

# Earthquake Hazard Near Almaty, Kazakhstan

## Introduction

This document provides an overview of the current understanding of the earthquake hazard near Almaty. These findings are the result of a long-term collaboration between scientists in Kazakhstan, Kyrgyzstan, the United Kingdom and Germany.

## Active Faults Near Almaty

Almaty lies at the foot of the Tian Shan mountains which were uplifted over millions of years due to movement on faults. Some of these faults are still active today and are capable of producing earthquakes.

There are several active faults located very close to Almaty. These faults have historically produced three very large earthquakes:

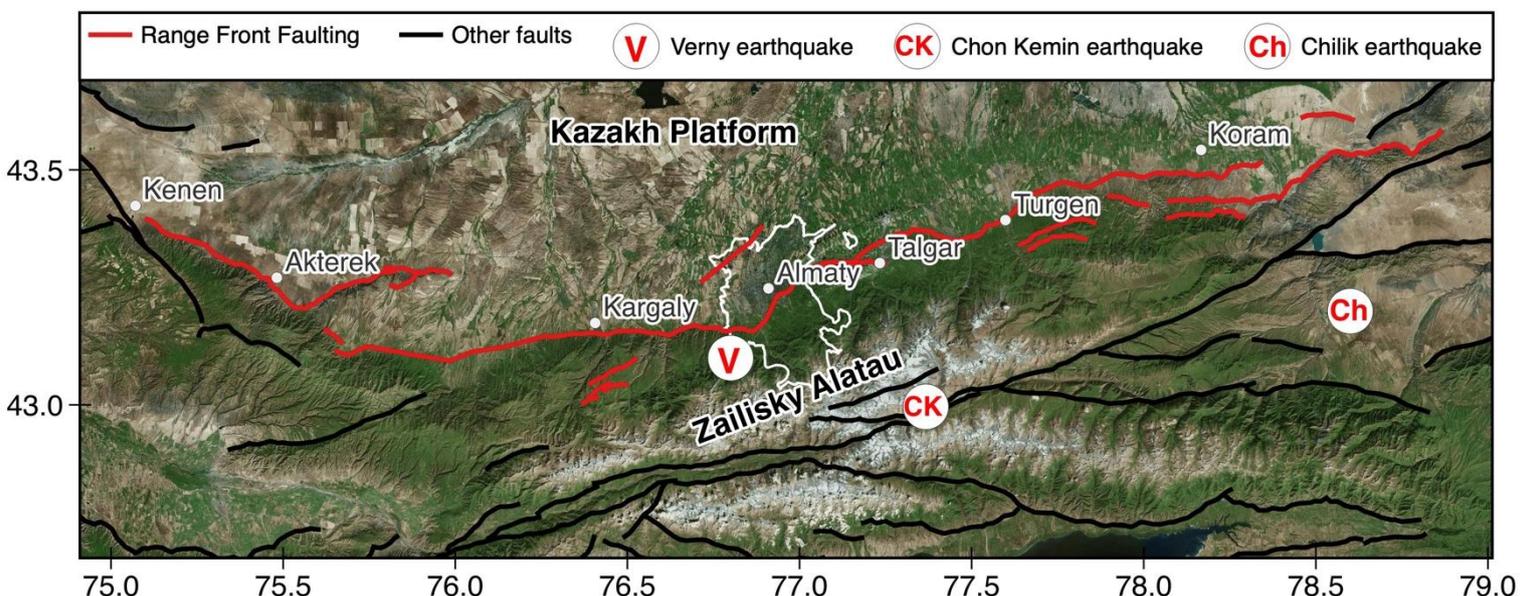
- 1887 Magnitude 7.3 Verny earthquake
- 1889 Magnitude 8.0 – 8.3 Chilik earthquake
- 1911 Magnitude 8.0 Chon Kemin earthquake.

Almaty is also located directly on top of an active fault, shown in red in Figure 1 below. Evidence of past earthquakes has been mapped for ~300 km. This is the Zailisky Range Front Fault, which lies at the northern edge of the Zailisky Alatau.

## Key Points

- Almaty is located very close to several active faults, which means it is exposed to a high earthquake hazard
- There is evidence for past earthquakes along 300 km of the mountain front
- The Big Almaty Canal is built on top of the fault and could be destroyed in an earthquake
- Modelling shows that an earthquake near Almaty could cause thousands of fatalities, thousands of building collapses, and financial losses worth millions of dollars
- Unreinforced masonry buildings are very vulnerable to collapse but are the most common type of building in all districts of Almaty
- Information on earthquake hazard should be used to inform a scenario-based planning exercise to identify vulnerabilities and develop mitigation strategies
- Learning more about the geological structures and their earthquake potential will help to inform these preparations

**Earthquakes** occur when rocks quickly slip past each other along cracks called **faults**, producing seismic waves which shake the ground.



