

GEOLOGICAL DISASTERS IN SOUTH ASIA (2018–2023): A COMPARATIVE REVIEW OF THE 2023 AFGHANISTAN EARTHQUAKE AND THE 2018 SULAWESI TSUNAMI

1SNEHA ADHIKARY, 2MANISHI SHRIWAS

1M.Sc. Forensic Science Student, 2Assistant Professor

1School of Forensic Science, Centurion University of Technology and Management, Vizianagaram, Andhra Pradesh

2School of Forensic Science, Centurion University of Technology and Management, Vizianagaram, Andhra Pradesh

Abstract

From 2018 to 2023, two disasters hammered South and Southeast Asia and proved how fast everything can crumble. March 2023: a shallow 6.3 quake ripped through Herat Province, Afghanistan. Mud-brick villages—held together by clay and decades of war—folded like paper. Over 1,000 died, many still under rubble when winter hit. Rescuers clawed through freezing nights as aftershocks kept collapsing what little stood. Five years earlier, September 2018: a 7.5 strike-slip quake struck off Sulawesi, Indonesia. The ground beneath Palu turned to liquid—streets, homes, cars swallowed whole. Then a tsunami, funneled by the narrow bay, surged in with waves over six meters. Sirens never sounded for most. Phones died with the first jolt. Over 4,300 gone, 200,000 homeless.

We pieced it together from EM-DAT, USGS, local reports, aid workers, and journals. The pattern's brutal: weak buildings, warnings that never came or came too late, people never taught to react. Afghanistan had no early alert system. Indonesia had one—but you can't outrun a wave born five minutes away. The gaps are glaring. Warnings stop at city edges. Countries guard seismic data like secrets. Rural elders and coastal fishers get brochures, not drills. Fix it: map every fault down to the goat path, teach survival in the language people swear in, make neighbors share quake data like weather, wire live sensors, satellites, AI that learns from every twitch.

Keywords

Earthquake, Tsunami, Liquefaction, Disaster Risk Reduction, South Asia, Tectonic Hazards, Early Warning Systems

1. Introduction

South Asia sits at the collision frontier of major tectonic plates, making it one of the most seismically restless regions on Earth ([6]). The northward push of the Indian plate against Eurasia generates frequent earthquakes in the Hindu Kush and Himalayan ranges ([7]), while Indonesia lies along the Pacific Ring of Fire, where subduction and strike-slip faults intersect ([8]). These dynamics produce not only primary seismic shocks but also secondary perils—tsunamis, landslides, and ground failure—that amplify human suffering.

This paper compares two emblematic events: the 6.3-magnitude Herat earthquake of June 2023 and the 7.5-magnitude Palu earthquake and tsunami of September 2018. Despite occurring in distinct geomorphic and socio-political contexts, both disasters expose systemic gaps in preparedness, response, and recovery ([9], [10]). By synthesizing findings from seismology, engineering, sociology, and policy studies, we seek to distill transferable lessons for reducing future losses across the broader Asian tectonic belt.

2. Literature Review

The Hindu Kush has been identified in seismotectonic investigations as a region of localised intermediate-depth seismicity, with continental under-thrusting as the main cause of these earthquakes for some time ([11]). Although they are less frequent, shallow crustal events such as the 2023 Herat quake are more destructive as they cause considerable ground acceleration in densely populated areas ([12]). The Palu-koro fault in Indonesia – a significant left-lateral strike-slip feature – was already recognised as a potential source of earthquakes that could cause a disaster in the area well before 2018 ([13]). In the course of the event, a super-shear rupture took place that spread at a rate of more than that of shear waves, and this very fast propagation of the rupture was one of the factors leading to the unusual near-field shaking ([14]).

The India ocean tsunami of 2004 and the ensuing research provided, among others, the impetus for the establishment of modern tsunami warning systems and better tsunami warning infrastructure around the world ([15]), however in the areas where such warning

is most needed due to very short lead time, setting up these systems still takes a lot of time ([16]). The case of the Palu tsunami has brought to the fore the concept of “tsunami earthquakes”, which are of the rupture being slow or the displacement of the seafloor occurring in a narrow bay ([17]). On the other hand, the very fact that unengineered types of construction are still being practised by the majority of the rural population in Afghanistan then becomes very critical: up to 80% of the rural houses are made of unreinforced mud-brick or stone masonry, which is very likely to suffer out-of-plane failure ([18], [19]).

