Supplement to: The propagation of seismic waves, misinformation, and disinformation from the 2024-10-05 M 4.5 Iran earthquake

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1. P/S ratios for comparable events

Figs. S1.1-S1.4 illustrate waveforms and P/S ratios for three events with locations and magnitudes comparable to the 2024-10-05 event (Fig. S1.1). The next two (2015-08-25 and 2018-01-15, Figs. S1.2-1.3) were noted by the CTBTO to have similar characteristics. The last, 2024-11-03 (Fig. S1.4), is more recent and was detected on many more seismometers.

These four figures illustrate higher-than-expected P/S ratios—along with significant variability between stations— suggesting that such phenomena might be features of the seismicity of this region, rather than signatures of a nuclear test. Magnitudes in figure titles are taken from the USGS catalogue, keeping the same naming convention (i.e. "M" in titles rather than mb or Mw, etc).

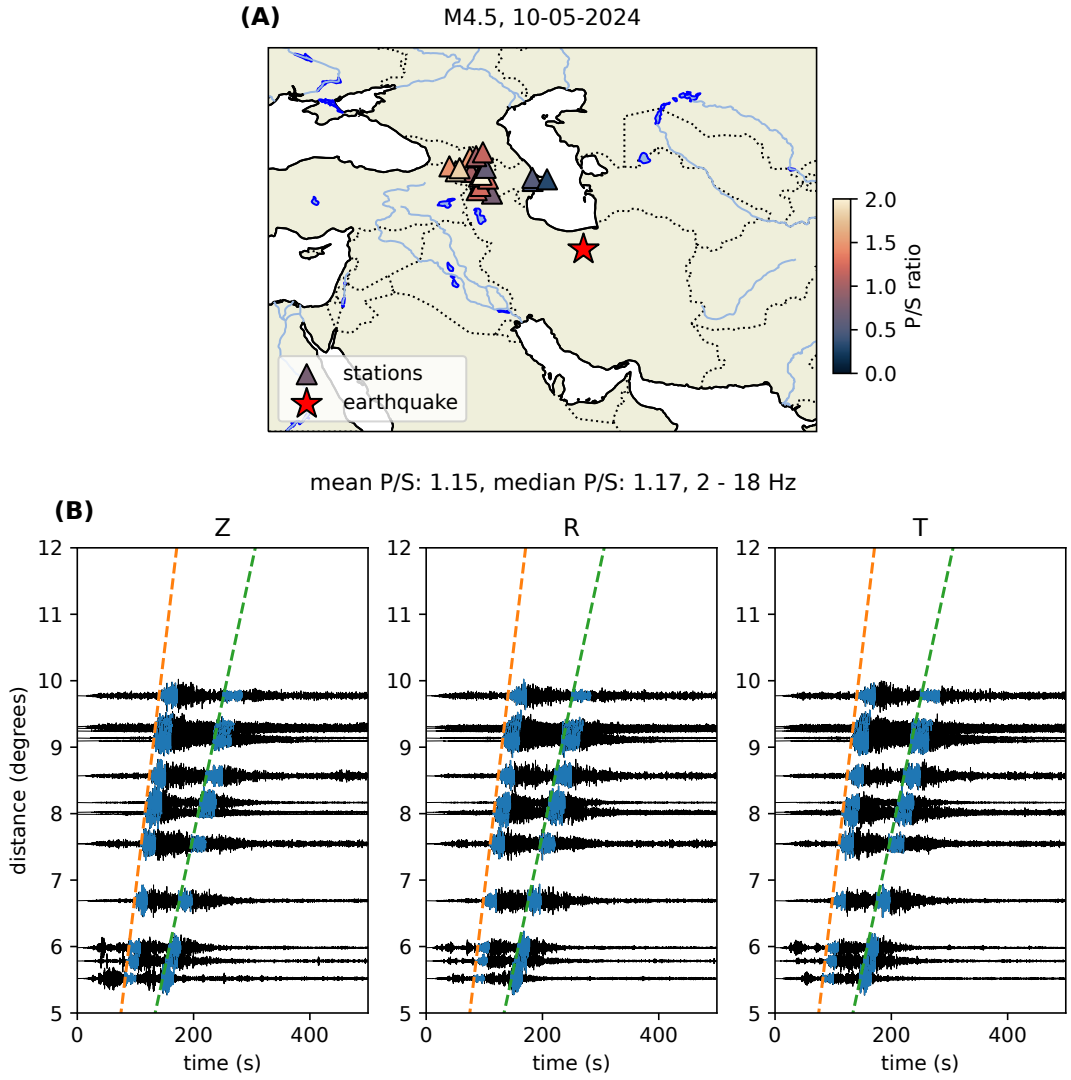


Fig. S1.1 Three-component waveforms and their corresponding recording locations for the event on 2024-10-05 which is the main topic of this paper.

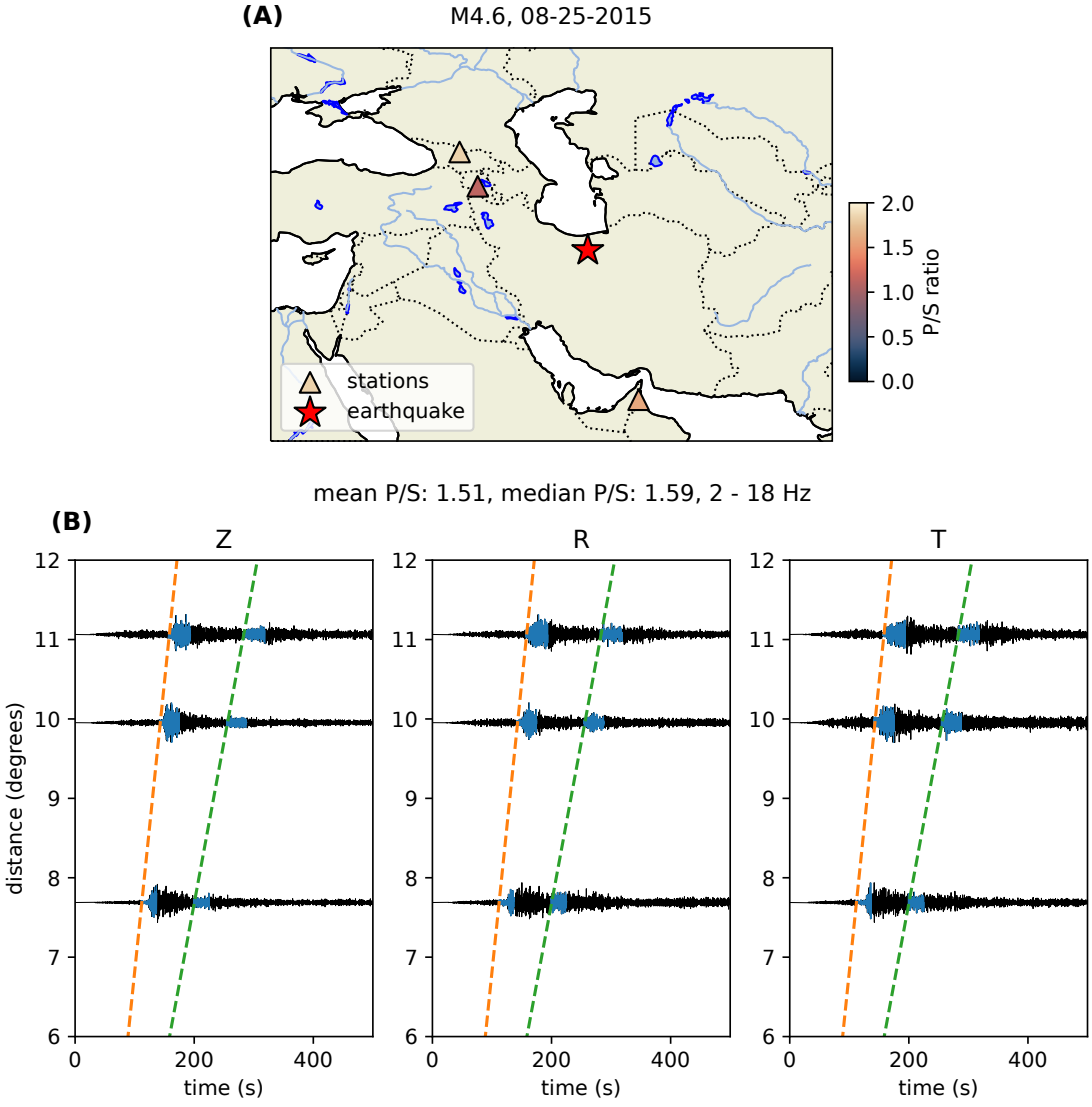


Fig. S1.2 Three-component waveforms and their corresponding recording locations for an event on 2015-08-25.

