

INDEPENDENT EVIDENCE-BASED STUDY

When Mining Moves the Earth

Human-induced and potentially human-induced earthquakes in Kuzbass:
twenty years of observations and international evidence from open-pit and
underground mining

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AI participation forms part of the Experiment project.

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When Mining Moves the Earth

Document type	Independent evidentiary research with the author's introduction, methodology, chronology, calculations, verification tables and sources.
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The principle of the document. The web article tells the story; this PDF provides the evidence needed to verify it. Proximity to mining alone does not establish an event's origin. Catalogue entries, industrial blasts, rockbursts, collapses, mainshocks and aftershocks are distinguished as far as the sources allow.

What's in this PDF

4,977

recorded earthquakes in the regional sample of 2006–2026

42

key event records in the verification register

18

sequences, swarms, and reactivations

38,234

industrial-blast records in a separate dataset

15

international coal-mining cases examined in detail

38

tests of relationships among investment, production and seismicity

The complete large catalogues are preserved as machine-readable appendices. This PDF contains the principal summary tables, underlying assumptions, source conflicts and limits of interpretation.

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From the Author



Natalia Alexandrovna Zubkova.

When we talk about the consequences of coal mining, the first things that usually come to mind are polluted air, coal dust and emissions of harmful substances. But I want to begin deeper down—with what happens to the earth itself.

Open-pit and underground coal mining interfere with the structure of the subsurface. Rock is removed from the ground, mine workings are created, enormous masses of overburden are moved into waste dumps, and

water is pumped out. The topography changes, the soil cover is disturbed, and loads and stresses in the rock are redistributed.

The subsurface of Kuzbass has a long and complex history. Coal-bearing sediments accumulated here, folds and faults formed, and magma intruded into the rock. Modern mining has entered this geological history as a new influence. To understand its possible consequences, it is not enough to look only at the amount of coal extracted.

One possible consequence of this intervention is a human-induced earthquake. Mining can change the conditions that keep rock stable and initiate movement along an already stressed fault. The focus of such an event may lie considerably deeper than the mine workings themselves.

I had known about the Bachatsky earthquake for a long time. Now I wanted to look at the question more broadly: where else has open-pit extraction of solid minerals been accompanied by strong earthquakes? How close were their hypocentres to the pits? How did researchers establish a link with mining? And what do twenty years of observations in Kuzbass show—is seismic activity increasing, decreasing, or changing in a more complicated way than we might expect?

SECTION 1

Summary and Limits of Knowledge

The main conclusion

Kuzbass cannot be described as a place where only one exceptional human-induced earthquake occurred. Over several decades, a number of repeatedly reactivated zones have developed near coal open-pit mines, underground mines, waste dumps and iron-ore mines. Human-induced origin is most firmly established for the 2013 Bachatsky earthquake and its subsequent activation, for the Kaltan–Alardinskaya zone, and for several events that the official 2020 catalogue itself classified as human-induced.

At the same time, not every tremor in a coal-mining region can be declared human-induced. For many events, only coordinates and magnitude are available; in recent years, depth and magnitude type are often missing. Proximity to mining supports a hypothesis, not a conclusion. Establishing causation requires waveform records, a focal mechanism, accurate three-dimensional geometry and data on industrial activity.

Five levels of confidence

1. **Established in detail:** the local network, mechanism, three-dimensional structure, and mining history are consistent; an example is the Bachatsky open-pit mine.
2. **Classified by specialists or in a catalogue:** the authors or catalogue classify the event directly, but the full supporting analysis is not available; an example is three events of the Krasnobrod zone in 2020.
3. **Probably related:** Several independent indicators point to mining, but some of the necessary data are missing.
4. **Proposed or disputed:** a link has been proposed, but there is a serious alternative interpretation; an example is Newcastle.
5. **Origin not established:** Only spatial proximity or an operational event card is available; an example is the event on 10 October 2026 at the current stage.

This scale preserves the strength of established cases and does not make the inference stronger than the data.

What can be said right now

- human-induced earthquakes during the extraction of solid minerals are an established world phenomenon.

- The Bachatsky earthquake of 2013 is classified by scientific works as human-induced.
- Kuzbass contains several repeatedly active zones associated with industrial sites.
- A strong event need not itself be a blast in order to have an industrial cause.
- The event on 10 October 2026 took place near the Krasnobrodsky mine and inside the previously active zone.
- Its origin as of 10 October 2026 has not been established.
- Open data are insufficient for residents to test the mining hypothesis independently immediately after a tremor.

What cannot be said yet

- That every tremor in Kuzbass is caused by coal mining.
- That magnitude or distance itself prove the cause.
- That raw annual numbers show monotonous growth.
- That every catalogue row represents an independent event.
- That all of the world's coal seismicity is fully represented in HiQuake.
- That the Newcastle earthquake is proven to be caused by coal mining.
- That the operational magnitude 4.9 reported in 2026 is directly comparable to ML 4.9 in 2020 before publication of the type and revision.

Main unknowns

1. Revised parameters of the 10 October 2026 event.
2. Blast logs and records of mining operations of Krasnobrodsky and neighboring enterprises.
3. Complete individual catalogues of Osinniki and Polysaevsky swarms.
4. Historical polygons of mine workings and waste dumps by year.
5. Comparable monthly series of extraction, overburden and drainage for the main zones.
6. Complete revised regional catalogue for 2024-2026.
7. Independent surveys of possible damage to homes after felt events.

SECTION 2

Geological history of Kuzbass and modern intervention

To understand earthquakes near mining, it was important for me to first understand what exactly mining is interfering with. Kuzbass is not a homogeneous stratum in which coal lies. It is a sedimentary basin with a complex history of sediment accumulation, folding, faulting, uplift and erosion of older structures.



Folded layers of rocks in Kuzbass uncovered by mining. July 21, 2019. The precise location and photographer have not been established. The photo is stored in the archive of Natalia Zubkova.

How the coal basin came about

The formation of the basin began long before the appearance of the main coal strata. In the Devonian, the territory was sinking, the sea advanced into the area. Later conditions became predominantly continental. In the Late Carboniferous and throughout the Permian, sandstones, siltstones and mudstones and the plant material that would form future coal seams accumulated. In the central and western parts of the basin, the total thickness of the Upper Carboniferous and Permian continental deposits reaches about 7-8 kilometres. Coal layers alternate with sandstones, siltstones and mudstones, so the massif is heterogeneous both in strength and permeability. [Radioisotope study of the Permian stratigraphy of Kuzbass.](#)

Studies of sedimentary strata describe the Kuznetsk basin as a trough surrounded by folded-thrust belts and shear zones. The load of the incoming masses from different sides influenced the sinking of the basin and the sediment accumulation. Later tectonic movements crumpled the marginal parts of the strata into folds, cut them with faults and created blocks with different structures. [Study of sedimentation and deformations of the Kuznetsk basin.](#)

What happened near the border of the Permian and Triassic

The Carboniferous and Permian coal-bearing strata are older than the basalt bodies and sills studied in Kuzbass. In the Late Permian-Middle Triassic section, sheet-like basalt bodies and intrusions of about 250–248 million years old were found. They are associated with the large Permo-Triassic magmatic province of Siberia. This is an ancient geological event, and not a sign of a modern active volcano near Kuzbass. [Study of the age and composition of Kuznetsk basalts.](#)

After the accumulation of coals and magmatic intrusions, the story did not end. Uplift, erosion and new deformations changed the topography and position of the blocks. The study of modern tectonics shows that some of the faults expressed in the modern topography and Cenozoic

deposits have a relatively young appearance; the most noticeable vertical movements are confined to the boundaries of the basin, and within it the movements differ by area. This does not mean that any such fault is active today or that mining will necessarily cause an earthquake on it. This means that each site requires its own geological model. [Study of the stages of activity and tectonic division of the Kuznetsk basin.](#)

Why the structure of a particular site is important today

An open-pit mine removes an enormous mass of rock and transfers it to waste dumps. An underground mine creates a mined-out void around which stresses are redistributed. Drainage reduces the water pressure in fractures; after pumping stops, it can grow again. These influences are superimposed on existing layers, folds, cracks, faults and aquifers.

Therefore, the same annual tonnage does not mean the same impact. The depth and area of the working, the direction of the mining front, the dip of the seams, the position of pit walls and waste dumps, the volume of removed rock, drainage and orientation of faults relative to the modern stress field are important.

I consider modern mining as a new impact within this long geological history. Ancient magmatism explains part of the structure of rocks, but does not itself explain modern seismicity. The test of the human-induced hypothesis does not begin with the image of the "awakening" of an ancient process, but with measurable things: the position of the hypocentre, the mechanism of rupture, the geometry of mining, water, dumps, and stress changes.

SECTION 3

Method, definitions and confidence levels

Working cut-off date: **10 October 2026.**

Two linked datasets

1. **Kuzbass.** Detailed chronology of individual events and series: origin time, coordinates, depth, all published magnitude estimates with the magnitude type stated explicitly, intensity, consequences, nearby mining sites and classification grounds.
2. **Worldwide.** A complete register of known industrial projects and series from HiQuake, supplemented by an event chronology of the most studied cases. A single industrial site can generate thousands of tremors, so a project or swarm is counted with a single line if the original source does not publish a complete individual catalogue.

What counts as a separate entity

- **Earthquake** – an event identified as an earthquake by a seismological catalogue or study;
- **induced or human-induced earthquake** – an event for which the source provides the grounds for linking it to human activity;
- **Presumably human-induced** - such a connection is proposed, but remains incomplete or controversial;
- **Event of unknown origin** – there are not yet sufficient data to draw a conclusion;
- **Rockburst or mining-induced tectonic shock** – a separate category of source, not automatically renamed to an earthquake;
- **Industrial blast** - a separate category that is not included in the number of earthquakes;
- **Mainshock, foreshock, aftershock and swarm** - related events within the same sequence. They are stored as separate records, but are not considered independent cases.

The proximity of the epicentre to a mine, open-pit mine, waste dump, well, reservoir or other object **does not by itself establish the origin of the event**.

Stages of origin assessment

The source's own wording and reasoning are preserved in the working register. For the final analysis, a single scale of five levels is used:

1. **Established in detail.** The local network, the focal mechanism, three-dimensional structure and mining history are consistent.
2. **Classified by specialists or catalog.** The source directly calls the event human-induced, but the full supporting analysis is not available.
3. **Probably connected.** Several independent signs point to extraction, but some of the required data are missing.
4. **Proposed or disputed.** A link is proposed, but the data are incomplete or there is a serious alternative interpretation.
5. **Origin not established.** In the available primary material there is no inference about the cause; proximity to the object alone is not enough.

The short labels in the source register map to this scale as follows: **strong evidence** – Level 1 or 3, depending on the completeness of the local analysis; **source-classified** – Level 2; **proposed/disputed** – Level 4; **unestablished** - Level 5. The level is assigned after reviewing the underlying evidence, not merely from a machine-readable tag.

For the worldwide corpus, the original **E-PIE** assessment is preserved. It indicates the strength of the published evidence and does not replace examination of the original source. Entries marked "insufficient evidence" (**Insufficient evidence**) remain in the corpus precisely as cases with

insufficient data.

Rules for working with numbers

- UTC and local time are kept separately. This is especially important for the Bachatsky earthquake: the mainshock occurred on June 18, 2013 UTC and June 19 local time.
- ML, mb, Mw, MS, unified M and the energy class are not considered interchangeable. If the catalogues give different solutions, all the solutions and their authors are preserved.
- A fixed or calculated depth is identified separately from an instrumentally determined depth.
- Macroseismic intensity is not conflated with magnitude.
- Distance to a mining site is calculated to its verified boundary, not to the label on the map. Until the boundary is verified, the field remains empty.
- Event counts from different catalogues must not be added without deduplication.

Spatial coverage of Kuzbass

The working sample includes:

- events attributed by sources to the Kuznetsk basin;
- events in the Kemerovo Region – Kuzbass, if they are related to mining sites or are considered as a background against which to test a possible relationship;
- events near the border of the region, if the study directly connects them to an object inside the coal basin.

The coordinate export from the official database is used as background data, not as a ready-made list of human-induced earthquakes. The administrative boundary must then be checked, duplicate records removed, and events classified from primary publications.

Dataset after cleaning and cross-checking

- HiQuake: **1,385** projects and series in **84** countries, version dated 24 September 2026.
- Official annual regional catalogues of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS): **4,806** records in the administrative boundary of the Kemerovo Region for the complete 2006–2023 calendar years. After the exclusion of two events preceding the exact boundary on 10 October 2006, the twenty-year series included **4,804**. This is a catalogue of registered earthquakes, not a list of proven human-induced events.
- Operational cards of the Altai-Sayan Branch for 2024: **62 successfully retrieved entries**, designated as earthquakes within the administrative boundary of the region, and **292**

records of other types, mainly industrial blasts. Ten more cards from a wide coordinate sample could not be parsed; it is not known whether they belong to the Kemerovo region. Therefore, 62 is a confirmed number of retrieved cards, not a guarantee of a complete revised annual total.

- Detailed catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS) for 2024 near three objects: 3 earthquakes and 51 explosions at the Rospadskaya-Koksovaya mine, 13 and 1,442 at the Krasnobrodsky mine. Another 8 earthquakes and 507 explosions at the Kolyvansky mine were excluded from the Kuzbass totals: this site is in Novosibirsk Oblast.
- Operational cards within the administrative boundary: **74** earthquake records in 2025 and **37** from 1 January to 10 October 2026. Until revised catalogues become available, these numbers cannot be directly compared with the reviewed annual catalogues of previous years without noting the different thresholds and processing procedures.
- The combined series from 10 October 2006 to 10 October 2026 contains **4,977** records: 4,804 official records through the end of 2023, 62 operational cards for 2024, and 111 cards for 2025-2026. Swarms and aftershock sequences are stored line by line, so the number of records is not equal to the number of independent processes.
- The event on 10 October 2026 is listed as an event **of unknown origin** with several preliminary catalogue solutions.

Prepared output tables

1. `data/kuzbass-recorded-earthquakes-2006-2026-scope-aware.csv` is a twenty-year series with geographic mixing removed and source types identified.
2. `data/kuzbass-core-events-v0.2.csv` — 42 reference events with parameters, classification, consequences, and unresolved issues.
3. `data/kuzbass-series-v0.2.csv` - series, swarms, reactivated zones and separate catalogues; the Kolyvansky site is clearly marked as lying outside Kemerovo Oblast.
4. `data/kuzbass-regional-blasts-2006-2023.csv` and operational tables 2024-2026 — industrial blasts that are not included in the number of earthquakes.
5. `data/kuzbass-computational-episodes-2006-2026.csv` - only reproducible breakdown after a break of 30 days; it does not replace the scientific definition of swarms and aftershock sequences.
6. `data/global-hiquake-projects-2026-09-24.csv` and `data/global-hiquake-coal-mining.csv` — the worldwide register and its coal subsample.
7. `data/global-coal-key-cases-reviewed.csv` — reviewed key international cases and differences in interpretation.
8. `data/source-conflicts-and-open-questions.csv` - contradictions of sources and open questions.

SECTION 4

Chronology of Kuzbass: events, series and swarms

Coverage: from the first found instrumental and research information to 10 October 2026.

Status: The full line-by-line chronology is in CSV; the principal events, series and gaps are presented here.

What exactly is collected

We separated five different types of records:

1. earthquakes included in the regional catalogues of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS);
2. events that the researchers directly described as human-induced or triggered;
3. events whose human-induced origin has been proposed by an individual author but has not been confirmed by a full study of that particular case;
4. rockbursts and collapses in workings;
5. industrial blasts.

These groups cannot be combined as though they represented the same phenomenon. A strong earthquake, its aftershocks and a prolonged swarm likewise do not represent multiple independent “cases”.

Machine-readable chronology

- `data/kuzbass-recorded-earthquakes-2006-2026-scope-aware.csv` - 4,977 records for the exact period from 10 October 2006 to 10 October 2026, with the coverage of each source preserved;
- `data/kuzbass-regional-earthquakes-2006-2023.csv` - 4,806 lines of published annual regional catalogues, including two 2006 records that predate the beginning of the twenty-year period; 4,804 included in the combined series;
- `data/seishub-kemerovo-2024-earthquakes.csv` – 62 operational cards of 2024 within the administrative border of the region;
- `data/seishub-kemerovo-2025-2026-earthquakes.csv` - 111 operational cards for 2025 and the period until 10 October 2026;
- `data/kuzbass-detailed-local-series-2007-2020.csv` 15,984 rows of detailed local tables, of which 9,360 records of earthquakes or unclassified events and 6,624 explosions; the tables overlap and therefore are not added together;

- `data/kuzbass-regional-blasts-2006-2023.csv` - 38,234 explosion records from available annual catalogues, with gaps for some years;
- `data/gstras-kuzbass-2024-normalized.csv` — a separate verified site-specific catalogue: the Krasnobrodsky mine, the Raspadskaya-Koksovaya mine and the Kolyvansky mine located outside the Kemerovo region.

The number 4,977 means the number of records in sources with different coverage, not the number of proven human-induced earthquakes and not a count of independent hazardous episodes.

Main chronology

Period or date	District	What is established	Status of origin
Since the 1960s	Kuzbass	Researchers report an increase in weak human-induced seismicity as mining and blasting intensify	Summary based on historical catalogues, rather than a list of each event
20.09.1966	53.40; 87.40	V. V. Adushkin's table lists an event at approximately mb 5.0	Proposed as human-induced tectonic in time and magnitude; the site and consequences could not be reconstructed
February 1988	3 km from Tashtagol Mine	Depth 0.8–1.5 km, energy about 10^9 J, intensity 5–6 in the village of Kochura	The study calls it human-induced
14.09.1995	Prokopyevsk district	mb 4.5–4.9; sources have different estimates of depth	Proposed as human-induced tectonic; source bulletin verification required
25 and 27.04.1997	The field of the closed mine "Anzherskaya"	Two events mb 2.3, shaking of up to intensity 5 after the water rises during flooding.	A link to flooding is proposed in the study
1999	Tashtagol	HiQuake includes an event ML 3.6 as a possible rockburst	There is insufficient evidence for a confident assessment
2005	Osinniki	Shallow swarm activation in the mine field; repeated tremors damaged residential buildings	Researchers describe it as related to mining; a complete individual catalogue is not yet available

Period or date	District	What is established	Status of origin
Winter 2007–2008	Polysaevo	Swarm at depths of approximately 0.6–1.0 and 1.2–2.5 km; repeated felt tremors and damage to houses	Researchers refer to mining activation; there is no complete open list
2008	Different parts of the basin	Adushkin singled out three strong entries mb 4.5–4.6 as possible human-induced tectonics	Author's classification diverges from the normalized annual series; entries are not automatically merged
09.02.2012–2013	Bachatsky open-pit mine	The beginning of strong activation; the event on 09.02.2012 has different solutions (ML 4.3 in the regional catalogue and mb 4.6 in another table)	In detailed studies, it is part of the natural–human-induced/human-induced activation
18.06.2013 UTC	Bachatsky open-pit mine	ML 6.1 , depth about 4 km, intensity 7 in Bachatsky and Starobachaty, then about 5,000 aftershocks	Detailed studies attribute the earthquake to human-induced
End of 2016–2018	Kaltansky Mine, dumps, Alardinskaya Mine	Pulsed activation: stronger events near the waste-dump zone, a weaker local group above underground workings	The monitoring-study authors classified the activity as induced or human-induced
11.01, 26.02 and 17.10.2020	Krasnobrodsko-Kiselyovskaya zone	ML 4.1 , ML 3.9 and ML 4.9 ; depths 6, 1 and 4 km	In the macroseismic field of the official annual catalogue, “human-induced earthquake” is stated explicitly.
12.08.2021 UTC	Taldinsky zone	ML 5.6 , unified M 5.1 , depth 3 km; 4 points in Bolshaya Talda and Prokopyevsk	Authorities called the event natural, while linking energy accumulation to blasting; no separate causality study has been found, and the status remains controversial.
28.03 and 02.09.2023	Kiselevsk—Krasnobrodsky	ML 4.5 at a depth of 1 km and ML 4.2 At a depth of 1 km	The spatial relationship requires verification; the catalogue does not automatically transfer the classification of 2020 events
24.07 and 19.09.2024	Mountain Shoria and the south of the region	Two operational cards with a magnitude of 4.6; research reports link notable events of 2024 to Sheregesh and Tashtagol	A published study or reviewed annual catalogue is needed for final parameters

Period or date	District	What is established	Status of origin
26.09.2024	Krasnobrodsky open-pit mine	In the site-specific catalogue ML 4.25 , depth 0.7 km; in the operational card, coordinates and magnitude are slightly different.	The catalog separates the event from 1,442 explosions, but one "earthquake" field does not by itself establish an induced mechanism
25.08.2025	Kiselevsk—Krasnobrodsky	Operational magnitude 3.9, coordinates 54.09; 86.49	Origin not established in the card
10.10.2026	Kiselevsk—Krasnobrodsky	Operational magnitude 4.9; 54.09; 86.54; estimated intensity 6.2 MSK-64; no destruction detected by authorities	Origin not yet established

Series that cannot be considered a set of independent cases

Osinniki, 2005

The source describes a swarm of weak shallow events in the mine field. Because of their shallow depth, the repeated shocks were felt and damaged residential buildings. No open event-by-event catalogue has yet been found, so the series is represented by one row and the gaps in its event count and parameters remain explicit.

Polysaevo, 2007–2009

This is not a single mainshock with ordinary aftershocks, but a long-term activation. The publication singles out two depth groups. Detailed monitoring existed, but in the materials found there is no complete list suitable for re-analysis.

Bachatsky sequence, 2012–2020

The mainshock of June 18, 2013 cannot be considered separately from the previous activation and subsequent aftershocks. The 2023 study refers to approximately 5,000 aftershocks; the long axis of the area runs along the open-pit mine, most hypocentres lie beneath the excavation, and an area of elevated focal density outside it lies beneath the waste dumps. The authors emphasize

that the process after the mainshock was continuous and non-stationary, so the boundary between the fading aftershock sequence and ongoing human-induced activation is not reduced to one end date.

Kaltan-Alardinskaya, 2016–2018

The local network showed two different source patterns: stronger events at open-pit workings and dumps, and weaker events over an underground mine. This is an argument against mechanically combining all shocks into one type.

Krasnobrodsko-Kiselyovskaya zone, 2020–2026

Repeated strong events occurred in 2020, 2023, 2024, 2025 and 2026. This is a stable area of activity, but not one proven aftershock sequence. New data on the depth, focal mechanism and production operations are needed for the 10 October 2026 event.

What the twenty-year series showed

After taking into account 2024, the picture has become more complete: 62 operational cards of earthquakes within the administrative boundary, including four events with a magnitude of at least 4. However, the general conclusion has not changed.

- The series does not show simple uniform growth year after year.
- The activity is concentrated in pulses near different mining zones and shifts over time.
- The number of rows is very strongly influenced by network density and publication threshold. For example, in 2022, the catalogue included events from $M 1.3$, and in 2023 — from $M 2.4$.
- Many notable events are shallow — about 1–7 km — but some depths are fixed or preliminary.
- Detailed catalogues can distinguish explosions from earthquakes. A strong earthquake near an open-pit mine should not be called "too big an explosion": it may be fault slip triggered by a prolonged change in stress.

Inconsistency of two historical series

Adushkin's tables for 1998–2016 and published regional catalogues of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS) cannot be merged without explanation. Adushkin has hundreds of events $m_b \geq 3$ per year; the author selects night events and applies a criterion based on the maximum expected magnitude of an industrial blast.

Annual catalogues use a different data composition, scales and inclusion rules. Therefore, the Adushkin table is preserved as a separate proposed series of human-induced and tectonic events, and not as a substitute for the official catalogue of earthquakes.

Gaps that remain visible

- For early events, there are often no digital wave records, exact coordinates and boundaries of historical workings.
- A complete individual list of Osinniki and Polysaev swarms has not been found.
- Operational cards for 2024-2026 usually do not give depth and magnitude type; later catalogue solutions may change.
- Ten links from the 2024 operational card index could not be parsed or obtained; it is not known whether they belong to the Kemerovo region.
- The geometry of active workings, dumps, old underground workings and explosion logs are not publicly available for all events.
- The "earthquake" field in the catalogue separates the signal from the explosion, but does not by itself establish a natural or induced origin.

Main sources

1. [Yakovlev, Lazarevich, Tsirel. Natural and human-induced seismicity of Kuzbass, 2013.](#)
2. [Emanov et al. human-induced Bachatsky earthquake, 2016.](#)
3. [Emanov et al. Kaltansky Mine and Alardinskaya Mine, 2019.](#)
4. [Emanov et al. Induced seismicity in Kuzbass, 2020.](#)
5. [Emanov et al. Volumetric structure of aftershocks of the Bachatsky earthquake, 2023.](#)
6. [Repository of annual catalogues of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences.](#)
7. [Catalog of observed objects for 2024.](#)
8. [Operational card of the event on 10 October 2026.](#)

SECTION 5

Key cases of Kuzbass: evidence cards

How to read the evidence cards

"human-induced" here means an earthquake, whose origin or timing researchers associate with an industrial change in stress. This is not necessarily an industrial explosion. In strong cases, the source represents a shift in an already existing geological structure; industrial activity may have brought it closer to failure.



Open-pit coal mine in Kiselevsk; benches, haul roads and exposed rock layers. March 10, 2019. The photograph is held in Natalia Zubkova's archive; the photographer has not been identified.

1. Tashtagol event, February 1988

- **Location:** about 3 km from the Tashtagol mine.
- **Parameters:** depth 0.8–1.5 km; seismic energy about 10^9 J; Date and coordinates are not given in the clear text.
- **Impact:** intensity 5–6 in the working village of Kochura.
- **Classification:** D. V. Yakovlev, T. I. Lazarevich and S. V. Tsirel call the event human-induced.
- **Reason:** shallow depth and proximity to the mine, considered against the background of a long increase in human-induced seismicity.
- **Limitation:** This is an iron-ore, not a coal-mining, site; for an accurate card, you still need a primary bulletin and information about the damage.

