Researchers categorize foreshocks for large earthquakes

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Seismologists agree that foreshocks are the most widely identified signal of an upcoming mainshock earthquake. But do these foreshock sequences have distinctive characteristics that separate them from

aftershock sequences, and could these characteristics be used to help forecast mainshocks?

In a new paper in *Seismological Research Letters*, Nadav Wetzler of the Geological Survey of Israel and colleagues identify some global trends in foreshock sequences for earthquakes of magnitude 7 or larger. These trends pinpoint the kinds of earthquakes and regions where foreshock sequences are more prevalent.

Foreshocks "are one of the few—perhaps the only—observable phenomena precursory to upcoming dominant earthquakes," said Wetzler. "However, foreshocks vary greatly in occurrence and their basic physical relationship to the mainshock remains enigmatic."

The researchers examined data from more than 400 mainshock earthquakes of magnitude 7 or larger in the U.S. Geological Survey National Earthquake Information Center's global earthquake catalog. They used three clustering algorithms to distinguish foreshocks from background seismic activity. Using these methods, Wetzler and colleagues determined that between 15% and 43% of large mainshocks have at least one foreshock, and a range of 13% to 26% have at least one foreshock of a magnitude within two units of its mainshock's magnitude.

The percentage of foreshock occurrences is slightly higher for mainshocks that rupture along plate boundaries compared to faults within a plate, they found. The researchers also noted that foreshock sequences are also more common for reverse faulting mainshocks—where the block above the faulting plane is compressed against the lower block—compared to strike-slip faults or normal faults.

Wetzler and colleagues confirm that conditions that promote high aftershock activity also appear to promote high foreshock activity. Although the exact conditions aren't known, the researchers suggest that

both kinds of sequences might be controlled by the number of available faults, or a critical stress threshold necessary to generate a cascade of seismic activity.

The researchers also noted that in their study, mainshocks in the western circum-Pacific region—in places like Vanuatu, Solomon Islands, west Aleutians, and the Kuril Islands—were prone to having slightly more foreshock activity than the eastern circum-Pacific in places like South America and Mexico.

The difference may arise in part from differences in the age of the subducted plate, Wetzler and colleagues suggest. Older, thicker plates have more faulted crust that can host both foreshock and aftershock sequences.

"As far as we know, this tendency for foreshocks was not previously reported, although similar circum-Pacific differences in aftershock productivity have been noted," said Wetzler. "The common tendency supports general similarity of the stress conditions influencing foreshock and aftershock productivity."

While more needs to be done to define this similarity, the seismologists suggest that foreshocks might be used more often as one of the forecasting tools for large earthquakes, in places where aftershock activity is high.

One finding that seemed to distinguish foreshocks from aftershocks in the study was the global composite b-value, a measure that characterizes the relationship between earthquake magnitude and frequency of occurrence of earthquakes of a certain magnitude. The composite b-value that the researchers calculated for their global set of data was lower for foreshocks compared to aftershocks.

This relationship was less consistent when certain foreshock earthquakes in a sequence were excluded, however, and the researchers say that it will be important to study this measure more carefully for individual earthquakes.

More information: Nadav Wetzler et al, Global Characteristics of Observable Foreshocks for Large Earthquakes, *Seismological Research Letters* (2023). DOI: 10.1785/0220220397

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