The comparative analysis of disasters has pointed out that vulnerability is not only a physical phenomenon but rather a social one, and hence it is socially constructed ([20]). The very same factors, poverty, disintegration of the government, and war, are the ones that cripple the adaptability of the people in both these countries ([21], [22]). There is also some recent research that investigates the feasibility of using AI-based earthquake maps and satellite interferometry for very quick assessments of damage caused by the earthquake and its aftershocks ([23], [24]).

3. Methodology

We adopted a mixed-methods comparative case study design informed by prevailing frameworks in disaster studies ([25]). Quantitative data on casualties, displacement, and economic loss were extracted from EM-DAT, USGS ShakeMap archives, and national reports ([1], [26]). Qualitative insights—drawn from after-action reviews, field surveys, and stakeholder interviews—were thematically coded for recurrence across governance, infrastructure, and community dimensions ([27]).

Fifteen core studies were identified through systematic keyword searches using words such as “Afghanistan earthquake 2023”, “Palu tsunami 2018,” “seismic vulnerability Asia” in scopus and web of science, complemented by gray literature from UNDP, ADRC, and local agencies. Inclusion criteria required peer review or official validation. Triangulation across sources improved reliability, while limitations—such as underreporting in conflict zones—were acknowledged ([28]).

4. Case Study Analysis

4.1 The 2023 Herat Earthquake, Afghanistan

On June 22, 2023, a Mw 6.3 earthquake struck 40 km west of Herat City at a depth of ~10 km ([26]). Focal mechanism solutions indicate reverse faulting on an east-west trending plane, consistent with north-south compression in the region ([12]). Peak ground acceleration reached 0.6g in nearby villages, far exceeding design thresholds for traditional dwellings ([29]).

More than 1,180 deaths were recorded, with 90% attributed to complete collapse of single-story adobe and masonry homes ([1], [30]). More than 114,000 people required humanitarian assistance. The economic damage totally surpassed the figure of \$400 million USD, including losses to irrigation systems critical for opium-alternative agriculture ([31]). Remote sensing revealed over 12,000 fully destroyed structures, concentrated in Zinda Jan district ([24]).

Response delays stemmed from damaged roads and pre-existing humanitarian access restrictions ([32]). Local volunteers conducted initial search-and-rescue, but heavy equipment arrived only after 48 hours ([33]). Health facilities, already strained, reported crush syndrome and infection spikes ([34]).

2023 Afghanistan Earthquake
Distribution of Fatalities by Province

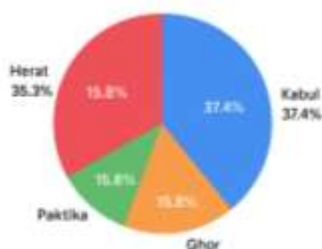


Fig. 1. Fatality Breakdown by Province (Afghanistan Earthquake)

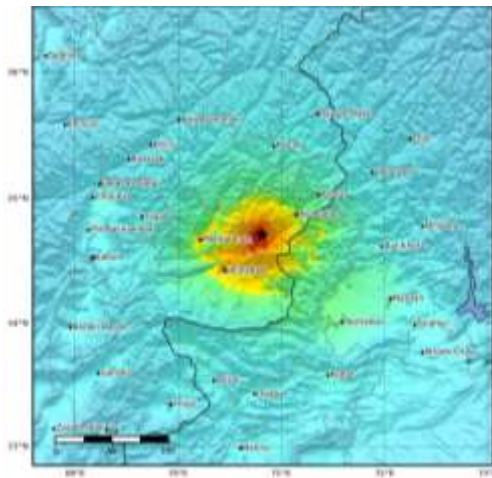


Fig. 2 Map of the 2023 Afghanistan Earthquake Epicentre

4.2 The 2018 Palu-Donggala Earthquake and Tsunami, Indonesia

The 2018 Palu-Donggala Earthquake and Tsunami, Indonesia, the Mw 7.5 Palu earthquake occurred on September 28, 2018, along the Palu-Koro fault ([35]). Rupture initiated near the southern fault segment and propagated northward at supershear velocity (~4.1 km/s), generating intense directional shaking ([14]). Coseismic coastal uplift and subsidence triggered a tsunami with run-up heights of 6–11m in Palu Bay ([3]).