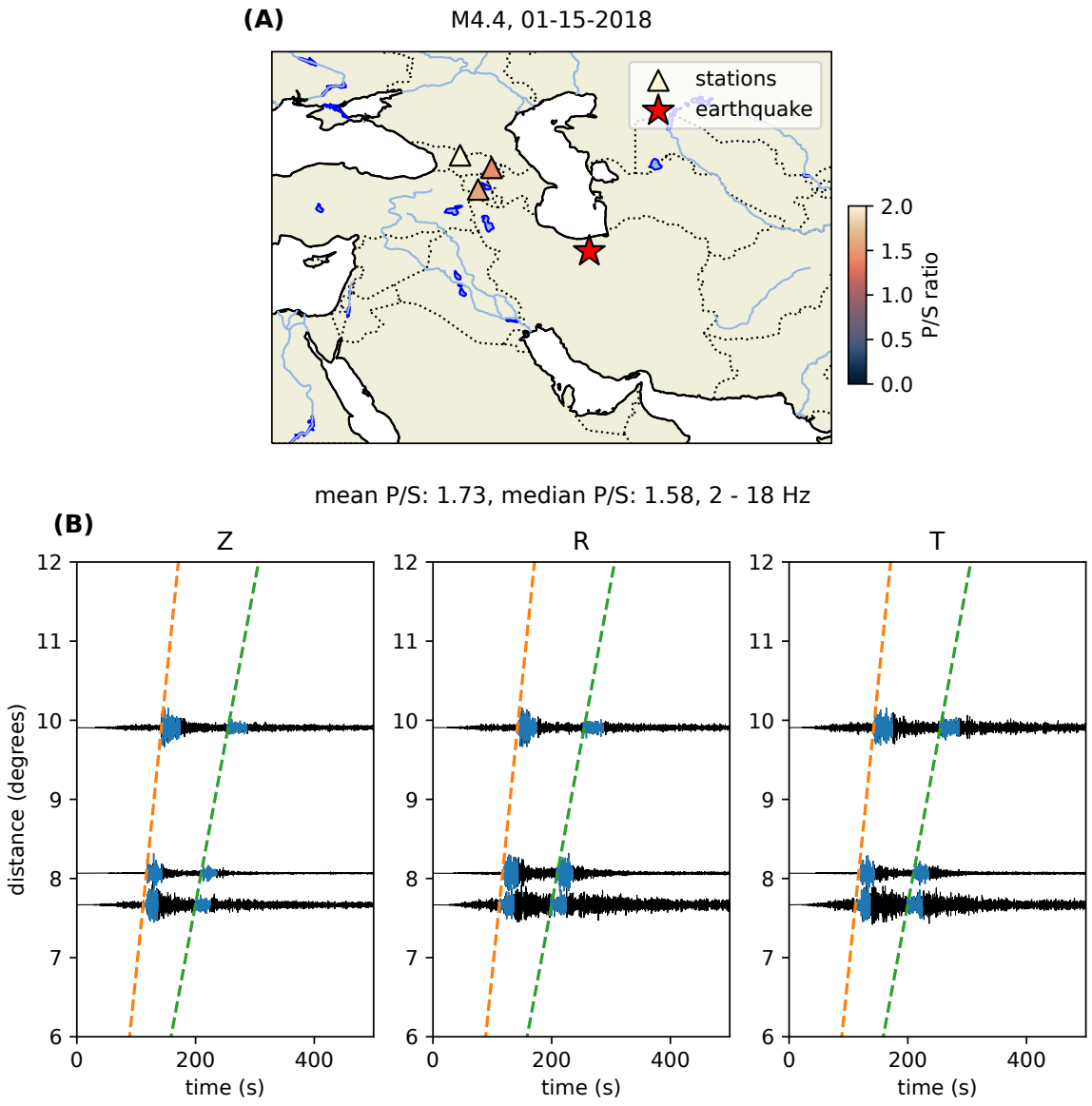


Fig. S1.3 Three-component waveforms and their corresponding recording locations for an event on 2018-01-15.

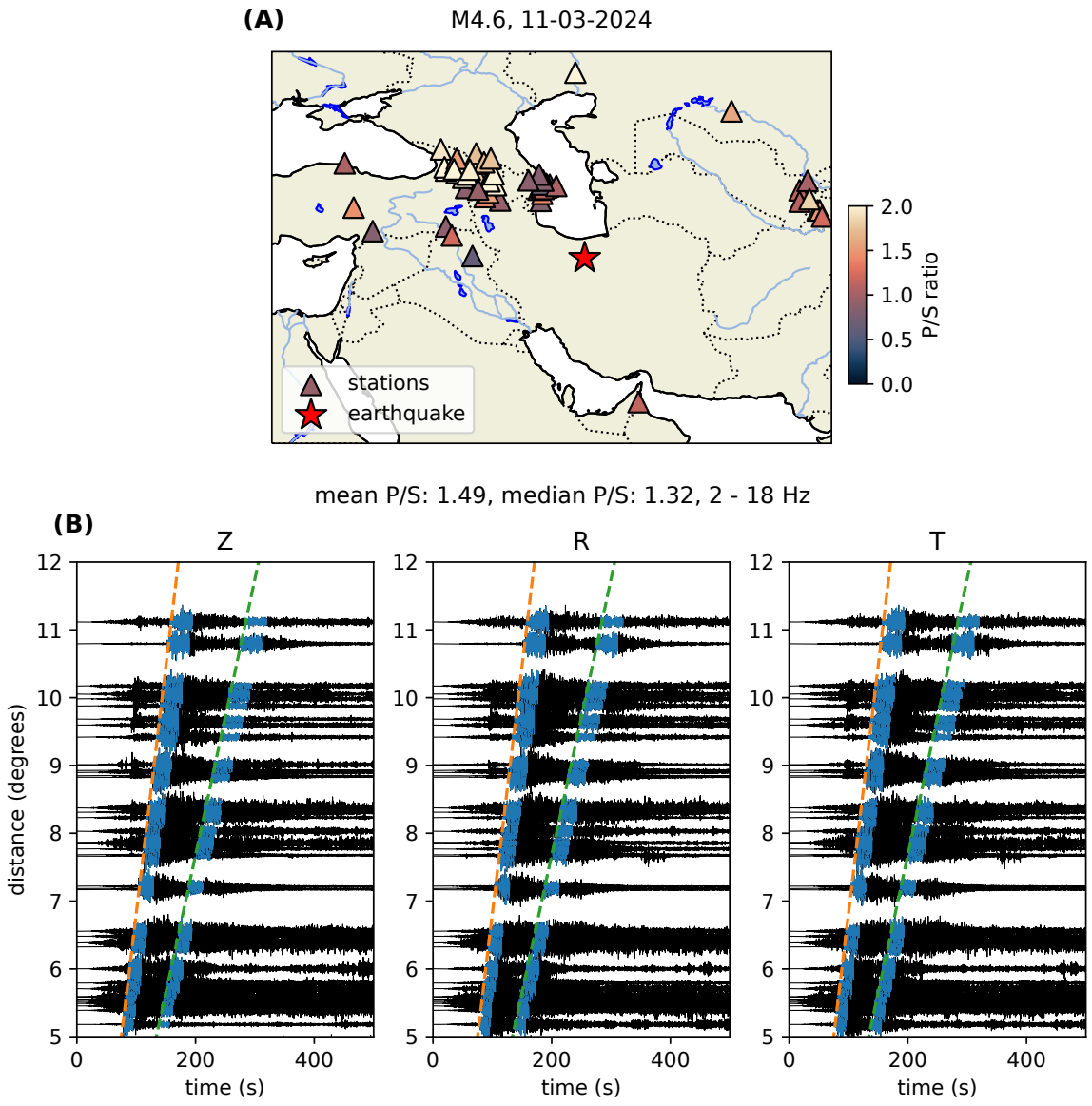


Fig. S1.4 Three-component waveforms and their corresponding recording locations for an event on 2024-11-03.

2. Introduction and search methodology

The authors claim no ownership or copyright over the social media posts quoted in this paper. They are provided only for the purposes of criticism, commentary and scholarly report. These activities are covered under the *Fair Use* doctrine of relevant copyright laws in the United States and other countries.

2.1 Twitter/X

Searches made use of Twitter's advanced search function. The general query structure used was:

X lang:Y since:2024-10-05 until:2024-10-06

Where X included the relevant search term (given in Table 1 below) and Y was the ISO639 two-letter language code:

Language	ISO 639 code	Search terms
English	en	Iran nuclear test, Iran earthquake
Farsi	fa	زلزله ایران , لرزه, هسته ای, اتمی, آزمایش، زمین لرزه
Arabic	ar	زلزال (إيران OR طهران)
Hebrew	he	רעידת אדמה

Table S2.1: languages used and relevant search terms ("Iran earthquake", etc).

Members of the authorial team fluent in each language designed the search queries in each language, and whilst they are approximately commensurate there are minor differences (e.g., the Arabic search included the words إيران or طهران (Tehran/Iran) to differentiate from another earthquake that was reported on social media to have occurred the same day in Israel).

Note that any posting times shown in the screenshots reflect the authors' local timezone (EDT/ UTC-04:00) rather than UTC or Iran Standard Time (IRST, UTC+03:30). Captions and discussion in both this supplement and the main text are all in UTC.

2.2 Facebook, Telegram, and Bluesky

For searches on these platforms, we used the same terminology as on X/Twitter. However, the volume of subsequent posts related to earthquakes occurring after 2024-10-05 was significantly smaller. As a result, date filters were less necessary, and all relevant posts could be manually parsed.

2.3 Search methodology

We were unable to make use of Twitter/X's API due to recent changes limiting access for users without a subscription. Instead, we made use of the advanced search function to identify posts containing relevant search terms (e.g. 'Iran earthquake' or 'Iran nuclear test') within the days after the event. We note that it is also possible to view some of this material through archives such as Perma (https://perma.cc).

We explicitly acknowledge that this is necessarily an incomplete dataset, as users have an ability to make private, delete, or edit content after it has been posted. Furthermore, posts making only metaphorical or non-technical reference to the earthquake (e.g. 'ground moving' or 'Iran shaking') would have been missed by our search.

Where Twitter/X posts are made by accounts representing or purporting to represent organisations, we have identified them directly. Where posts have been made by accounts claiming to be individuals, we have directly quoted from them without identifying them or providing their username. This decision has been taken to avoid 'outing' individual users who unintentionally posted speculation or misinformation about the event, as doing so could potentially expose them to harm.

A sample of both attributed and unattributed material are compiled in the supplement to this paper. We have not included every single one of the thousands of tweets identified, but rather a subset which includes a representative sample of:

- The ‘first' posts in each language that we identify as marking the transition from informational to speculative to misinformational,
- The first appearance of relevant graphics or seismograms, or relevant repeats therein with additional commentary (focussing on those in English and Persian), and
- Posts from the accounts with the largest number of followers (> 100,000).

3. Social and earned media

As noted in the main text, we found that tweets fell into one of the following categories: information, speculation, misinformation, and disinformation. In this section, we provide representative examples of English tweets in each of the categories which informed our analysis. Where multiple posts are shown in the same window, earlier tweets appear further down (as is the case on social media feeds).

3.1 Initial informational posts

The first tweets reporting the event are classified as 'informational,' as they report its occurrence without further speculation. The first, from a self-identified 'aggregator', is depicted in Fig. S3.1. It was posted at 19:26 UTC, approximately 11 minutes after the earthquake. Many of the subsequent tweets are attributed to 'bot' accounts which repeated the initial report verbatim.

Figure S3.1. Screenshots of first informational tweets reporting the earthquake shortly after it occurred. The first was posted at 19:26 UTC, with others following within seconds.

3.2 Non-nuclear speculation

Within minutes of the first report of the earthquake, numerous social media posts began to doubt the 'true origin' of the event, often as replies to the informational reports themselves (e.g. Fig. S3.2). These speculative posts are defined as raising unsupported questions about the earthquake's origin or casting doubt on the explanations supplied in the initial reports, typically in a questioning tone.

