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Migrating earthquakes and faults switching on and off: a complex system view of intracontinental earthquakes (Stephan Mueller Medal Lecture)

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Continental intraplate seismic zones have traditionally been treated like slowly deforming (< 2 mm/yr) plate boundaries. We expected steady deformation focused in narrow zones, such that the past rates and locations shown by geology and the earthquake record would be consistent with present deformation shown by geodesy, and predict future seismicity. However, data from China, North America, NW Europe, and Australia show a different picture. Earthquakes migrate between faults, which remain inactive for long periods and then have pulses of activity. A 2000-year record from North China shows that large (M>7) earthquakes migrated, with none repeating on the same fault segment. Such migration can be observed today: GPS studies in the New Madrid seismic zone show no detectable motion, so the recent cluster of large magnitude events does not reflect long-term behavior, and appears to be ending.

This time- and space-variable behavior results from a network of faults that are slowly loaded, causing both stress transfer from earthquake interactions and local stress sources to be more significant than at boundaries that are rapidly loaded by plate motions. Slow loading also causes aftershock sequences to continue for hundreds or thousands of years, much longer than at plate boundaries. As a result, the past earthquake history can be a poor predictor of the future. Conventional seismic hazard assessment, which assumes steady behavior over 500-2500 years, can overestimate risks in regions of recent large earthquakes and underestimate them elsewhere. For example, the May 2008 Sichuan earthquake occurred on a fault that was not considered hazardous, due to the lack of recent seismicity, despite GPS data showing deformation across it.

It is useful to view midcontinent earthquakes as arising on a complex system of interacting faults. Although an isolated fault gives quasi-period earthquakes, the interacting faults give complex variability. Numerical modeling shows that the interactions can give rise to variability without local or time-variable loading, either of which can provide further variability. Such a complex system view seems likely to lead to an improved understanding of midcontinental tectonics, the resulting earthquakes, and the hazards they pose.