2. Swarms of Osinniki and Polysaevoa, 2005 and 2007–2009

- **Type:** Many weak events clustered closely in space and time.
- **Depth:** shallow; for Polysaevo, groups of approximately 0.6–1.0 and 1.2–2.5 km have been described.
- **Consequences:** Due to the shallow depth, tremors were felt; repeated tremors damaged residential buildings.
- **Classification:** Researchers associate activations with mine fields.
- **Limitation:** In the discovered materials there is no complete individual list. It is correct to consider each swarm as one series, and not as a set of proven independent earthquakes.

3. Bachatsky earthquake, June 18, 2013 UTC

- **Time:** 23:02:09.6 UTC, or 06:02 June 19 local time.
- **Epicenter:** Approx. 54.29° N, 86.17° E.
- **Depth:** About 4 km in the preferred local solution.
- **Magnitude:** ML 6.1 ; in other catalogues, there are smaller values and other types of magnitude.
- **Intensity:** up to 7 points in Bachatsky and Starobachaty.
- **Consequences:** operational monitoring of the Ministry of Emergency Situations reported damage to more than 500 houses, thousands of chimneys and social facilities; the final act of damage has not yet been found.
- **Sequence:** About 5,000 registered aftershocks.
- **Position relative to mining:** The epicentre and most of the large aftershocks are confined to the pit wall; the largest number of weak foci are beneath the excavation; increased density outside it is observed under the dumps.
- **Classification:** detailed works of Yemanov and co-authors call the event human-induced. The 2023 publication says that researchers have a good agreement regarding this nature.
- **Proposed mechanism:** Movement of huge masses of rock, deepening of the excavation, growth of dumps and changes in the stress state of the upper part of the crust.
- **Industrial Context:** Mining has been under way since 1948; by 2018, the excavation had expanded to approximately 3×11 km and reached a depth of 400 m; in the latest years covered by the authors, annual output was about 9.5 million tonnes.
- **Why this is not an ordinary explosion:** A strong shear source, a depth of several kilometres and a long aftershock area do not correspond to a single quarry explosion.
- **Status:** The strongest well-studied human-induced earthquake during the extraction of solid minerals in the published literature and in the HiQuake coal subset.

4. Kaltan—Alardinskaya activation, since the end of 2016

- **Objects:** Kaltansky coal mine, dump-forming zone of the Osinniki field and underground works of the Alardinskaya mine.
- **Observations:** After the intensification of activity, five temporary stations were installed; the data of the enterprises on explosions were checked for the presence of an air wave.
- **Structure:** Stronger events $ML \geq 2.5$ grouped at open-pit workings and dump boundaries; a separate group of events $ML < 2$ coincided with underground works.
- **Depth:** Within the upper few kilometres; a later paper identifies depth maxima at approximately 1–1.5 km and 2–3 km, deeper than the workings themselves.
- **Classification:** Induced / human-induced activation, pulsating in time.

- **Conclusion:** One industrial area may contain different mechanisms and different scales of events.

5. Krasnobrodsko-Kiselyovskie events of 2020

UTC Date	Coordinates	Depth	Magnitude	Official classification or note
11.01.2020 21:20	54.190; 86.404	6 km	ML 4.1	human-induced earthquake
26.02.2020 07:41	54.106; 86.475	1 km	ML 3.9	human-induced earthquake
17.10.2020 17:21	54.125; 86.515	4 km	ML 4.9	human-induced earthquake

The mark is located in the macroseismic field of the annual catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences. It is a direct classification of these three events, but does not automatically apply to all subsequent tremors in the same area.

6. Taldinsky earthquake, August 12, 2021 UTC

- **Time:** 20:41:55.8 UTC, or 03:41 August 13 local time.
- **Epicenter:** 54.247° N, 87.042° E, area of Taldinsky open-pit mine.
- **Depth:** 3 km.
- **Magnitude:** ML 5.6 ; unified M 5.1 .
- **Felt intensity:** 4 points in Bolshaya Talda and Prokopyevsk, 3 points in Novokuznetsk, 2 points in Kemerovo according to the annual catalogue.
- **Consequences:** More than a hundred appeals to dispatch services; according to operational reports, there were no deaths or destruction.
- **Public wording:** The regional agency called the event natural, while linking the energy storage to the blasting operations at several coal enterprises. This is a mixed explanation, not strict seismological attribution.
- **Status:** The origin remains disputed. In the tested open materials, no separate study of the focal mechanism was found, which would allow to support a stronger classification.
- **Limitation:** Wave analysis, production data and the exact border of the Taldinsky open-pit mine are needed.

7. Krasnobrodsky district, 2023–2025

UTC Date	Parameters	What can be said
28.03.2023	54.028; 86.459; depth 1 km; ML 4.5	It was felt in Kiselevsk, Krasnobrodsky, Novokuznetsk and Prokopyevsk; origin is not indicated in the catalogue
02.09.2023	54.193; 86.417; depth 1 km; ML 4.2	Repeated strong event of the same wide area; causal classification not published
26.09.2024	54.090; 86.489; depth 0.7 km; ML 4.25	In the detailed catalogue of the Krasnobrodsky object it is separated from explosions; the origin cannot be inferred from the signal class alone
25.08.2025	54.09; 86.49; operational M 3.9	Depth and type of magnitude are not available on the card

Repeatability and shallow depth make the zone a priority for analysis, but do not replace the focal mechanism and production data.

8. Event on 10 October 2026

- **Time:** 00:47:01.75 UTC, 07:47 local time.
- **Main preliminary solution:** 54.09°; 86.54°; magnitude 4.9; intensity 6.2 MSK-64.
- **Depth and type of magnitude:** Not indicated in the primary operational card. Media reports about a depth of about 5 km are not yet a substitute for the revised bulletin.
- **Consequences:** According to the results of operational surveys, no damages or casualties were revealed; the enterprises continued to work.
- **Nearest sites by main point:** about 1.0 km to the wide cartographic contour of the Krasnobrodsky open-pit mine in OpenStreetMap; 9.6 km to the border of the license area of the Krasnobrodsky Field in Global Energy Monitor data; 9.6 km to the wide contour of the Vakhrushevsky open-pit mine.
- **Solution dependence:** For the other published epicentre solutions, the distance to the Krasnobrodsky polygon is approximately 3–7 km. The distances to the licence boundaries differ because those polygons answer a different question.
- **Historical context:** Within 15 km of the main coordinate, there are dozens of events in the collected series $M \geq 2.5$, including ML 3.9–4.9 in 2020–2025.
- **Status:** The origin has not yet been established. The correct wording is: **mining could have been one of the contributing factors, but this hypothesis requires testing.**

What you need to check the 2026 event

1. Revised coordinates, depth and uncertainties.
2. Initial waveforms, ratio of P- and S-waves, polarity and moment tensor.
3. Logs of explosions on October 9–10 with time, coordinates and mass of charges.
4. Boundaries of existing faces, old workings, dumps and faults.
5. Local network for aftershocks and relocation of all events with one velocity model.
6. Compile time series of mining activity: extraction, overburden removal, drainage and waste-dump development.
7. A geomechanical model capable of showing the sign and magnitude of stress changes on the found rupture plane.
8. Testing a competing natural hypothesis.

Main card output

For Bachatsky, Kaltansky, and part of the events of 2020, the connection with the mining is formulated by the researchers themselves or by the official catalogue. For other cases, the degree of knowledge is different, from a convincing spatio-temporal connection to a single entry in an overview table. Therefore, the study should not show a binary list of "human-induced/non-human-induced", but a scale of evidence.

SECTION 6

Seismicity and Extraction: Spatiotemporal Comparison

Short answer

For the most well-studied Kuzbass activations, epicentres and hypocentres are indeed located near the active mining sites, under them or near dumps. But the expression "in all cases nearby" would be incorrect:

- some of the early coordinates are roughly defined;
- historical boundaries of workings changed;
- The administrative catalog also contains natural events;
- The radius around the industrial zone selected after reviewing the data is not independent evidence of the cause;
- for a number of strong entries in Adushkin's tables, the exact object has not yet been established.

Therefore, proximity is an important first sign, but convincing attribution appears only when the proximity, time of industrial impact, depth, focal mechanism, development of the series and physical model of stresses coincide.

Result of analytical zones

To describe the spatial pattern, we have defined seven wide zones around the recurring catalogue clusters. **These descriptive zones do not represent the legal boundaries of mines or open pits.**



Mining infrastructure and waste dumps in the winter landscape of Kiselevsk. 2 January 2019. Photograph by Smogman; held in Natalia Zubkova's archive.

Zone	Radius from center	All entries	M ≥ 2.5	M ≥ 3.0	M ≥ 3.5	Maximum
Kiselevsk—Krasnobrodsky	16 km	139	62	29	15	4.9
Bachatsky open-pit mine	14 km	288	82	36	20	ML 6.1
Polysaevo—Leninsk-Kuznetsky	22 km	746	107	7	0	3.29
Taldinskaya	18 km	620	59	12	2	ML 5.6
Kaltan-Alardinskaya-Malinovka	20 km	237	33	11	8	ML 4.06
Mezhdurechensk-Raspadskaya	22 km	1 674	156	43	17	ML 4.4
Mountain Shoria: Tashtagol—Sheregesh	24 km	385	76	39	16	4.6

These zones include 82.1% of the rows of the combined series and 70.7% of events with a magnitude of at least 2.5. Percentages should not be converted to "proportion of earthquakes caused by extraction": centers and radii are chosen as descriptive areas of activity, rather than exact polygons of impact.

How the spatial pattern changed

2006–2011

The regional catalogue is sparse, although local networks have already registered many more weak events. From the literature, the swarms of Osinniki and Polysaev are known. The main problem of the period is not the lack of activity, but the incomparability of regional and local registration.

2012–2014: Bachatsky open-pit mine

In 2012, 25 temporary stations were installed around the mine before the mainshock. This is particularly important: dense monitoring was already in place **before** the ML 6.1 earthquake; it was not created only after the disaster. After the mainshock, 10 temporary and 17 permanent stations were operating. The spatial structure around the open-pit mine is therefore much better established than in most other cases.

Mining at the Bachatsky mine has been carried out since 1948. According to the publication of 2023, by that time about 400 million tonnes of coal had been mined; the size of the mine increased from 2.3×10 km and a depth of about 320 m in 2013 to 3×11 km and 400 m in 2018.

2015–2018: Kaltan and Alardinskaya

At the end of 2016, the stationary network detected increased seismic activity near the Kaltansky open-pit mine. The deployment of temporary stations made it possible to separate industrial blasts, stronger earthquakes near the dump and a weak group over underground work. This is one of the best examples of how the hypothesis is tested by operational data from the enterprises and waveform characteristics, and not just a map of epicentres.

2019–2023: Multiple zones at the same time

Large concentrations were observed in the Rapsadskaya underground mine and the Taldinsky open-pit mine, in Gornaya Shoria and in the Krasnobrodsko-Kiselevskaya part of the basin. During this period, one common indicator for the region hides the main thing: seismic activity occurs in pulses at different sites.

Production at the Rapsadskaya mine began in the 1970s; the company continued to introduce new longwall panels, and the Rapsadskaya-Koksovaya mine was built from 2004. However, open corporate production data cannot be directly compared to each catalogue record: monthly data

on specific longwall panels, drainage and ground support are required, rather than the annual totals of the entire company.

2024–10 October 2026

Operational cards confirm that activity continued in several areas. In 2024, Gornaya Shoria, Krasnobrodsky and Bachatskaya zones are distinguished. In 2025–2026, noticeable repeated events occur near Krasnobrodsky, Bachatsky and other facilities.

The complete regional revised catalogue for these years is not yet available in the compiled corpus. Therefore, the numbers of recent years are preliminary.

Event on 10 October 2026 and Nearest Production

The distance depends on which coordinate of the epicentre and which contour is considered the boundary of the object.

Epicenter Solution	Krasnobrodsky, OSM Wide Outline	Krasnobrodskoye GEM License Field	Vakhrushevsky, OSM wide contour	Vakhrushevskoye field GEM
Altai-Sayan Branch of FRC GS RAS 54.09; 86.54	1.0 km	9.6 km	9.6 km	12.7 km
Kazakhstan NDC 54.04; 86.47	7.2 km	14.1 km	8.1 km	10.6 km
Preliminary epicentre solution from Mayak's message 54.16; 86.37	3.0 km	5.3 km	22.0 km	24.8 km
GCCC of Ukraine 54.17; 86.32	5.4 km	6.8 km	24.9 km	27.7 km

The first preliminary solution was published by Mayak on 10 October 2026 at 08:40 with M 4.8, but without the name of the original seismological center and without depth. The second is in the official operational feed of the Main Center for Special Control of Ukraine: M 4.8, time 03:47:06, depth not specified; time zone of the line on the page is not labeled. These solutions cannot be mixed.

All three regional solutions place the epicentre in the Kiselevsk–Krasnobrodsky coal mining area. This makes a mining-related origin a hypothesis worth testing. Until depth, a focal mechanism and operational records are available, however, the link to mining remains a hypothesis rather than an established conclusion.

Why a magnitude of 4.9 does not rule out an industrial cause

The energy of a conventional industrial explosion and the magnitude of an induced earthquake are different things. An explosion can be only a short-term impact, and long-term excavation, dumps and drainage change the stresses in a large volume of rocks. If an already stressed fault breaks down, mainly the energy accumulated in the earth's crust is released. ML 6.1 is a direct example of an event much stronger than a single industrial explosion, but recognized as human-induced.

Is it possible to prove a correlation with production volumes?

So far, it is only for individual objects and periods, not for the whole of Kuzbass by one coefficient.

To make a full match, you need the same time intervals:

- monthly coal mining and overburden in each field;
- the location of faces and dump boundaries by dates;
- the mass, time and coordinates of each large explosion;
- drainage and mine flooding;
- a single seismic catalog with a constant threshold of completeness;
- changes in the number and location of stations.

The annual production of the entire company is too rough. For example, a decrease in production may coincide with a strong event due to the accumulated effects of previous years, and an increase in the number of weak records with the installation of new stations.

Checked patterns

1. **Migration:** the most active industrial cluster shifted - Bachatsky, then Kaltansky, later Taldinsky, Krasnobrodsky, Raspadskaya and the districts of Gornaya Shoria.
2. **Impulsivity:** Strong activations are usually shorter than the total life of the enterprise and can last weeks or months.
3. **Repeatability:** one zone is able to become active again after years; Kiselevsk-Krasnobrodsky shows this especially clearly.
4. **Shallow depth:** Many notable events are located in the upper kilometres of the crust, but the reliability of depth is not the same.
5. **Different mechanisms:** Open excavation and dumps, underground works, collapses, drainage and flooding create different spatial pictures.

6. **Need a local network:** The strongest conclusions were obtained where dense observation made it possible to separate earthquakes from explosions and to build a three-dimensional structure of foci.

Conclusion

Over the past twenty years, earthquakes have not just become "more frequent" or "stronger". Observations have changed, and activity has moved between mining zones. The most stable conclusion is not a linear trend, but repeated local responses of the subsurface near rapidly changing mining sites. For a particular event, causality is decided not from distance in kilometres alone, but by a set of independent data.

SECTION 7

Event on 10 October 2026 near Kiselevsk

Policy Brief · 10 October 2026

Event

- Time: 10 October 2026, 07:47 local time (00:47 UTC).
- The main preliminary solution of the Altai-Sayan Branch of FRC GS RAS: 54.09° N, 86.54° E; magnitude 4.9; estimated intensity at the epicentre 6.2 points MSK-64. Depth is not indicated in the operational card.
- The Main Directorate of the Ministry of Emergency Situations in the Kemerovo region reported on the perceived event on the territory of Krasnobrodskoye, the absence of casualties and destruction as of 10:45 and the regular operation of coal enterprises.
- The operational coordinates of different services differ markedly. Therefore, below are not one "exact" distance, but results calculated for several published solutions.



Cemetery in the Afonino area and adjacent coal mining area. Kiselevsk, May 8, 2019. The photograph is held in Natalia Zubkova's archive; the photographer has not been identified.

What's nearby

According to the main coordinates of the Altai-Sayan Branch of FRC GS RAS: 54.09; 86.54

Object	Horizontal distance to the plotted outline of the object
Krasnobrodsky coal mine	1.0 km
Unnamed Polygon <code>landuse=quarry</code> in OpenStreetMap	1.8 km
Vakhrushevsky coal mine	9.6 km
Bachatsky coal mine	27.8 km
Belovskaya open-pit mine	31.2 km
Shestaki open-pit mine	39.8 km

The unnamed polygon cannot be confidently called an operating coal mine: in the open cartographic record there is no name, type of raw materials and status of work.

Validation by the boundaries of license areas of Global Energy Monitor

Global Energy Monitor reproduces the two boundaries of the Krasnobrodsky enterprise sites based on information on licenses verified on December 15, 2025:

- Krasnobrodskoye field, license KEM 11669 TE: 9.6 km from the main coordinate of the event;
- Vakhrushevskoye field, license KEM 01797 TE: 12.7 km.

Outline `landuse=quarry` in OpenStreetMap is much wider than the GEM license boundary and probably includes not only the license field, but also the entire disturbed or production area mapped by cartographers. Therefore, the 1.0 and 9.6 km estimates answer different questions: the first is the distance to the broad mapped polygon of the open-pit mine, the second is to the published boundary of a particular license area.

How much the result depends on the coordinates of the epicentre

Operational solution	Krasnobrodsky: to the OSM outline	Krasnobrodskoye Field: to the border of GEM	Vakhrushevsky: to the OSM outline	Vakhrushevskoye field: to the border of GEM
Altai-Sayan Branch of FRC GS RAS: 54.09; 86.54	1.0 km	9.6 km	9.6 km	12.7 km
Kazakhstan NDC: 54.04; 86.47	7.2 km	14.1 km	8.1 km	10.6 km

Operational solution	Krasnobrodsky: to the OSM outline	Krasnobrodskoye Field: to the border of GEM	Vakhrushevsky: to the OSM outline	Vakhrushevskoye field: to the border of GEM
Preliminary epicentre solution reproduced by Mayak: 54.16; 86.37	3.0 km	5.3 km	22.0 km	24.8 km
Main Center of Special Control of Ukraine: 54.17; 86.32	5.4 km	6.8 km	24.9 km	27.7 km

These are two different preliminary epicentre solutions, not rounding of the same point. For 54.16; 86.37, a report by Mayak was found, published on 10 October 2026 at 08:40: it indicates M 4.8, time 03:47 Moscow time / 07:47 in Kuzbass and does not report depth; the source bulletin, from which the coordinates were reprinted, is not specified in the verified materials. Item 54.17; 86.32 published in the operational feed of the official Main Center for Special Control of Ukraine with M 4.8 and time 03:47:06; time zone on the line is not signed, depth is not specified. The feed was checked on 11 October 2026. The preliminary solutions and the distances calculated from them are therefore retained separately.

The Euro-Mediterranean Seismological Center has published a significantly more distant preliminary solution. Until a verified catalogue solution appears, it cannot be mechanically combined with regional coordinates.

Conclusion

All available regional solutions place the event in the Kiselevsk–Krasnobrodsky coal mining area. The nearest major named object in all these solutions remains the Krasnobrodsky open-pit mine; in the southern solution of the NDC of Kazakhstan, the distance to the Vakhrushevsky open-pit mine becomes comparable.

Proximity to the open-pit mine provides grounds for testing the human-induced hypothesis, but does not establish the tremor's origin. Drawing a conclusion requires the specified coordinates and depth of the hypocentre, the focal mechanism, the network recordings, the time and parameters of industrial blasts, the location of active workings and dumps, as well as the analysis of the sequence of foreshocks and aftershocks.

How to test a human-induced hypothesis

1. Retrieve the revised seismological bulletin: stations used, times of arrival of P- and S-waves, coordinates, depth and errors. Relocate the mainshock and subsequent events using a single method.

2. Obtain the original wave records. By the ratio of P- and S-waves, spectrum, first-motion polarities, and seismic moment tensor, distinguish a conventional industrial explosion from a fault shear, collapse, or mixed source.
3. Request from enterprises and Rostekhnadzor the explosion logs for 9–10 October: exact time, coordinates of blocks, mass of charges and the firing pattern of the short-delay blast. A time match with a blast would test whether the signal came directly from that blast. The absence of a coincidence does not exclude an earthquake induced by the long-term effects of mining.
4. Superimpose refined hypocentres on the official boundaries of licenses, active pit floors, old workings, dumps and geological faults. Calculate not only the distance along the surface, but also the three-dimensional distance to the inferred rupture plane.
5. Establish a temporary local network of stations around the epicentre. Aftershocks will make it possible to delineate more accurately the rupture, assess its depth and check whether its direction coincides with mining operations or known tectonic structure.
6. Compile time series of mining activity: the volumes and advance of mining and overburden removal, large explosions, drainage, flooding of workings. Check whether the frequency of earthquakes changed after these impacts and whether it differs from the background seismicity of neighboring areas.
7. Build a geomechanical model. It should show whether the removal of rock mass, changes in the support of the sides and water pressure could change the stresses on the found fault in the right place, direction and scale.
8. Test the competing natural hypothesis: regional tectonics, past earthquakes outside the mining zones and the correspondence of the mechanism to the modern field of natural stresses.

A strong conclusion is possible not by one feature, but by the coincidence of several independent lines: an exact spatiotemporal relationship, the focal mechanism, a sequence of aftershocks, and a physically plausible model of stress changes.

Methodology

Distances are calculated horizontally from the published point of the epicentre to the nearest point of the polygon. This is not the distance from the hypocentre to an underground working, quarry or geological fault. The contours of OpenStreetMap are not legal boundaries. For the Krasnobrodsky enterprise, they are additionally compared with the boundaries of licenses published by Global Energy Monitor based on data from NedraExpert and the company's annual report.

Sources

1. [Operational card of the Altai-Sayan Branch of FRC GS RAS.](#)
2. [Clarification of the Main Directorate of the Ministry of Emergency Situations of Russia in the Kemerovo region.](#)
3. [Global Energy Monitor: Krasnobrodsky coal mine.](#)
4. [OpenStreetMap: Krasnobrodsky coal mine, reference 1239498.](#)
5. [OpenStreetMap: Vakhrushevsky coal mine, relation 1239499.](#)
6. [OpenStreetMap: Bachatsky coal mine, way 153510259.](#)
7. [Mayak: preliminary epicentre solution 54.16; 86.37, published on 10 October 2026 at 08:40.](#)
8. [Main Center of Special Control of Ukraine: operational feed, preliminary solution 54.17; 86.32.](#)



*Industrial and residential landscape of Kiselevsk in winter. 2 January 2019.
Photograph by Smogman; held in Natalia Zubkova's archive.*

SECTION 8

Kiselevsk among nine open-pit mines: what risks do residents face?



Kiselevsk, 2019. Quarry excavations and dumps are located among residential buildings. Image source: Greenpeace España, satellite comparison 2004/2019. The image shows the scale of landscape disturbance, but is not a map of the legal boundaries of enterprises.

Short answer

The Bachatsky case demonstrates that open-pit mining can trigger strong earthquakes. However, the available data do not establish whether an ML 6.1 earthquake could occur in Kiselevsk.

There are reasons to take the issue seriously. For decades, Kiselevsk has been experiencing the joint impact of open excavations, large dumps, old underground workings, mass blasts and drainage. A few kilometres from the administrative border of the city, shallow-focus events with a magnitude of up to ML 4.9, and three events in 2020 were directly named human-induced earthquakes by the official catalogue. In 2023–2026, this wide zone was reactivated, although the origin of each of these later events has not yet been established.

But for an earthquake like Bachatsky's ML 6.1, the mere presence of large open pits and waste dumps is not enough. A geological structure is needed that can give a rupture of the appropriate size, a stress state close to failure, and an industrial change in loads or water regime sufficient to start movement. There is no open three-dimensional model of faults, mining and stresses of Kiselevsk in the studied materials.

Therefore, the scientifically accurate wording is as follows:

Kiselevsk lies in an industrial and geological setting where human-induced earthquakes are physically possible and have already been recorded in the wider neighbouring zone. A strong shallow-focus event cannot be ruled out without dedicated research. However, the available data do not allow the probability of an ML 6.1 event in the city to be assessed, nor do they establish the maximum possible magnitude.

What does "Bachatsky-like" mean?

The Bachatsky earthquake of 18 June 2013 is not simply the number 6.1 in a catalogue. For comparison, the whole set of features is important:

- a hypocentre at a depth of about 4 km, that is, much deeper than the quarry excavation;
- shear failure in the rock, not a single industrial explosion;
- the mainshock and long sequence of about 5,000 aftershocks;
- a focal volume elongated along the open-pit mine and extending to a depth of about 6 km;
- the association of stronger events with the pit wall, most weaker foci with the volume beneath the excavation, and increased focal density beneath the waste dumps;
- intensity up to 7 points in Bachatsky and Starobachaty;
- operational monitoring reports of damage to more than 500 houses, thousands of chimneys and social facilities.

The researchers explain this case by the redistribution of stresses during the long-term extraction and movement of huge masses of rocks. The open-pit mine did not "create" the earthquake's energy in the way explosives create blast energy. Mining changed the conditions in the already stressed and fractured massif and could trigger a shift in the geological structure. That is why the magnitude turned out to be much larger than an ordinary quarry explosion.

For the safety of residents, three issues should be distinguished:

1. **Similarity of mechanism:** Can mining trigger movement along a fault at a depth of several kilometres?
2. **Similarity of potential magnitude:** Is there a structure capable of producing an event of magnitude 6?
3. **Similarity of consequences:** Could even a lower-magnitude but very shallow event cause serious damage due to the proximity of residential buildings, slopes, dumps and old workings?

The first possibility is physically plausible and requires testing. The second has neither been confirmed nor ruled out. The third is especially important for the city because the danger is not determined by magnitude alone.