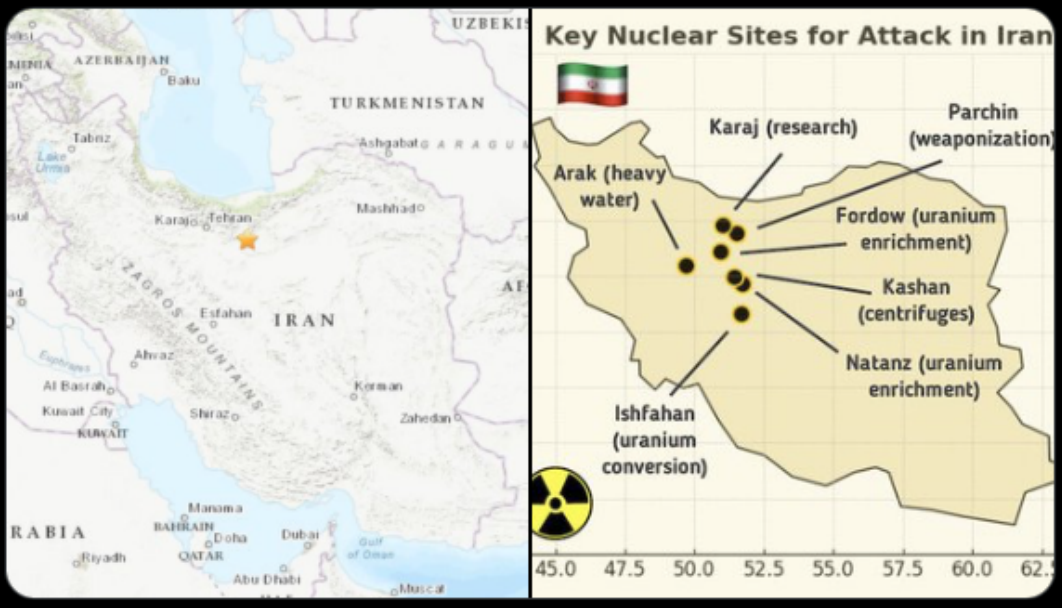
Not an earth quick. Netanyahu's speech was a go ahead of an operation. And this is it.

3:32 PM · Oct 5, 2024 · **1,022** Views

There are official reports of an earthquake,
M 4.5 - 48 km SW of Semnan, Iran
2024-10-05 19:15:33 (UTC) 35.291°N 52.992°E 10.0 km depth

I found a map claiming to show key nuclear sites in Iran, if accurate, some facilities seem to be close to the epicenter

earthquake.usgs.gov/earthquakes/ev...



4:23 PM · Oct 5, 2024 · **189** Views

Figure S3.2 Posts suggesting that this event may have been the signature of an Israeli strike on Iran. Note that the bottom post highlights Iranian nuclear facilities as "sites for attack in Iran".

3.3 Misinformation

Amongst the first tweets following the event, we find a broad spread of conspiracy theories being discussed, from weather machines to HAARP (Fig. S3.3). These are all references to unsupported claims of deliberate triggering of seismic events.

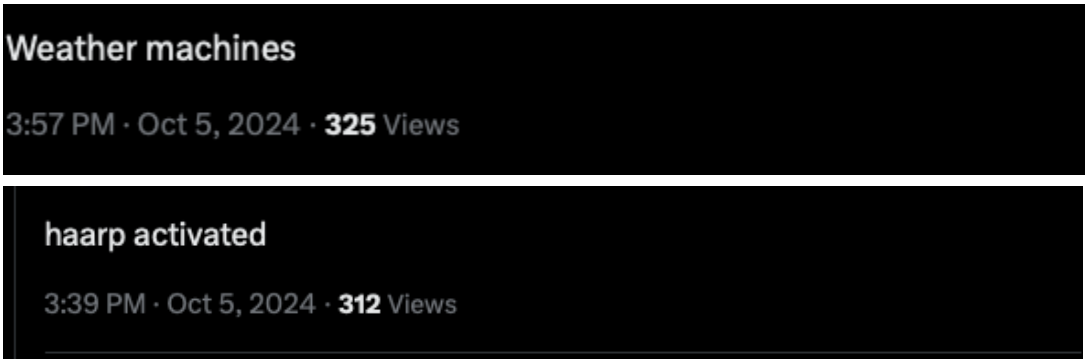


Figure S3.3 Posts suggesting that the earthquake was triggered deliberately by non-seismic (and non-nuclear) means.

While some tweets may have intended to be humorous in tone (e.g. Fig. S3.4), they may be perceived by others users as serious, and hence they can become equivalent to sharing misinformation.

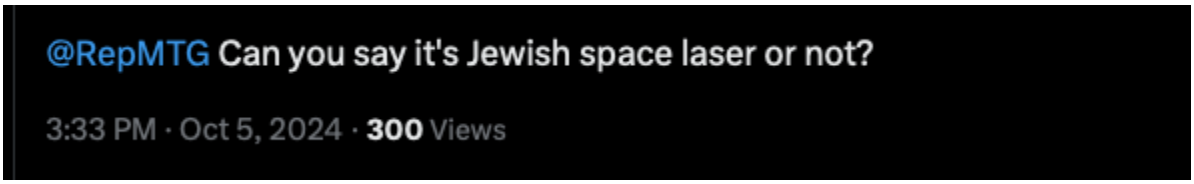


Figure S3.4 A potentially satirical post suggesting that the event was caused by ‘Jewish space lasers’, a reference to an unsubstantiated comment made by the tagged US Politician Rep. Marjorie Taylor Greene that wildfires in 2018 were started by ‘Jewish space lasers’.

3.4 Nuclear speculation

Next, we consider posts speculating that this was a nuclear test. These clearly constitute misinformation and are shown in Fig. S3.5.

Figure S3.5. Screenshots of the initial speculative tweets. The first tweet speculating on the connection between the seismic reports and supposed Iranian nuclear testing was posted at 19:38 UTC and is shown in the top panel.

3.5 Nuclear misinformation

Next, we consider posts claiming—rather than questioning or speculating—that this was a nuclear test. These clearly constitute misinformation and are shown in Fig. S3.5. We note that some of these have tens of thousands of reported views.

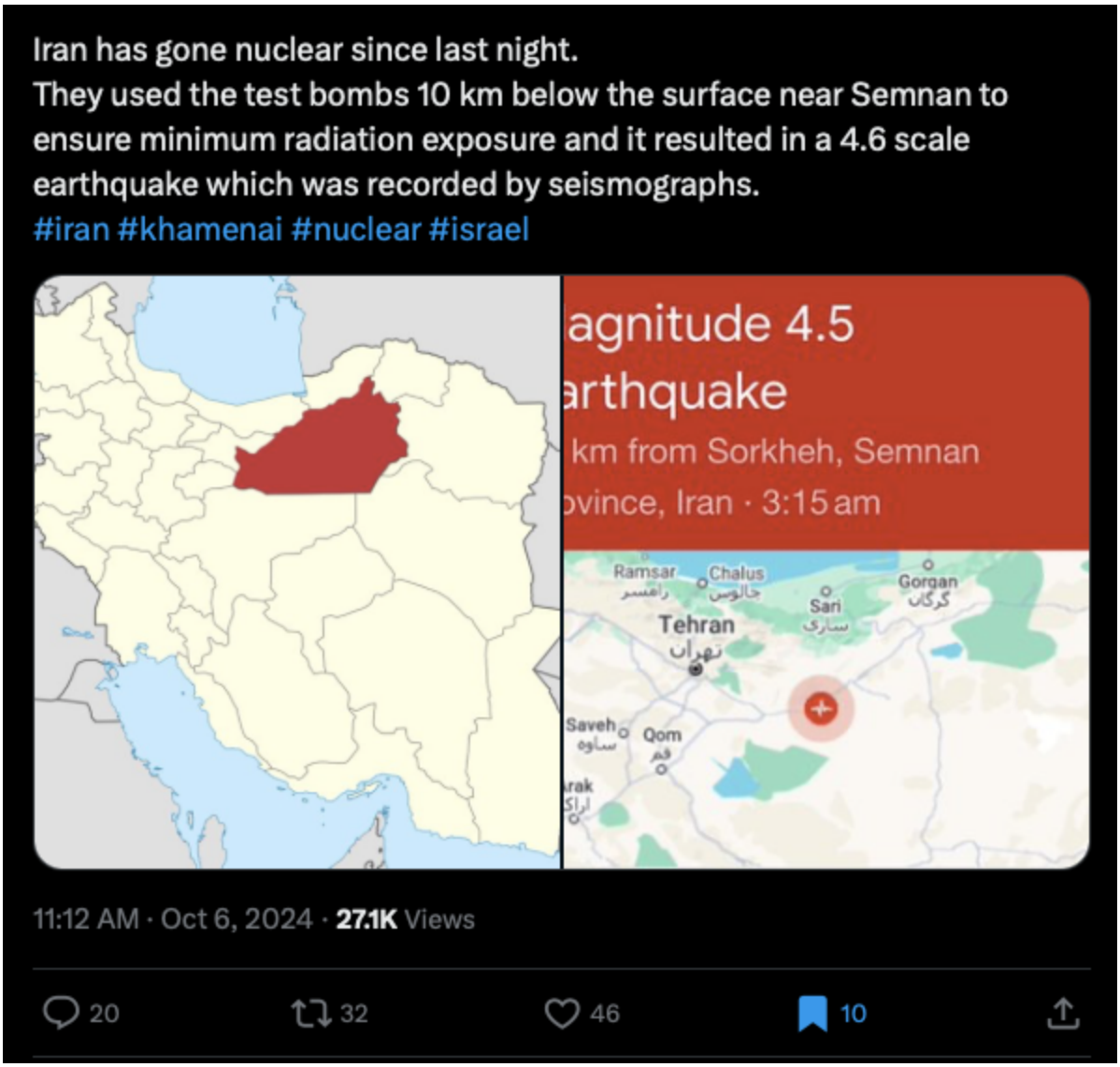


Figure S3.6 A post claiming definitively that this event was the signature of an Iranian nuclear test. We note that interestingly, the post was made at 15:12 PM UTC on October 6, and screenshots an earthquake which occurred at "3:15 am." The event occurred at 00:45 local time on October 6, indicating that the poster was located well east of Iran for the alert to show up as "3:15 am."

We also note that some posts (e.g. Fig. S3.7) cross the line from speculation into propagation of misinformation, beginning with a reference that Iran 'may' have tested a nuclear bomb (speculation), but going on to claim that the event more closely resembles a nuclear test (misinformation).

