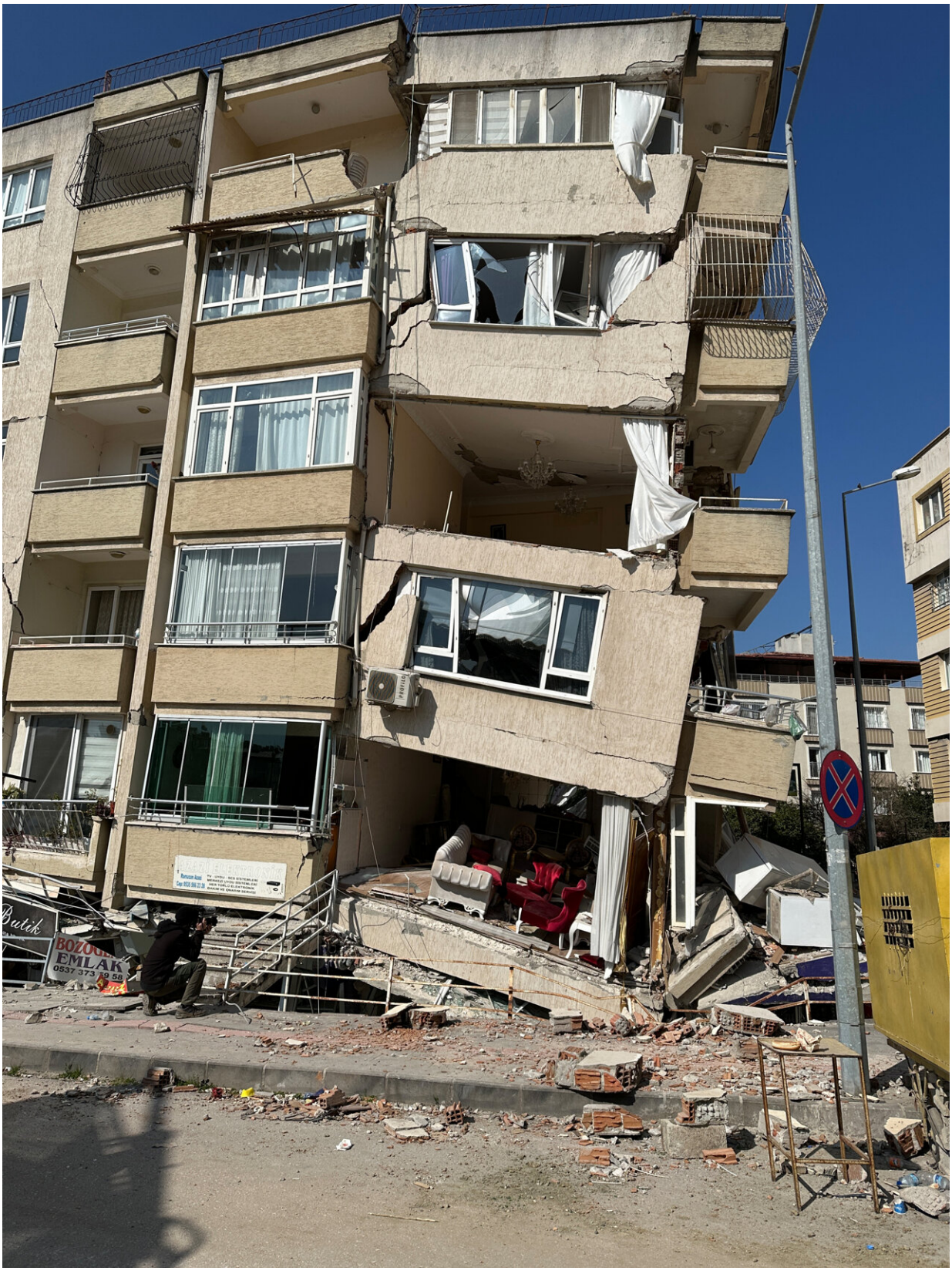
Analyses of the Kahramanmaraş earthquake from February 2023

November 28 2023


Butik
EMLAK
0537 373 59 58

Destruction in the city of Antakya. Credit: Kristina Karas

On February 6, 2023, the devastating magnitude M_W 7.8 Kahramanmaraş earthquake in South East Türkiye ruptured multiple fault segments of the "East Anatolian Fault Zone' separating the Anatolian and Arabian tectonic plates.

This earthquake and its aftershock sequence was followed by a second large earthquake with M_W 7.6 about 9 hours later and some 90 kilometers away from the epicenter of the first mainshock. Combined, the ground shaking from these powerful devastating earthquakes led to nearly 60,000 casualties, 300,000 affected buildings and about 120 billion USD in financial damage.