**Figure 1.** Faults and earthquakes near Almaty. Black faults adapted from [1], red faults from [2] our own mapping. Earthquake locations from [3], [4] and [5].

# Earthquake Hazard Near Almaty, Kazakhstan

Imagery from satellites and drone surveys, GPS data and field investigations show that the ground surface has been deformed in earthquakes which occurred many hundreds or thousands of years ago, before historical records began. In more recent times, the section of the Zailisky Range Front Fault beneath Almaty might have been the source of the 1887 Verny earthquake, but we cannot be certain. [2]

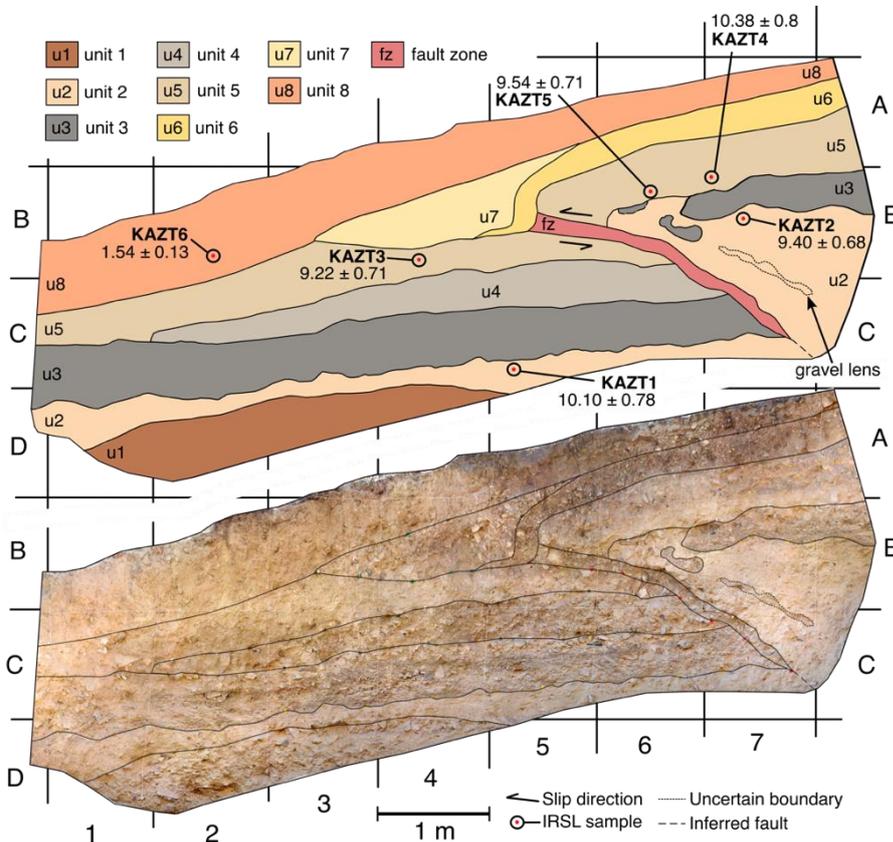
## Evidence of earthquakes

The photo (Figure 2) shows evidence of past earthquakes beneath Almaty. The northern part of the road has been uplifted in multiple earthquakes producing a **fault scarp**. There are similar **fault scarps** many places along the mountain front, including in the town of Talgar.

**Figure 2.** A fault scarp in Almaty. Fault marked in red.



Photo credit: Ruth Amey



**Figure 3.** Excavation of the Zailisky Range Front Fault revealing 2 earthquakes.

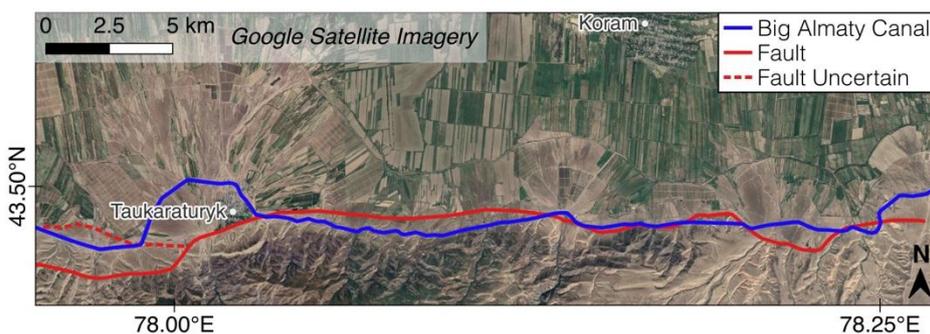
There are similar **fault scarps** many places along the mountain front, including in the town of Talgar.