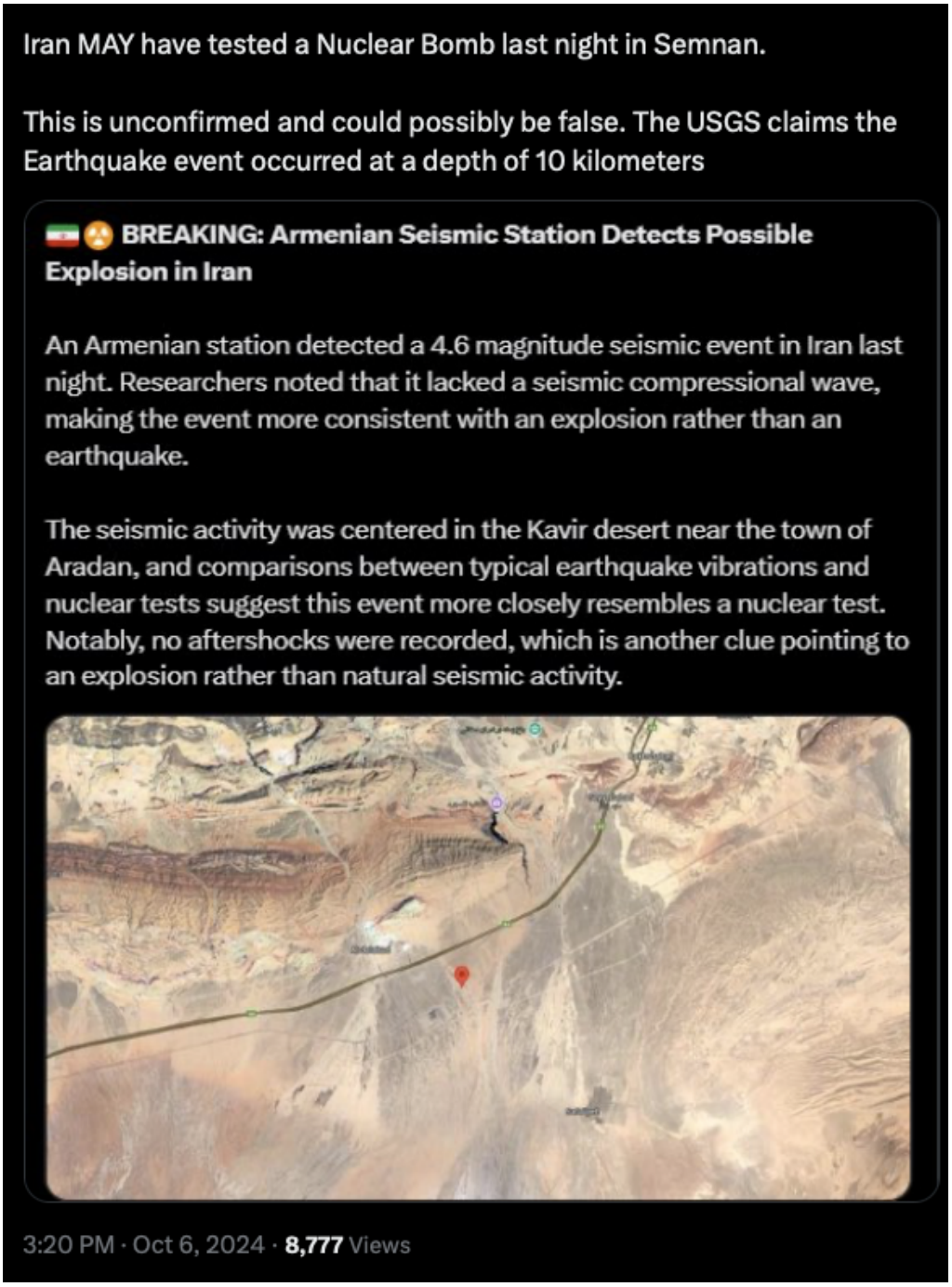
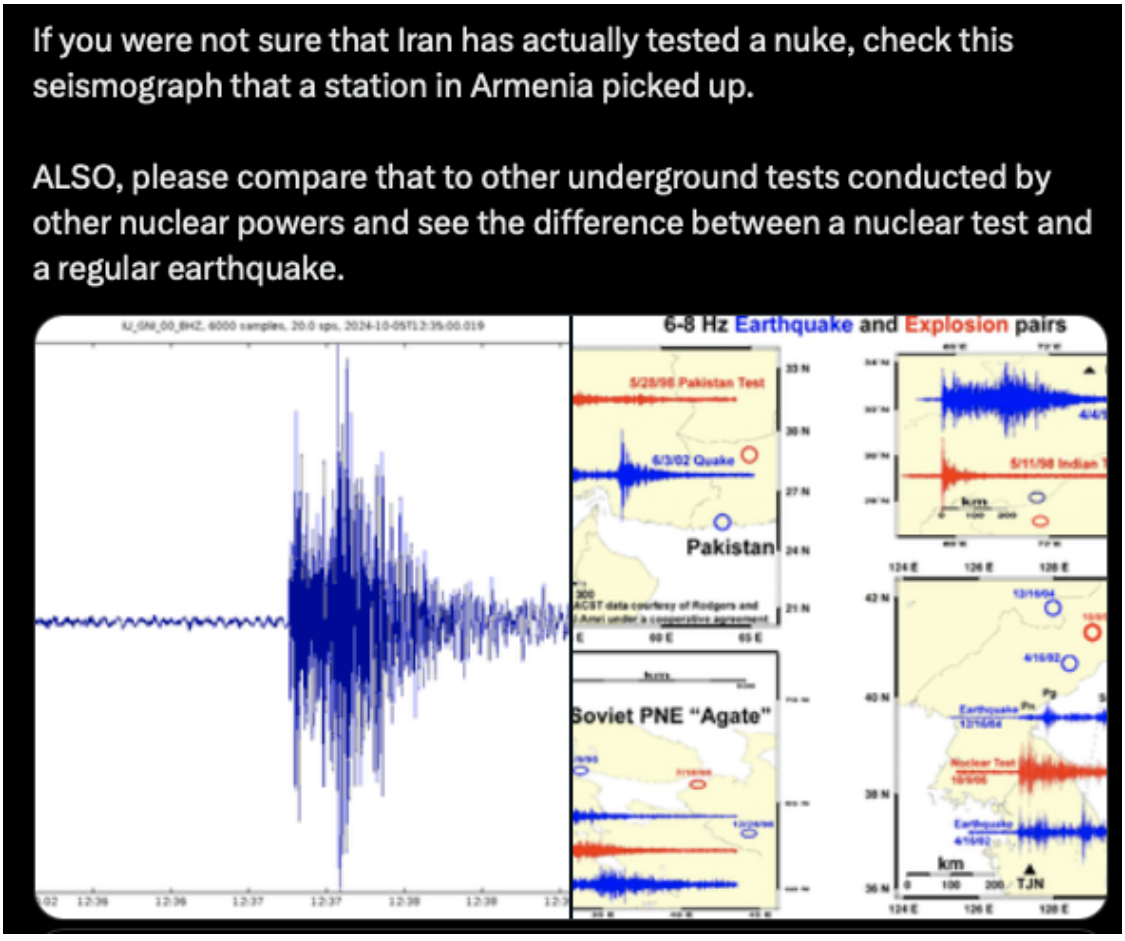


Figure S3.7 A post crossing the line from speculation into misinformation, in which initial suggestions that this 'may' have been a nuclear test give way to misinformation about its origin.

3.6 Misleading and misinterpreted seismograms

A number of sources began sharing misleading or misinterpreted seismograms in the hours after the event, or commenting on supposed features in the seismograms identified as nuclear test fingerprints by unnamed, uncited 'Armenian scientists.' These are shown in Fig. S3.8. Many of these posts received over 100,000 impressions.



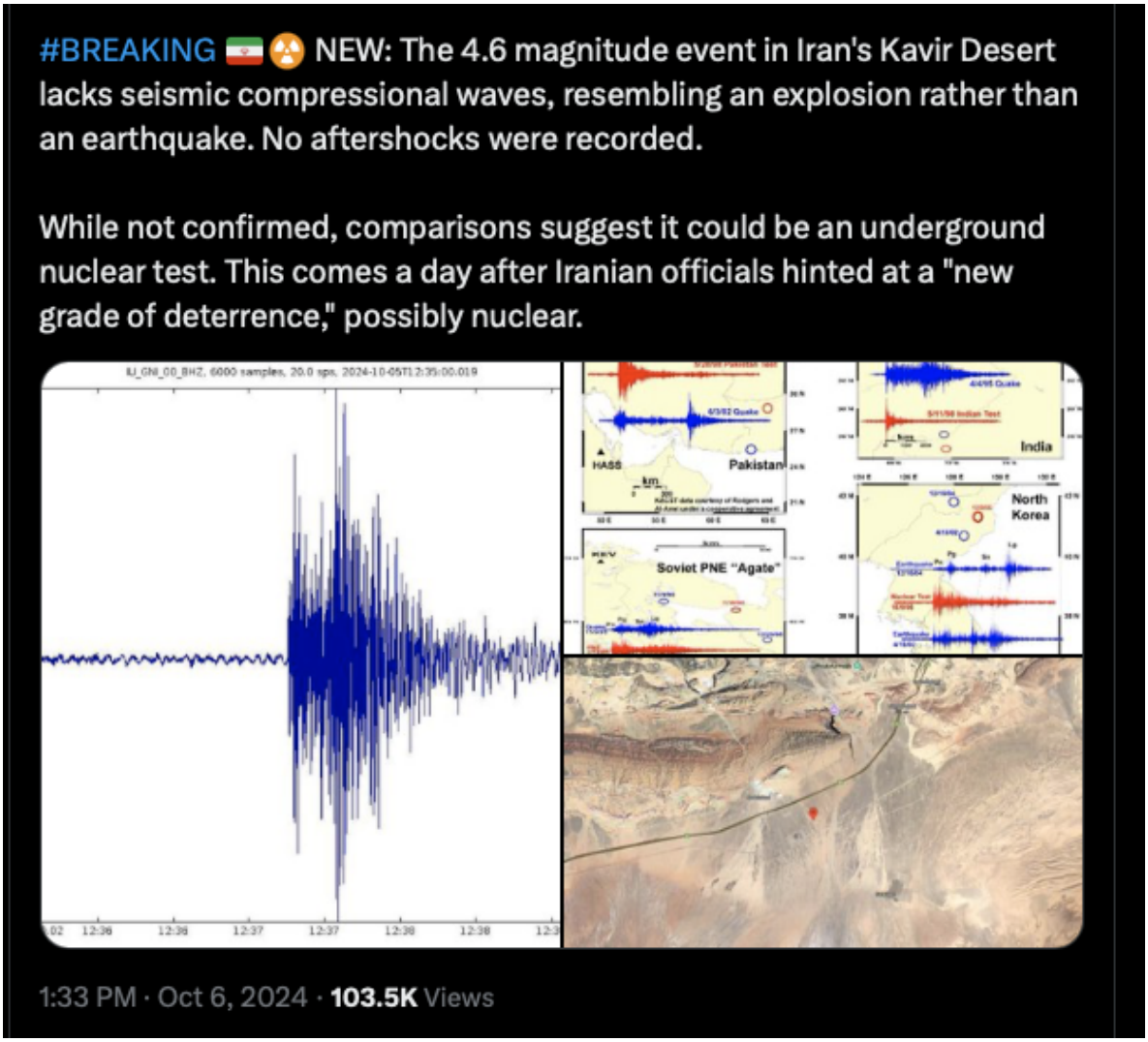


Figure S3.8 Multiple misinformation posts commenting on the similarity of this event to a nuclear test. Each of the above posts had around 100,000 views.