Search for precursor phenomena for such earthquakes

Although the short-term prediction of the time, magnitude, and location of future earthquakes is currently not possible, some field observations and numerous measurable parameters derived from seismic and geodetic data are currently being explored in the context of containing potential information on an incoming earthquake.

In a study now published in the journal *Nature Communications*, seismologists led by Grzegorz Kwiatek, Patricia Martínez-Garcón, and Marco Bohnhoff from the GFZ German Research Centre for Geosciences Potsdam, together with colleagues from Stanford University (California, UDA), Gebze Technical University (Türkiye), and Kandilli Observatory and Earthquake Research Institute Istanbul (Türkiye) employed seismic catalog and waveform data from regional seismic

networks recorded since 2014 to study seismic processes preceding the M_W 7.8 Kahramanmaraş mainshock.

Spatiotemporal analysis of regional seismicity using the latest statistical and machine learning methods

The spatiotemporal analysis of regional seismicity allowed us to observe an 8-month-long crustal seismicity transient suggesting a preparation process in the region around the epicenter. This highlighted the high and—more importantly—increasing seismic hazard there. The observed spatiotemporal clustering and localization of seismicity is known from controlled laboratory rock deformation experiments and has been observed for some—but by far not all—large continental earthquakes during the last decades.

Dr. Grzegorz Kwiatek, lead author of the study, states, "With the goal to identify specific signatures in the seismic catalog and waveform data from the region, we employed statistical and machine-learning-based data processing techniques. That allowed [us] to identify peculiar characteristics of the seismicity observed within a radius of 50 kilometers around the mainshock starting about eight months before the earthquake."

Seismicity clusters near the epicenter started eight months before the main earthquake

In particular, the occurrence of two transient spatiotemporal clusters of seismicity starting in June 2022 and located about 20 kilometers from the future earthquake epicenter attracted the attention of the seismologists. They represent an observable acceleration of seismic activity in the epicenter region with a significantly greater proportion of larger events with respect to the small ones.

Dr. Patricia Martínez-Garzón, who led the research team of the study, emphasizes, "These observations suggest a build-up of stress within the future epicenter region during the months prior to its rupture. Although other seismicity clusters were previously observed within the analyzed time period (2014-2023) as far as 65 kilometers from the future earthquake epicenter, they did not display equivalent spatiotemporal and statistical properties."

"Comparing our observations with the findings before other recent large earthquakes in California suggests that in the future, monitoring seismicity transients may help intermediate-term earthquake forecasting systems in the future to better prepare for a big one."

Short-term forecast still not possible

The last weeks before the Kahramanmaraş earthquake, the future mainshock epicentral area within 10 kilometers presented scarce seismic activity, as derived from the waveform data using machine learning techniques. This activity provided no evidence for the final short-term acceleration before the mainshock, as observed in the 1999 M_W 7.6 Izmit earthquake in the western portion of the North Anatolian Fault.

Prof Marco Bohnhoff, head of the GFZ section "Geomechanics and Scientific Drilling," concludes, "While our observations are a key finding to better understand the processes leading to big earthquakes on the time scale of months, short-term prediction of such events remains to be a long-term goal in seismology and is currently not possible. This said, identifying hot spots for future events months before they occur gives local authorities important information at hand to improve the resilience of population centers located near active faults."

Outlook and application to Istanbul

The seismicity preceding the Kahramanmaraş earthquake show some similarities with those observed on other comparably complex and multi-segment strike-slip fault ruptures such as the 1992 M_W 7.3 Landers and 2019 M_W 7.1 Ridgecrest 2019 earthquakes in California.

The observable trends of seismicity-derived parameters also follow those previously documented in both laboratory experiments and numerical models of complex earthquake rupture affecting multiple fault segments.

However, the variability of apparent earthquake nucleation processes observed for different events, the difficulty of distinguishing preparatory processes from other deformation transients that do not lead to major earthquakes, the participation of secondary faults, and an unknown false alarm rate, all suggest that with our current state of knowledge, intermediate-term earthquake warning—if possible—still lies in seismology's future.

The refined methods used in this study will be transferred to long-term observations in the Istanbul region, with about 20 million inhabitants where a large (M>7) earthquake is overdue. There, GFZ Potsdam is operating the borehole-based GONAF observatory aiming to reduce the observational gap between controllable laboratory experiments and uncontrollable natural earthquakes posing a huge threat to mankind.

More information: G. Kwiatek et al, Months-long seismicity transients preceding the 2023 MW 7.8 Kahramanmaraş earthquake, Türkiye, *Nature Communications* (2023). DOI: 10.1038/s41467-023-42419-8

Provided by Helmholtz Association of German Research Centres