100 km to the east of Almaty, near the village of Koram, an excavation of the fault scarp revealed layers of sediment that were offset in two earthquakes (Figure 3). Dating these sediments in the laboratory showed that two earthquakes occurred within the past 10 thousand years, and that thousands of years have passed since the last earthquake. This proved that this section of the fault is active and could produce another earthquake in the present day.

Based on the evidence from fault scarps and the excavation, past earthquakes on the Zailisky Range Front Fault were magnitude 6.6 – 7.2, but might have been much larger.

## The Big Almaty Canal

Near Koram, the Big Almaty Canal crosses over the fault in multiple locations (Figure 4). If an earthquake ruptures on this fault section, different parts of the canal will be pulled in different directions. This would cause significant damage to the canal, in addition to damage from the shaking.



**Figure 4.** The Big Almaty Canal crosses the fault in multiple locations.

# Earthquake Hazard Near Almaty, Kazakhstan

## Models of Earthquake Damage and Losses

The 1887, 1889 and 1911 earthquakes caused damage in Almaty. Now the city is much larger, a similar earthquake today would be even more destructive.

Seven different earthquake scenarios were modelled using the Global Earthquake Model's OpenQuake Engine, in order to investigate the potential impacts on Almaty [6]. The results suggest that an earthquake close to Almaty would cause thousands of fatalities and thousands of buildings would collapse.

The scenario with the biggest modelled impacts is a magnitude 6.5 earthquake directly beneath the city. The model suggests such an event could lead to **4,100 fatalities**, **12,300 building collapses**, and **\$4,700 million (USD) in financial losses**.

These modelled impacts are for Almaty only: further impacts should be expected in other towns along the range front. The modelled scenarios are based on initial mapping and measuring of the faults near Almaty. Other scenarios involving larger magnitude events may also be possible. Further geological research will help to refine the estimates.

Figure 5. The seven different earthquake scenarios [6].