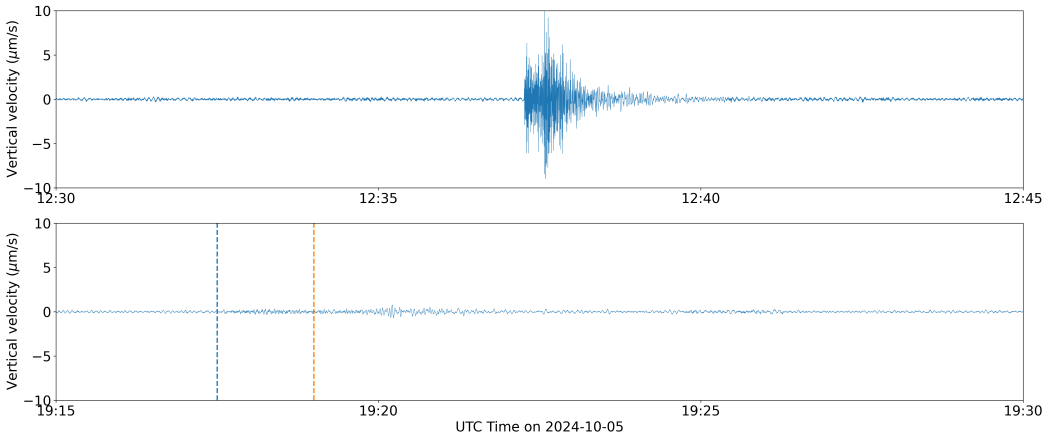


Figure S3.9 Data from station IU.GNI, located outside of Yerevan, Armenia. Top panel: Data from approximately 12:30 UTC on the same day as the Iran earthquake, about seven hours earlier. This panel reproduces a figure commonly shared online purporting to show the 19:15 UTC event. We have removed the instrument response and applied a high-pass filter above 50 s, which the plots shared online appear not to do. Bottom panel: Data from the 19:15 UTC Iran earthquake, similarly processed. TauP arrival times for the 19:15 UTC event are shown as dashed blue and orange lines, representing the P and S first arrivals, respectively. Both traces are 15 minutes long, with equivalent vertical amplitude scales.

3.7 Potential deliberate disinformation

We define disinformation posts as those where there is deliberate intent to share false information.

The following screenshots (S3.9-S3.10) exemplify the phenomenon of disinformation propagation by which accounts posture as credible news outlets through the use of ‘Breaking News’ imagery or language. These accounts create posts with phrasing and graphics that mimic traditional news media, aiming to increase trust in their assertions. We consider that this can reasonably be considered evidence of disinformation, given the scale of such posts and the choice of imagery resembling that of reputable organisations.

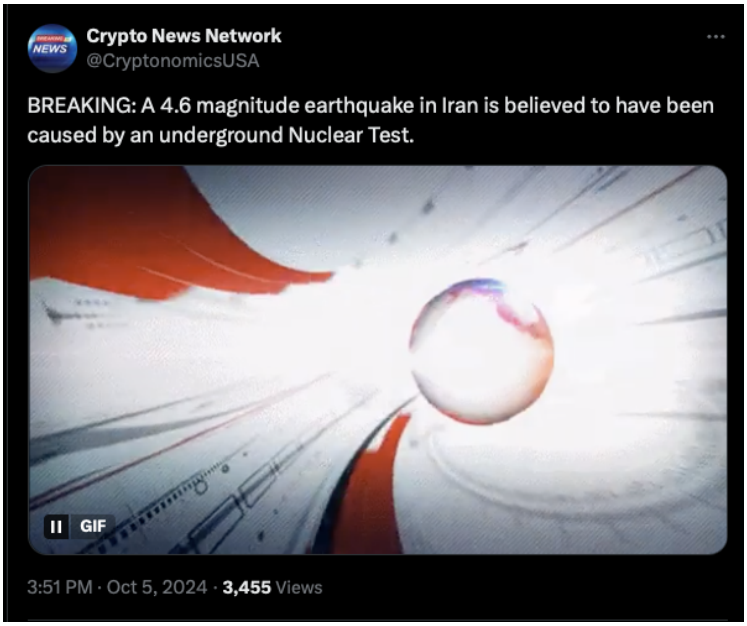


Figure S3.10 Screenshots from a purported 'news' account (top) or which use 'news' imagery (bottom), claiming 'Breaking News' using logos that are extremely similar to those used by the British Broadcasting Corporation (BBC), for example. We consider that this could reasonably be considered an attempt to add authority by impersonating the logos of other, more reputable organisations.

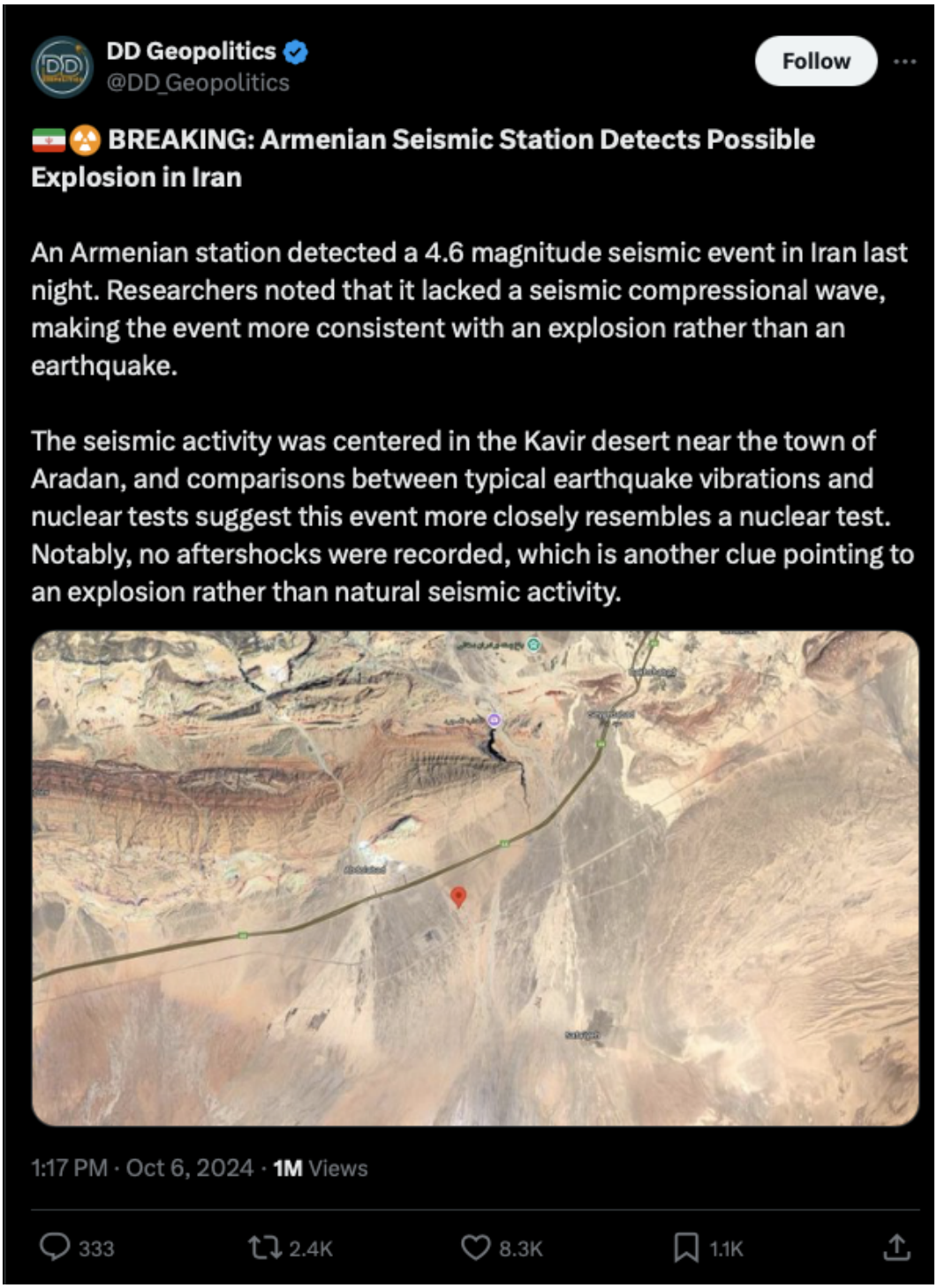


Figure S3.11. Another post claiming 'breaking news' which received over 1M views. This account has over 300,000 followers and has been linked to Russian state-supporting disinformation campaigns.

3.8 A false alarm in Israel

It appears that internet traffic searches for information about the Iranian event in Israel were sufficiently high in volume to trigger an automated crowdsourced detection for an earthquake in Israel (Fig. S3.12), which never actually happened.

