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Why earthquakes on high-angle reverse faults produces voluminous aftershocks and triggered mainshocks: A presumption from the 2004 Niigata-ken Chuetsu Japan earthquake

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The October 23, 2004, Mjma=6.8 Niigata-ken Chuetsu, Japan, earthquake produced extraordinary numbers of moderate-to-large aftershocks, including four M≥6 and more than 100 M≥4 shocks in the first month. The Niigata shock exhibits 10 times more M≥5.5 aftershocks and 3 times more M≥4 aftershocks than the much larger Kobe (Mjma=7.3) shock. This difference is also evident in magnitude-frequency relation: The Niigata sequence displays a Gutenberg-Richter distribution rather than the typical pattern seen at Kobe, in which the mainshock is significantly larger than the largest aftershocks. Here we argue that these attributes are all a product of slip on high-angle (50-60°) blind reverse faults, which are not optimally oriented to relieve the compressional tectonic stress. At Niigata, these faults originated as tightly spaced normal faults during the mid-Tertiary opening of the Japan Sea. Reverse slip on these faults today causes short-wave-length active folding at the surface and the high surface strain rates measured by GPS. But such slip is ineffective at shortening the crust. Coulomb stress modeling reveals that slip on unfavorably dipping blind reverse faults cannot fully relieve the tectonic stress, and instead raises the stress in close proximity to the mainshock rupture. In contrast, slip on low-angle thrust faults, or on optimally oriented strike-slip faults such as Kobe, drops the stress over much of the surrounding region, lowering the aftershock productivity. The local stress increase associated with blind reverse fault slip thus leads to abundant triggered earthquakes, and a higher than normal likelihood of successive mainshocks.