Bachatsky open-pit mine and Kiselevsk: What Is Similar and What Is Different

Sign	The Bachatsky case	Kiselevsk	What does this mean for evaluation
Spatial organization of production	One exceptionally large open-pit mine; in 2013 the excavation was estimated at approximately 2.3×10 km, and later at about 3×11 km	Several quarry excavations, dumps, industrial sites and old mine fields within the city	Kiselevsk cannot be modeled as a single quarry; it is necessary to add and separate the effects of different objects
Duration of the intervention	Mining since 1948, long-term deepening of excavations and growth of dumps	Long-term underground mining, mine closure and subsequent development of open pit works	In both cases, the history of load changes is important, not production only over the past year
Mass Movement	Large excavation and large dumps spatially compared with the focal area	The mass is distributed among several excavations and dumps; there is no consolidated balance by year	The number of open pits in itself does not replace the calculation of the removed and added load
Water	Changes in the hydrogeological regime were considered together with mining operations	There are drainage, closed and flooded workings, but there is no single open series of water levels and flow rates	Water pressure in cracks can change the stability of faults; this mechanism must be measured
Strong events recorded	ML 6.1, a well-studied aftershock sequence	Within the nearby band, the catalogue records ML 3.9–4.9; three events of 2020 called human-induced	human-induced seismicity in the wide Kiselyovsko-Krasnobrodskaya zone is no longer just a hypothesis, but this does not prove the future magnitude of 6.1
Local Network	After the mainshock, a dense network worked, which made it possible to restore the three-dimensional structure of the sequence	A permanent open urban network sufficient for the same detail was not found	Without local stations, weak precursor series, foci migration, and precise depths may remain indistinguishable
People and buildings	The strongest tremors affected nearby villages	Residential areas are located between open-pit mining and dumps.	With the same source, the exposure of Kiselevsk can be high due to the location of housing within the industrial landscape

This comparison does not show that nine open-pit mines are automatically more dangerous than one Bachatsky. Several smaller objects can create a complex field of unloading and additional loading, but its sign and magnitude depend on the depth, shape, sequence of development and position of the faults.

Nine quarries remain in the urban landscape

When I refer to Kiselevsk's nine open pits, I mean nine physical quarries that remain in the urban landscape. This is not the number of companies operating today. The enterprise can stop, change ownership or disappear as a legal entity, but the physical excavation does not disappear. Along with it, there are altered pit walls and ground conditions, dumps, disturbed water regime and the need to monitor the stability of the territory near homes and utility networks.

Open sources do not provide a single named geographical register, which would allow you to reliably compare each of the nine physical excavations of the enterprise, license and current status. Therefore, the following list is **historical information about enterprises**, and not the name identification of the nine pits.

The municipal program of 2013 reported two mines and seven open-pit mines: "Kiselevsky", "Koksovy Site", "Oktyabrinsky", "Lugovoye", "Polyany", "Yurginsky Site" and Krasnobrodsky coal mine. The official health profile, compiled with data for 2019, listed nine in the Kiselevsk Municipal District **coal mining operations**:

1. LLC "Kiselevsky open-pit mine";
2. Shakhta No. 12 LLC;
3. OJSC "Oktyabrsky Mine";
4. "Koksovy Site" LLC;
5. OJSC "Lugovoe";
6. OJSC "Polyany";
7. Invest-Uglesbyt LLC;
8. Krasnobrodsky Coal Mine Branch – Vakhrushevskoye Field;
9. LLC "SHU Karagailinskoye".

In May–June 2020, the industry magazine described the same set as nine operating open-pit mines. This is a historical snapshot from 2019–2020, not a verified count of operating open-pit mines in 2026 and not a map of nine physical excavations. The source assigns the enterprises to the Kiselevsk Municipal District, and the names of legal entities, license areas, open pits, and old mine fields do not coincide with each other. For example, "Mine No. 12" is the name of the enterprise with open-pit workings, and the Karagaylinsky object has an underground and open history. For each excavation, it is also necessary to check the dated boundaries and position - within the built-up area, at the administrative boundary or near the municipal district.

This does not alter the spatial conclusion. Satellite images show large excavations and dumps among residential areas. The project situational map of Shakhta No. 12 LLC plots license areas, open-pit mining, industrial sites, reclamation and residential development of Kiselevsk in one field. In the notes for the particular modelled site, the nearest houses are indicated approximately 300 metres to the north and 450 metres to the west.

These distances cannot be extended to the entire city. They are important as documentary evidence of the very type of neighborhood: the industrial facility and the houses are within the same urban fabric. Seismic risk requires measuring distances from each house not only to the visible edge of the quarry bowl, but also to dumps, old underground workings and proposed faults.

What has already happened in the Kiselevsk–Krasnobrodsky zone

The combined catalogue for 10 October 2006 to 10 October 2026 contains 45 records within the boundary of the Kiselevsk Municipal District and in an outer band extending up to 5 km beyond it. **This is the total count**, not an additional figure: it comprises seven events within the municipal district and 38 events in the outer five-kilometre band. Of all 45 records, 24 have a published magnitude of at least 2.5, 13 of at least 3.0, and seven of at least 3.5. The records include sequences and do not represent 45 independent episodes of activation.

The most important entries are strong shallow-focus events in and around the nearest band. For regional context, the table also includes two events outside the five-kilometre band; those two events are not included in the count of 45 records:

Date	Published Parameters	Distance to the administrative border of the Kiselevsk Municipal District	Position relative to the calculation zone	What is known about the origin
11 January 2020	ML 4.1 , depth 6 km	about 9.8 km	Separate contextual example outside the five-kilometre band	Official annual catalogue: human-induced Earthquake
26 February 2020	ML 3.9 , depth 1 km	about 4.2 km	outer band up to 5 km	Official annual catalogue: human-induced Earthquake
17 October 2020	ML 4.9 , depth 4 km	about 1.7 km	outer band up to 5 km	Official annual catalogue: human-induced Earthquake
28 March 2023	ML 4.5 , depth 1 km	about 2.4 km	outer band up to 5 km	origin is not indicated in the catalogue; in Kiselevsk the intensity of 3 points is noted.

Date	Published Parameters	Distance to the administrative border of the Kiselevsk Municipal District	Position relative to the calculation zone	What is known about the origin
2 September 2023	ML 4.2 , depth 1 km	about 9.2 km	Separate contextual example outside the five-kilometre band	Origin not listed in the catalogue
10 October 2026	operational M 4.9 ; depth not published in primary card	about 1.3 km for the solution of the Altai-Sayan Branch of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences	outer band up to 5 km	Origin not yet established

The administrative boundary is used only as a reproducible landmark. It is not a boundary of industrial influence. Some of the mining sites related to the life of Kiselevsk cross the municipal boundaries or are located near them. Therefore, the next calculation should be made from the dated contours of excavations, dumps and underground fields.

The events of 2020 fundamentally change the formulation of the question. They show that not only blasts and weak tremors have already occurred in the nearest industrial zone, but also earthquakes ML 3.9–4.9, directly classified by the official catalogue as human-induced. However, the official label for the three events cannot be automatically transferred to events 2023, 2024, 2025 and 2026.

Why an event with a magnitude near 5 does not yet answer the question about the magnitude of 6.1

The maximum possible magnitude is determined primarily by the size and properties of the fault segment capable of rupturing, and not by the number of enterprises on the map. Mining can change the stresses on the fault and bring the moment of rupture closer, but it does not allow the size of a future rupture to be assumed in advance.

Answering this question for Kiselevsk requires:

- map of active and potentially activated faults in the first kilometres of the crust;
- their strike, dip, length and continuity and position relative to excavations and dumps;
- modern stress field;
- focal mechanisms of already recorded events;
- relocation of events by one velocity model with uncertainty estimates;
- calculation of stress changes from rock removal, placement of dumps and changes in water pressure.

Without these data, it is impossible to establish whether there is a single fault plane near Kiselevsk that can give an event of Bachatsky's scale. The absence of such an open model is not proof of safety; it is a specific and measurable evidence gap.

How a strong induced event can occur

For Kiselevsk, it is necessary to check several interacting mechanisms.

Weight removal in quarry excavations

Rock extraction unloads the surface, changes vertical and horizontal stresses and the geometry of the sides. The influence spreads deeper than the visible bowl, but its magnitude depends on the shape and pace of deepening of the quarry.

Adding Mass in Dumps

Dumps create a load where it did not exist before. In the Bachatsky case, part of the increased density of foci was under the dumps. For Kiselevsk, you need volume, height, density, speed of build-up and dated contours of each large dump. A photo or area in a picture does not give mass without these parameters.

Old underground workings

A closed mine continues to affect the massif. Collapses, redistribution of support pressure, surface subsidence and changes in water flow paths are possible. These processes are different from deep fault shear, but can interact with it and increase surface vulnerability.

Drainage and flooding

Water pumping reduces pressure in some areas and changes the flow of groundwater; stopping pumping raises water levels and pressure in cracks in others. Water pressure reduces effective compression of fault surfaces and, under certain conditions, can bring its break closer.

Mass explosions

An ordinary open-pit blast does not explain the long aftershock area of an earthquake with a magnitude 6. But explosions should be taken into account as repetitive dynamic influences and, first of all, separated from earthquakes by waveforms. In the collected catalogs 4,611 records are classified as explosions inside the Kiselevsk Municipal District and at a distance of up to 5 km

outside. This total includes 2,991 records within Kiselevsk Municipal District and 1,620 records in the outer five-kilometre strip. The series is incomplete and is not equal to the actual number of all explosions.

For residents, it is not only the maximum magnitude that is dangerous

Even if the event does not reach the scale of Bachatsky, Kiselevsk could receive significant damage at a lower magnitude due to a combination of shallow depth, close distance, and vulnerability of a particular location.

Separately, the following should be evaluated:

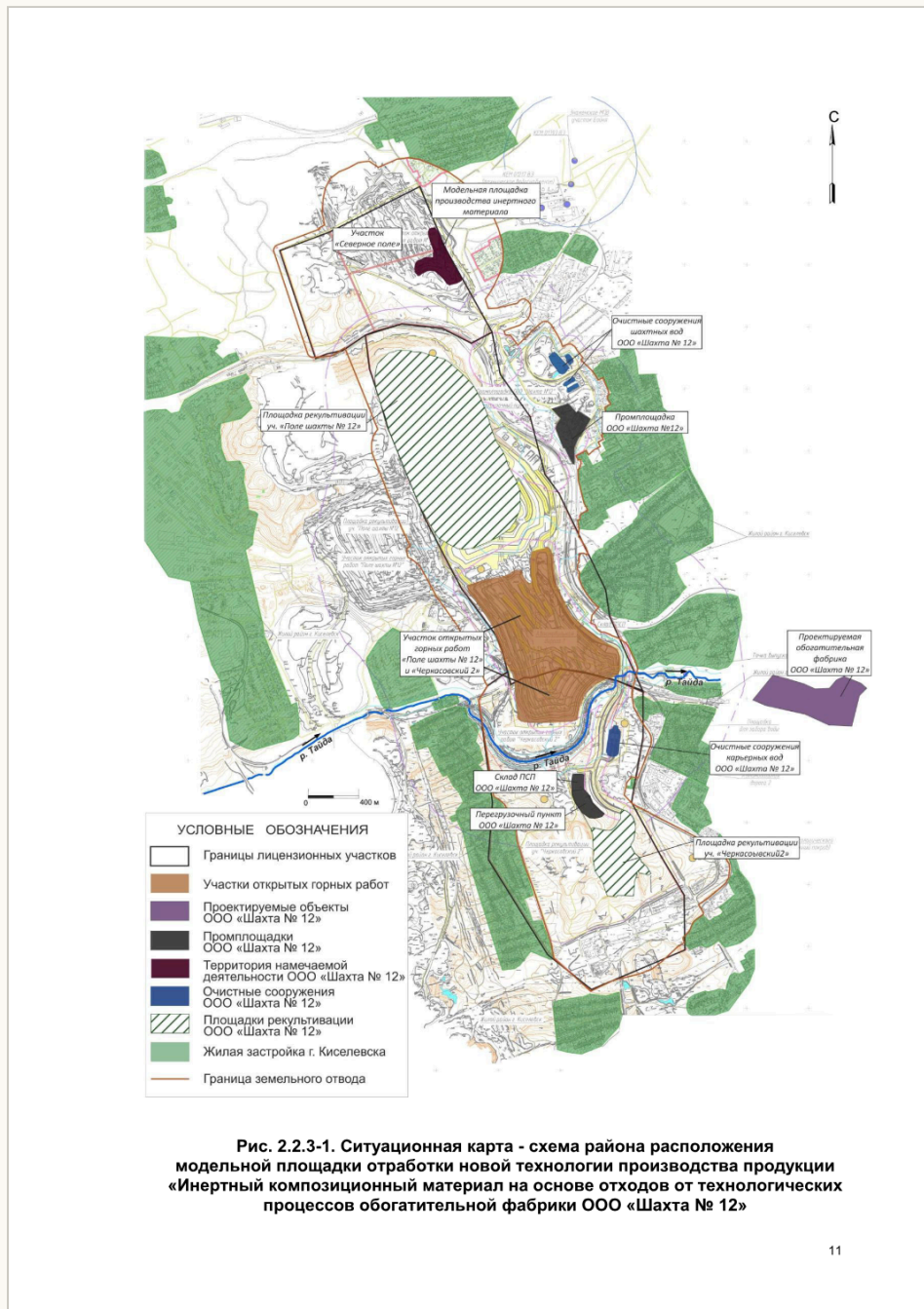
- wooden and brick houses of different ages and conditions;
- buildings above areas affected by underground mining;
- sides of excavations and steep slopes;
- stability of dumps, including heated and burning areas;
- old sinkholes and areas of possible subsidence;
- water pipes, roads, power lines, schools and hospitals;
- changes in springs, wells, mine water and channels after seismic shaking.

Seismic risk is not only the probability of shaking. It reflects the combination of hazard, exposure and vulnerability. In Kiselevsk, the proximity of houses to industrial facilities makes the last two components particularly important.

It is documented that quarry excavations, dumps, industrial sites and residential buildings coexist within the urban landscape; the design materials of one complex indicate houses approximately 300 and 450 metres from a particular site. Individual human-induced events in the wide Kiselyovsko-Krasnobrodskaya zone have also been documented. However, the presented data do not establish which houses have already been damaged by seismicity, do not prove the instability of each dump or slope and do not show that utility networks will necessarily be damaged. These are possible consequences that need to be checked by surveying soils, buildings and networks.

What the available maps show — and what they do not show

The Greenpeace satellite image 2019 shows large quarry excavations and dumps, between which residential buildings are preserved. It conveys the scale of the change in the territory, but does not show the legal boundaries of the enterprises, the depth of work, old underground workings, faults or the location of epicentres.



Situation map of Shakhta No. 12 LLC: license areas, open-pit mining, industrial sites, reclamation and residential development of Kiselevsk. Source: EIA materials of the enterprise. This is a diagram of one complex, not a map of all nine physical quarries.

The situation map of Shakhta No. 12 LLC shows the license areas of this enterprise, open-pit mining, industrial sites, reclamation and residential development. This is a map of one complex, not all objects of the original list. It does not provide a single layer showing all nine enterprises listed in 2019, all of the city's waste dumps, the dated advance of mining, and seismic hypocentres.

Thus, the maps confirm the spatial proximity of mining and housing, but do not provide a ready-made calculation of seismic risk for each area. It requires a single dated geoinformation model: dated excavations, waste dumps, mine fields, faults, buildings, utility networks and refined hypocentres in the general coordinate system.

How to test the Bachatsky scenario for Kiselevsk

First stage: do not wait for a strong earthquake

We need a local network of several stations around the city and the neighboring Krasnobrodskaya zone, which should continuously record faint events and explosions, transmit open data, and allow depth determination with a single seismic velocity model.

Second stage: integrate the data that are currently separated

A unified GIS model incorporating dated records should include:

- advance of open-pit mining fronts;
- depth and volume of excavation;
- overburden removal and extraction by site;
- contours, height and weight of dumps;
- schemes of old underground workings and their flooding;
- drainage, groundwater levels and pressure;
- blast logs with exact times and coordinates;
- focal mechanisms and relocated hypocentres;
- faults and rock properties.

Third stage: test competing explanations

The geomechanical model should show whether specific works increased or decreased the stress on the found rupture planes. The result is then compared with the natural background, the error of the position of the foci, changes in the network and alternative mechanisms - collapse, rockburst or explosion.

Fourth stage: prepare the city for shaking, regardless of its cause

Even before the completion of causal attribution, it is possible to inspect vulnerable houses, dumps, slopes, and vital infrastructure; determine the procedure for prompt inspection after the tremor; and publish reporting channels and rules of action for residents. The origin of an earthquake is important for prevention, but buildings are damaged by a quake regardless of the legal classification of the source.

Conclusion

The Bachatsky earthquake confirms the very mechanism of strong induced seismicity during open-pit mining in Kuzbass: with a certain combination of the structure of the massif, stresses and long-term movement of rocks, mining operations are able to trigger a shift at a depth of several kilometres.

Kiselevsk has reason to demand the same seriousness of observations. In the urban industrial fabric there are numerous open-pit workings and dumps, under it and next to it - the heritage of mines, and in the nearest zone officially classified human-induced events with magnitudes up to ML 4.9 have already occurred. However, the data presented **do not establish the physical possibility of the event ML 6.1 in Kiselevsk**: for this purpose, the size and condition of potentially activated faults are unknown. They also do not allow predicting Bachatsky repetition.

The main answer of the chapter is therefore as follows: **The Bachatsky case shows that open-pit mining can trigger a strong induced earthquake. However, the data presented do not establish whether an ML 6.1 event could occur specifically in Kiselevsk.** Neither its probability nor the maximum expected magnitude has been established. The absence of this data cannot be turned into proof of the city's safety: answering that question requires a local monitoring network, a reconstructed mining history, surveys of vulnerable buildings and utility networks, and a three-dimensional geomechanical model.

Chapter Sources

1. [Emanov A. F. et al. "human-induced Bachatsky earthquake 18.06.2013 g."](#).
2. [Emanov A.F. et al. "Volumetric structure of the aftershock area of the Bachatsky earthquake"](#).
3. [Emanov A. F. et al. Mining-Induced Seismicity at Open Pit Mines in Kuzbass.](#)

4. [Health profile of residents of Kiselevsk Municipal District](#), p. 55.
5. [Decree of the Kiselevsk Administration from 10.06.2013 № 221-n](#).
6. ["Coal of Kuzbass", May–June 2020, "Mining Cities"](#).
7. [Materials of EIA of Shakhta No. 12 LLC with situational map](#).
8. [Greenpeace España: satellite comparison of Kiselevsk 2004 and 2019](#).
9. [Clarification of the Main Directorate of the Ministry of Emergency Situations of Russia in the Kemerovo region after the event 10 October 2026](#).
10. Annual catalogues of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences and calculation tables of this study: `data/kiselevsk-city-seismicity-2006-2026.csv`, `data/kiselevsk-city-blasts-2006-2026.csv` and `data/kiselevsk-osm-mining-and-waste-polygons-2026-10-11.csv`.

SECTION 9

Investments, coal mining and seismicity, 2006–2026

Cut-off date: **10 October 2026**. An addition to the finished study of human-induced and presumably human-induced seismicity of Kuzbass.

Brief conclusion

Over the past twenty years, coal production in Kemerovostat's statistical series increased from 174 million tonnes in 2006 to a peak of 256 million tonnes in 2018, then declined to 191.8 million tonnes in 2025. Investments in the coal industry at current prices also grew on the whole, but this growth cannot be read as a direct measure of the expansion of mining operations: money was spent on new construction, equipment upgrades, enrichment, production maintenance, safety and treatment facilities, and there is no full annual breakdown of costs.

In nominal rubles, industry investments and production in the same year show a moderate rank relationship: Spearman's $\rho = 0.584$, $n = 18$. After recalculating the same investments at 2025 prices, the connection practically disappears: $\rho = -0.011$. With a delay of one to three years, it does not increase. This means that a significant part of the visible joint growth of money and production is due to inflation, the trend of time and the heterogeneity of the investment series.

The relationship between regional production and the number of recorded earthquakes is even more sensitive to the method of counting. Throughout the series, it looks positive, but monitoring was less sensitive in the early years, in 2012–2013 there was a dense local network, and in 2022 the threshold of the regional catalogue fell to about $M \geq 1.3$. In a more comparable window, 2012–2025, if we remove the exceptional Bachatsky earthquake 2013 and the

methodological shift in 2022, the relationship of production with the number of events $M \geq 3.5$ becomes almost zero: $\rho = 0.110$, $n = 12$. For defined seismic episodes with a maximum of $M \geq 3.0$, it is slightly negative: $\rho = -0.274$.

Consequently, regional annual tonnage does not explain when and where activation will occur. Temporal coincidences exist, but this series does not provide a stable regional formula "more investment or tonnes - more earthquakes". Local features work better: geometry and depth of working, removed and displaced rock mass, dump position, drainage, longwall advance, large explosions, existing faults and the density of the observation network.

What exactly was compared?

Investments

Total investments in fixed assets of Kuzbass are taken from a Rosstat series in current prices. For comparison over time, not the consumer price index was used, but published by Rosstat **Index of Physical Volume of Fixed Capital Investment**. From the nominal change and the index of physical volume, a chain index of capital investment prices is constructed; all values are converted to 2025 prices.

This method better reflects the rise in the cost of construction and equipment than consumer inflation. But for the coal industry, this is an approximation: there is no separate continuous coal deflator in the materials found, so the general regional deflator of capital investments is applied to the industry amounts.

The main industry series included only the values reported as investment actually made. The announced plans were not substituted in empty years. An open comparable fact for 2021, 2025 and the incomplete year 2026 was not found. The value of 2020 — 123.5 billion rubles — was preserved with reduced confidence: it is reproduced in educational and scientific material with reference to regional data, but the primary statistical release is still needed.

A check of 2017, 2022 and 2023 showed that earlier different concepts were mixed in one column. In 2017, the regional report called 63 billion rubles "investments in the development of the coal industry", but later the industry agency clarified for Interfax 79 billion rubles **investments in fixed assets**. The figure of RUB 79 billion is consistent with the 2022 interview, which reports an increase of RUB 72 billion to RUB 151 billion. In the same interview, however, the RUB 151 billion figure is defined more broadly as company spending on production modernisation and social programmes. For 2022, Kemerovostat reports approximately RUB 126 billion in fixed-capital investment in coal mining; an official report of a RUB 9.1 billion increase in 2023 to RUB 135.3 billion yields a revised preceding level of RUB 126.2 billion. The main series therefore now uses RUB 79 billion, RUB 126.2 billion and RUB 135.3 billion. The RUB 63 billion and RUB 151 billion figures are retained separately as measures with different coverage,

rather than deleted. Because the definitions and sources used in the series remain heterogeneous across years, conclusions from the correlation comparison of investment, production and seismicity should be regarded as preliminary.

Mining

The main series is the data of Kemerovostat, reproduced in the regional environmental reports. It is selected as a single statistical line. The operational results of the Ministry of Coal Industry sometimes differ: for example, for 2023 the ministry reported 214.2 million tonnes, while the statistical series gives 211.4 million tonnes.

The division into open and underground mining is given only for the years where it is found. For 2006–2009 the values are calculated from the published proportion of open-pit mining and the annual total; for later years, these are the operational absolute values of the ministry. Therefore, the sum of the methods may refer to a slightly different coverage than the main statistical total.

Seismicity

Seismic indicators are taken from the existing prepared dataset from the already prepared package:

- all records that fell within the boundary and threshold of the relevant source;
- number of events $M \geq 3.0$, $M \geq 3.5$ and $M \geq 4.0$;
- maximum magnitude of the year;
- The number of computational episodes separated by a break of more than 30 days within one analytical zone.

The last indicator is needed so that a multi-thousand aftershock sequence or swarm is not counted as thousands of independent cases. It remains a technical grouping, not a proof of the common origin of events.

Single annual table

In the investment columns, the first amount is stated in current prices and the second at 2025 prices. The seismic column sequentially indicates: all records in source coverage; events $M \geq 3.5$; maximum magnitude; computational episodes with maximum $M \geq 3.0$. Sign — means that no comparable value is found.

Year	All investment, RUB billion: nominal / at 2025 prices	Coal-industry investment, RUB billion: nominal / at 2025 prices	Production, million tonnes	Open-pit / underground, million tonnes	Recorded waste, million tonnes	Seismicity: all / $M \geq 3.5$ / max M / episodes	Sources, structure and qualifications
2006	91.0 / 488.5	33.8 / 181.6	174.0	91.7 / 82.3	—	3† / 0 / 2.94 / 0	†Seismic coverage only from 10 October; economic indicators for the full year.
2007	115.7 / 538.4	39.0 / 181.7	181.0	97.2 / 83.8	—	1 / 0 / 2.89 / 0	The separation of methods is calculated according to the published share.
2008	152.9 / 597.1	54.7 / 213.8	182.0	103.0 / 79.0	—	3 / 0 / 3.06 / 1	Three new mines were reported; there is no single open register of capacities.
2009	110.1 / 427.5	32.0 / 124.3	178.0	94.5 / 83.5	—	3 / 0 / 2.20 / 0	Decline in investment and production.
2010	156.5 / 587.4	50.0 / 187.6	178.0	—	—	2 / 0 / 2.11 / 0	New open-pit mines and a coal preparation plant; about 8 million tonnes/year of declared production capacity.
2011	214.8 / 732.2	72.0 / 245.4	189.0	—	—	0 / 0 / — / 0	There are no records in the open regional catalogue within the boundary of the region.

Year	All investment, RUB billion: nominal / at 2025 prices	Coal-industry investment, RUB billion: nominal / at 2025 prices	Production, million tonnes	Open-pit / underground, million tonnes	Recorded waste, million tonnes	Seismicity: all / $M \geq 3.5$ / max M / episodes	Sources, structure and qualifications
2012	267.8 / 845.3	94.0 / 296.7	201.9	—	—	2 / 2 / 4.30 / 2	A temporary network had been deployed around the Bachatsky open-pit mine before the mainshock.
2013	217.7 / 661.8	56.0 / 170.2	198.0	—	—	74 / 8 / 6.10 / 5	Bachatsky human-induced earthquake and aftershocks; locally registered about 5 thousand aftershocks, which were not included in this regional amount.
2014	231.0 / 678.3	44.0 / 129.2	208.0	—	—	124 / 1 / 3.60 / 3	After the Bachatsky event, the network and attention to the area are already different than in the early years.
2015	170.5 / 441.6	46.0 / 119.2	215.0	—	—	167 / 1 / 3.70 / 2	Three new coal preparation plants, with about 7 million tonnes/year of preparation capacity; this is not extraction capacity.
2016	165.7 / 404.1	52.0 / 126.8	226.0	—	—	121 / 8 / 4.68 / 7	The beginning of the well-observed Kaltan–Alardinskaya activation.

