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The rupture behavior of the Sagaing fault: lessons learned from the 2025 Myanmar earthquake

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1. INTRODUCTION

The Sagaing fault is known as a major seismic source in mainland Southeast Asia. This more-than-1000-km-long transform fault connects the Andaman Spreading system in the south to the Eastern Himalayan Syntax in the north, accommodating ~200 to ~400km of dextral slip since the initiation of the fault[1, 2]. Based on the geomorphological analysis of its fault trace and the earthquake history at the beginning of the 20th century, the Sagaing fault can be subdivided into the northern, central, and southern sections[1]. The northern section is featured by a series of subparallel fault traces, forming a horsetail geometry in northern Myanmar. The central and southern sections are characterized by a simple, smooth, and continuous dextral fault trace, with a limited number of fault splays and stepovers found along its main fault trace. The lack of these fault discontinues thus makes the fault rupture easy to propagate along its fault interface, forming a large magnitude of earthquake with prolonged surface ruptures[3].

The historical earthquake catalog supports that the Sagaing fault is a major seismogenic fault in this region[4-6]. This plate-boundary fault has been considered the source of several destructive earthquakes in Southeast Asia, and the most recent event is the Mw 7.7 Mandalay (Sagaing) earthquake on 28 March 2025. In addition to damaging earthquakes in the past hundred years, geodetic analyses in the past three decades also suggest that the majority of the fault sections are locked interseismically[7-10]. All of these lines of evidence point out the high earthquake potential along this plate-boundary fault, especially for the central and southern sections of the Sagaing fault, prior to the destructive 2025 Mandalay (Sagaing) earthquake.

2. The 2025 Mandalay (Sagaing) earthquake

In order to understand the coseismic rupture of the Mw 7.7 2025 earthquake, and its relationship to other earthquakes along the Sagaing fault, we conducted a series of remote sensing analyses to characterize its rupture behavior. Interferogram from the Sentinel-1 SAR satellite and the pixel-tracking result from the Sentinel-2 Optical satellite suggest that Mw 7.7 earthquake is accompanied by a ~470-km-long rupture along the fault, extending from the southern margin of Singu Basalt in the north to ~18°N in the south[11]. The rupture extends beyond the seismic gap defined by previous earthquake events in the central Sagaing fault [1, 12], with its rupture extending deep into the Dec-1930 rupture patch, south of Myanmar's capital, Naypyidaw. The largest coseismic offset found from the optical satellite data reached ~5 meters at the northernmost part of the rupture, and in many parts of the fault rupture, the coseismic rupture is approximately ~4 m. The amount of the coseismic slip on the surface roughly matches the slip accumulated since the 1839 Ava earthquake, assuming the mean fault slip rate is ~2 cm/yr based on the geodetic observation along the central section of the fault. Close to the southern part of the fault near the Pyu township, our remote sensing observation suggests the coseismic dextral fault slip is slightly more than 2 m, matching the slip accumulated in the 1930 earthquakes. The breach of the seismic gap on the central section of the Sagaing fault, the change of the fault slip along different sections of the fault, together with the historical rupture patterns in the past century, indicate that the 2025 rupture is a multi-section fault rupture event, with the coseismic fault slip roughly following the slip-predictable behavior.

3. The rupture behavior of Central and Southern Sagaing fault

The ~5 meter or larger offset found in the northern 100-km-long fault section of the fault rupture, and the ~4 meter offset found in the central part of the 2025 rupture not only roughly match the slip accumulated between the interseismic period between the 2025 and the 1839 earthquake, the spatial distribution of these coseismic offsets also show high similarity to the geomorphic offset resulting from the previous earthquakes. The largest single-event offset we found along the northern 100-km-long fault section that ruptured in 2025 reaches 5 to 7 meters based on our analysis prior to the 2025 earthquake[13]. To the central part of the 2025 fault rupture, our previous analysis suggests ~4 meters offset during the past several rupture events, and the youngest one is likely occurred within one to two hundred years ago. These geomorphological and geological investigations thus suggest the central section of the Sagaing fault tends to have ~4 meters of coseismic event during the major rupture events, at least in the past several hundred years. It also hints that the rupture of the 2025 Mandalay (Sagaing) earthquake largely resembles the pattern of major fault rupture events along the central section of the Sagaing fault.

Due to the lack of reliable geological evidence prior to the 2025 earthquake, our previous estimation did not expect the coseismic rupture to extend to the Pyu section south of the Naypyidaw area [1]. However, previous paleoseismological studies did suggest a short recurrence interval at the Pyu section (~100 years; Tsutsumi et al., unpublished), suggesting a potential for a cascading rupture extending from the central section of the Sagaing fault. The mean rupture interval in the Bago section, east of Yangon, is also likely to be short, based on the rupture scenario interpreted from the offset fortress wall [14] and the remains of offset markers, which are likely associated with the May 1930 Bago earthquake [15]. These lines of evidence suggest that the simple geometry of the Central and the Southern Sagaing fault exhibits a relatively simple but slightly different rupture behavior, with potentially shorter rupture intervals in the southern part of the fault section than the central part of the fault.

4. The 2025 Mandalay (Sagaing) earthquake and the 1839 Ava earthquake

In addition to investigating the surface rupture pattern from the remote sensing data, we also collected the earthquake damage and felt report (macroseismic data) of the 2025 earthquake in Myanmar, and compared its macroseismic pattern to the felt account of the 1839 Ava earthquake. The macroseismic data we collected covers nearly the entire mainland Southeast Asia, showing a widespread felt area during the 2025 Mandalay (Sagaing) earthquake. Even away from the epicenter and the fault rupture, the macroseismic intensity could still reach intensity V in southern Myanmar and northern Thailand, and the felt intensity in Bangkok is estimated to be IV and V, about 1000 km away from the epicenter. Our rapid assessment suggests that the macroseismic distribution of the 2025 earthquake is strongly controlled by the unilateral southward propagation of the Sagaing fault rupture, and is likely affected by the nature of supershear rupture in the mainshock. The 2025 earthquake's macroseismic map also shows high similarity to the felt account of the 1839 Ava earthquake, in which the intensity at Bangkok could also reach MMI IV during the Ava earthquake. The finding echoes our geological and geomorphological assessment that the 2025 and the 1839 earthquakes shared many similarities, and the 2025 earthquake is, at least on the central section of the fault, the repeating event of 1839 Ava earthquake.

It is worthwhile noting that even though the 2025 earthquake is accompanied by a prolonged ~470-km-long rupture in the central and southern sections of the Sagaing fault, several sections of the Sagaing fault remain unruptured since the first half of the 20th century. The remaining fault section is still capable of generating a magnitude 7 and above event close to the populated cities within the next few decades. Hence, it is important to review the seismic design of major infrastructures and buildings to enhance the seismic resilience of the region.

5. REFERENCE

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6. BIOGRAPHY

WANG Yu is an associate professor from the Department of Geosciences, National Taiwan University, Taiwan. He has been working on the active tectonics and earthquake geology of Myanmar since 2006, especially on the oblique convergent boundary offshore western Myanmar, and the southern and central sections of the Sagaing Fault. Wang Yu’s research use several different techniques to observe and quantify the tectonic deformation associated with the seismic cycle. These techniques include optical remote sensing, paleoseismological investigation, topographic and geodetic surveys. His current research targets include the shallow rupture behavior of active faults in Southeast Asia, the active fault system in eastern Taiwan, and the rapid assessment of natural hazards and fault ruptures.