Seismogenic width controls nucleation and aspect ratio of earthquake ruptures

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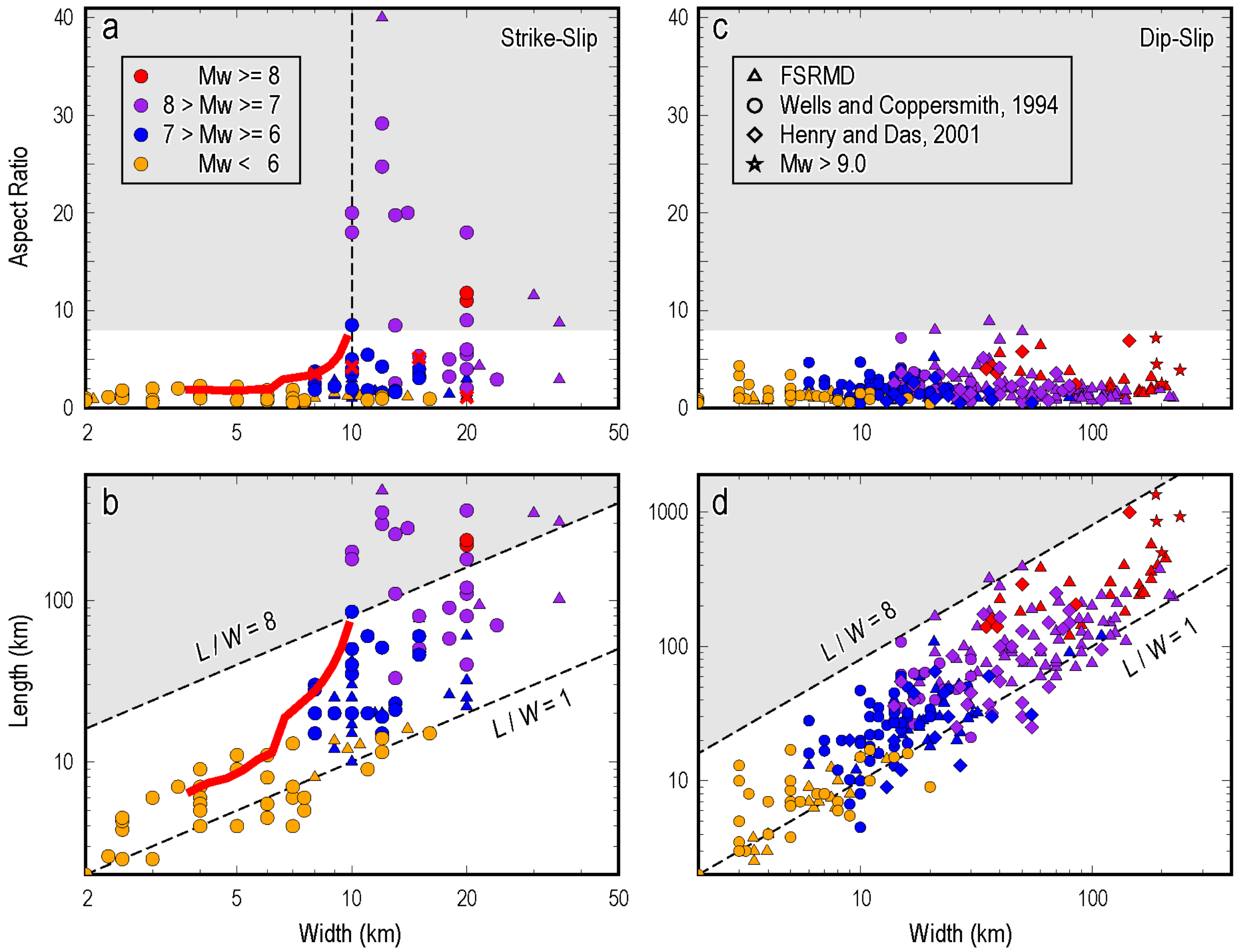
Whether the magnitude of earthquakes depends on the nucleation process is a key question in earthquake physics. Several observations of strike-slip and dip-slip earthquakes suggest that the eventual earthquake moment may increase with the size of the nucleation zone. However, it has also been proposed that the earthquake sizes may be not nucleation-related. We investigate the effect of seismogenic width on nucleation and aspect ratio of earthquake ruptures using numerical simulations of strike-slip faulting with a finite seismogenic depth (width). The seismogenic width has a significant effect on rupture propagation by controlling the energy balance near rupture tips. If the seismogenic width is smaller than a critical value, ruptures cannot propagate along the seismogenic fault continually, regardless of the size of the nucleation zone. The seismic moments of these self-arresting ruptures increase with the nucleation size, forming nucleation-related events. The aspect ratios increase with the seismogenic width but are generally smaller than 8, consistent with observations. In contrast, ruptures are breakaway ruptures and tend to have high aspect ratios (>8) if the seismogenic width is sufficiently large. But the critical nucleation size for breakaway rupture is larger than the theoretical estimate for an unbounded fault. The eventual seismic moments of breakaway ruptures do not depend on the nucleation size. Our results suggest that estimating final earthquake magnitude from the nucleation phase may only be plausible on faults with small seismogenic widths.

Keywords: seismogenic width, rupture nucleation, rupture aspect ratio



a
Strike-Slip
Mw >= 8
8 > Mw >= 7
7 > Mw >= 6
Mw < 6
Aspect Ratio
40
30
20
10
0
2
5
10
20
50
b
L / W = 8
L / W = 1
Length (km)
100
10
Width (km)
c
Dip-Slip
FSRMD
Wells and Coppersmith, 1994
Henry and Das, 2001
Mw > 9.0
d
1000
100
Width (km)