Year	All investment, RUB billion: nominal / at 2025 prices	Coal-industry investment, RUB billion: nominal / at 2025 prices	Production, million tonnes	Open-pit / underground, million tonnes	Recorded waste, million tonnes	Seismicity: all / M $\geq$ 3.5 / max M / episodes	Sources, structure and qualifications
2017	215.2 / 486.1	79.0 / 178.4	240.0	—	—	354 / 1 / 3.54 / 2	Fixed assets investments; separately reported 63 billion "in the development of the industry". Four production enterprises with a total capacity 6.3 million tonnes/year were commissioned.
2018	248.7 / 522.1	97.3 / 204.2	256.0	165.8 / 89.5	—	30 / 4 / 4.00 / 7	Peak of the main production series; the split of methods refers to the operational result 255.3 million tonnes.
2019	288.4 / 549.5	105.0 / 200.1	248.7	—	—	388 / 13 / 4.10 / 7	81% of industry investments — re-equipment and reconstruction, 19% — new facilities; Uvalnaya coal preparation plant 5 million tonnes/year.

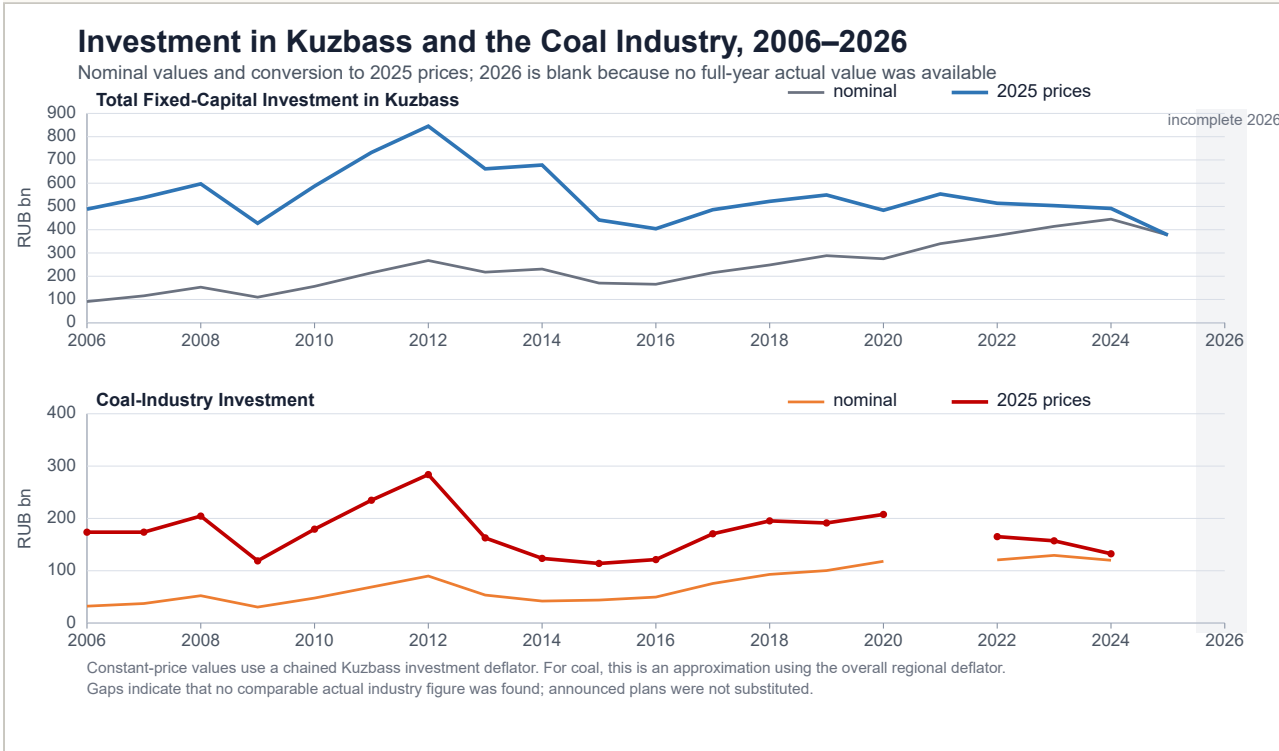
Year	All investment, RUB billion: nominal / at 2025 prices	Coal-industry investment, RUB billion: nominal / at 2025 prices	Production, million tonnes	Open-pit / underground, million tonnes	Recorded waste, million tonnes	Seismicity: all / M $\geq$ 3.5 / max M / episodes	Sources, structure and qualifications
2020	275.0 / 483.5	123.5 / 217.1*	220.1	—	—	378 / 8 / 4.90 / 10	*The industry fact requires primary-source confirmation; RUB 5.5 billion is reported as safety expenditure. The catalogue classified three events in the Krasnobrodsky zone as human-induced.
2021	340.0 / 553.6	—	239.3	156.0 / 87.1	3 804.6	533 / 7 / 5.60 / 9	The commissioning of large underground mines and a coal preparation plant was announced; the sum of the projects cannot be considered a general fact of the industry.
2022	375.4 / 513.7	126.2 / 172.7	223.3	151.7 / 71.9	4 038.8	2,514 / 11 / 4.40 / 3	Investments in coal mining fixed assets; separately reported 151 billion of wider company investments, including social programs. Catalog threshold lowered to approximately M $\geq$ 1.3.

Year	All investment, RUB billion: nominal / at 2025 prices	Coal-industry investment, RUB billion: nominal / at 2025 prices	Production, million tonnes	Open-pit / underground, million tonnes	Recorded waste, million tonnes	Seismicity: all / M $\geq$ 3.5 / max M / episodes	Sources, structure and qualifications
2023	414.4 / 503.4	135.3 / 164.4	211.4	143.1 / 71.1	4 080.7	107 / 13 / 4.50 / 16	The catalogue threshold has been raised to approximately M $\geq$ 2.4; operational output is 214.2 million tonnes.
2024	445.3 / 491.4	125.5 / 138.5	193.7	132.5 / 65.9	3 311.0	62 / 7 / 4.60 / 16	Seismicity is an operational card; the region reports 15 new enterprises announced for 2018–2025 without annual layout.
2025	377.4 / 377.4	—	191.8	—	2 189.1	74 / 7 / 4.20 / 10	Seismicity — operational cards. The fall of recorded waste is affected by changes in the rules of rock classification.
2026†	—	—	120.6†	81.2 / 39.4†	—	37† / 6† / 4.90† / 11†	†Production only for January–August; seismicity by 10 October. Not compared with full years.

The complete machine-readable table with the status of each value, parallel operational series of production, sources and methodological marks: `data/kuzbass-investment-production-seismicity-2006-2026.csv` .

Three graphs on the overall timeline

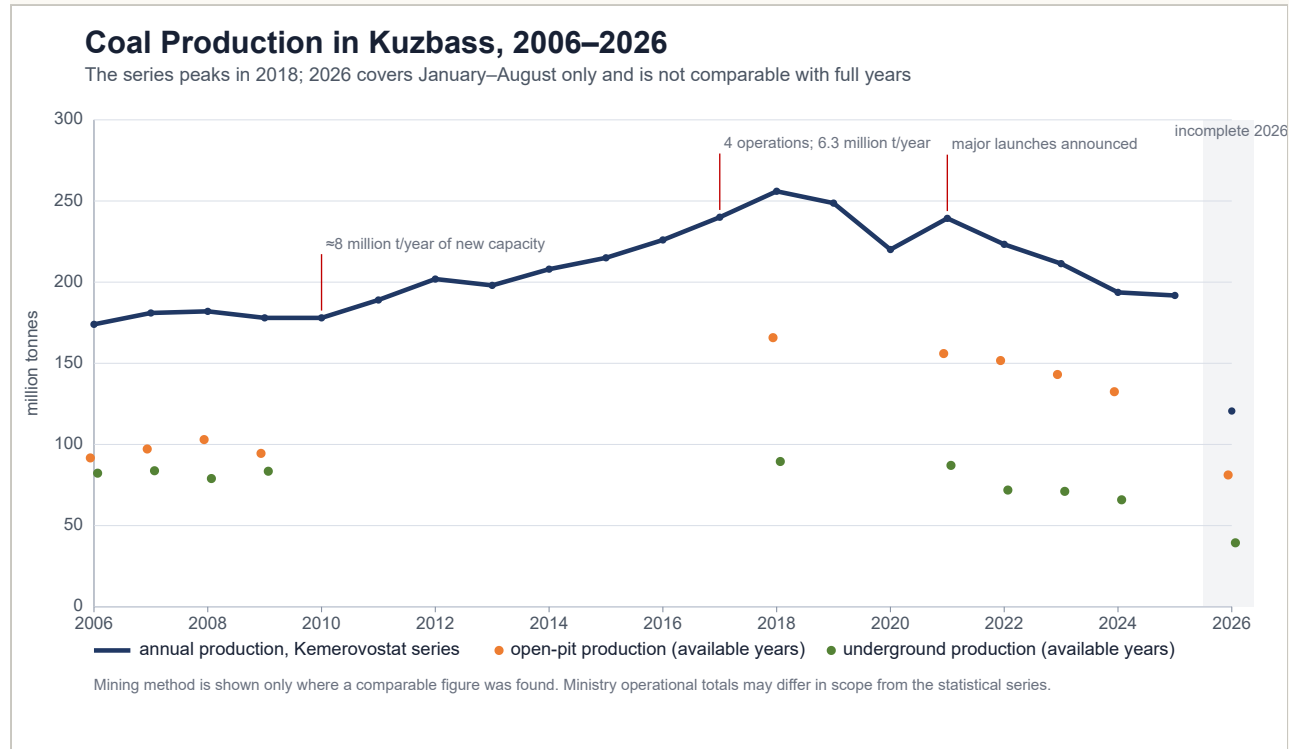
1. Investments



Investments in Kuzbass and the coal industry, 2006–2026. Coverage and restrictions are explained in the text next to the graph.

The chart shows why it is dangerous to mistake current rubles for a physical increase in investment. In general, the nominal investment in the coal industry increased from 33.8 billion rubles in 2006 to 126.2 billion in 2022 and RUB 135.3 billion in 2023. After applying the regional fixed-capital-investment deflator, the maximum in the available constant-price series falls in 2012 rather than in recent years. This does not prove the exact peak in real coal-industry investment: a general regional deflator is used, not a special coal deflator.

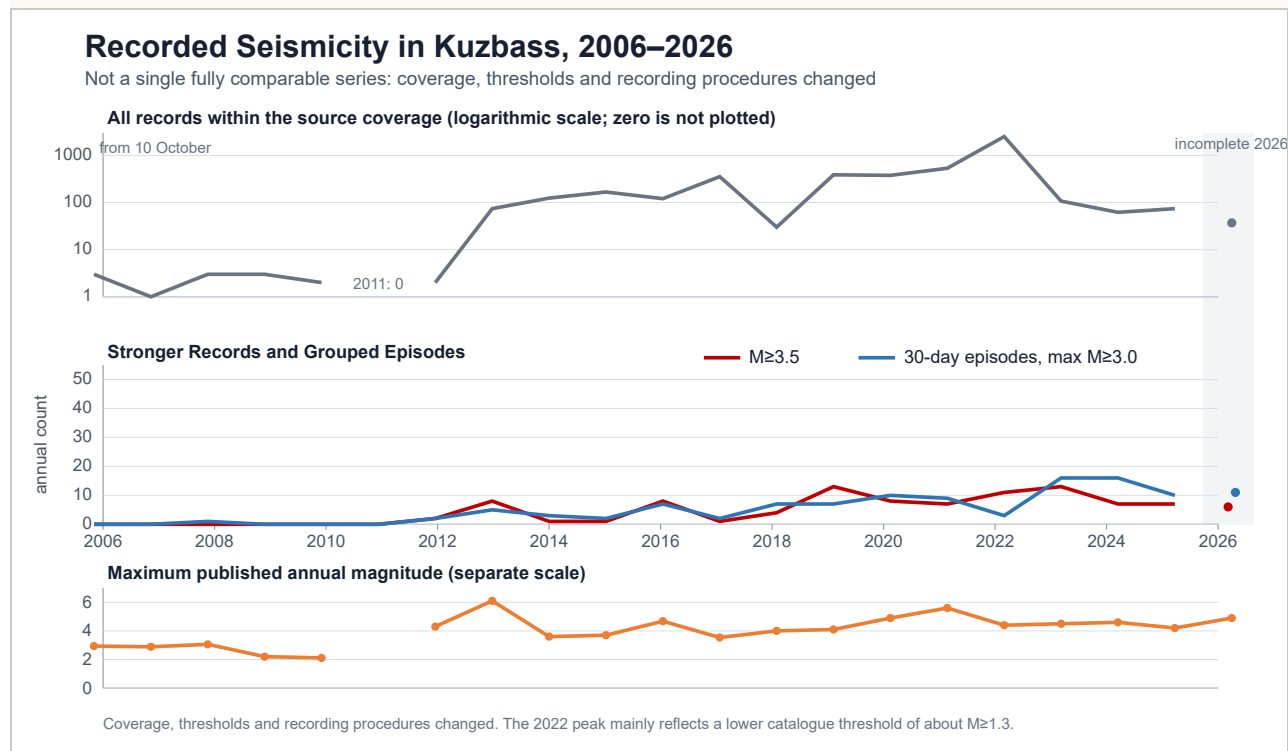
2. Mining



Coal production in Kuzbass, 2006–2026. Coverage and restrictions are explained in the text next to the graph.

The increase in production is particularly noticeable after 2011: 189 million tonnes in 2011, 226 million in 2016, 240 million in 2017 and 256 million in 2018. However, a drop in tonnage does not mean an immediate cessation of geomechanical impact: deep workings, sides, dumps, drainage and altered stresses remain; some processes can continue after the work stops.

3. Seismicity



Recorded seismicity of Kuzbass, 2006–2026. Coverage and restrictions are explained in the text next to the graph.

The upper panel deliberately uses a logarithmic scale: the 2,514 records in 2022 would otherwise hide the other years. The zero value for 2011 is labelled separately and not converted to one for the sake of the logarithmic scale. The middle panel shows events $M \geq 3.5$ and the number of separate 30-day episodes with a maximum $M \geq 3.0$, and the lower panel shows the maximum published magnitude of the year on its own scale. None of these series can be unconditionally called comparable: the network, thresholds, local catalogs, and publishing rules have changed.

Correlations and time lags

The correlations below are descriptive. p -Values were not calculated: short time series are autocorrelated, have gaps and structural breaks, and observations before and after network changes are not the same.

Comparison	Delay	n	Spearman's ρ	Interpretation
Coal-industry investment, nominal → production	0 years	18	0.584	Moderate coincidence in current rubles.
Same	1 year	18	0.368	The connection is weaker.
Same	2	17	0.215	Weak.
Same	3	16	0.163	Weak.

Comparison	Delay	n	Spearman's ρ	Interpretation
Coal-industry investment, at 2025 prices $\rightarrow$ production	0 years	18	-0.011	The association disappears after adjustment for prices.
Same	1 year	18	-0.039	No stable positive lag is apparent.
Same	2	17	-0.218	The sign changes.
Same	3	16	-0.355	The result reflects cycles and gaps, not proven investment effects.
Mining $\rightarrow$ events $M \geq 3.5$, total seismic years 2007–2025	0 years	19	0.626	A shared time trend and changes in observation coverage produce a positive association.
Mining $\rightarrow$ events $M \geq 3.5$, 2012–2025 without 2013 and 2022	0 years	12	0.110	In more comparable sensitivity, there is almost no connection.
Mining $\rightarrow$ episodes $M \geq 3.0$, 2012–2025 without 2013 and 2022	0 years	12	-0.274	Weak negative correlation, insufficient to infer a mechanism.
Change in coal production $\rightarrow$ change $M \geq 3.5$	0 years	18	-0.088	Annual changes almost do not coincide.
Same	1 year	17	0.573	A positive result of one lag.
Same	2	16	0.165	Weak.
Same	3	15	-0.502	The sign is changing; there is no stable lag pattern.
Change in coal production $\rightarrow$ change the number of episodes	0 years	18	-0.032	Almost zero.
Same	1 year	17	0.027	Almost zero.
Same	2	16	0.614	A positive result of one lag.
Same	3	15	-0.113	The connection weakens again and changes the sign.

All 38 calculations, including the total count of catalogue entries and sensitivity checks:

`data/kuzbass-investment-correlation-results.csv` .

Why the calculations do not provide a ready-made answer

If you check many indicators and four delays in a short series, a single high correlation can arise by chance. Here, positive coefficients on one or two lags are replaced by negative ones on another, and the result depends sharply on the choice of period and the way to count sequences. In addition, one year's investment can be related to equipment, a coal preparation plant or a wastewater treatment plant, while the seismic effect is determined by the work at a specific site.

Therefore, the calculation does not refute local human-induced seismicity. It shows otherwise:

The regional financial and production series are insufficient for causal inference.

What the individual areas show

Bachatsky open-pit mine

The Bachatsky earthquake `ML 6.1` occurred in 2013, when regional production was about 198 million tonnes—lower than in 2016–2019. A dense temporary network had already been deployed around the open-pit mine before the mainshock; afterwards, approximately 5,000 aftershocks were recorded. The studies relate the activation to the cumulative change in topography, the removal and relocation of an enormous mass of rock, the depth of the open-pit mine, waste dumps and stress redistribution—not to a single year's production or one blast.

By 2018, the excavation had expanded from approximately `2.3 × 10 km` at a depth of about 320 m to `3 × 11 km` at a depth of 400 m. This is an example of why the area and depth of the workings may matter more than regional tonnage.

Kaltansky Mine and Alardinskaya Mine

The activation was detected at the end of 2016, when the region's production was growing. The temporary network made it possible to separate industrial blasts, stronger earthquakes near the dump zone and a weak group over underground workings. Here there is a time coincidence with the growth of production, but the causal argument is based not on regional correlation, but on hypocentre locations and differences between the signals.

Krasnobrodsko-Kiselyovskaya zone

In 2020, when regional production fell sharply to 220.1 million tonnes, the official catalogue directly called three events near the Krasnobrodsky facility human-induced. Repeated activations were observed in 2023–2026 against the background of a further decline in regional production.

This is an important counterexample of a simple hypothesis about an immediate dependence on annual tonnage. Event 10 October 2026 M4.9 remains an event of unknown origin: proximity to mining makes the hypothesis verifiable, but does not prove it.

Other areas

Raspadskaya, Polysaev, Taldinsky District and Gornaya Shoria show that activity migrates between objects and occurs in impulses. Annual reports of the company or the entire region do not replace monthly data of a specific longwall panel, open-pit mine, waste dump and dewatering system.

Stripping, dumps and mine water: what was and could not be added

A continuous open annual series for the physical volume of overburden removed in Kuzbass by year in cubic metres was not found. The indicator "waste generated" cannot be used as its replacement. For 2021–2025, the recorded totals were, respectively 3.805; 4.039; 4.081; 3.311 and 2.189 billion tonnes of waste, but the total includes not only overburden, and after 2023, part of the overburden and host rock could no longer be counted as waste under the use envisaged by the project. Therefore, a sharp statistical decrease is not equal to the same decrease in physical movement of rocks.

For the same reason, model stripping ratios are not substituted in the annual table. To test the seismic hypothesis, you need actual annual or monthly values for each object:

- the volume of overburden removed and the position of the work front;
- the area and depth of the workings;
- weight, height and date of formation of dumps;
- water inflow, drainage, flooding and changes in the groundwater level;
- longwall advance and extraction volumes by mine field;
- time and charge of mass blasts;
- continuous sensitivity of the local seismic network.

An open regional annual series of drainage for 2006–2026 years has also not been found. Individual reports on treatment facilities document environmental investment, but they do not allow changes in water pressure within the rock mass to be reconstructed.

Actual investment and plans

A few examples show why plans are separated from fact:

- in 2019 the actual 105 billion rubles were divided into 85 billion for technical re-equipment and reconstruction and 20 billion for new facilities;

- in the material found for 2020, RUB 5.5 billion of the reported RUB 123.5 billion is identified separately as spending on mining safety; primary confirmation of the full amount is still required;
- for 2021, the 7 November–Novaya mine with a capacity of 4.8 million tonnes per year, the Sibirskaya mine with a capacity of 5 million tonnes per year and a coal preparation plant with a capacity of 4 million tonnes per year were announced. The approximately RUB 40 billion cost of those projects cannot be substituted for the industry's total actual investment;
- the regional page reports 15 new enterprises announced for 2018–2025, but does not provide an annual breakdown of commissioning dates, capacity and actual costs.

For causal analysis, not only the amount is important. Investing in a new quarry, deepening of a pit wall or new longwall panel potentially changes the geomechanical load differently than buying dump trucks, reconstructing a coal preparation plant, relocating residents or building a sewage treatment plant.

What the trends suggest

1. **Coincides:** In 2011–2018, production was growing, new capacities were commissioned and work was expanded. During this period, the Bachatsky earthquake and the Kaltan–Alardinskaya activation occurred.
2. **Diverge:** after the peak of production 2018, tonnage decreased, but strong events, swarms and reactivations continued. The Krasnobrod zone is particularly clear in the absence of simple simultaneous dependence.
3. **The nominal association is misleading:** A moderate correlation between current rubles and production disappears after an approximate adjustment for prices.
4. **Raw account of events is misleading:** The number of catalogue records changes dramatically along with the network and the registration threshold. The peak of 2022 is primarily methodological.
5. **Strong local evidence persists:** The absence of a stable regional correlation does not cancel the Bachatsky and Kaltan–Alardinskaya cases, because their origin was investigated by local networks, geometry of foci and industrial context.
6. **The main limitation is production data:** Without a history of depth, area, overburden removal, waste dumps and water for each object, it is impossible to verify the physical mechanism and delay in 1–3 years as required by causal analysis.

What these data do not allow us to establish:

- what proportion of all Kuzbass earthquakes were caused by mining;
- what share of investment directly expanded excavations and what share maintained, modernised or made existing operations safer;

- whether there is a uniform threshold of tonnage, depth or overburden for all underground mines and open pits;
- whether a particular event is a consequence of mining only because there was high investment in the region that year;
- the origin of the 10 October 2026 event without depth, focal mechanism, wave records and work logs of neighboring enterprises.

Reproducibility

Script [tools/build-investment-mining-analysis.mjs](#) re-reads the final annual seismic summary and episode table, calculates the chain-linked deflator and builds a combined annual table, all correlation checks and three graphs. The seismic catalogue is not rebuilt.

Sources for the economic analysis

1. [Rosstat: investments in fixed assets by constituent entities of the Russian Federation, current prices; Roschart submission.](#)
2. [Rosstat: indices of the physical volume of investments by constituent entities of the Russian Federation; presented by Roschart.](#)
3. [Kuzbass state report for 2013: historical production series.](#)
4. [Kuzbass state report for 2019.](#)
5. [Kuzbass state report for 2021.](#)
6. [Kuzbass state report for 2023.](#)
7. [Kuzbass state report for 2024.](#)
8. [Kemerovostat: "Kuzbass in 2025".](#)
9. [Kemerovostat on sectoral investments 2011–2015, reproduced by Kommersant.](#)
10. [Interfax: clarification of the industry department — 79 billion rubles of investments in fixed assets of the coal industry in 2017.](#)
11. [Regional message: 63 billion rubles of "investments in the development of the coal industry" in 2017.](#)
12. [Kemerovostat: about 126 billion rubles of investments in fixed assets of coal mining in 2022.](#)
13. [Industry interview: 151 billion rubles in 2022, including production modernization and social programs.](#)
14. [2019 results: investment, its structure and the Uvalnaya facility.](#)
15. [Ministry of Coal Industry of Kuzbass: production and investment in 2023.](#)
16. [Official Kuzbass industry page: 2024 and the number of new enterprises.](#)
17. [Ministry of Coal Industry of Kuzbass: production in January–August 2026.](#)
18. [Rosnedra: overview of projects announced for commissioning in 2021, their capacities and investment.](#)
19. [Program for the development of the coal industry of Russia until 2035: projects and reported investment actually used at individual facilities.](#)

Annual source register and visible gaps: [data/kuzbass-investment-source-notes.csv](#) .



Multi-level open-pit excavation in the winter landscape of Kuzbass. 2 January 2019; exact location not established. Photograph from Natalia Zubkova's archive; photographer not established.

SECTION 10

Five documented cases in open-pit mining

It was important for me to compare the Bachatsky earthquake not only with the events in underground mines. Below are five cases at open-pit mining sites of coal, anthracite, limestone and other carbonate rocks. This is not necessarily the five strongest cases worldwide: different magnitude scales cannot be ranked on a single scale, and the worldwide register is incomplete. The cases were selected because the studies allow at least some key parameters, consequences, the position of the open-pit workings and the basis for human-induced classification to be reconstructed.