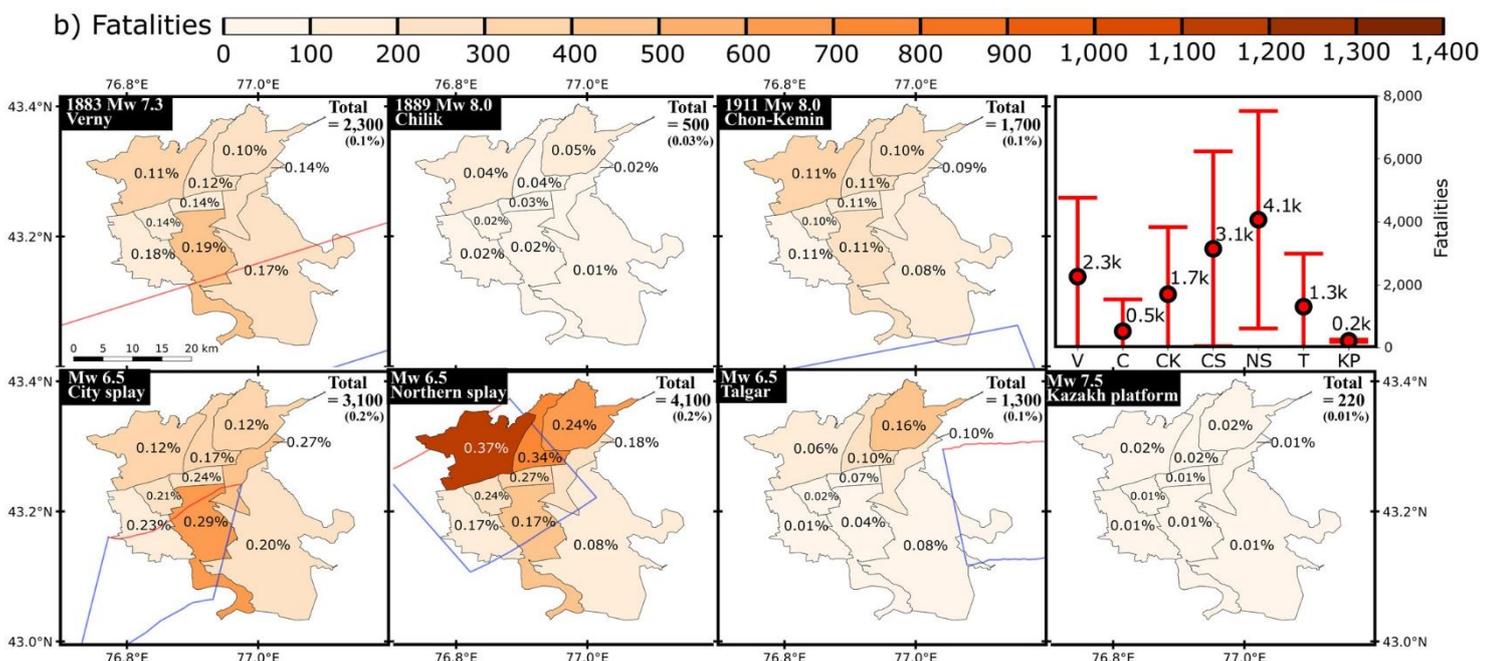
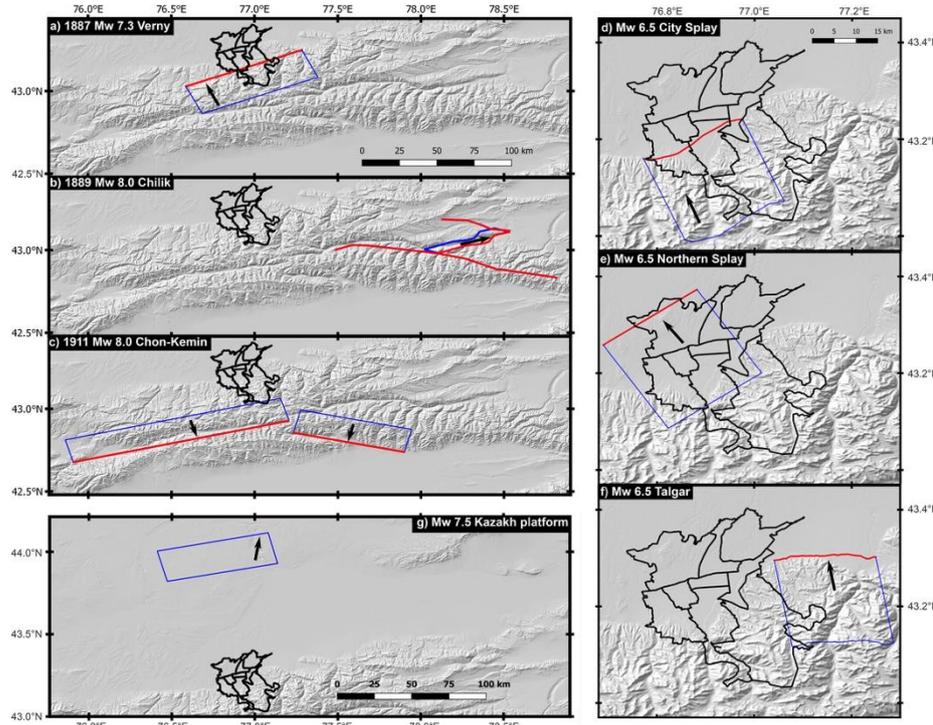
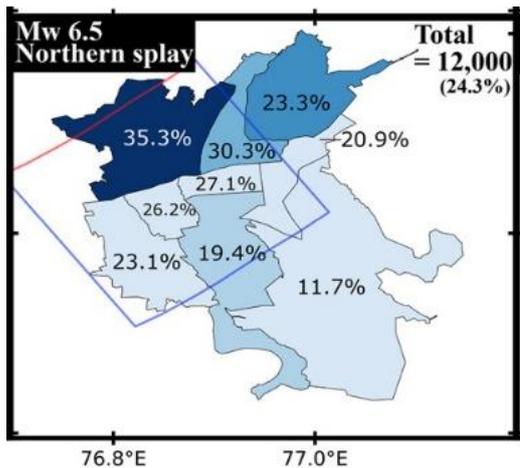


Figure 6. Modelled fatalities in Almaty from seven different earthquake scenarios [6].

# Earthquake Hazard Near Almaty, Kazakhstan

**Retrofitting:** Making additions to buildings to make them less vulnerable to damage or collapse in an earthquake

**Figure 7.** Modelled percentage of completely damaged buildings in each district of Almaty in the most damaging earthquake scenario [6]



## Building types and Vulnerability

In every district of Almaty the most common building type is unreinforced masonry. Unreinforced masonry is more likely to collapse in earthquakes compared to other types of buildings. The potential impacts of an earthquake could be reduced by retrofitting buildings and ensuring new buildings are constructed to withstand shaking.

