subshear rupture region, while relatively few are observed in the supershear zone. This pattern is consistent with the findings by Bouchon and Karabulut [47], who showed that aftershocks in continental supershear earthquakes tend to be concentrated around the subshear rupture area and are largely absent in the supershear segment. The distinct aftershock distribution observed in the 2025 Myanmar event thus lends further support to the interpretation of it as a supershear rupture.

In terms of energy characteristics, the moment-scaled radiated energy, defined as the ratio of the radiated seismic energy (ER) to the seismic moment (M_0), is a critical parameter for understanding energy partitioning during earthquakes and for investigating rupture dynamics [48,49]. According to IRIS EQEnergy data (<https://ds.iris.edu/spud/eqenergy/23108918>), the radiated energy for the 2025 Myanmar event is estimated to be 6.1×10^{15} J. Using the seismic moment derived from our Model II (6.18×10^{20} N·m Table 1), the resulting moment-scaled radiated energy is of 1.0×10^{-5} , which is slightly lower than the average value of about 4.0×10^{-5} reported for strike-slip earthquake with $M_W \geq 6.7$ by Convers and Newman [50]. This low ratio aligns with the findings of Zhang et al. [51], which demonstrated that supershear events, particularly those along simple, linear fault geometries, tend to have significantly lower moment-scaled radiated energy than their subshear counterparts. As illustrated in the yellow-shaded region of Fig. 10, this energy signature provides further compelling evidence that the 2025 Myanmar event involved a supershear rupture.

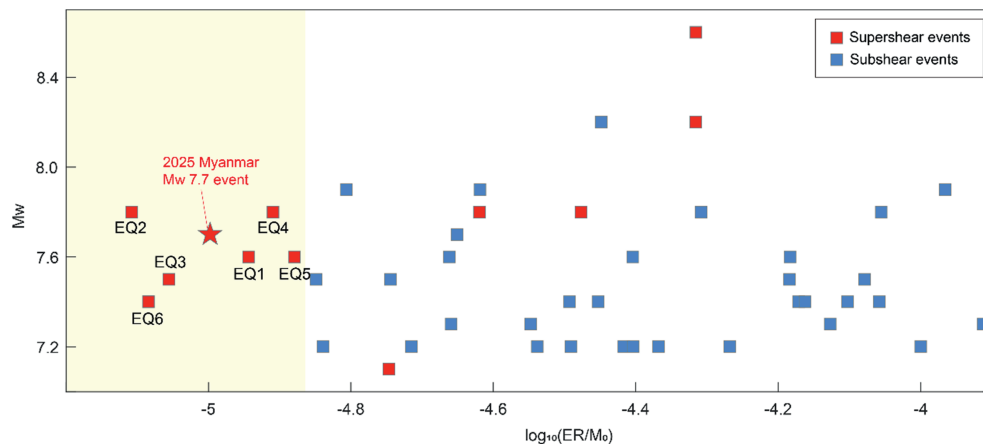


Fig. 10. The relationship between the moment-scale radiation energy and moment magnitude of strike-slip earthquakes (modified from Zhang et al. [51]). ER: the radiated seismic energy, M_0 : the seismic moment. The red and blue squares represent the supershear and subshear events, respectively. The red star represents the 2025 Myanmar event. EQ1–EQ6 are the 1999 Izmit $M_W 7.6$, 2001 Kunlunshan $M_W 7.8$, 2013 Craig $M_W 7.5$, 2013 Pakistan $M_W 7.7$, 2018 Palu $M_W 7.6$, and 2021 Maduo $M_W 7.4$ earthquakes, respectively.

5. Conclusions

The 2025 M_w 7.7 Myanmar earthquake, the most powerful seismic event along the Sagaing fault in the past century, provides critical insights into the rupture dynamics and tectonic behavior of mature continental strike-slip faults. Based on InSAR and POT observations, we construct a detailed three segment fault model with variable dip angles (70° – 88°), which outperforms the simpler uniform-dip model. The optimal inversion reveals a about 500 km-long surface rupture with a maximum surface slip of 4.6 m. The rupture predominantly propagates southward from the epicenter, likely driven by stress accumulation in a southern seismic gap. Coulomb stress transfer analyses confirm that slip on S1 dynamically promotes failure on S2 and S3. In contrast to many large strike-slip earthquakes globally, this event exhibits no evidence of SSD, a feature attributed to the structural maturity of the Sagaing fault. Based on the coseismic and interseismic released seismic moments, we estimate a recurrence interval of large-magnitude earthquakes ($M_w > 7$) of 104–131 years for the southern segment of the fault. Furthermore, the observed scarcity of aftershocks in the supershear rupture zone—along with a moment-scaled radiated energy of 1.0×10^{-5} , lower than the global average for strike-slip events—provides compelling evidence for supershear rupture. Overall, our findings advance the understanding of supershear dynamics on mature strike-slip faults and offer critical input for seismic hazard assessments across South-east Asia.