Date and location	Object and raw materials	Parameters	Position relative to open-pit workings	Consequences	Basis for the mining link and evidentiary limits
18 June 2013 UTC, Bachatsky, Russia	Bachatsky mine, coal	ML 6.1 ; local solution near 54.277° N, 86.172° E; depth approximately 4 km	The mainshock and the three-dimensional distribution of aftershocks are spatially associated with the open-pit mine: stronger events tended towards the pit wall, most weaker hypocentres lay beneath the excavation, and elevated focal density was also observed beneath the waste dumps. A reliable distance to the historical legal boundary could not be reconstructed	Intensity up to 7 points; damage to homes, chimneys and social facilities; approximately 5,000 aftershocks	Observations before and after the mainshock, the focal mechanism, shallow depth, geometry of aftershocks and the history of changes at the open-pit mine are consistent with human-induced origin. The exact contribution of explosions, mass removal and groundwater changes cannot be separated
29 November 1980, Bełchatów, Poland	Bełchatów Mine, brown coal	Reported as M 4.66 ; for the early series, depths were discussed approximately 0.5; 3–4 and 5 km	The event occurred in the open-pit mine area; the distance to the historical 1980 boundary of the workings could not be reconstructed from the available materials	Cracks and damage to chimneys were reported	The authors associated the series with load removal, groundwater drawdown and existing tectonic stress. Depth uncertainty does not allow for an accurate separation of mechanisms

Date and location	Object and raw materials	Parameters	Position relative to open-pit workings	Consequences	Basis for the mining link and evidentiary limits
16 January 1994, Cacoosing Valley, Pennsylvania, U.S.	Closed carbonate rock quarry	mbLg 4.6 ; later recalculations about Mw 4.3 and ML 4.4 ; aftershocks in the upper 2.5 km	The quarry, approximately 800 m wide, lay directly above the identified rupture zone; the distance to the historical pit boundary was not published	Intensity VI–VII; damage about 2 million dollars	After the cessation of drainage, the quarry was filled with water. The temporary seismic network, the mapped aftershock plane and calculations of Coulomb stress change supported the conclusion that the sequence was probably triggered by unloading and rising pore pressure.
9 January 2019, Kolyvansky, Novosibirsk Oblast, Russia	Kolyvansky open-pit mine, Anthracite	ML 4.3 ; depth about 4 km	The epicentre was located in the area of open-pit workings of the Gorlovka basin; the exact distance to the verified historical boundary has not been published	The tremor was felt in settlements, including Novosibirsk; no confirmed damage register found	Detailed observations and comparison with the development of the open-pit workings allowed the authors to call the activation human-induced. Open data are not enough for independent calculation of distance and total damage
7 June 1974, Wappingers Falls, New York, U.S.	Large limestone aggregate quarry	mbLg 3.3 , also ML 2.9 ; approx. 0.5–1.5 km	The foci were located directly under the quarry, inside its projection; this is not a calculation to the historical border	Intensity VI; broken windows and minor damage; more than 100 aftershocks in six days	The authors associated the series with the removal of tens of millions of cubic metres of rock and the unloading of an already tense structure. The event is weaker than the others, but the spatial connection is described especially clearly

Bachatsky open-pit mine: The Most Complete Set of Evidence

The mainshock occurred on 18 June 2013 at 23:02:09.6 UTC — in the morning 19 June local time. ML 6.1. In Bachatsky and Starobachaty, the intensity reached 7 points. Official and scientific materials describe damage to residential buildings, chimneys and social facilities. [Yemanov et al., Study of the Bachatsky Earthquake](#); [Official Impact Statement](#).

Before the main event, an observation network was already operating near the open-pit. After that, additional stations were installed and about five thousand aftershocks were registered. Their area was stretched along the open-pit mine, extended beneath the excavation and at depth, and elevated focal density outside the excavation was observed beneath the waste dumps. Later modeling showed that mining could bring the existing geological structure closer to failure, and not produce all the energy of the event in a single explosion. [Repeated geomechanical analysis](#).

Belchatów: load removal and groundwater drawdown

In the early work on Belchatów, the authors considered several possible depths and several influences at once: removal of mass above the quarry, pumping out water and stress on pre-existing structures in the basement. This is a useful limitation: proximity to the surface does not automatically allow the focus to be placed at the level of the bottom of the quarry. [Original study of the series](#).

Cacoosing Valley: changes continued after the closure

The quarry closed in December 1992. After the cessation of drainage, the water level began to rise, and in 1993 a seismic sequence appeared. The temporary seismic network delineated the rupture plane under the quarry. The authors calculated a small but physically significant stress change and concluded that the sequence 1993–1997 was probably triggered by a combination of unloading and water pressure increase. [Primary research](#).

This case shows me why shutting down an enterprise does not always immediately stop geomechanical processes. A change in groundwater conditions can therefore initiate a new phase even after extraction has ended.

Kolyvansky open-pit mine

The Kolyvansky site is in Novosibirsk Oblast, not Kuzbass, and is therefore excluded from the Kuzbass statistics. The authors of the study of the 9 January 2019 earthquake compared it with the expansion of open-pit mining and the observed seismic activation, and classified it as human-induced. I retain their classification, but I do not add exact distances or a list of damage that are absent from the available publication. [Study of Kolyvansky activation](#).

Wappingers Falls

This event is weaker than the others, but its foci were located directly under a large quarry. More than a hundred aftershocks were recorded in six days. The case entered the classic literature about earthquakes triggered by load removal during surface mining. [Overview of the United States Geological Survey](#).

Comparing the five sites does not provide a universal threshold for depth or extraction volume. It reveals recurring mechanisms: load removal, transfer of mass to waste dumps, changes in groundwater conditions and the triggering of movement along an already stressed structure. The strength of the evidence differs among the five cases, so the limitations are retained separately for each one.

SECTION 11

International Corpus of Mining-Induced Seismicity

Short answer

In the well-studied Kuzbass series, the events were really concentrated **within mining sites, near their sides, under dumps or above underground workings**. But for all the world cases registered, the exact distance cannot be established now: the global database rarely reports these distances, and the approximate point of the project does not replace the border of the enterprise and the coordinates of the epicentre at the same time.

Proximity is an important argument, but it does not prove causality in itself. For a major event, it is also necessary to take into account depth, consistency in time, changes in seismicity after the start of work, the focal mechanism, the location of faults, the volumes of excavation or injection, and the possibility of excluding an industrial explosion.



Work in the open-pit coal mine: open layer and quarry equipment. Koksovy open-pit mine, 22 January 2019. The author of the photo is Smogman. The photo is stored in the archive of Natalia Zubkova.

What HiQuake's Quantitative Verification Shows

The full HiQuake 'Mining' category

The upload contains 343 projects or series of the category **Mining**. The name of this category is broader than the Russian words "mining": it includes not only mines and quarries, but also tunnelling, underground excavation, solution mining, collapses, rockbursts, flooding of closed workings and some mixed hydrogeological cases. Therefore, 343 records cannot be presented as 343 cases caused specifically by the extraction of solid raw materials.

Distance field from maximum event to project	Number of records	Share
Exact numerical value	4	1.2%
Upper Limit or Range	2	0.6%
Not reported	337	98.3%

The six published values are within five kilometres:

Country and project	Maximum Event	Reported distance
China, Yuzixi I Tunnel	magnitude not specified in the line	25 m
Germany, Saar–Primsmulde	ML 4.0	174 m
China, Erlangshan Tunnel	magnitude not specified in the line	1–1.5 km
USA, Wauregan Tilcon Quarry	MLG 3.1	1.5 km
Bulgaria, Provadia	MD 3.1	4.5 km
USA, Solvay Mine	mb 5.2	less than 5 km

These six cases are not a random or representative sample. It cannot be used to conclude that 100% of mining earthquakes occur closer than five kilometres: distances are simply missing for most rows in the table.

Approximate coordinates are available for 318 of the 343 mining records. However, the HiQuake field contains one approximate point of the project/case. For independent calculation, two geometries are needed: the coordinates of the epicentre of the maximum event and the historical boundary of the workings on the corresponding date. Therefore, the distance between the event and the enterprise cannot be calculated using the same approximate point.

Coal mining

The coal subsample contains 150 projects or series. The numerical distance is indicated only for Saar–Primsmulde in Germany - 174 m. For the rest of the 149 rows, the field is empty. Even for the Bachat, Newcastle and Ellalong events, HiQuake preserves the project, magnitude and literature, but does not provide a ready-made distance to the site boundary.

Therefore, the wording "in all world coal cases the epicentre was located directly near the mine" would not be supported by the existing summary table. This must be checked against the primary maps in each study.

What can be collected "all over the world"

There is no single complete catalog of all individual mine tremors. In deep mines, huge arrays of microseismic events are recorded every year; some remain inside production systems, and some of the literature is not available in English or Russian.

The broadest open starting dataset is the Human-Induced Earthquake Database, HiQuake. Its records represent **Projects, mines or series**, and not necessarily a single jolt. The database snapshot from 24 September 2026 contains 1,385 proposed cases of induced seismicity of all types in 84 countries. After filtering for the resource `Coal`, 150 projects or series remain across 13 countries.

The full set is saved in `data/global-hiquake-coal-mining.csv`. A reviewed set of key cases has been prepared separately: `data/global-coal-key-cases-reviewed.csv`.

Distribution of HiQuake coal records

Country	Projects or series
China	90
USA	20
Poland	9
United Kingdom	8
Australia	6
Germany	6
Russia	3
Japan	2
Czech Republic	2
India	1
Spain	1
Netherlands	1
South Korea	1

This distribution reflects not only the actual frequency, but also the availability of publications, the development of networks and the rules of inclusion in the database.

The strongest records in the coal corpus

Place	Recorded maximum	Knowledge status
Bachatsky Mine, Russia	ML 6.1	Thoroughly researched and recognized as human-induced
Newcastle, Australia	ML 5.6 (Mw 5.4)	The hypothesis that mining and groundwater drawdown triggered the event is scientifically disputed
Ellalong, Australia	ML 5.4	A mining link has been proposed for shallow depth and the location of the sequence above the workings.
Boolaroo and Maitland, Australia	to ML 5.3	Historical records; individual evidence is limited
Bełchatów, Poland	approximately 4.66 for the event of 29.11.1980	The open-pit mining and groundwater-drawdown sequence is classified as induced; the scales in the sources are not the same.

Place	Recorded maximum	Knowledge status
Ibbenbüren, Germany	ML 4.3 in German review; 4.6 in HiQuake	The event is regarded as mining-related, but the HiQuake record itself has insufficient evidence and a controversial reference
Moss Mine No. 2, USA	ML 4.5	Historical review of rockbursts; limited event-specific data
Taiji, China	ML 4.3	Reviews named China's largest coal-mining event

Therefore, the cautious answer to the question about the strongest case is as follows: **Bachatsky ML 6.1 is the strongest well-documented and human-induced event in the coal-mining corpus.** Newcastle was destructive, but the causal link to coal mining remains a subject of scientific debate.

Main international examples

Australia: Newcastle and Ellalong

The Newcastle earthquake of 28 December 1989 ML 5.6 / Mw 5.4 occurred at a depth of approximately 11 km. Thirteen people died, more than 160 were hospitalised, approximately 50,000 buildings were damaged.

K. Klose proposed a mechanism: long-term coal extraction and groundwater pumping reduced the load and changed the stresses at the fault. His calculation showed the physical possibility of such an influence. C. Quinn, R. Glen and C. Dissel objected that the model and regional history of earthquakes do not support the final causal conclusion. The case must therefore be presented as **disputed**, not as an established example.

The Ellalong earthquake, ML 5.4 6 August 1994 was very shallow — approximately 1.3–1.5 km. Researchers have linked hundreds of events to the beginning of longwall mining; epicentres were located above the central part of the mine. The initial report of 1994 has yet to be obtained in full, so the parameters are taken from subsequent reviews.

Germany: Ibbenbüren and Saarland

At Ibbenbüren, events above magnitude 4 occurred in 1981, 1991 and 2000. German reports give the event of 16 May 1991 ML 4.3 and the intensity of VI. HiQuake cites 4.6, but assigns it “insufficient evidence”, and the reference in the database refers to gas fields in northern Germany. This is a bibliographic problem of the database that has been discovered; the conclusions of the study should use the German estimate 4.3 and show the discrepancy.

On 23 February 2008, a mining-related earthquake occurred in Saarland ML 4.0–4.1 at a depth of about one kilometre. BGR considered it highly likely to have been caused by coal mining. Numerous buildings were damaged; no serious injuries were reported. The state government

stopped mining and then a plan was adopted to stop coal mining in the Saar. This is a rare example where a strong event immediately changed an industrial decision.

Poland: Belchatów and Upper Silesia

Open-pit coal mining at Belchatów began in 1976. The first five events studied occurred in 1979–1980; the three largest had **ML 3.5**, intensity 5–6 and an estimated depth of 1–5 km. The authors associated them with unloading and large-scale groundwater drawdown in an already stressed tectonic structure.

For 29 November 1980, later reports give a magnitude of about 4.66. This should not be confused with the five events of the early article, which ended the observed period in May 1980. Other strong events later occurred at Belchatów, including in 2010.

In the Upper Silesian coal basin, large datasets of mine seismicity and rockbursts have been registered. Here it is especially important not to mix a routinely recorded micro-event, a devastating rockburst and an earthquake tangible on the surface.

Czech Republic: Ostrava-Karvina Basin

Regional and underground networks document sustained induced seismicity of deep mines. A study of 80 rockbursts recorded from 1993 to 2005 used 240 three-component records.

Rockburst is a subset of mine seismic events that caused damage to mining or people; not every recorded event is a rockburst.

USA: Willow Creek and Crandall Canyon

The **ML 4.2** event at the Willow Creek Mine in Utah on 6 March 2000 was the largest historical mining-related event in the corresponding regional sample. The University of Utah emphasized the usual uncertainty of the local magnitude around ± 0.3 .

The **ML 3.9** signal recorded at Crandall Canyon on 6 August 2007 was fundamentally different. Initial reports considered an earthquake as a possible cause of the accident, but first-motion polarities, the moment tensor and satellite interferometry showed that the principal source was the catastrophic collapse itself, with a normal-faulting component. Six miners died. This case should be in a separate category **collapsed**, and not used as an example of an earthquake that destroyed the mine.

China

HiQuake contains 90 coal projects or series, more than any other country. A review of 2007 attributes the increase in danger to deepening of the mines and stress redistribution. Chinese data include both microseismicity and destructive rockbursts.

For the Taiji Mine in Liaoning, the 1977 **ML 4.3** event was felt across approximately 1,200 km² and damaged about 2,100 m of mine workings. For the Mentougou mine in Beijing, the 1994 event is reported at magnitude 4.2, with damage to about 530 m of mine workings. This is

information from review papers; for the publication of detailed individual cards, it is desirable to obtain primary Chinese articles.

United Kingdom

Studies of North Staffordshire and Midlothian show a long history of recording coal-mining seismicity by the national network. Numerous small tremors predominate, and their relationship with mining has been studied using waveforms, timing and spatial location. The database contains no single event comparable in its consequences to Bachatsky or Newcastle.

What E-PIE Says and What It Doesn't Say

In 2024, the E-PIE authors evaluated 1,235 proposed HiQuake cases. For 881 cases, the evidence was sufficient to assign a score: 87% were classified as "confidently induced", 10% were classified as "probably induced", 2% were classified as uncertain, less than 1% were classified as confidently natural. For 354 cases, the available material was insufficient for assessment.

This is the result of an initial unified assessment by one expert, and not a judicial or final verdict. The authors directly call it preliminary and invite specialists to clarify individual cases.

In the current snapshot of the coal subset 97 of the 150 records are marked "insufficient evidence" (Insufficient evidence), another one is "Not assessed" (Not assessed). This does not mean that 97 cases are natural. It means that the database does not contain enough published information to apply the questionnaire.

Global Corpus Problems Discovered

1. HiQuake combines single events, mines and multi-year series.

2. The maximum magnitude field is sometimes based on secondary review and diverges from the primary publication.

3. In some lines, there are obvious date errors, for example, the year 9484 in Boolaroo.

4. The reference for Ibbenbüren does not correspond to the coal event.
5. For Newcastle, the base gives a high E-PIE, but there is a direct counter-analysis in the peer-reviewed literature.

6. Most of the Chinese lines go back to the overview article, not to the available individual cards.

7. The consequences for people and buildings are incomplete; the absence of a record does not equal the absence of consequences.

Therefore, a full CSV is a pointer to search, not a ready-made table of proven facts.

What international experience adds to Kuzbass

- A strong event near the mining can be an induced earthquake, collapse or natural earthquake; these variants are distinguished by waves and mechanism.

• Open-pit mining acts not only with explosions: mass removal and water lowering are capable of changing stresses at depth.

- Underground mining creates its own seismicity, and rockbursts can directly destroy workings.
- After the closure of mines, the risk does not necessarily disappear immediately: flooding and stress restructuring require observation.
- The strongest scientific attribution occurs where local networks, production data, and independent research exist.
- The reaction of the authorities varies, from the continuation of observations to the immediate cessation of production, as in the Saarland in 2008.

Main sources

1. [HiQuake — Human-Induced Earthquake Database.](#)
2. [Wilson et al. HiQuake: the human-induced earthquake database.](#)
3. [Wilkinson et al. The plausibility of claimed induced seismicity.](#)
4. [Foulger et al. Global review of human-induced earthquakes.](#)
5. [Klose. Newcastle geomechanical model.](#)
6. [Quinn, Glen, Diessel. Discussion of the Newcastle model.](#)
7. [Geoscience Australia: Consequences of the Newcastle Earthquake.](#)
8. [BGR: Saarland Coal District Earthquake 23 February 2008.](#)
9. [Gibowicz et al. Bełchatów earthquakes induced by surface mining.](#)
10. [USGS: Crandall Canyon collapse.](#)
11. [Li, Cai, Cai. Review of mining-induced seismicity in China.](#)
12. [Holub, Petroš. Rockbursts in the Ostrava-Karviná basin.](#)

SECTION 12

Quality Assurance and Reproducibility

Validation date: 2026-10-10.

Verification	Actual	Expected	Result
Records in the combined dataset	4977	4977	Passed
Sum of annual lines	4977	4977	Passed
Operational cards 2024	62	62	Passed
Operational cards 2025	74	74	Passed
Operational cards 2026 to 10 October	37	37	Passed
Invalid time formats in the combined series	0	0	Passed
Kolyvansky-site records in the combined Kuzbass dataset	0	0	Passed

Verification	Actual	Expected	Result
Reference events	42	42	Passed
Event of 10 October 2026 in the reference catalogue	1	1	Passed
Series and Aggregate Sets Rows	18	18	Passed
Kolyvansky set is marked as out of scope	1	1	Passed
Events assigned to the seven analytical zones	4089	4089	Passed
M $\geq$ 2.5 within a radius of 15 km from the main point 2026	55	55	Passed
Auxiliary 30-day episodes	206	206	Passed
All HiQuake projects	1385	1385	Passed
HiQuake coal subset	150	150	Passed
Countries in the coal subsample	13	13	Passed
Coal records marked "Insufficient evidence"	97	97	Passed
Verified international cards	15	15	Passed
Distance of the main point to the wide contour of OSM, km	1.024	1.024	Passed
Distance of the main point to the border of the Krasnobrodsky field of GEM, km	9.586	9.586	Passed

The check confirms the internal consistency of numbers and files, but does not turn operational solutions into reviewed catalogue parameters and does not establish the causality of events.

Verification date: **10 October 2026**.

Verification	Result	Detail
21 consecutive years	Passed	21 lines
seismic results are not changed	Passed	Checked all years with a ready-made summary
2006 marked as partial for seismicity only	Passed	economic indicators for the full year; seismicity only from 10 October

Verification	Result	Detail
2026 marked as incomplete	Passed	incomplete year: production January–August; seismicity according to 10 October
2026: Mining and methods	Passed	120.6 = 81.2 + 39.4 million tonnes for January-August
the 2022 catalogue peak is preserved	Passed	2,514 records
38 correlation calculations	Passed	38 lines
Nominal Investment – Mining	Passed	$\rho=0.584$ after separating figures with different coverage
Real Investment – Mining	Passed	$\rho=-0.011$ after separating figures with different coverage
2017: conflict 63/79 billion rubles	Passed	79 billion — fixed capital investments; 63 billion — previously published amount "for the development of the industry", kept separately
2022: conflict 126.2/151 billion rubles	Passed	126.2 billion — the main statistical series; 151 billion — wide investments of companies, including social programs, are kept separately
sensitivity 2012–2025	Passed	$\rho=0.110$
01_investment_2006_2026: SVG	Passed	9560 bytes
01_investment_2006_2026: PNG	Passed	2800×1640
02_coal_production_2006_2026: SVG	Passed	7793 bytes
02_coal_production_2006_2026: PNG	Passed	2800×1640
03_seismicity_2006_2026: SVG	Passed	8907 bytes
03_seismicity_2006_2026: PNG	Passed	2800×1640

Summary: All automatic checks have been passed. Validation confirms the internal consistency of files; it does not replace causality validation and does not turn correlation into proof of human-induced origin of events.

SECTION 13

Detailed Study Tables

The appendix provides the main summary tables on which the conclusions of the study are based. Large catalogues containing 4,977 recorded earthquakes, 38,234 industrial-blast records and 1,385 HiQuake projects are kept separately: their line-by-line inclusion would make the PDF unreadable. [Download a set of data, calculations and scripts.](#)

How gaps are marked. "Not reported" means that the source does not provide a numerical value; "not found" means that the value or document could not be detected in the audited corpus; "Not assessed" means that an individual evaluation was not performed; "not applicable" means that the field does not relate to this record. Zero indicates only published or calculated null value.

13.1. Key events of Kuzbass: parameters

42 entries. Magnitude types are preserved: the values of different scales cannot be considered completely interchangeable.

ID	Date and time UTC	Latitude	Longitude	Depth, km	Depth Status	Magnitude	Type	Intensity	Other solutions
KUZ-1966-09-20	1966-09-20 22:15	53.40	87.40	15	Catalogue value / research source	~5.0	mb	not found	not found
KUZ-1988-02-TASHTAGOL	1988-02 (exact date not found yet)	not found	not found	0.8-1.5	Evaluation of the study	Not reported	Not reported	5-6, Kochura settlement	seismic energy near 10^9 J
KUZ-1995-09-14	1995-09-14 04:24	53.60	86.80	0.2 or 31.6	Alternative depth solutions	4.5-4.9	mb	not found	not found
KUZ-1997-04-25-ANZHERSK	1997-04-25 (time not found yet)	not found	not found	Not reported	Not reported	2.3	mb	up to 5	second event on 1997-04-27 also mb 2.3

ID	Date and time UTC	Latitude	Longitude	Depth, km	Depth Status	Magnitude	Type	Intensity	Other solutions
KUZ-1997-04-27-ANZHERSK	1997-04-27 (time not found yet)	not found	not found	Not reported	Not reported	2.3	mb	up to 5	paired with 1997-04-25 event
KUZ-1998-05-13	1998-05-13 23:40	54.35	85.14	Not reported	Not reported	4.1	mb	not found	not found
KUZ-1999-10-24-TASHTAGOL	1999-10-24	52.76453	87.90915	Not reported	Not reported	3.6	ML	not found	not found
KUZ-2002-03-06	2002-03-06 09:22	53.40	87.30	0	fixed depth	4.6	mb	not found	not found
KUZ-2008-01-11	2008-01-11 09:40	53.60	88.30	8 or 13.3	Alternative solutions	4.5	mb	not found	not found
KUZ-2008-04-02	2008-04-02 19:31	53.97	88.20	15 or 14	Alternative solutions	4.6	mb	not found	not found
KUZ-2008-10-13	2008-10-13 06:17	53.86	85.88	0	fixed depth	4.6	mb	not found	not found
KUZ-2011-02-12	2011-02-12 00:55	53.48	87.50	10 or 0	fixed alternative solutions	4.5	mb	not found	not found
KUZ-2011-03-15	2011-03-15 (time not found yet)	55.17	86.19	Not reported	Not reported	3.9	mb	not found	not found
KUZ-2011-04-17	2011-04-17 23:07	53.39	87.15	0 or 33	Alternative solutions	4.5	mb	not found	not found
KUZ-2012-02-09-ANZHERO	2012-02-09 (time not found yet)	55.90	86.15	Not reported	Not reported	2.6	mb	not found	not found

ID	Date and time UTC	Latitude	Longitude	Depth, km	Depth Status	Magnitude	Type	Intensity	Other solutions
KUZ-2012-02-09-BACHAT	2012-02-09 13:24	54.27	86.21	5 or 10	Fixed / Alternative Solutions	4.6	mb	not found	VNIMI/local solution reported M 3.8 at about 54.3029 N, 86.0756 E
KUZ-2013-03-04-BACHAT	2013-03-04 17:30	54.23	86.03	Not reported	Not reported	4.4	mb	not found	not found
KUZ-2013-06-18-BACHAT	2013-06-18 23:02:09.6	54.277	86.172	4	Preferred regional solution	6.1	ML	7 in Bachatsky and Starobachaty	unified catalog M 5.1; Adushkin table mb 5.8 and depths 11/4 km
KUZ-2013-06-18-BACHAT-A1	2013-06-18 23:37	54.30	86.08	Not reported	Not reported	4.3	mb	not found	not found
KUZ-2013-06-19-BACHAT-A2	2013-06-19 01:11	54.24	86.25	Not reported	Not reported	3.9	mb	not found	not found
KUZ-2013-06-19-BACHAT-A3	2013-06-19 06:00	54.27	86.09	Not reported	Not reported	4.4	mb	not found	not found
KUZ-2013-06-19-BACHAT-A4	2013-06-19 12:40	54.18	86.18	Not reported	Not reported	3.6	mb	not found	not found
KUZ-2013-06-19-BACHAT-A5	2013-06-19 14:53	54.21	86.18	Not reported	Not reported	3.6	mb	not found	not found
KUZ-2013-06-19-BACHAT-A6	2013-06-19 16:10	54.29	86.22	Not reported	Not reported	4.0	mb	not found	not found

ID	Date and time UTC	Latitude	Longitude	Depth, km	Depth Status	Magnitude	Type	Intensity	Other solutions
KUZ-2013-06-20-BACHAT-A7	2013-06-20 09:52	54.20	86.22	Not reported	Not reported	4.3	mb	not found	not found
KUZ-2013-06-26-BACHAT-A8	2013-06-26 16:09	54.25	86.11	Not reported	Not reported	4.0	mb	not found	not found
KUZ-2016-10-24	2016-10-24 16:14	53.45	87.47	0 or 10	Fixed / Alternative Solutions	4.5	mb	not found	not found
KUZ-2016-11-08	2016-11-08 21:38	53.35	87.36	0 or 10	Fixed / Alternative Solutions	4.6	mb	not found	not found
KUZ-2016-11-09	2016-11-09 12:57	54.07	86.44	0	fixed depth	4.6	mb	not found	not found
KUZ-2016-11-24	2016-11-24 11:08	53.36	87.26	10 or 0	fixed alternative solutions	4.5	mb	not found	not found
KUZ-2016-12-09	2016-12-09 08:26	53.36	87.49	0	fixed depth	4.6	mb	not found	not found
KUZ-2020-01-11-KRAS	2020-01-11 21:20:23.37	54.190	86.404	6	Verified annual catalogue	4.1	ML	not found	unified M 3.6
KUZ-2020-02-26-KRAS	2020-02-26 07:41:19.34	54.106	86.475	1	Verified annual catalogue	3.9	ML	not found	unified M 3.5
KUZ-2020-10-17-KRAS	2020-10-17 17:21:04.8	54.125	86.515	4	Verified annual catalogue	4.9	ML	not found	unified M 4.6
KUZ-2021-08-12-TALDA	2021-08-12 20:41:55.8	54.247	87.042	3	Verified annual catalogue	5.6	ML	4 in Bolshaya Talda and Prokopyevsk; 3 Novokuznetsk; 2 Kemerovo	unified M 5.1; early public values varied