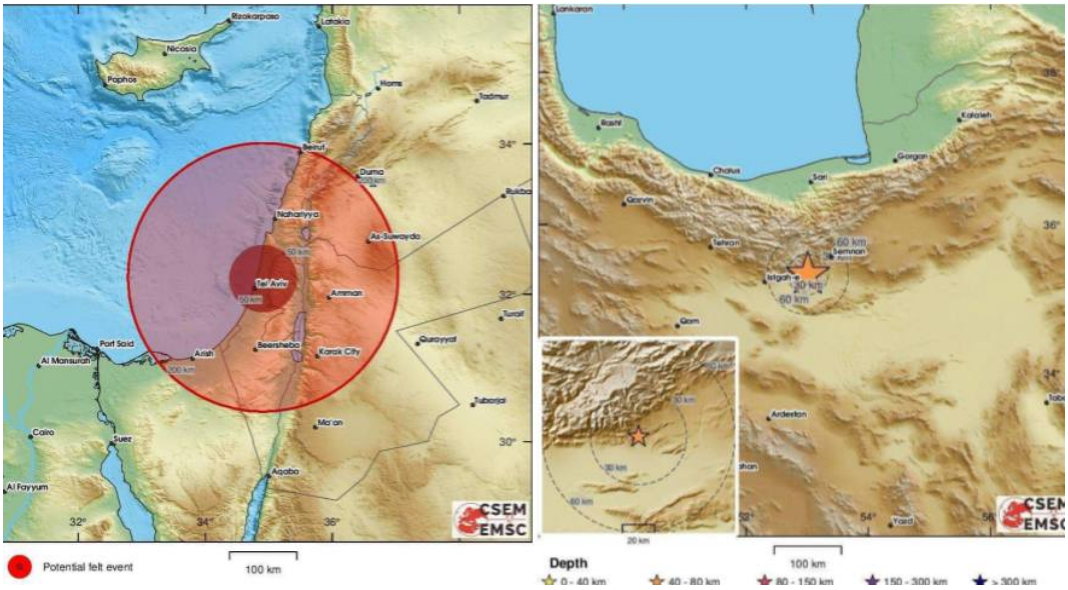


Figure S3.12 Top: Screenshots of posts made by the EMSC illustrating the actual earthquake in Iran (right panel) and a false alert in Israel (left panel) that were shared online extensively.

3.9 Other social media platforms and attempts at fact checking

Whilst more limited than those on Twitter/X, we note that similar misinformation posts appeared in English on Facebook and Bluesky (e.g. https://trendsinthenews.substack.com/p/nuclear-bomb-test-or-earthquake-in). These appeared to be far less influential in the spread of news than posts on Twitter/X, though some shared a BBC report on seismic source discrimination (https://www.bbc.com/news/world-asia-37582518), which was then misinterpreted.

Many accounts, both personal and organisational, contributed fact-checking efforts and community notes to posts about this event. Most notably, monitoring agencies like the CTBTO issued clarifying statements (see https://www.ctbto.org/news-and-events/news/ctbto-detects-two-earthquakes-northern-iran-5-october). However, these posts received only a fraction of the number of views of the most far-reaching misinformation posts (e.g. those in Fig. S3.9).

3.10 Earned media outlets: English

Tab. S3.1 lists English-language publications reporting on speculation or misinformation that this may have been a nuclear test, as identified through news aggregation sites. This list does not include publications which reported only factual information about the earthquake.

Date	Outlet	Country
October 7	Bulawayo	Zimbabwe
October 7	Jewish Press	USA
October 7	NDTV	India
October 7	Hindustan Times	India
October 8	FirstPost	India
October 8	The Times of India	India
October 8	The Express Tribune	Pakistan
October 9	Daily Mirror	UK
October 9	The Economic Times	India
October 9	Euronews	EU (France)
October 9	United News of Bangladesh	Bangladesh
October 13	Jerusalem Post	Israel

3.10 Summaries of material posted in other languages

In this section, we briefly detail posts made in other languages, focusing on differences from English-language content. Samples of content in Persian (Figs. S4.1-4.4), Arabic (Fig. S5.1), and Hebrew (Fig. S6.1-S6.6) are included in this supplement.

The most significant fraction of these were simply informational tweets about the earthquake and its potential impact on population health. These included posts made on social media by mainstream news agencies in Persian, such as BBC Persian.

We also identified a large number of posts commenting on political aspects of Iranian society whilst discussing this event; for example, many linked the test to government actions and heightened tensions in the Middle East. These included both pro- and anti-government sentiments, similar to those in English-language posts. Although posts had significant variability in outlook, we note that a number of pro-government users expressed excitement or happiness at ‘evidence’ that Iran had chosen to demonstrate its nuclear capacity. This strong sentiment seen on social media was also covered in subsequent mainstream media coverage.

Graphics shared included the same incorrectly identified seismograms as discussed in Sec. 4.1.3, as well as computer-generated images showing missiles and nuclear weapons emblazoned with Iranian flags.

The timeline of news posts in this language mirrored those in others, beginning with informational tweets about the occurrence of the earthquake within the first hour, followed by speculation about a nuclear test in tweets and replies over the course of the first day.

Interestingly, one of the most widely-followed accounts spreading misinformation about this event was an Arabic-language account named 'Russia News.' Less than an hour after the event, this account shared a post speculating that the event was a nuclear test to nearly 500,000 followers. This message was viewed at least 30,000 times (noting that Twitter/X statistics may be counting non-human or 'bot' users in this figure). Despite this account's substantial following, we were unable to find any information about its owners or operators online, other than much smaller presences on other social media platforms such as Telegram and Facebook.

Posts in Hebrew were similar in number on Twitter/X to those in Arabic; though we found a higher fraction of posts to be on other platforms in this language. This included Telegram and 'Hamal' (a Hebrew-language social-media like website, with a name meaning 'War Room')

Although this study focused primarily on false information spread through Twitter/X, we also analysed content from other social media sites including Facebook, Bluesky, and Telegram (Fig. S3.13-S3.14 and S6.4).

We find that posts about this event on Facebook and Telegram closely resemble those on Twitter/X, focusing on this event being a nuclear test rather than an earthquake. Much of the content, in both English and other languages, appears to be nearly identical to that posted on Twitter/X. This suggests a common origin for misinformation, which could be explained either through coordinated posting on multiple channels and/or uncredited copying and cross-posting of misleading seismograms and graphics by users across different platforms.

Significantly fewer posts (< 100) were made on Bluesky about this event than other platforms, probably reflecting its smaller user base; but it is interesting to note that the proportion of bot tweets or comments (as indicated by near-instantaneous, verbatim word-for-word copy-pasting between multiple accounts) was almost zero. Furthermore, the majority of posts that we categorise as misinformation consisted of sharing mainstream media articles about the event, or excerpts therein, rather than tweets containing 'original' misinformation.

4. Social Media Posts: Persian

4.1 Initial informational tweets

As described in the main text, tweets in Persian began on similar timescales to those in English, and are catagorised the same way. We emphasise that these tweets in particular should be seen within the context of active hostilities between Iran and Israel in October 2024.

Early, initial informational tweets referred to communications from the Iranian Seismological Center (Fig. S4.1). Using the reported depth, many surmised that the event was an earthquake. Some of these users even compared seismic simulations of nuclear tests to those of earthquakes to try and demonstrate that they are distinctly different. A few users also provided links to the interview of a Tehran University professor which offers an explanation that this event is not a nuclear test but rather an actual earthquake.

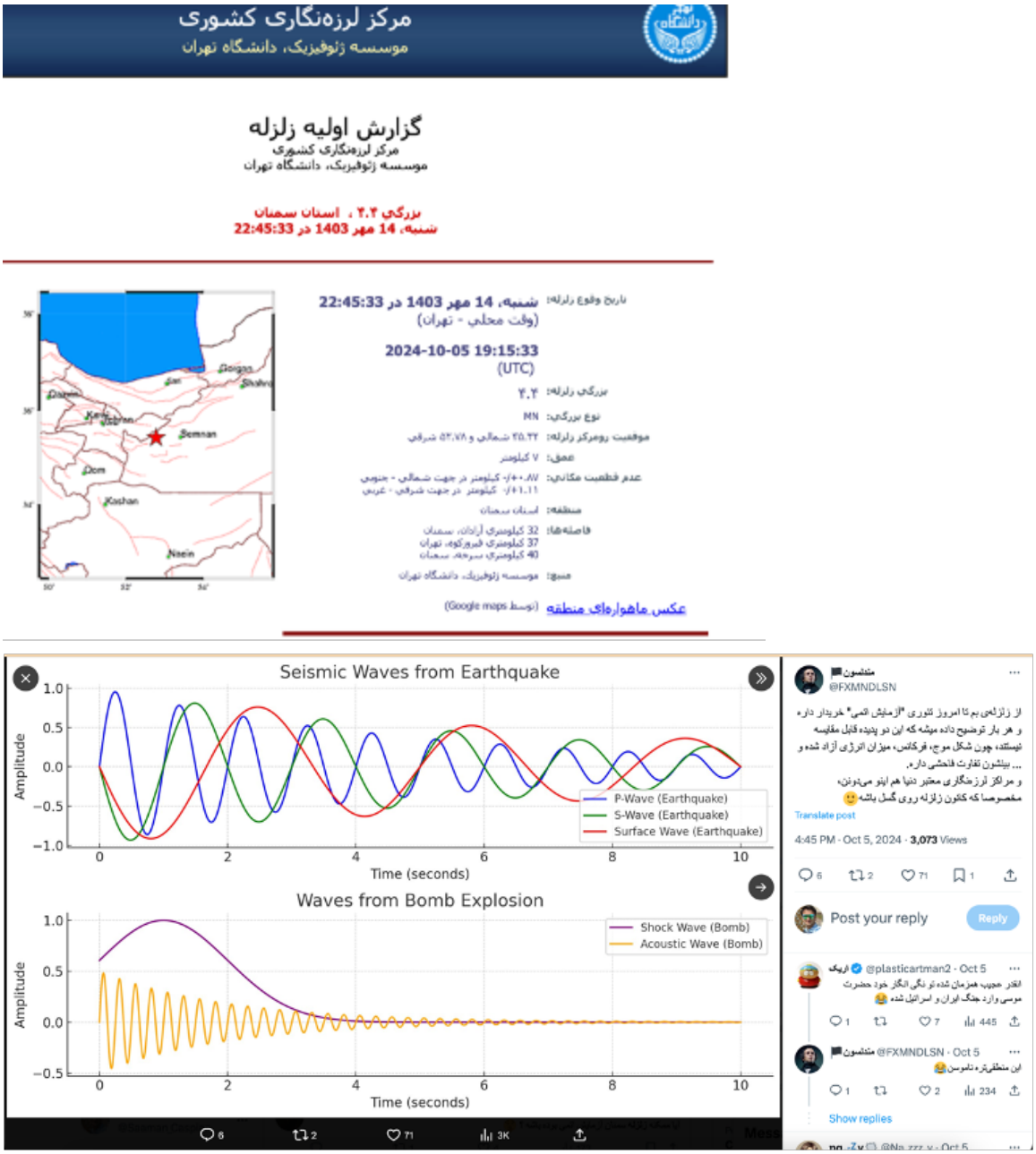


Figure S4.1. Top: The event report by the Iranian Seismological Center. Bottom: A tweet comparing simulations of an earthquake and a nuclear explosion, shared to highlight differences between the two.

4.2 Speculative and misinformational tweets

Speculative and misinformational tweets in Persian were similar to those in English, with users expressing varying degrees of certainty that this was a nuclear test. A sample of these tweets are shown in Fig. S4.2.