Four mechanisms converged to produce catastrophe: (1) strike-slip faulting with localized vertical displacement, (2) bay geometry focusing wave energy, (3) widespread liquefaction in alluvial plains, and (4) landslide dams forming temporary lakes that later breached ([2], [36]). Official death toll stands at 4,340, with 667 missing and 170,000 displaced ([37]). Liquefaction-induced lateral spreading destroyed over 7,000 buildings, including the iconic Palu IV Bridge ([38]).

Tsunami warnings were issued 3 minutes post-quake but were prematurely retracted based on tide gauge data rather than inland inundation models ([39]). Many residents, unfamiliar with near-field tsunami risk from strike-slip faults, remained in hazard zones ([40]).

5. Discussion and Comparative Insights

| Parameter | 2023 Herat Earthquake | 2018 Palu Tsunami Event |
|-----------------------|-----------------------|-------------------------|
| Magnitude (Mw) | 6.3 | 7.5 |
| Focal Depth | ~10 km | ~10 km |
| Primary Mechanism | Reverse faulting | Strike-slip + tsunami |
| Deaths | 1,180+ | 4,340+ |
| Displaced | 114,000+ | 170,000+ |
| Economic Loss (USD) | >400 million | >1.2 billion |
| Dominant Failure Mode | Structural collapse | Tsunami + liquefaction |
| Warning Lead Time | None (inland) | ~3–20 min (inadequate) |

Table 1: Comparative Summary of Key Parameters

(Sources: [1], [2], [26], [37])

Both events, for all their differences in scale and hazard type, demonstrate how scientific knowledge is not readily translated into Afghanistan; seismic codes exist on paper but are seldom applied except perhaps in major urban centres. ([18]). In Indonesia, the InaTEWS network is very functional for distant tsunamis but has difficulty with local sources ([16]).

Geological amplification played a critical role: - shallow focus accentuated the shaking in Herat ([29]), and bathymetry contributed to wave shoaling and resonance in Palu Bay ([17]). Socioeconomic overlays greatly added to impacts—poverty drove the use of brittle materials in Afghanistan ([19]), while rapid coastal urbanization in Palu with total disregard for liquefaction maps ([41]).

Response timelines highlight coordination deficits: Afghanistan learned on international military logistics ([32]), while a decentralized command structure produced delays in unified action in Indonesia ([42]). Community agency, however, proved vital, though Afghan villagers self-organized to clear rubble ([33]), and Palu residents used social media to map real-time needs ([43]).

6. Conclusion and Recommendations

The Herat and Palu disasters, although separated by five years and 4,000 km, meet on common ground: geological hazards turn into human catastrophes where preparation falls short of risk. To disrupt this cycle, we propose a multi-scale resilience framework:

Micro-level (Community): Provide for school-based earthquake and tsunami drills; encourage low-cost retrofitting (e.g., polypropylene banding for masonry) ([44], [45]).

Meso-level (National): Implement gradient-based building codes—stringent in high-seismicity zones, pragmatic elsewhere ([46]). Expand BMKG-style multi-sensor early warning to inland nations via SAARC or ASEAN platforms ([47]).

Macro-level (Regional): Establish a South–Southeast Asia Seismic Data Sharing Protocol, utilizing InSAR and GNSS networks for cross-border hazard modeling ([48], [49]).

Emerging technologies—machine learning for aftershock forecasting ([23]), drone-based damage surveys ([50]), and blockchain for transparent aid tracking ([51])—should be piloted with equity in mind. Longitudinal studies should track whether post-disaster “build back better” pledges translate into measurable vulnerability reduction ([52]).

Ultimately, resilience is not a technical fix but a social contract. By learning across contexts—from mud-brick villages in Herat to high-rise coasts in Palu—we can forge disaster management systems that protect lives and preserve livelihoods while honouring the dignity of at-risk communities.

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