ID	Date and time UTC	Latitude	Longitude	Depth, km	Depth Status	Magnitude	Type	Intensity	Other solutions
KUZ-2023-03-28-KIS	2023-03-28 09:11:22.9	54.028	86.459	1	Verified annual catalogue	4.5	ML	3 Kiselevsk; 2-3 Krasnobrodsky, Novokuznetsk, Prokopyevsk	unified M 4.2
KUZ-2023-09-02-KRAS	2023-09-02 23:56:04.9	54.193	86.417	1	Verified annual catalogue	4.2	ML	not found	unified M 3.9
KUZ-2024-07-24-SHORIA	2024-07-24 13:47:37.75	52.76	88.01	Not reported	Not specified in the operational message	4.6	not specified	Calculated 5.8 MSK-64	not found
KUZ-2024-09-19-SOUTH	2024-09-19 17:01:27.51	53.21	87.90	Not reported	Not specified in the operational message	4.6	not specified	Calculated 5.8 MSK-64	not found
KUZ-2024-09-26-KRAS	2024-09-26 15:55:27.65	54.090	86.48933	0.7	Verified site-specific catalogue	4.25	ML	operational calculation 5.3 MSK-64	operational 54.07, 86.40, M4.3
KUZ-2025-08-25-KRAS	2025-08-25 14:46:41.90	54.09	86.49	Not reported	Not specified in the operational message	3.9	not specified	Calculated 4.7 MSK-64	not found
KUZ-2026-10-10	2026-10-10 00:47:01.75	54.09	86.54	Not reported	not specified in the operational card of ASF	4.9	type not specified ASF	6.2 estimated, MSK-64	Kazakhstan NDC: M 5.2, K 11.8, 54.04 N, 86.47 E, depth 1 km; Mayak reproduction of a preliminary solution, published 2026-10-10 08:40: M 4.8, 54.16 N, 86.37 E, depth not specified; Main Center for Special Control of Ukraine operational feed, checked 2026-10-11: M 4.8, displayed time 03:47:06, 54.17 N, 86.32 E, time zone and depth not specified; EMSC: mb 5.1, 53.8438 N, 86.1776 E, depth 35 km

13.2. Key events of Kuzbass: origin, sequence and consequences

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-1966-09-20	not found	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude above the range attributed to industrial blasts in the study	Main / Separate	not found	not established within this check
KUZ-1988-02-TASHTAGOL	Tashtagol Mine	about 3 km according to study narrative	Classified as human-induced in the study	Yakovlev, Lazarevich, Tsirel 2013	shallow focus and proximity to mining	Separate / main	not found	shaking in Kochura; detailed damage not yet found
KUZ-1995-09-14	not found	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude criterion used by the author	Main / Separate	not found	not established within this check
KUZ-1997-04-25-ANZHERSK	closed Anzherskaya mine field	inside/near field of closed mine; exact distance not yet established	Associated with mine flooding in the study	Adushkin 2018	Hypocentres in the field of a closed mine after water level rose during flooding	Series element	ANZHERS K-FLOOD-1997	surface shaking up to 5 points; other consequences not yet established
KUZ-1997-04-27-ANZHERSK	closed Anzherskaya mine field	inside/near field of closed mine; exact distance not yet established	Associated with mine flooding in the study	Adushkin 2018	Hypocentres in the field of a closed mine after water level rose during flooding	Series element	ANZHERS K-FLOOD-1997	surface shaking up to 5 points; other consequences not yet established

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-1998-05-13	south of Kemerovo / Bachat-region table	Not reported	In the context of the study, a mining-related or human-induced tectonic origin is proposed.	Adushkin 2018	included in the number of events considered after the flooding of the mine and in selected Bachat-region chronology	Separate / Undefined	not found	not established within this check
KUZ-1999-10-24-TASHTAGOL	Tashtagol Mine	The project and event coordinates are approximately the same; the distance to the border has not yet been established.	presumed mining impact; E-PIE evidence insufficient	Lovchikov 2013 via HiQuake	listed as mining (rock burst); HiQuake E-PIE field says insufficient evidence	Separate / Undefined	not found	not established within this check
KUZ-2002-03-06	not found	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude criterion used by the author	Main / Separate	not found	not established within this check
KUZ-2008-01-11	Mezhdurechensk-area mining	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude and proximity-to-mining-area criteria used by the author	Main / Separate	not found	not established within this check
KUZ-2008-04-02	Mezhdurechensk-area mining	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude and proximity-to-mining-area criteria used by the author	Main / Separate	not found	not established within this check
KUZ-2008-10-13	Belovo-area mining	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude and proximity-to-mining-area criteria used by the author	Main / Separate	not found	not established within this check
KUZ-2011-02-12	mining in the Osinniki area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude and proximity-to-mining criteria used by the author	Main / Separate	not found	not established within this check

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2011-03-15	south of Kemerovo / flooded-mine context	Not reported	The study proposes a connection with the flooding of the mine	Adushkin 2018	indicated in the seismic analysis after the flooding of the mine	Separate / Undefined	not found	not established within this check
KUZ-2011-04-17	mining in the Osinniki area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event; magnitude and proximity-to-mining criteria used by the author	Main / Separate	not found	not established within this check
KUZ-2012-02-09-ANZHERO	Anzhero-Sudzhensk area of closed mines	Not reported	The study proposes a connection with the flooding of the mine	Adushkin 2018	indicated in the seismic analysis after the flooding of the mine	Separate / Undefined	not found	not established within this check
KUZ-2012-02-09-BACHAT	Bachatsky open-pit mine and nearby Mokhovskiy/Sartaki workings	Yakovlev et al. describe the 2012-2013 pre-mainshock group as 2-4 km west of the then open-pit mine boundary; event-specific distance remains to be measured	The researchers classified it as natural-human-induced; proposed human-induced tectonic by Adushkin	VNIMI expert investigation; Yakovlev et al. 2013; Adushkin 2018	the nature of the aftershock, waveforms and energy do not correspond to an industrial explosion; Rostekhnadzor did not identify the source of the explosion; the discrepancy between catalogue solutions was preserved	Main event of the pre-Bachatsky activation	BACHAT-2012-2014	tangible event; detailed consequences not yet established
KUZ-2013-03-04-BACHAT	Bachatsky-area mining	The distance to the verified border has not yet been established.	part of the extraction-induced activation according to the study.	Adushkin 2018; Emanov studies	Temporal and spatial sequence before the mainshock	Foreshock / Sequence Element	BACHAT-2012-2014	not established within this check

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2013-06-18-BACHAT	Bachatsky open-pit mine	epicentre attributed to the pit wall by Emanov et al. 2023; numeric distance to the historical boundary remains to be measured	In detailed studies, classified as human-induced/extractive-induced	Emanov et al. 2014, 2016, 2023	local observations before and after the event; shallow focus under the mining area; spatial structure and sequence; conclusion of the study	The mainshock	BACHAT-2012-2014	intensity 7 in Bachatsky and Starobachaty; official MChS media monitoring reported damage to more than 500 homes, about 5,000 stove chimneys and social facilities, a temporary accommodation point, and suspension of blasting; the final verified damage inventory remains to be recovered
KUZ-2013-06-18-BACHAT-A1	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the aftershock sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-19-BACHAT-A2	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-19-BACHAT-A3	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2013-06-19-BACHAT-A4	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-19-BACHAT-A5	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-19-BACHAT-A6	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-20-BACHAT-A7	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2013-06-26-BACHAT-A8	Bachatsky open-pit mine	Distance not yet established	aftershock in the Bachatskaya sequence	Adushkin 2018; Emanov studies	Spatiotemporal membership in the sequence	Aftershock	BACHAT-2012-2014	not established within this check
KUZ-2016-10-24	mining in the Osinniki area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event and magnitude criterion used by the author	Notable event / series element	KUZBASS-2016-ACTIVATION	not established within this check
KUZ-2016-11-08	mining in the Osinniki area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Night-time event and magnitude criterion used by the author	Notable event / series element	KUZBASS-2016-ACTIVATION	not established within this check
KUZ-2016-11-09	Belovo/Kaltan assignment requires verification	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Magnitude criterion used by author	Notable event / series element	KUZBASS-2016-ACTIVATION	not established within this check

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2016-11-24	Osinniki/Kaltan mining area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Magnitude criterion and mining proximity used by author	Notable event / series element	KUZBASS-2016-ACTIVATION	not established within this check
KUZ-2016-12-09	Osinniki/Kaltan mining area	Not reported	human-induced tectonic origin is proposed	Adushkin 2018	Magnitude criterion and mining proximity used by author	Notable event / series element	KUZBASS-2016-ACTIVATION	not established within this check
KUZ-2020-01-11-KRAS	Krasnobrodsky/Kiselevsk mining zone	The distance to the site boundary has not yet been established.	human-induced earthquake according to the official annual catalogue note	Annual catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences	Direct catalogue note	Event in a reactivated zone	KRASNOBRODSKY-2020-2026	not established within this check
KUZ-2020-02-26-KRAS	Krasnobrodsky/Kiselevsk mining zone	The distance to the site boundary has not yet been established.	human-induced earthquake according to the official annual catalogue note	Annual catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences	Direct catalogue note	Event in a reactivated zone	KRASNOBRODSKY-2020-2026	not established within this check
KUZ-2020-10-17-KRAS	Krasnobrodsky/Kiselevsk mining zone	The distance to the site boundary has not yet been established.	human-induced earthquake according to the official annual catalogue note	Annual catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences	Direct catalogue note	Event in a reactivated zone	KRASNOBRODSKY-2020-2026	felt in the region; confirmed damage not identified

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2021-08-12-TALDA	Taldinsky open-pit mine	The exact distance to the border on the relevant date has not yet been established	disputed/proposed mixed origin; special causal study not found	Regional authority statement; the annual catalogue provides parameters, not attribution	authority described a natural event with energy accumulated from nearby blasting; proximity and shallow focus do not resolve causality	Main / Separate	TALDINSK Y-2021	more than 100 calls; no deaths, injuries or destruction in the first messages
KUZ-2023-03-28-KIS	Krasnobrodsky/Kiselevsk mining zone	dated distance to the border not yet established	Origin not specified	not found	Proximity alone is not enough	Event in a reactivated zone	KRASNOB RODSKY-2020-2026	felt in several municipalities
KUZ-2023-09-02-KRAS	Krasnobrodsky mining zone	dated distance to the border not yet established	Origin not specified	not found	Proximity alone is not enough	Event in a reactivated zone	KRASNOB RODSKY-2020-2026	not established within this check
KUZ-2024-07-24-SHORIA	Tashtagol/Sheregesh Mining Area	not yet established	The message does not establish an origin; the latest scientific report describes the activations of 2024 in the mining areas	not found	Operational signal class only	Event in a reactivated zone	SHORIA-2024	felt; confirmed effects not yet established
KUZ-2024-09-19-SOUTH	southern Kuzbass mining area; exact site not yet established	not yet established	Origin not established in operational report	not found	Operational signal class only	Main / separate, requires verification	not found	felt; confirmed effects not yet established

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2024-09-26-KRAS	Krasnobrodsky open-pit mine	within the mapped site; the exact distance to the legal boundary has not yet been established.	The catalogue lists it as an earthquake; the cause is not explicitly stated	site-specific catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences	separated from 1,442 explosion records; signal class does not establish cause	Event in a reactivated zone	KRASNOB RODSKY-2020-2026	not established within this check
KUZ-2025-08-25-KRAS	Krasnobrodsky open-pit mine	about 3.3 km from 2026 ASF epicentre; distance to border not yet established	Origin not established	not found	Operational signal class only	Event in a reactivated zone	KRASNOB RODSKY-2020-2026	not established within this check

ID	Nearest site	Distance	Classification	Who classified	Reason	Role in the series	Series	Consequences
KUZ-2026-10-10	Krasnobrodsky open-pit mining district	distance depends on the solution of the epicentre and the boundary dataset; see separate distance tables	Origin not established	Working classification of the study	ASF classifies the signal as an earthquake, but its human or natural origin is not established; proximity alone is not enough; preliminary catalogue solutions differ materially	not assigned	not found	official MChS update at 10:45 local: information calls from residents; felt in four municipalities; housing and socially significant facilities inspected; no casualties or damage; coal enterprises and life-support systems operating normally

13.3. Key events of Kuzbass: sources and unresolved issues

ID	Primary or best available source	What remains undetermined
KUZ-1966-09-20	Adushkin 2018, table 4	nearest mine and boundary distance; consequences
KUZ-1988-02-TASHTAGOL	Yakovlev et al. 2013	exact date, time and coordinates
KUZ-1995-09-14	Adushkin 2018, table 4	verify apparent local-date typo; object, consequences and preferred depth

ID	Primary or best available source	What remains undetermined
KUZ-1997-04-25-ANZHERSK	Adushkin 2018	Time, coordinates and individual parameters of both events
KUZ-1997-04-27-ANZHERSK	Adushkin 2018	Time, coordinates and individual parameters
KUZ-1998-05-13	Adushkin 2018, table 5 and text	exact implicated object and causal basis require closer reading
KUZ-1999-10-24-TASHTAGOL	HiQuake 2026-09-24; Lovchikov 2013	time, depth, intensity and consequences
KUZ-2002-03-06	Adushkin 2018, table 4	object, consequences and alternative catalogue solutions
KUZ-2008-01-11	Adushkin 2018, table 4	Mine, distance and consequences
KUZ-2008-04-02	Adushkin 2018, table 4	Mine, distance and consequences
KUZ-2008-10-13	Adushkin 2018, table 4	Object, distance and consequences
KUZ-2011-02-12	Adushkin 2018, table 4	Object, distance and consequences
KUZ-2011-03-15	Adushkin 2018	time, object, preferred depth and consequences
KUZ-2011-04-17	Adushkin 2018, table 4	Object, distance and consequences
KUZ-2012-02-09-ANZHERO	Adushkin 2018	time, object, preferred depth and consequences
KUZ-2012-02-09-BACHAT	Yakovlev et al. 2013; Adushkin 2018 tables 4-5	Coordinate coordinates, type of magnitudes and depths between sources
KUZ-2013-03-04-BACHAT	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-18-BACHAT	FRC GS RAS event 86196; Emanov et al. 2014, 2016, 2023; Adushkin 2018; MChS Kuzbass media monitoring June 2013	final damage inventory, injuries/casualties confirmation and numerical distance to the historical open-pit mine boundary
KUZ-2013-06-18-BACHAT-A1	Adushkin 2018, table 5	Depth, intensity and consequences

ID	Primary or best available source	What remains undetermined
KUZ-2013-06-19-BACHAT-A2	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-19-BACHAT-A3	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-19-BACHAT-A4	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-19-BACHAT-A5	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-19-BACHAT-A6	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-20-BACHAT-A7	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2013-06-26-BACHAT-A8	Adushkin 2018, table 5	Depth, intensity and consequences
KUZ-2016-10-24	Adushkin 2018, table 4	Object, distance, consequences
KUZ-2016-11-08	Adushkin 2018, table 4	Object, distance, consequences
KUZ-2016-11-09	Adushkin 2018, table 4	object and location label need verification
KUZ-2016-11-24	Adushkin 2018, table 4	Object, distance, consequences
KUZ-2016-12-09	Adushkin 2018, table 4	Object, distance, consequences
KUZ-2020-01-11-KRAS	2020-ER_App05_Altai-and-Sayan-Mountains.xls, ASR2000243	Distance to the mine boundary and detailed mechanism
KUZ-2020-02-26-KRAS	2020-ER_App05_Altai-and-Sayan-Mountains.xls, ASR2001725	Distance to the mine boundary and detailed mechanism
KUZ-2020-10-17-KRAS	2020-ER_App05_Altai-and-Sayan-Mountains.xls, ASR2008725	Distance to the mine boundary and detailed mechanism

ID	Primary or best available source	What remains undetermined
KUZ-2021-08-12-TALDA	2021-ER_App05_Altai-and-Sayan-Mountains.xls, ASR2107250; regional authority statement reported by Interfax 2021-08-13	Dedicated focal-mechanism study, production/blast records and dated open-pit mine boundary
KUZ-2023-03-28-KIS	2023-ER_App06_Altai-and-Sayan-Mountains.xlsx, ASR2303006	Origin, mechanism and data of the mine
KUZ-2023-09-02-KRAS	2023-ER_App06_Altai-and-Sayan-Mountains.xlsx, ASR2308214	Origin, mechanism and data of the mine
KUZ-2024-07-24-SHORIA	https://seishub.ru/latest/event/asb2024onjhy.pdf	Proven depth, magnitude type, object, mechanism and consequences
KUZ-2024-09-19-SOUTH	https://seishub.ru/latest/event/asb2024sogcle.pdf	reviewed location, depth, magnitude type, object and mechanism
KUZ-2024-09-26-KRAS	https://doi.org/10.35540/gsras.er.2026.1.23 , ASRD2401690	Mechanism and history of mining
KUZ-2025-08-25-KRAS	https://seishub.ru/latest/event/asb2025qsitur.pdf	Proven depth, type, mechanism and consequences
KUZ-2026-10-10	Altai-Sayan Branch of FRC GS RAS operational notice asb2026txsirz; MChS Kuzbass updates 2026-10-10; Kazakhstan NDC; Mayak 2026-10-10 08:40; Main Center for Special Control of Ukraine operational feed checked 2026-10-11; EMSC	final reviewed hypocentre and type magnitude; final inspection results; causal assessment

13.4. Sequences, swarms, and reactivations

18 series. Major shocks, aftershocks and swarms are not considered independent identical cases.

Series ID	Period	Area or site	Number of records	Threshold/Coverage	Composition	Maximum Event	Evaluation	Reason
KUZBASS-1962-1980	1962-1980	Kuzbass regional observations	not yet extracted	not found	mixed background before rapid mining-related growth	1966 event about mb 5.0	background/pre-technogenic period in study	comparison with 1981-1995 and later periods

Series ID	Period	Area or site	Number of records	Threshold/Coverage	Composition	Maximum Event	Evaluation	Reason
OSINNIKI-2005	2005	Osinniki Mine Field	not yet found	not found	seismic swarm/flow-type events	not yet found	Mining-related shallow-focus activation	Shallow-focus events within the mine field and repeated felt tremors
POLYSAEVO-2007-2008	2007-2008 winter	Polysaev Mine Field	not yet found	not found	Clusters/swarms	not yet found	Mining-related shallow focus activation.	many hypocentres at 0.6-1.0 km and a deeper group around 1.2-2.5 km; repeated shaking
KUZBASS-1998-2016-PROPOSED	1998-2016	Kuzbass	more than 100	mb $\geq$ 3	Night-time events selected after excluding or contrasting industrial blasts	mb 5.8 in Adushkin table; ML 6.1 in Emanov solution for Bachat	proposed human-induced tectonic by author	night-time criterion and maximum expected blast magnitude
KUZBASS-2007-2016-NIGHT	2007-2016	Kuzbass	102	mb $\geq$ 3	51 at mb 3.0-3.4; 34 at 3.5-3.9; 11 at 4.0-4.4; 6 at $\geq$ 4.5	Bachatsky mainshock	proposed human-induced tectonic by author	events at night when industrial blasts were prohibited
BACHAT-2012-2014	2012-2014 with longer continuation	Bachatsky open-pit mine and surrounding mining area	initially 30-50 per day after mainshock; complete total not yet set	The threshold of the local network changed	foreshocks, ML 6.1 mainshock, aftershock sequence	ML 6.1 on 2013-06-18 UTC	classified as mining-induced/technogenic in detailed studies	Local networks before and after; shallow hypocentre, spatial structure; focal evidence and mining history
KUZBASS-2016-ACTIVATION	2016	Osinniki, Kaltan/Alardinskaya and Belovo-area clusters	at least five mb $\geq$ 4.5 events in Adushkin table	mb $\geq$ 4.5 for listed strong events	Multiple clusters	mb 4.6	proposed human-induced tectonic by Adushkin; more detailed local interpretation varies by cluster	magnitude/night criteria plus spatial monitoring

Series ID	Period	Area or site	Number of records	Threshold/Coverage	Composition	Maximum Event	Evaluation	Reason
KALTAN-2016-2017	late 2016 to April 2017	Kaltansky open-pit mine, adjacent dump, Alardinskaya underground workings	not yet found	about 2.5 $\leq$ ML $\leq$ 4 for described earthquakes	Felt sequence and local clusters recorded by a temporary seismic network of five stations	about ML 4	mining-related activation investigated; spatial clusters have different likely sources	stronger events outside pit at dump edge; separate cluster over underground workings
EQRU-KUZBASS-BBOX-2003-2023	2003-2023	52-56 N, 84-89 E coordinate background	4882	database detection/catalog threshold varies by year	earthquakes, rockbursts, induced and unclear events may all be present; industrial blasts are not assumed absent without annual-catalog check	official unified M maximum calculation not yet set	unclassified background	official database does not provide enough causal classification in export
GSRAS-RASPADSKAYA-2024	2024	Raspadskaya-Koksovaya mine area	3 earthquakes; 51 blasts	M $\geq$ 2.0	Earthquakes and industrial blasts are separated in the catalogue	unified M 3.0 among earthquake rows	catalogue event classification	official detailed catalogue
GSRAS-KOLYVANSKY-2024	2024	Kolyvansky Open-pit Mining District, Novosibirsk Oblast (outside Kemerovo Oblast)	8 earthquakes; 507 blasts	M $\geq$ 1.6	Earthquakes and industrial blasts are separated in the catalogue	ML 4.4 / unified M 3.8 on 2024-03-17	comparison out of coverage; excluded from the results for Kuzbass	site coordinates and administrative-boundary check
GSRAS-KRASNOBRODSKY-2024	2024	Krasnobrodsky open-pit mining district	13 earthquakes; 1442 blasts	M $\geq$ 1.6	Earthquakes and industrial blasts are separated in the catalogue	ML 4.25 / unified M 3.7 on 2024-09-26	catalogue event classification	official detailed catalogue
ASF-KEMEROVO-2025	2025	Administrative border of the Kemerovo region	74 earthquake notices; 234 quarry-blast notices	The threshold of operational registration is not fixed in the source index	Signals labeled "Earthquake" and "Quarry Explosion" are stored in separate files	M 4.2 on 2025-03-03 UTC	catalogue signal class only; causal origin of earthquake notices not established	Altai-Sayan Branch of FRC GS RAS operational notices; points filtered by the 2017 Kemerovo Oblast boundary from geoBoundaries/OSM

Series ID	Period	Area or site	Number of records	Threshold/Coverage	Composition	Maximum Event	Evaluation	Reason
ASF-KEMEROVO-2026	2026-01-01 to 2026-10-10	Administrative border of the Kemerovo region	37 earthquake notices; 113 quarry-blast notices	The threshold of operational registration is not fixed in the source index	Signals labeled "Earthquake" and "Quarry Explosion" are stored in separate files	M 4.9 on 2026-10-10 UTC; origin not established	catalogue signal class only; causal origin of earthquake notices not established	Altai-Sayan Branch of FRC GS RAS operational notices; points filtered by the 2017 Kemerovo Oblast boundary from geoBoundaries/OSM
KRASNOBRODSKY-2020	2020	Krasnobrodsky/Kiselevsk mining zone	3 explicitly identified technogenic earthquakes with ML 3.9-4.9; smaller events also catalogued	Only the above strong events	separate earthquakes, not treated as one aftershock sequence	2020-10-17 ML 4.9 (unified M 4.6)	technogenic earthquakes in the official annual catalogue	explicit notes in the reviewed FRC GS RAS catalog
TALDINSKY-2021	2021-08-12	Taldinsky open-pit mining area	One principal felt earthquake; associated sequence not reconstructed here.	ML 5.6 principal event	principal event; do not infer aftershocks without a dedicated sequence catalogue	ML 5.6; unified M 5.1; depth 3 km	disputed/proposed mixed origin; special causal study not found	regional authority described a natural event with energy accumulated from nearby blasting; shallow focus and mining-area location require further study
SEISHUB-KEMEROVO-2024	2024	Administrative border of the Kemerovo region	62 earthquake notices; 292 other operational notices, predominantly quarry blasts	The threshold of operational registration is not fixed	operational notices in which earthquakes are separated from blast and other signal labels	two operational M 4.6 notices (2024-07-24 and 2024-09-19)	signal labels, not cause	ASF operational PDF notices filtered by administrative boundary

Series ID	Period	Area or site	Number of records	Threshold/Coverage	Composition	Maximum Event	Evaluation	Reason
KRASNOBROD-SKY-2023-2026	2023 to 2026-10-10	Krasnobrodsky/Kiselevsk recurring seismic zone	multiple catalogued events; principal examples listed individually in core catalogue	Mixed proven and operational thresholds	recurrent events separated by months or years; not an aftershock sequence	2026-10-10 operational M 4.9	origin unresolved for the 2026 event and several recent events	spatial recurrence is a hypothesis-generating pattern only

13.5. Sequences: sources, event-level catalogues and gaps

Series ID	Source	Individual catalogue	Unresolved
KUZBASS-1962-1980	Yakovlev et al. 2013; Adushkin 2018	Only partial published tables	recover annual counts and exact inclusion rules
OSINNIKI-2005	Yakovlev et al. 2013	Complete event-by-event list not found	dates, count, coordinates, depths and damage
POLYSAEVO-2007-2008	Yakovlev et al. 2013	Complete event-by-event list not found	dates, count, coordinates and verified building damage
KUZBASS-1998-2016-PROPOSED	Adushkin 2018	tables of individual strong events; this is not a complete list	independent validation for each event
KUZBASS-2007-2016-NIGHT	Adushkin 2018	Aggregated quantities	individual list and exceptions
BACHAT-2012-2014	Emanov et al. 2014, 2016, 2023; Adushkin 2018	selected mb ≥ 3.5 events and official-catalog events available	full deduplicated local-network catalog
KUZBASS-2016-ACTIVATION	Adushkin 2018; Kaltan studies 2017 and 2019	Strong events are listed separately; local microseismic list not yet established	assign each event to verified underground-mine/open-pit-mine/waste-dump cluster
KALTAN-2016-2017	conference study 2017; Emanov et al. 2019, DOI 10.21455/VIS2019.3-1	Complete local list not found	event count, individual rows, impacts and exact boundaries

Series ID	Source	Individual catalogue	Unresolved
EQRU-KUZBASS-BBOX-2003-2023	FRC GS RAS Earthquakes of Russia database	Yes: data/eqru-kuzbass-bbox-2003-2023-with-ids.csv	polygon filtering, duplicates, nature of each event and monitoring-threshold changes
GSRAS-RASPADSKAYA-2024	FRC GS RAS DOI 10.35540/gsras.er.2026.1.23	Yes: data/gsras-kuzbass-2024-normalized.csv	The causal mechanism of the three earthquakes is not specified by the event-nature field
GSRAS-KOLYVANSKY-2024	FRC GS RAS DOI 10.35540/gsras.er.2026.1.23	Yes: data/gsras-kuzbass-2024-normalized.csv	retain only as a warning against geographic mixing
GSRAS-KRASNOBRODSKY-2024	FRC GS RAS DOI 10.35540/gsras.er.2026.1.23	Yes: data/gsras-kuzbass-2024-normalized.csv	causal mechanism and distances to verified open-pit mine boundary
ASF-KEMEROVO-2025	Altai-Sayan Branch of FRC GS RAS public event archive	Yes: data/kuzbass-operational-earthquakes-2025-2026.csv and data/seishub-kemerovo-2025-2026-blasts.csv	depth and magnitude type are absent from these notices; administrative boundary does not coincide with the geological boundary of the Kuznetsk basin; comparison with the verified annual catalogue and removal of duplicates has not yet been established
ASF-KEMEROVO-2026	Altai-Sayan Branch of FRC GS RAS public event archive	Yes: data/kuzbass-operational-earthquakes-2025-2026.csv and data/seishub-kemerovo-2025-2026-blasts.csv	series incomplete after 2026-10-10 by sample conditions; depth and magnitude type missing; deduplication against future reviewed annual catalogue not yet established
KRASNOBRODSKY-2020	2020-ER_App05_Altai-and-Sayan-Mountains.xls; ASR2000243, ASR2001725, ASR2008725	yes, in kuzbass-recorded-earthquakes-2006-2026-scope-aware.csv	dated mine boundaries, production/blast logs and focal mechanisms
TALDINSKY-2021	2021-ER_App05_Altai-and-Sayan-Mountains.xls, ASR2107250; regional authority statement reported by Interfax 2021-08-13	Yes	Dedicated focal-mechanism study, production and blast records, dated mine boundary
SEISHUB-KEMEROVO-2024	https://seishub.ru/ ; local archive sources/seishub-kuzbass-2024	yes, data/seishub-kemerovo-2024-earthquakes.csv and data/seishub-kemerovo-2024-blasts.csv	10 index cards failed to parse; unknown whether any fall inside Kemerovo Oblast; reviewed region-wide catalog not recovered
KRASNOBRODSKY-2023-2026	FRC GS RAS 2023-2024 catalogs; ASF operational notices 2025-2026	yes, data/kuzbass-core-events-v0.2.csv and the scope-aware catalog	reviewed 2025-2026 hypocentres, mechanisms, mine/blast/dewatering histories and consistent dated contours

13.6. Annual series of recorded events, 2006–2026

2006 and 2026 years are incomplete according to the accepted time window. Lower magnitudes reflect the composition of sources, not the proven threshold of network completeness.