Small differences in presented reasoning were observed, including the supposed absence of the earthquake in global databases (untrue), a perception that the event ‘felt like an atomic test’

(unevidenced), or those linking the event to a nearby ‘underground missile town’ (unevidenced). Similarly to the English tweets, many were likely from bots, as the quoted content is copied verbatim.

We note that there is a divide in political stances toward the Iranian government in these posts, many coming from users who frequently criticize the ruling system of the country.

Figure S4.2. Screenshots of tweets which claim that the earthquake was a nuclear test and may be relevant to an ‘underground missile town’.

A very small group of users, whose profiles promoted the ruling government of Iran, claimed in their tweets that the government had finally decided to test supposed Iranian nuclear weapons (Fig. S4.3). From the language of these tweets, they suggest the aim of the test was to project a sense of deterrence. However, these users provided no evidence to support their claims, nor did any of them indicate an actual affiliation to the Iranian government.

Figure S4.3. Screenshots from users who expressed sentiments inclined toward supporting the ruling system of Iran, and are suggesting that the event might have been a nuclear test.

4.3 Mainstream coverage and humanitarian concern.

The largest number of tweets, however, did not address the nuclear test, military aspects of the event, nor the ruling system. These tweets focused primarily on the earthquake's magnitude and the potential danger posed to people in the affected area and its vicinity. Such sentiments were largely absent from tweets in other languages, perhaps not unsurprisingly given that this was an event which took place in Iran.

Many of these sentiments were expressed in replies to posts from mainstream Persian-language media. Initially, all these outlets—regardless of their stance on the ruling system—covered the earthquake similarly, relying on information from either the Iranian Seismological Center or other seismic agencies (Fig. S4.4, top).

However, a few hours later, after speculation began circulating on social media (Fig. S4.2), some news agencies responded by contacting seismologists to inquire about the possibility of this event being a nuclear test. Every article we examined concluded that, based on its depth and the characteristics of its seismic waves, the event was a natural earthquake. This degree of expert involvement was not observed in articles in other languages, and may indicate a higher degree of seismic education or awareness in Iran.

Figure S4.4. Top: A screenshot from the website of a major news agency reporting the event. Bottom: A screenshot from another news agency that discussed the details of the event in conversation with a Tehran University professor.

5. Social Media Posts: Arabic

The information available online in Arabic in the wake of the earthquake was limited. In the initial hours following the earthquake, the information reported was generally factual. However, suggestions of a nuclear test came shortly after the earliest X posts with fact-based information. The earliest Arabic-language posts about the earthquake we identify were made at 19:32 UTC. The earliest suggestions—in replies to the posts—of a nuclear test occur only three minutes later. This is a near-identical timescale to those posts made in English. Fig. 5.1 shows posts by the "Russia News" account described in the main text.

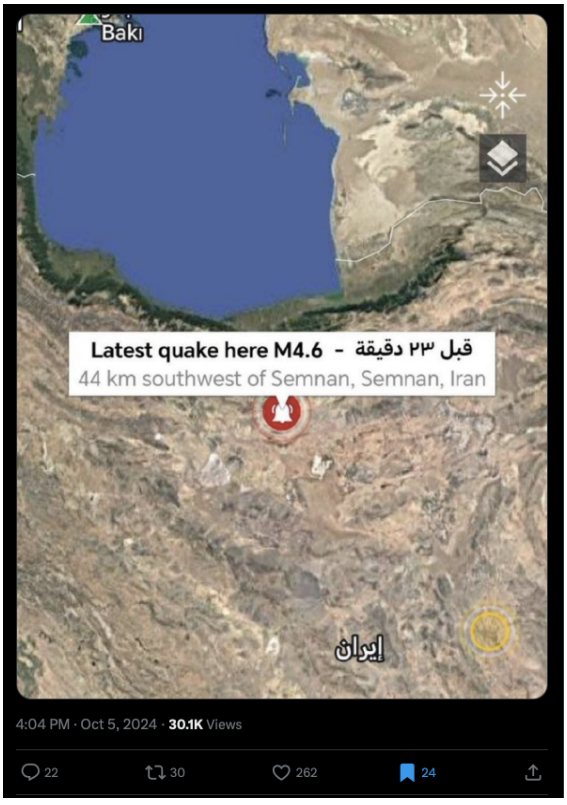


Figure S5.1 Screenshots of widely shared posts from "Russia News", an organisation about which we can find no independent information. Posts from this organisation spread misinformation about the event's origin to a large audience.

6. Social Media Posts: Hebrew

As in Arabic, posts in Hebrew about this event were limited. We note a similar pattern of informational (Fig. S6.1) posts in the minutes after the earthquake, giving way to speculation and misinformation later on (Fig. S6.2-3).

Figure S6.1. Initial informational tweets about the event in Iran, shared in Hebrew on Twitter.

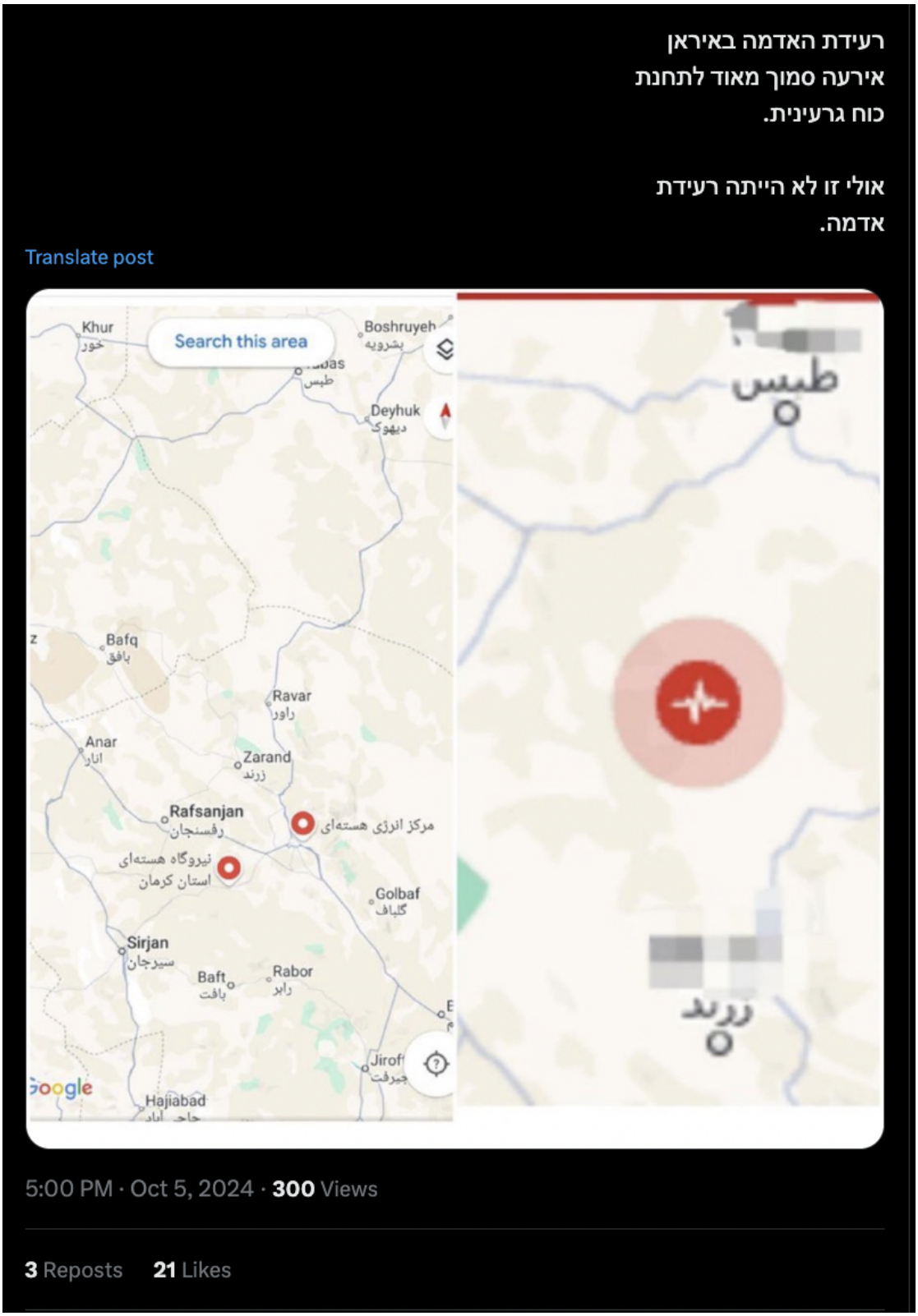


Figure S6.2. Speculative/misinformational tweets in Hebrew linking the event to nearby nuclear facilities in Iran, again shared on Twitter.

Figure S6.3. A reply to the tweet in Fig. S6.2. Translation: "In the end there will be an earthquake due to multiple nuclear tests that will swallow most of Iran Amen 🙏".

We also note numerous posts in Hebrew gaining widespread traction on Telegram (Fig. S.6.4) in the days after the event, which shared the misleading seismograms discussed in the main text. The fraction of users reached on Telegram versus other social media sites in Hebrew appeared to be larger than other languages.