## Conclusions & Recommendations

### Preparing for Earthquakes

There are several active faults underneath or close to Almaty which could produce destructive earthquakes leading to thousands of deaths and thousands of building collapses. It is necessary to take steps to prepare for such events to minimize damage and loss.

Knowledge of the earthquake hazard should be combined with information on buildings, infrastructure, utilities, and organisational networks in a scenario-based planning exercise to identify vulnerabilities. The outputs of such an exercise could provide important information for city planners to prepare for earthquakes and mitigate these vulnerabilities, including in the planning of future developments, in identifying and retrofitting dangerous buildings, and in developing effective earthquake emergency response mechanisms.

### Scientific Research

Despite significant progress in understanding the seismic hazard to Almaty, the exact locations of all the active faults, the magnitudes of earthquakes they might produce and the distribution of shaking they might cause are unknown or poorly constrained. Therefore, further scientific research is also needed to better understand the earthquake hazard to Almaty and to improve the information available for planning and mitigation. Examples of such research include but are not limited to:

- Local validation of the equations used to calculate the distribution and magnitude of shaking (Ground Motion Prediction Equations) and their underlying parameters. This would help with more accurate prediction of the shaking in a given earthquake scenario.
- Further investigations of the geological structures in the Kazakh Platform. Our research suggests there may be some active faults to the north of Almaty, but more work is needed to determine the size, location and earthquake potential of these structures.
- More excavations of fault scarps, especially close to Almaty. This will improve the understanding of earthquake magnitudes and typical behaviour of the Zailisky Range Front Fault

# Earthquake Hazard Near Almaty, Kazakhstan

## Further Reading

[Blog post](#) summarizing Amey *et al.* (2021) [research paper](#) on scenario modelling for Almaty earthquake hazards

[Blog post](#) summarizing Grützner *et al.* (2017) [research paper](#) on evidence for Active Faulting on the Zailisky Range Front

The fault scarp excavation is from a PhD thesis recently submitted at the University of Oxford which is currently being prepared for journal submission (Wilkinson *et al.* in prep)

## References

[1] Zelenin, E. *et al.* (2022) 'The Active Faults of Eurasia Database (AFEAD): the ontology and design behind the continental-scale dataset', *Earth System Science Data*, 14(10), pp. 4489–4503. Available at: <https://doi.org/10.5194/essd-14-4489-2022>.

[2] Grützner, C. *et al.* (2017) 'Active Tectonics Around Almaty and along the Zailisky Alatau Rangefront', *Tectonics*, 36(10), pp. 2192–2226. Available at: <https://doi.org/10.1002/2017TC004657>.

[3] Krüger, F., Kulikova, G. and Landgraf, A. (2017) 'Instrumental magnitude constraints for the 11 July 1889, Chilik earthquake', in A. Landgraf *et al.* (eds) *Seismicity, Fault Rupture and Earthquake Hazards in Slowly Deforming Regions*. London: The Geological Society, pp. 41–72. Available at: <https://doi.org/10.1144/SP432.8>.

[4] Kalmetieva Z.A. *et al.* (2009) *Atlas of Earthquakes in Kyrgyzstan*. Bishkek: The European Commission's Humanitarian Aid Department, The Secretariat of the United Nations International Strategy for Disaster Reduction, The Central Asian Institute for Applied Geosciences. Available at: <https://www.caiag.kg/en/projects/114-atlas-zemletryasenij-kyrgyzstana>.

[5] Kulikova, G. and Krüger, F. (2015) 'Source process of the 1911 M8.0 Chon-Kemin earthquake: investigation results by analogue seismic records', *Geophysical Journal International*, 201(3), pp. 1891–1911. Available at: <https://doi.org/10.1093/gji/ggv091>.

[6] Amey, R.M.J. *et al.* (2021) 'Significant Seismic Risk Potential From Buried Faults Beneath Almaty City, Kazakhstan, Revealed From High-Resolution Satellite DEMs', *Earth and Space Science*, 8(9), p. e2021EA001664. Available at: <https://doi.org/10.1029/2021EA001664>.

## Contact Details

### United Kingdom:

Professor Richard Walker  
University of Oxford  
[richard.walker@earth.ox.ac.uk](mailto:richard.walker@earth.ox.ac.uk)

### Kazakhstan:

Aidyn Mukambayev  
Kazakh National Data Centre  
*Aidyn's email*

### Kyrgyzstan:

Kanatbek Abdrakhmatoc  
Institute of Seismology  
*Kanatbek's email*