Year	All records within scope	M ≥ 2.5	M ≥ 3.0	M ≥ 3.5	M ≥ 4.0	Maximum	Source Coverage
2006	3	1	0	0	0	2.944	Official Regional Annual Catalogue
2007	1	1	0	0	0	2.889	Official Regional Annual Catalogue
2008	3	1	1	0	0	3.056	Official Regional Annual Catalogue
2009	3	0	0	0	0	2.2	Official Regional Annual Catalogue
2010	2	0	0	0	0	2.111	Official Regional Annual Catalogue
2011	0	0	0	0	0	Not reported	Official regional catalogue; no events within the boundaries of the region
2012	2	2	2	2	1	4.3	Official Regional Annual Catalogue
2013	74	50	18	8	2	6.1	Official Regional Annual Catalogue
2014	124	34	7	1	0	3.6	Official Regional Annual Catalogue
2015	167	27	4	1	0	3.7	Official Regional Annual Catalogue
2016	121	35	14	8	3	4.68	Official Regional Annual Catalogue
2017	354	18	4	1	0	3.54	Official Regional Annual Catalogue
2018	30	30	9	4	1	4	Official Regional Annual Catalogue
2019	388	105	24	13	1	4.1	Official Regional Annual Catalogue
2020	378	62	21	8	4	4.9	Official Regional Annual Catalogue
2021	533	137	30	7	2	5.6	Official Regional Annual Catalogue

Year	All records within scope	M ≥ 2.5	M ≥ 3.0	M ≥ 3.5	M ≥ 4.0	Maximum	Source Coverage
2022	2514	102	25	11	2	4.4	Official Regional Annual Catalogue
2023	107	107	34	13	4	4.5	Official Regional Annual Catalogue
2024	62	42	25	7	4	4.6	operational messages; selection by administrative boundary of the region; verified values may differ
2025	74	30	12	7	3	4.2	operational messages; verified annual catalogue not yet available
2026	37	27	14	6	3	4.9	operational messages; verified annual catalogue not yet available

13.7. Seven analytical zones of Kuzbass

ID	Zone	Centre latitude	Centre longitude	Radius, km	Entries	M ≥ 2.5	M ≥ 3.0	M ≥ 3.5	Maximum	First entry	Last record	Episodes
KRB-KIS	Kiselevsk—Krasnobrodsky	54.1	86.49	16	139	62	29	15	4.9	2013-10-25 23:25:28.805	2026-10-10 00:47:01.75	38
BAC	Bachatsky open-pit mine	54.28	86.16	14	288	82	36	20	6.1	2012-02-09 13:24:04.16	2026-09-18 13:39:25.94	30
POL	Polysaevo—Leninsk-Kuznetsky	54.61	86.25	22	746	107	7	0	3.29	2009-11-10 19:49:12.7	2026-05-30 19:39:14.24	21
TAL	Taldinsky zone	54.25	87.04	18	620	59	12	2	5.6	2013-10-24 13:32:57.089	2026-01-01 23:14:00.54	21
KAL	Kaltan-Alardinskaya-Malinovka	53.39	87.42	20	237	33	11	8	4.06	2013-01-12 14:42:30.56	2026-06-27 23:38:12.61	12
RAS	Mezhdurechensk-Raspadskaya	53.73	88.13	22	1674	156	43	17	4.4	2012-04-27 17:40:23.16	2026-10-06 08:59:12.40	26

ID	Zone	Centre latitude	Centre longitude	Radius, km	Entries	M ≥ 2.5	M ≥ 3.0	M ≥ 3.5	Maximum	First entry	Last record	Episodes
SHO	Mountain Shoria: Tashtagol—Sheregesh	52.93	88.02	24	385	76	39	16	4.6	2007-11-25 06:37:26	2026-03-05 17:49:54.56	25

13.8. Distances from epicentre solutions 10 October 2026 to the OSM outline

Boolean point-in-polygon field: “No” means that the published epicentre solution lies outside the relevant mapped polygon; it does not mean that geometry is unavailable.

Solution	Latitude	Longitude	Object	Inside polygon?	To the object, km	To the border, km	Geometry date
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	Krasnobrodsky coal mine	No	1.024	1.024	2023-08-25T09:49:39Z
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	Vakhrushevsky coal mine	No	9.608	9.608	2023-08-25T09:49:39Z
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	Bachatsky open-pit mine	No	27.754	27.754	2023-08-25T09:49:39Z
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	Belovskaya open-pit mine	No	31.180	31.180	2023-08-25T09:49:39Z
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	Shestaki open-pit mine	No	39.795	39.795	2024-01-09T20:21:42Z
Kazakhstan NDC	54.040	86.470	Krasnobrodsky coal mine	No	7.163	7.163	2023-08-25T09:49:39Z
Kazakhstan NDC	54.040	86.470	Vakhrushevsky coal mine	No	8.070	8.070	2023-08-25T09:49:39Z
Kazakhstan NDC	54.040	86.470	Bachatsky open-pit mine	No	28.463	28.463	2023-08-25T09:49:39Z
Kazakhstan NDC	54.040	86.470	Belovskaya open-pit mine	No	38.161	38.161	2023-08-25T09:49:39Z
Kazakhstan NDC	54.040	86.470	Shestaki open-pit mine	No	40.817	40.817	2024-01-09T20:21:42Z

Solution	Latitude	Longitude	Object	Inside polygon?	To the object, km	To the border, km	Geometry date
The solution from the Mayak message, M 4.8	54.160	86.370	Krasnobrodsky coal mine	No	2.973	2.973	2023-08-25T09:49:39Z
The solution from the Mayak message, M 4.8	54.160	86.370	Bachatsky open-pit mine	No	14.243	14.243	2023-08-25T09:49:39Z
The solution from the Mayak message, M 4.8	54.160	86.370	Vakhrushevsky coal mine	No	21.970	21.970	2023-08-25T09:49:39Z
The solution from the Mayak message, M 4.8	54.160	86.370	Shestaki open-pit mine	No	26.426	26.426	2024-01-09T20:21:42Z
The solution from the Mayak message, M 4.8	54.160	86.370	Belovskaya open-pit mine	No	31.563	31.563	2023-08-25T09:49:39Z
operational feed of the GCCC of Ukraine, M 4.8	54.170	86.320	Krasnobrodsky coal mine	No	5.395	5.395	2023-08-25T09:49:39Z
operational feed of the GCCC of Ukraine, M 4.8	54.170	86.320	Bachatsky open-pit mine	No	11.122	11.122	2023-08-25T09:49:39Z
operational feed of the GCCC of Ukraine, M 4.8	54.170	86.320	Shestaki open-pit mine	No	23.434	23.434	2024-01-09T20:21:42Z
operational feed of the GCCC of Ukraine, M 4.8	54.170	86.320	Vakhrushevsky coal mine	No	24.935	24.935	2023-08-25T09:49:39Z
operational feed of the GCCC of Ukraine, M 4.8	54.170	86.320	Belovskaya open-pit mine	No	33.405	33.405	2023-08-25T09:49:39Z
EMSC	53.844	86.178	Vakhrushevsky coal mine	No	29.220	29.220	2023-08-25T09:49:39Z
EMSC	53.844	86.178	Krasnobrodsky coal mine	No	35.439	35.439	2023-08-25T09:49:39Z
EMSC	53.844	86.178	Bachatsky open-pit mine	No	44.192	44.192	2023-08-25T09:49:39Z
EMSC	53.844	86.178	Shestaki open-pit mine	No	54.251	54.251	2024-01-09T20:21:42Z

Solution	Latitude	Longitude	Object	Inside polygon?	To the object, km	To the border, km	Geometry date
EMSC	53.844	86.178	Belovskaya open-pit mine	No	66.674	66.674	2023-08-25T09:49:39Z

13.9. Distance to the boundary of the Global Energy Monitor object

Boolean point-in-polygon field: “No” means that the published epicentre solution lies outside the relevant mapped polygon; it does not mean that geometry is unavailable.

OSM and GEM describe different contours. Distances near 1 and 9.6 km are not two equivalent estimates of the same boundary.

Solution	Latitude	Longitude	ID GEM	Description of the outline	Inside polygon?	To the object, km	To the border, km
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	M0812.B1	Krasnobrodsky coal mine boundary, Krasnobrodskoye field	No	9.586	9.586
Altai-Sayan Branch of FRC GS RAS	54.090	86.540	M0812.B2	Krasnobrodsky coal mine boundary, Vakhrushevskoye field	No	12.688	12.688
Kazakhstan NDC	54.040	86.470	M0812.B1	Krasnobrodsky coal mine boundary, Krasnobrodskoye field	No	14.074	14.074
Kazakhstan NDC	54.040	86.470	M0812.B2	Krasnobrodsky coal mine boundary, Vakhrushevskoye field	No	10.583	10.583
Preliminary solution reproduced in the Mayak report	54.160	86.370	M0812.B1	Krasnobrodsky coal mine boundary, Krasnobrodskoye field	No	5.278	5.278
Preliminary solution reproduced in the Mayak report	54.160	86.370	M0812.B2	Krasnobrodsky coal mine boundary, Vakhrushevskoye field	No	24.814	24.814
operational feed of the GCCC of Ukraine	54.170	86.320	M0812.B1	Krasnobrodsky coal mine boundary, Krasnobrodskoye field	No	6.767	6.767

Solution	Latitude	Longitude	ID GEM	Description of the outline	Inside polygon?	To the object, km	To the border, km
operational feed of the GCCC of Ukraine	54.170	86.320	M0812.B2	Krasnobrodsky coal mine boundary, Vakhrushevskoye field	No	27.696	27.696

13.10. International Verified Cases: Parameters and Evaluation

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
Russia	Bachatsky open-pit mine, Kuzbass	2012-2020	Mainshock and approximately 5,000 aftershocks	6.1	ML	mainshock about 4 km	Open-pit coal mining	classified as human-induced in detailed studies	Dense observations before and after; hypocentres beneath the open pit, along it and under dumps; analysis of mechanism and stresses
Australia	Newcastle coalfield	1989-12-28 local	Newcastle earthquake	5.6; 5.4	ML / Mw	about 11 km in Geoscience Australia; HiQuake 9.1 km	Underground coal mining and drainage	Controversial connection	The Klose model proposes triggering by mining and groundwater drawdown; Quinn and co-authors believe that the model and regional seismicity do not support the conclusion

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
Australia	Ellalong Colliery, Hunter Valley	1994-08-06	Ellalong earthquake and preceding sequence	5.4	ML	about 1.3-1.5 km	Underground longwall coal mining	probable mining connection according to the cited studies	shallow focus and a sequence above the mine workings; complete original report not obtained
Poland	Bełchatów open-pit mine	1979 onward; strongest 1980-11-29	Series of seismicity in open-pit mining	~4.66 (1980-11-29)	reported M / ML	about 1-5 km for early events	open-pit mining of lignite and drainage	classified as induced in the cited primary studies	The first value comes from later reports; the second describes the first five studied events. Unloading and groundwater drawdown are direct factors; tectonic stress is an important indirect factor; magnitude sources are heterogeneous.

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
Germany	Ibbenbüren	1981, 1991, 2000	Coal-basin events	4.3 (1991); 4.6*	ML	less than 1 km in regional compilation	Underground coal mining	widely described as caused by extraction; HiQuake notes insufficient evidence	The first value comes from the German summary for the principal event, whereas HiQuake lists the second; the discrepancy and the mismatched HiQuake reference require caution.
Germany	Saar mine, Primsmulde	2008-02-23	Mining-related earthquake	4.0–4.1	ML / Mw	about 1.0-1.45 km	Underground coal mining	highly likely caused by mining	BGR location and the increase in activity over time; the government halted mining; later geomechanical study. Published Mw estimates differ.
Germany	Ruhr coalfield	19th-21st centuries	Recurrent coal-basin seismicity	~4.1; 3.9	Mw / ML	Shallow-focus	Underground coal mining	related to mining in regional literature	The values come from historical compilations; the industrial history is long and the evidence differs from event to event.

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
USA	Willow Creek Mine, Utah	2000-03-06/07	Major seismic event associated with mining	4.2	ML	about 1.8 km in HiQuake	Underground coal mining	related to mining in reports of the University of Utah	the largest historical mine event in the area studied; uncertainty of magnitude around ± 0.3
USA	Crandall Canyon Mine, Utah	2007-08-06	Seismic source in case of catastrophic mine collapse	3.9	ML	mine depth near 0.5-0.6 km	Underground coal mining	collapse, not the earthquake that caused the collapse	downward first-motion polarities, the moment tensor and InSAR; a trapdoor-style collapse with a faulting component
Czech Republic	Ostrava-Karviná coal basin	20th-21st centuries	Large dataset of observed mine events and rockbursts	up to about 3.75	Various	Mine depths	Underground coal mining	Established seismicity caused by mining	The magnitude value comes from the HiQuake coal subset; regional and underground networks document many more events, and for 1993–2005 alone, 80 rockbursts were analysed.

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
United Kingdom	North Staffordshire coalfield	20th century	Seismicity of the coal basin	Not reported	Various	Mine depth	Underground coal mining	mining-induced in published study	Magnitudes are case-specific; the published study examines spatial and temporal links with coal mining, subject to the limitations of older observations.
United Kingdom	Midlothian coalfield, Scotland	1980s	Local coal-basin events	Not reported	Various	Mine depth	Underground coal mining	Tremors associated with coal mining	Small local events were studied by comparing waveforms.
China	Mentougou coal mine, Beijing	1994-05-19	Mine earthquake	4.2	Reported magnitude	not recovered	Underground coal mining	Classified as mining-induced in the Chinese review	The review reports severe surface shaking and mine damage; primary Chinese study is still needed.
China	Taiji mine, Beipiao, Liaoning	1977-04-28	Mine earthquake	4.3	ML	not recovered	Underground coal mining	Classified as caused by mining in the review	the largest Chinese coal-mining event identified in the global review; an event-specific source is still needed

Country	Object	Date/Period	Event/Series	M	Magnitude type	Depth	Mining method	Origin assessment	Basis and limit
Russia	Kolyvansky open-pit mine, Novosibirsk Oblast	2019-01-09	Gorlovsky basin event	4.3	ML	about 4 km	Open-pit anthracite mining	human-induced activation according to Yemanov et al.	production growth after 2011 and detailed observations; the site is outside Kemerovo Oblast and is not part of the administrative series of Kuzbass

13.11. International cases: consequences and sources

Country	Object	Recorded consequences	Primary or best available source
Russia	Bachatsky open-pit mine, Kuzbass	local intensity 7 points; numerous damage to buildings and chimneys has been reported	https://doi.org/10.21455/VIS2016.4-3 ; https://doi.org/10.15372/GiG2023149
Australia	Newcastle coalfield	13 dead; more than 160 were hospitalised; damage to approximately 50,000 buildings	https://doi.org/10.1016/j.epsl.2007.02.009 ; https://doi.org/10.1016/j.epsl.2007.11.067 ; https://www.ga.gov.au/news/30-years-on-commemorating-the-1989-newcastle-earthquake
Australia	Ellalong Colliery, Hunter Valley	was felt in the region; detailed damage was not identified in this inspection	Jones et al. 1994 as cited by HiQuake and Australian Earthquake Engineering Society; Klose 2007
Poland	Bełchatów open-pit mine	intensity of early events 5–6 points; for the strongest, cracks and damage to chimneys were reported	https://doi.org/10.1016/0013-7952(81)90002-8 ; https://doi.org/10.2478/s11600-010-0030-9
Germany	Ibbenbüren	intensity about VI according to the German report; detailed damage not established	Grünthal and Minkley 2005 as summarized by German sources; GFZ/FKPE triggered-seismicity overview

Country	Object	Recorded consequences	Primary or best available source
Germany	Saar mine, Primsmulde	numerous building damages; no serious casualties; regional report reports approximately 8 000 claims of damage	https://www.seismologie.bgr.de/sdac/erdbeben/big_quakes/germany_080223_de_u.html ; Fritschen 2010
Germany	Ruhr coalfield	Building shaking and individual damages; here it is not summarized for each event	Grünthal 2014; German regional post-mining seismicity sources
USA	Willow Creek Mine, Utah	Ground-motion records are available; detailed consequences are not established here.	University of Utah/USGS Joes Valley working-group reports
USA	Crandall Canyon Mine, Utah	Six miners died in the collapse; a subsequent rockburst during rescue operations led to the death of rescuers	https://www.usgs.gov/publications/characterizing-6-august-2007-crandall-canyon-mine-collapse-alos-palsar-insar ; MSHA investigation
Czech Republic	Ostrava-Karviná coal basin	Damage to workings determines a subset of rockbursts; not every seismic event causes damage	https://doi.org/10.1016/j.tecto.2006.12.013 ; Holub et al. 2013
United Kingdom	North Staffordshire coalfield	The consequences depend on the event; here are not summarized	https://doi.org/10.1016/0148-9062(80)90005-4
United Kingdom	Midlothian coalfield, Scotland	not established	https://doi.org/10.1111/j.1365-246X.1989.tb02021.x
China	Mentougou coal mine, Beijing	damaged about 530 m of underground workings	https://doi.org/10.1016/j.ijrmms.2007.06.002
China	Taiji mine, Beipiao, Liaoning	felt in an area of about 1 200 km ² ; the Chinese review reports damage to approximately 2 100 m of workings	https://doi.org/10.1016/j.ijrmms.2007.06.002 ; https://doi.org/10.1016/j.earscirev.2017.07.008
Russia	Kolyvansky open-pit mine, Novosibirsk Oblast	was felt in nearby settlements; detailed damage has not been established.	Emanov et al. 2020/2021, Gorlovsky coal basin study

13.11A. Worldwide HiQuake mining corpus: event and site

The Mining category extends beyond conventional mineral extraction: it includes tunnelling, shaft mining and solution mining, collapses, rockbursts, flooding and mixed cases. The coordinates refer to the approximate point of the project and do not replace the coordinates of the epicentre and the historical boundary of the working.

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Russia	Mining	Bachatsky, Kuzbass	Coal	54.28395	86.16022	6.1	ML	2013-06-18	4000	0.58
China	Dissolution mining	Changning, Sichuan	salt	28.41	104.93	5.8	MW	2019-06-17	3400-5600	0.89
Germany	Mining: collapse/rockburst with liquid influence	Volkershausen (Ernst Thaelmann/Merkers mine)	Potassium salts	50.80275	10.05225	5.6	ML	1989-03-13	850-900	0.83
Australia	Mining and groundwater pumping	Newcastle	Coal	-32.96419	151.60697	5.6	ML	1989-12-27	9100	0.94
South Africa	Mining	President Brand Mine, Welkom	Gold	-28.032	26.738	5.6	mb	1994-10-30	2000-3000	0.61
South Africa	Mining	Moab Khotsonk near Orkney	Gold	-26.98734	26.80219	5.5	ML	2014-08-05	Not reported	0.25
Australia	Mining	Ellalong	Coal	-32.92418	151.29503	5.4	ML	1994-08-06	1300	0.83
Australia	Mining	Maitland	Coal	-32.73443	151.55632	5.3	ML	18/06/1868	Not reported	0.83
Australia	Mining	Boolaroo	Coal	-32.99646	151.59321	5.3	ML	9484	Not reported	0.83
South Africa	Mining	Klerksdorp (DRDGold's North West Operations)	Gold	-26.85294	26.64795	5.3	ML	2005-03-09	Not reported	0.3

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Dissolution mining	Attica, New York	not specified in the database	42.86403	-78.28051	5.2	ML	1929-08-12	Not reported	Insufficient evidence
Germany	Mining	Sunna (Suenna)	Potassium salts	50.79651	9.99865	5.2	ML	1975-06-23	800	Insufficient evidence
South Africa	Mining	Welkom	Gold	-27.9954	26.78156	5.2	ML	1976-12-08	Not reported	0.03
USA	Mining: collapse	Solvay mine, Wyoming	Trona (evaporite)	41.5011	-109.75818	5.2	mb	1995-02-03	500	0.33
USA	Mining	Morenci Mine, Arizona	Copper	33.10667	-109.3618	5.2	Not reported	2014-06-26	Not reported	0.06
Russia	Mining: rockburst	Umbozero Mine	Rare metals	67.6671	34.13314	5.1	ML	1999-08-17	Not reported	Insufficient evidence
Germany	Mining	Heringen	Potassium salts	50.90516	9.98956	5	ML	not found	Not reported	Insufficient evidence
Poland	Mining	Lubin mine	Copper	51.43429	16.12295	5	ML	1977-03-24	Not reported	Insufficient evidence
South Africa	Mining	Hartebeesfontein	Gold	-26.76111	26.42315	5	ML	1997-08-21	Not reported	Insufficient evidence
Australia	Mining	Kalgoorlie Super Pit	Gold	-30.77685	121.50537	5	ML	2010-04-20	10000	0.28
Canada	Mining: rockburst	Wright-Hargreaves mine, Ontario	Gold	48.15213	-80.03889	5	Not reported	1964	Not reported	0.3
Canada	Mining; reverse injection is possible.	Mosaic Company, Yorkton, Saskatchewan	Potassium salts	50.73218	-101.94425	5	Not reported	not found	Not reported	0
France	Quarrying	Le Teil Quarry	Limestone	44.52146	4.67745	4.9	MW	2019-11-11	<5000	0.64

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Dissolution mining	Changning, Sichuan	salt	28.58333	104.91667	4.8	ML	2008-02-01	Not reported	0.58
South Africa	Mining	Free State Goldfield	Gold	-27.962	26.76	4.7	ML	1989-01-25	1800	0.64
South Africa	Mining	Carletonville	Gold	-26.37486	27.40679	4.7	ML	1992-03-07	Not reported	0.28
Russia	Mining: collapse	Solikamsk, Upper Kama	Potassium salts	59.64149	56.91436	4.7	Not reported	1994-01-05	Not reported	0.03
Germany	Mining: collapse	Saale (Halle) (Teutschental mine)	Salt/potassium salts	51.48	11.79	4.6	MW	1940-05-24	1000	Insufficient evidence
Poland	Mining	Bełchatów	Coal	51.24477	19.28215	4.6	Not reported	1980-11-29	Not reported	0.58
China	Dissolution mining	Salt mine, Zigong, Sichuan	salt	29.4	104.78	4.6	ML	1985-03-29	Not reported	0.58
Germany	Mining	Ibbenbüren	Coal	52.29067	7.74219	4.6	ML	1991-05-16	Not reported	Insufficient evidence
Russia	Mining	Dnieper–Donets aulacogen	Iron	50.5	34	4.6	mb	2015-02-03	Not reported	0.06
USA	Mining	Moss No. 2, Virginia	Coal	36.95523	-82.18191	4.5	ML	1972-05-20	Not reported	0.3
Kazakhstan	Mining: collapse	Zhezkazgan Deposit (Zlatoyust-Belovskiy Quarry)	Copper	47.83596	67.38815	4.5	MS	1994-08-01	Not reported	0.58
Russia	Mining: rockburst	Rosvumchorr mine	not specified in the database	67.66374	33.73542	4.5	M	1995-10-26	Not reported	0.64
South Korea	Mining: collapse	Korea Airport Pyeonghae Mine, Uljin-gun, Gyeongbuk province	Limestone	36.93	129.37	4.4	MW	2016-02-23	Not reported	0.58