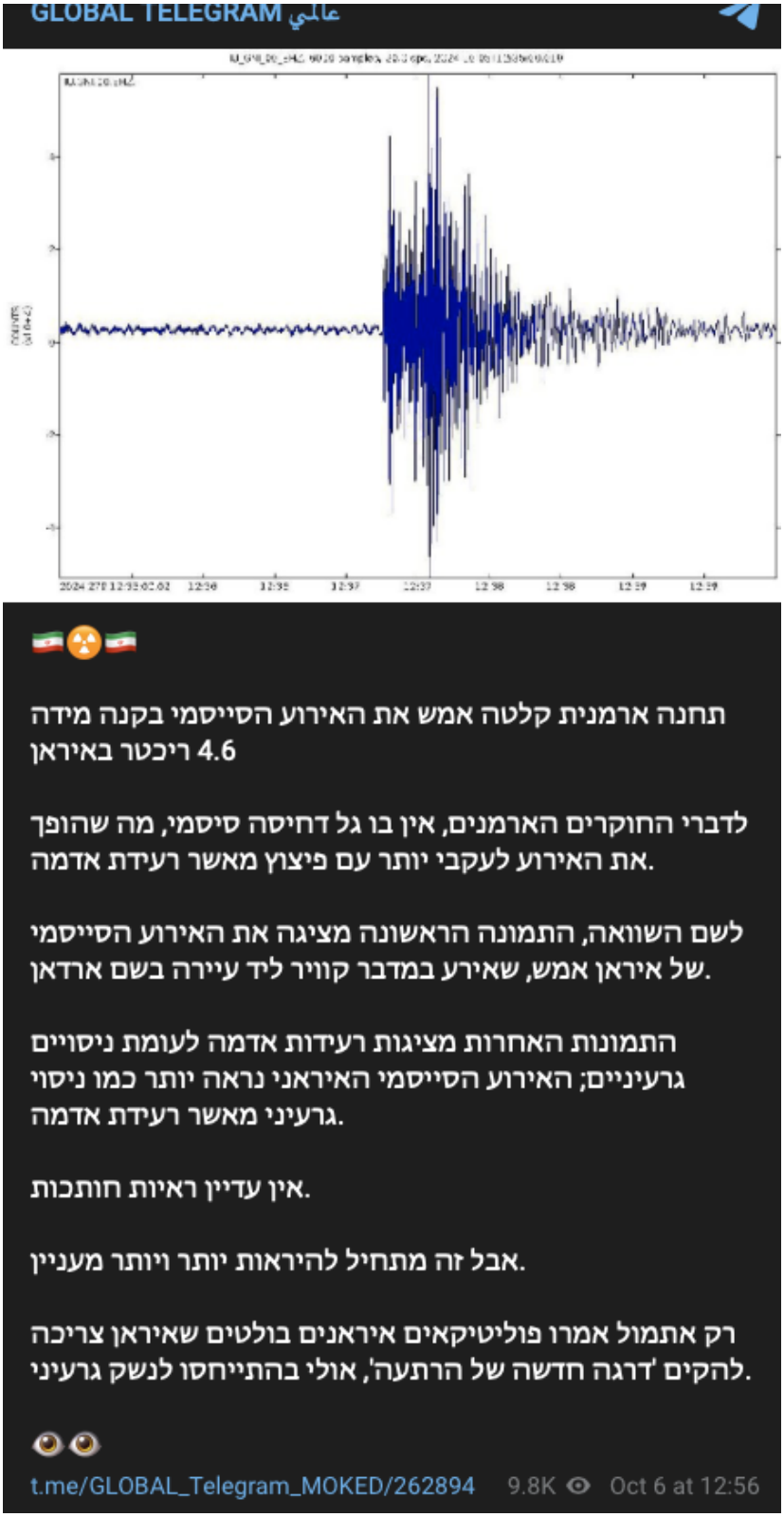


Figure S6.4. A post on Telegram in Hebrew sharing misleading seismograms from station IU.GNI as evidence of a nuclear test.

Significant numbers of widely-read posts were also made on a site called “Hamal” (meaning ‘war room’), which was unique to Hebrew-language social media posts (Fig. S6.5-6).

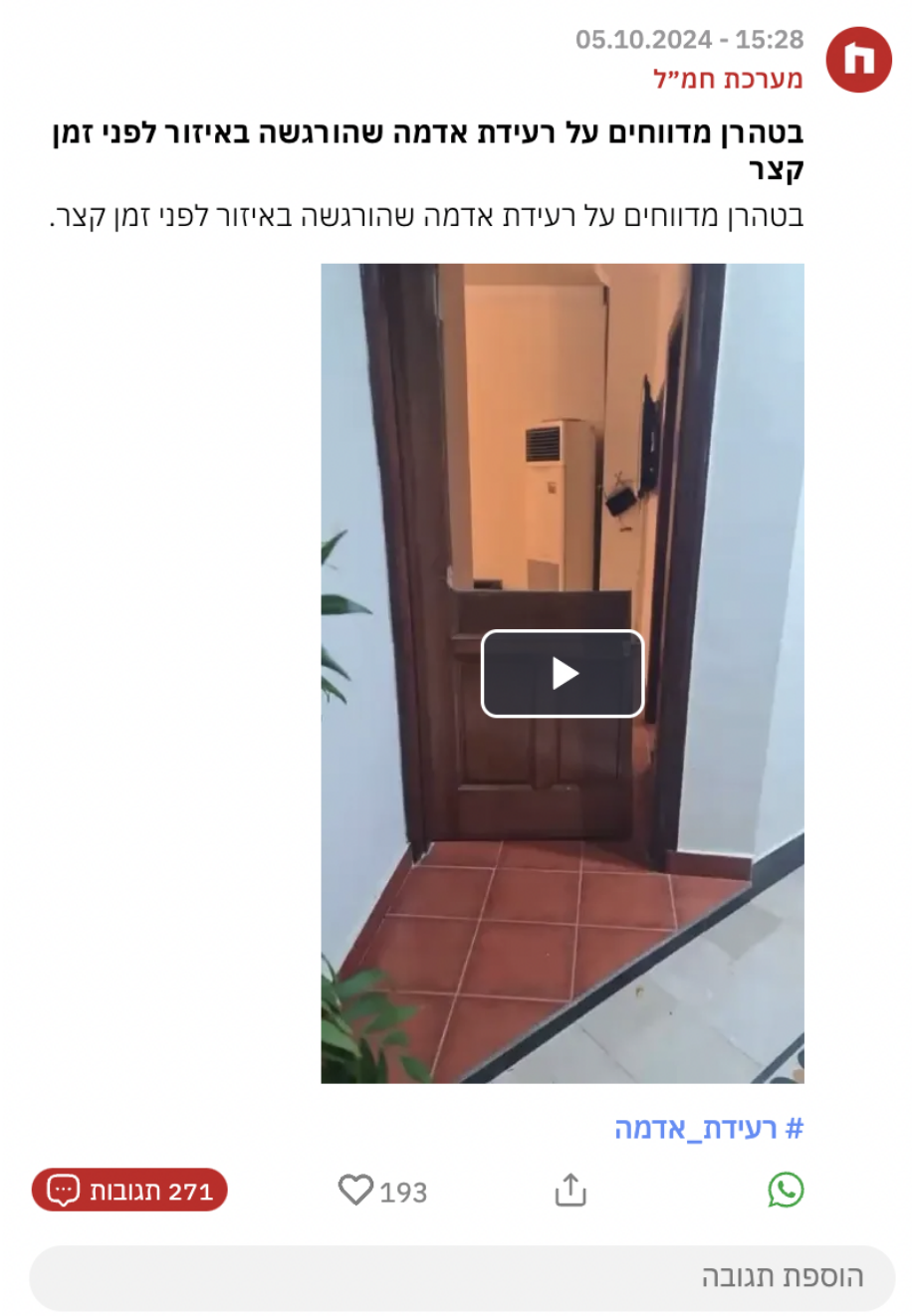


Figure S6.5. Likely misinformation on Hamal reporting on the Iran earthquake and purporting to show damage from it. There is no indication that this footage is genuine.

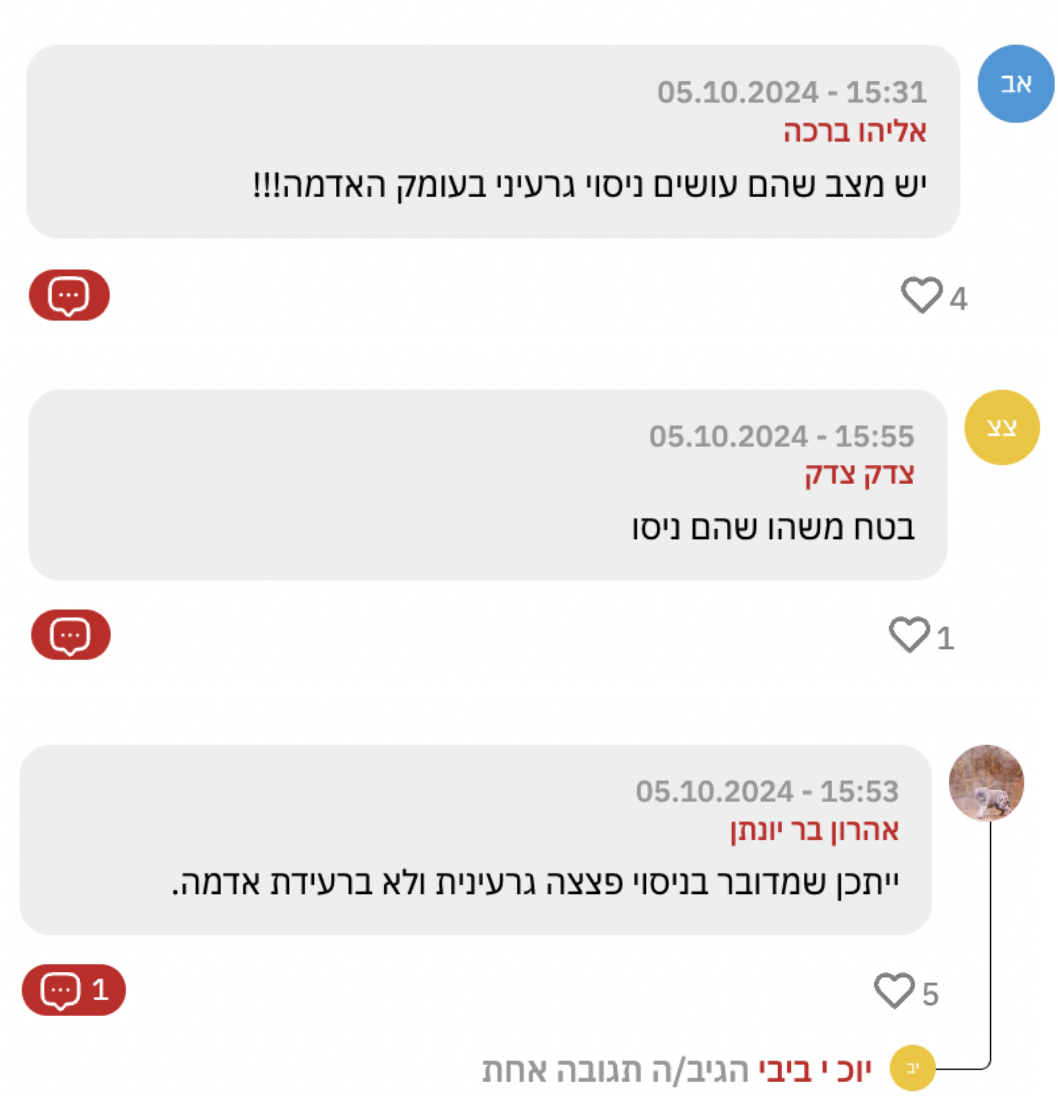


Figure S6.6. Posts on Hamal linking the event to a nuclear weapons test, ranging from speculative ("There's a possibility that they're doing nuclear tests under the ground") to misinformation ("Definitely something that they're testing").