CRedit authorship contribution statement

Zhe Ding: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Formal analysis, Data curation. **Xin Wang:** Data curation, Methodology. **Shuai Wang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Caijun Xu:** Writing – review & editing, Visualization, Validation, Formal analysis, Data curation. **Limei Wang:** Writing – review & editing, Funding acquisition, Formal analysis, Data curation.

Data availability statement

The CosInv software we used to conduct the distributed slip model in this study can be freely accessed from <http://doi.org/10.5281/zenodo.5098387> (accessed on 20 May 2025). The aftershocks we used in this study can be freely accessed from <https://www.usgs.gov/programs/earthquake-hazards/earthquakes> (accessed 28 May 2025). The IRIS EQEnergy data we used in this study can be freely accessed from <https://ds.iris.edu/spud/eqenergy/23108918> (accessed 5 June 2025).

Declaration of competing interest

Caijun Xu is an Editorial Board Member for Geodesy and Geodynamics and was not involved in the editorial review or the decision to publish this article. All authors declare that there are no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.geog.2025.09.008>.

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Zhe Ding is a Master's student of the School of Geomatics Science and Technology in Nanjing Tech University, Nanjing, China. His research interest focuses on earthquake deformation, utilizing interferometric synthetic aperture radar.



Xin Wang is a Ph.D. student in Geophysics at the School of Earth and Space Sciences, University of Science and Technology of China, Hefei, China. His research focuses on earthquake deformation and fault mechanics, utilizing interferometric synthetic aperture radar (InSAR) to investigate crustal deformation processes and seismic hazards in tectonically active regions.



Shuai Wang received the M.S. degree in geodesy and surveying engineering from the College of Geological Engineering and Geomatics, Chang'an University, Xi'an, China, in 2015, and the Ph.D. degree in geodesy and surveying engineering from the School of Geodesy and Geomatics, Wuhan University, Wuhan, China, in 2019. From 2017 to 2018, he worked as a Research Assistant at the Department of Land Surveying and Geo-informatics in The Hong Kong Polytechnic University, Hong Kong, China. From 2019 to 2025/04, he worked at the School of Geomatics Science and Technology in Nanjing Tech University, Nanjing, China. Currently, he holds the position of an Associate Professor at the School of Environment Science and Spatial Informatics, China University of Mining and Technology, Xuzhou, China. His currently research interests focus on earthquake-cycle deformation and induced deformation caused by industrial activities, utilizing interferometric synthetic aperture radar and Global Navigation Satellite System.



Caijun Xu received the M.S. and Ph.D. degrees from the Wuhan Technical University of Surveying and Mapping Geodesy in 1988 and 1994, respectively. He is currently a specially-appointed Professor in the Cheung Kong Scholars Program at the School of Geodesy and Geomatics, Wuhan University, Wuhan, China. He serves as the deputy director of the Key Laboratory of Geospatial Environment and Geodesy under the Ministry of Education, China, and the deputy director of the Key Laboratory of Geophysical Geodesy and Natural Resources under the Ministry of Natural Resources, China. His ongoing research focuses on studying the tectonic deformation in the Qinghai-Xizang Plateau and its surroundings and investigating human-induced seismic and crustal deformation in the Sichuan Basin through multi-source observations from space geodesy and seismic data.

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Limei Wang received the B.S. degree in geomatics engineering from Shandong University of Science and Technology, Qingdao, China, in 2007, and the M.S. degree in photogrammetry and remote sensing from Liaoning Technical University, Fuxin, China, in 2010. She is currently a Lecturer with the School of Surveying and Urban Spatial Information, Henan University of Urban Construction, Pingdingshan 467,000, China. Her research interests include SAR-optical image processing and application, classification, and change detection.