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining: Mining and Closure	Cacoosing Valley (Sinking Springs), Pennsylvania	Carbonate rock	40.34399	-76.01052	4.4	ML	1994-01-16	2000	0.3
Russia	Mining: rockburst	SKRU-2, Ural Mountains	Potassium salts	59.32471	56.93445	4.4	Not reported	1995-01-05	Not reported	0.58
Australia	Mining	Appin, Tower and West Cliff Collieries	Coal	-34.22093	150.81736	4.4	Not reported	1999-03-17	Not reported	0.58
Belarus	Mining	Soligorsk (Starobin deposit)	Potassium salts	52.86137	27.55946	4.4	Not reported	2003-12-18	Not reported	0.3
South Africa	Mining	Savuka, Carletonville	Gold	-26.42374	27.40873	4.4	ML	2007	Not reported	0.58
Russia	Mining	Kachkanar earthquake	not specified in the database	58.911	59.18406	4.4	ML	2010-03-30	21000	Insufficient evidence
China	Mining: collapse	Yuanfa mine, Lanling County, Shandong Province	Gypsum	117.89	34.66	4.39	MW	2019-12-28	0.1	Not assessed
China	Mining: collapse	Wanzao and Yurong Gypsum Mine, Pingyi County, Shandong Province	Gypsum	35.50251	117.63584	4.32	MW	2015-12-25	300	0.3
China	Mining	Taiji mine, Beipiao, Liaoning	Coal	41.79835	120.72424	4.3	ML	1977-04-28	550	0.89
China	Mining	Chayuan mine, Shizhu, Sichuan	Coal	not found	not found	4.3	ML	1987-07-02	Not reported	Insufficient evidence
Russia	Mining: rockburst	Kurgazakskaya Mine	Bauxite	54.44841	61.26422	4.3	ML	1990-05-28	Not reported	Insufficient evidence
China	Mining	Louguanshan #4 well, South Bureau, Sichuan	not specified in the database	not found	not found	4.3	ML	1994-04-15	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Russia	Mining	Kolyvansky open-pit mine, Gorlovsky Coal Basin	Coal	54.69	83.64	4.3	ML	2019-01-09	4000	0.89
South Korea	Mining: collapse	Taeyoung EMC, Samcheok city, Gangwon province	Limestone	37.25	129.09	4.2	MW	2015-01-31	Not reported	Insufficient evidence
China	Mining	Weixi mine, Leshan, Sichuan	salt	not found	not found	4.2	ML	1979-08-15	Not reported	Insufficient evidence
China	Mining	Mentougou mine, Beijing, Beijing	Coal	39.933	116.062	4.2	ML	1994-05-19	200	0.61
USA	Mining	Willow Creek, Utah	Coal	39.74916	-110.8365	4.2	ML	2000-03-07	1800	0.3
Poland	Mining	Rudna mine	Copper	51.50083	16.10818	4.2	MW	2013-03-19	1000	0.89
Sweden	Mining	Kiruna (Kiirunavaara) mine	Iron ore	67.83632	20.17337	4.2	MW	2020 (May)	Not reported	0.64
Spain	Mining: collapse	Reocín mine	Zinc	43.34444	-4.08556	4.1	mbLg	1965-01-07	Not reported	Insufficient evidence
Iran	Mining	Sangan mine	Iron	34.44841	60.39178	4.1	ML	not found	Not reported	0.28
Germany	Mining	Ruhr area	Coal	51.55	7.3	4.1	MW	1936-11-03	1000	Insufficient evidence
China	Mining	Huachu mine, Liuzhi, Guizhou	Coal	26.21275	105.64115	4.1	ML	1982-03-20	Not reported	Insufficient evidence
Russia	Mining: rockburst	Kirovsky Mine, Khibiny Massif (Kola Peninsula)	Apatite	67.63387	33.87671	4.1	ML	1989-04-16	220	0.03
Russia	Mining: rockburst	Blinovo-Kamensky Mine	Bauxite	56.36513	61.96131	4.1	ML	1994-07-29	Not reported	0.03

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Canada	Mining	Creighton, Ontario	not specified in the database	46.47332	-81.18664	4.1	MN	2006-11-29	Not reported	0.86
France	Mining	Lorraine	Iron	49.36	6.04	4	MW	1973-04-20	Not reported	Insufficient evidence
USA	Mining	Buchanan No. 1, Virginia	Coal	37.19794	-82.00844	4	ML	1988-04-14	Not reported	Insufficient evidence
USA	Mining	Lynch mine, Kentucky	Coal	36.96613	-82.91791	4	Not reported	1995-03-11	Not reported	0.3
South Africa	Mining	Western Deep Levels East	Gold	-26.41221	27.41237	4	ML	1996-05-05	3970?	0.58
Germany	Mining	Saar (Primsmulde), Saarland	Coal	49.36585	6.84296	4	ML	2008-02-23	1100	0.58
South Africa	Mining	Kloof	Gold	-26.41752	27.66153	4	ML	not found	Not reported	0.33
Canada	Mining	Belle Plaine	Potassium salts	50.43701	-105.18062	4	Not reported	not found	Not reported	Insufficient evidence
China	Mining: collapse	Antai Gypsum mine, Shandong Province	Gypsum	117.69	35.56	3.97	MW	2016-03-07	600	Not assessed
Netherlands	Mining: Groundwater Level Restoration	Voerendaal-Kunrade	Coal	50.87594	5.93324	3.9	ML	2001-06-23	<10000	0.86
Italy	Tunnel work and hydrological changes	Gran Sasso	Carbonate rock	42.45706	13.5803	3.9	Not reported	1992-08-25	Not reported	0.66
USA	Mining: collapse	Crandall Canyon, Utah	Coal	39.45992	-111.16763	3.9	ML	2007-08-06	500-600	0.91

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
South Africa	Mining	Deelkraal	Gold	-26.4676	27.30934	3.9	ML	not found	Not reported	Insufficient evidence
South Africa	Mining	East Driefontain	Gold	-26.38623	27.50342	3.9	ML	not found	Not reported	0.3
Germany	Mining	Peissenberg	Coal	47.83	11.1	3.8	MW	1967-09-16	Not reported	0.58
China	Mining	Wacang/Shimacao/Chenji apo mines, Yichang, Hubei	Coal	not found	not found	3.8	ML	1971-06-17	Not reported	Insufficient evidence
USA	Mining: collapse	King #4, Utah	Coal	39.48106	-111.07848	3.8	ML	1981-05-14	700	0.3
USA	Mining	Lynch No. 37, Kentucky	Coal	36.94505	-83.00334	3.8	ML	1994-08-03	Not reported	Insufficient evidence
China	Mining	Wulong mine, Fuxin, Liaoning	Coal	41.96485	121.63662	3.8	ML	2004-06-16	Not reported	0.03
Poland	Mining	Bobrek mine	Coal	50.34601	18.87804	3.8	ML	2007-02-09	Not reported	0.89
Canada	Mining	Copper Cliff North, Ontario	Nickel	46.4773	-81.05592	3.8	MN	2008-09-11	Not reported	0.28
Canada	Mining	Kidd Creek, Ontario	Copper and zinc	48.69026	-81.37354	3.8	MN	2009-01-06	Not reported	Insufficient evidence
South Africa	Mining	Elandsrand	Gold	-26.45685	27.35916	3.8	ML	not found	Not reported	Insufficient evidence
Poland	Mining	Pstrowski mine	Coal	50.34118	18.82933	3.8	ML	not found	Not reported	0.3
Poland	Mining	Mechowice mine	Coal	50.34892	18.84212	3.8	ML	not found	Not reported	0.3
Poland	Mining	Szombierki mine	Coal	50.33162	18.90851	3.8	ML	not found	Not reported	0.3
Czech Republic	Mining	CSA Mine, Ostrava-Karvina Coal Basin	Coal	50.53909	13.52132	3.75	Not reported	1983-04-27	Not reported	0.86

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
South Africa	Mining	East Rand Proprietary Mine (ERPM)	Gold	-26.24238	28.22115	3.7	ML	1965-09-17	Not reported	0.28
China	Mining	Nanshan mine, Hegang, Heilongjiang	Coal	47.27107	130.28429	3.7	ML	2001-02-01	347	Insufficient evidence
China	Mining	Laohutai mine, Fushun, Liaoning	Coal	41.8434	123.94141	3.7	ML	2002-01-26	300	0.61
Germany	Mining	Saar/Lorraine	Coal	49.38	6.84	3.7	MW	2008-02-23	1000	Insufficient evidence
South Africa	Mining	Mponeng	Gold	-26.43649	27.43193	3.7	ML	not found	Not reported	Insufficient evidence
South Africa	Mining	Leeudoorn	Gold	-26.44523	27.56667	3.7	ML	not found	Not reported	Insufficient evidence
China	Mining	Event No. 35	not specified in the database	35.51	105.42	3.6	ML	2018-02-03	Not reported	Not assessed
China	Mining	Huaibaoshi mine, Zigui, Yichang, Hubei	Coal	30.85533	110.77314	3.6	ML	1972-03-13	Not reported	Insufficient evidence
China	Mining	Taozhuang mine, Zaozhuang, Shandong	Coal	34.87765	117.34998	3.6	ML	1982-01-07	450	0.58
USA	Mining: collapse and rockburst	Jim Walter Resources, Inc., No. 4, Alabama	Coal	33.27959	-87.30683	3.6	ML	1986-05-07	Not reported	Insufficient evidence
China	Mining	Bingshuijing mine, Yingpan, Liuzhi, Guizhou	Coal	not found	not found	3.6	ML	1991-07-09	Not reported	Insufficient evidence
China	Mining	Liu zhi mine, Yingpan, Liuzhi, Guizhou	Coal	26.232	105.45	3.6	ML	1991-07-09	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining	Soldier Creek, Utah	Coal	39.53178	-110.68705	3.6	ML	1993-01-21	Not reported	Insufficient evidence
USA	Mining: collapse	Retsof, New York	salt	42.82459	-77.88523	3.6	Not reported	1994-03-12	Not reported	Insufficient evidence
USA	Mining: collapse	Genesee, New York	not specified in the database	42.74759	-77.8371	3.6	Not reported	1994	Not reported	Insufficient evidence
Russia	Mining: rockburst	Tashtagol Mine	Iron ore	52.76453	87.90915	3.6	ML	1999-10-24	Not reported	Insufficient evidence
China	Mining: collapse	Shunyuan mine, Zaozhuang, Shandong	Gypsum	not found	not found	3.6	ML	2002-05-20	Not reported	0.28
Russia	Mining: rockburst	Karnasurt Mine	Rare metals	67.88047	34.66727	3.6	ML	2002-12-17	Not reported	Insufficient evidence
Russia	Mining: Rock Shocks and Flooding	Vorkutinskoe earthquake	Coal	67.7099	64.48994	3.6	mb	2005-05-23	10000	0.55
China	Mining	Shimen Huatou Gypsum mine	Gypsum	29.37	111.36	3.6	Not reported	2006-08-19	Not reported	Not assessed
Australia	Mining	Fosterville Gold Mine	Gold	-36.72105	144.49656	3.5	Not reported	2024-11-05	0	Not assessed
USA	Mining: collapse	Cottonwood, Utah	Coal	39.31328	-111.15986	3.5	ML	1992-07-05	5600	0.58
Germany	Mining	Saar (Dilsburg Ost), Saarland	Coal	49.32928	6.93648	3.5	ML	2000 (November)	Not reported	0.86
Russia	Mining	Mine 15-15bis	Bauxite	60.15828	59.95604	3.5	ML	2010-02-13	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Australia	Mining	Olympia Dam	not specified in the database	-30.44202	136.83501	3.5	Not reported	2013-05-01	Not reported	0.55
USA	Mining	Lucky Friday Mine, Idaho	Silver, Lead, Zinc	47.47063	-115.78487	3.5	Not reported	not found	Not reported	0.61
Kazakhstan	Mining: collapse	Stepnyak	Gold	52.83571	70.78663	3.5	mpv	2003-05-08	Not reported	0.3
USA	Mining	Olga, West Virginia	Coal	37.38776	-81.6519	3.4	ML	1965-04-26	Not reported	0
United Kingdom	Mining: mining and collapse	North Staffordshire (Stoke on Trent)	Coal	52.97284	-2.19628	3.4	mb	1975-07-15	1000	0.86
USA	Mining: collapse	Sunnyside #3, Utah	Coal	39.54292	-110.38871	3.4	ML	1981-09-21	1600	Insufficient evidence
China	Mining	Xujiadong 711 mine, Chenzhou, Hunan	Uranium	25.86889	113.10896	3.4	ML	1998-03-12	Not reported	Insufficient evidence
China	Mining	San he jian mine, Xuzhou, Jiangsu	Coal	34.901	116.809	3.4	ML	2003-05-08	545	Insufficient evidence
Australia	Mining	Cadia	Gold	-33.45845	148.99566	3.4	ML	2013-02-18	0	Insufficient evidence
Poland	Mining	Zofiowka coal mine, Jastrzebie-Zdroj	Coal	49.96623	18.5653	3.4	ML	2018-05-05	Not reported	Insufficient evidence
China	Mining	Chengzi mine, Beijing, Beijing	Coal	39.948	116.073	3.4	ML	1974-10-25	330	0.3
USA	Mining	Wappingers Falls, New York	Carbonate rock	41.62903	-73.93878	3.3	mbn	1974-06-07	1000	0.61
USA	Dissolution mining	Cane (Kane) Creek Mine, Utah	Potassium salts	38.48435	-109.68008	3.3	ML	1984-01-22	Not reported	0.86

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining	Trail Mountain, Utah	Coal	39.31166	-111.21533	3.3	ML	1987-12-16	500	0.89
Germany	Tunnel work	Saar (Primsmulde), Saarland (Roadway construction)	not specified in the database	49.36585	6.84296	3.3	ML	2005 (May)	Not reported	0.58
Canada	Mining	Garson, Ontario	not specified in the database	46.56795	-80.85662	3.3	MN	2008-12-05	Not reported	Insufficient evidence
Canada	Mining: rockburst	Campbell mine, Ontario	not specified in the database	51.04988	-93.73384	3.3	MN	not found	Not reported	0.61
China	Mining	Huating mine, Pingliang, Gansu	Coal	35.22133	106.67391	3.3	ML	not found	Not reported	Insufficient evidence
Poland	Mining	Centrum mine	Coal	50.35371	18.89326	3.3	ML	not found	Not reported	0.58
Brazil	Quarrying	Cajati open-pit mine	Carbonate rock	-24.70172	-48.13339	3.2	MW	2015	Not reported	Not assessed
China	Mining	Event No. 32	not specified in the database	35.09	108.18	3.2	ML	2017-09-04	Not reported	Not assessed
China	Mining	Event No. 49	not specified in the database	39.08	110.23	3.2	ML	2021-03-10	Not reported	Not assessed
United Kingdom	Mining	Nottinghamshire	Coal	53.3	-0.95	3.2	ML	1984-03-22	Not reported	0.3
China	Mining	Niumasi mine, Shaoyang, Hunan	Coal	27.27222	111.67928	3.2	ML	1997-09-04	Not reported	Insufficient evidence
Russia	Mining: rockburst	Mine 14-14bis	Bauxite	60.15828	59.95604	3.2	ML	2004-03-25	Not reported	Insufficient evidence
South Korea	Mining	Dogye/Backwoon GMC, Samcheok city, Gangwon province	Coal	37.19	129.08	3.2	ML	2017-03-01	Not reported	0.33

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Quarrying	Wauregan Tilcon bedrock quarry, Plainfield, Connecticut	Orthogneiss	41.74527	-71.89001	3.1	MLG	2015-01-12	0	Not assessed
China	Mining	Event No. 50	not specified in the database	39.04	110.62	3.1	ML	2021-03-18	Not reported	Not assessed
Sweden	Mining: rockburst	Grängesberg ore mine	Iron ore	60.07618	14.99352	3.1	ML	1974-08-30	Not reported	Insufficient evidence
Germany	Mining	S-Harz	Salt/potassium salts	51.42	10.66	3.1	MW	1983-07-02	1000	Insufficient evidence
USA	Mining: collapse	Star Point #2, Utah	Coal	39.49983	-111.07683	3.1	ML	1991-02-06	4300	Insufficient evidence
China	Mining	Xifeng Nan shan mine, Lindong, Guizhou	Coal	27.151	106.732	3.1	ML	1991-04-06	Not reported	Insufficient evidence
Bulgaria	Dissolution mining	Provadia	Potassium salts	43.06	27.45	3.1	MD	1994-06-20	Not reported	0.28
China	Mining	Qixingjiezhen mine, Lianyuan, Hunan	Coal	27.89696	111.86499	3.1	ML	1996-03-28	Not reported	Insufficient evidence
China	Mining	Yueliangtian mine, Panjiang, Guizhou	Coal	25.37261	104.61799	3.1	ML	1997-12-05	Not reported	Insufficient evidence
China	Mining	Shanjiaocun mine, Panjiang, Guizhou	Coal	25.944	104.822	3.1	ML	1997-12-05	Not reported	Insufficient evidence
Canada	Mining	Macassa, Ontario	not specified in the database	48.14189	-80.072	3.1	MN	2008-07-12	Not reported	0.89
China	Mining	Mei tan ba mine, Xifenglun, Hunan	Coal	28.239	112.366	3.1	ML	2009-03-21	5000-8000	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
India	Mining: closure	Champion Reef, Kolar Gold field	Gold	12.94127	78.25734	3.09	ML	not found	1220	0.55
China	Mining	Event No. 9	not specified in the database	38.48	109.89	3	ML	2015-07-09	Not reported	Not assessed
China	Mining	Event No. 46	not specified in the database	34.66	117.89	3	ML	2020-05-31	Not reported	Not assessed
China	Mining	Event No. 51	not specified in the database	39.25	109.73	3	ML	2021-06-11	Not reported	Not assessed
China	Mining	Event No. 52	not specified in the database	38.29	117	3	ML	2021-08-31	Not reported	Not assessed
China	Mining	Event No. 53	not specified in the database	34.53	113.5	3	ML	2021-09-21	Not reported	Not assessed
China	Mining	Event No. 55	not specified in the database	28.32	111.14	3	ML	2022-09-17	Not reported	Not assessed
China	Mining	Event No. 56	not specified in the database	42.73	123.02	3	ML	2022-09-28	Not reported	Not assessed
China	Mining	Event No. 58	not specified in the database	38.94	109.68	3	ML	2023-01-14	Not reported	Not assessed
China	Mining	Event No. 59	not specified in the database	39.31	110.59	3	ML	2023-05-25	Not reported	Not assessed
Canada	Mining	Cory Mine, Saskatchewan	Potassium salts	52.09293	-106.85564	3	mb	1980-02-29	Not reported	0.89
USA	Mining: collapse	Deer Creek, Utah	Coal	39.35786	-111.11193	3	ML	1984-03-21	100	Insufficient evidence
USA	Mining: collapse	Castle Gate #3, Utah	Coal	39.72876	-110.8648	3	ML	1986-10-30	5600	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining	VP No. 3, Virginia	Coal	37.23237	-82.09956	3	ML	1987-03-04	Not reported	Insufficient evidence
China	Mining	Xindong mine, Shaoyang, Hunan	Coal	27.32601	110.83422	3	ML	1994-11-20	Not reported	Insufficient evidence
USA	Mining	Skyline #3, Utah	Coal	39.62583	-111.24084	3	ML	1996-06-02	5500	-0.06
China	Mining	Fangshan mine, Beijing, Beijing	Coal	39.785	115.915	3	ML	1997-02-18	520	0.61
USA	Mining: closure and flooding	Mineville, New York	not specified in the database	44.09364	-73.52461	3	Mc	not found	Not reported	Insufficient evidence
Poland	Mining	Polkowice mine	Copper	51.55574	16.04137	3	MW	not found	Not reported	Insufficient evidence
Canada	Mining: rockburst	Quirke mine, Ontario	Uranium	46.51147	-82.64334	3	Not reported	not found	Not reported	0.86
USA	Dissolution mining	Cleveland, Ohio	salt	41.49447	-81.71524	3	ML	not found	Not reported	0.03
USA	Mining	Galena mine, Idaho	Silver	47.47803	-115.96684	3	ML	not found	Not reported	0.86
China	Mining	Event No. 24	not specified in the database	38	109.51	2.9	ML	2016-09-17	Not reported	Not assessed
China	Mining	Event No. 41	not specified in the database	42.41	123.59	2.9	ML	2018-09-23	Not reported	Not assessed
China	Mining	Event No. 44	not specified in the database	34.78	118.09	2.9	ML	2019-12-28	Not reported	Not assessed
China	Mining	En kou mine, Lowde, Hunan	Coal	27.791	112.017	2.9	ML	1976-01-08	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining	Dillsburg, Pennsylvania	Iron ore	40.10305	-77.01233	2.9	ML	2009-04-24	Not reported	0.55
China	Mining	Event No. 8	not specified in the database	38.81	110.4	2.8	ML	2015-05-19	Not reported	Not assessed
China	Mining	Event No. 18	not specified in the database	38.95	110.57	2.8	ML	2016-01-13	Not reported	Not assessed
China	Mining	Event No. 30	not specified in the database	39.9	115.73	2.8	ML	2017-08-28	Not reported	Not assessed
China	Mining	Huayazi mine, Zigui, Yichang, Hubei	Coal	not found	not found	2.8	ML	1973 (March)	Not reported	Insufficient evidence
China	Mining	Shengli mine, Fushun, Liaoning	Coal	41.837	123.845	2.8	ML	1978-09-21	300	Insufficient evidence
China	Mining	Da he bian mine, Shiucheng, Guizhou	Coal	26.711	104.802	2.8	ML	1985-07-09	Not reported	Insufficient evidence
United Kingdom	Mining	Midlothian	Coal	55.851	-3.129	2.8	ML	1986-10-09	Not reported	0.55
China	Mining	Niwan mine, Xiangtan, Hunan	Gypsum	27.69171	112.43885	2.8	ML	2003-01-17	Not reported	Insufficient evidence
China	Mining	Benxi Caitun mine, Shenyang, Liaoning	Coal	41.31085	123.73343	2.8	ML	2004-04-13	Not reported	Insufficient evidence
China	Mining	Event No. 2	not specified in the database	37.43	111.19	2.7	ML	2014-11-25	Not reported	Not assessed
China	Mining: rockburst	Yuejin mine, Yima, Henan	Coal	34.72229	111.88818	2.7	ML	2010-08-11	Not reported	Not assessed
China	Mining	Baidong mine, Datong, Shanxi	Coal	40.00008	113.05566	2.7	ML	1983 (September)	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Sijiaotian mine, Yingpan, Liuzhi, Guizhou	Coal	not found	not found	2.7	ML	1985-01-21	Not reported	Insufficient evidence
China	Mining	Dizong mine, Yingpan, Liuzhi, Guizhou	Coal	26.20352	105.46049	2.7	ML	1985-01-21	Not reported	Insufficient evidence
China	Mining	Dayong mine, Yingpan, Liuzhi, Guizhou	Coal	26.18785	105.54797	2.7	ML	1985-01-21	Not reported	Insufficient evidence
Canada	Mining	Strathcona, Ontario	not specified in the database	46.63339	-81.38483	2.7	mN	1988-06-19	678	0.55
China	Mining	Dahuatang mine, Shaoyang, Hunan	Coal	25.779	112.828	2.7	ML	1997-12-04	Not reported	Insufficient evidence
China	Mining	Doulishan mine, Lowde, Hunan	Coal	27.69059	111.83983	2.7	ML	2009-02-19	Not reported	Insufficient evidence
China	Mining	Event No. 1	not specified in the database	38.91	110.69	2.6	ML	2014-11-08	Not reported	Not assessed
China	Mining	Event No. 21	not specified in the database	38.76	110.18	2.6	ML	2016-05-27	Not reported	Not assessed
China	Mining	Event No. 31	not specified in the database	38.85	110.29	2.6	ML	2017-08-29	Not reported	Not assessed
China	Mining	Event No. 45	not specified in the database	39.15	110.71	2.6	ML	2020-05-08	Not reported	Not assessed
China	Mining	Qingshan mine, Lianyuan, Hunan	pyrite	not found	not found	2.6	ML	1996-07-01	Not reported	Insufficient evidence
Spain	Mining: collapse	San Nicolás (Mieres) and Montsacro (Morcín – Riosa) mines	Coal	43.25284	-5.81794	2.6	mb	2001-02-19	Not reported	0.3
Sweden	Mining	Zingruvan	Zinc	58.81265	15.10972	2.6	MW	not found	Not reported	0.55

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Pingmeidong mine	not specified in the database	not found	not found	2.6	ML	2008-10-22	Not reported	Not assessed
China	Mining	Event No. 36	not specified in the database	38.95	109.42	2.5	ML	2018-04-08	Not reported	Not assessed
USA	Mining: seismicity after landslides	Bingham Canyon Mine, Utah	Copper	40.52524	-112.14791	2.5	ML	2013-04-10	<2000	0.86
China	Mining	Longfeng mine, Fushun, Liaoning	Coal	41.84868	124.00356	2.5	ML	1981-02-16	300	0.61
China	Mining	Yan guan mine, Zigui, Yichang, Hubei	Coal	31.095	110.76	2.5	ML	1988-05-14	Not reported	Insufficient evidence
France	Mining: closure and flooding	Gardanne	not specified in the database	43.45149	5.47133	2.5	Not reported	2005 (November)	Not reported	0.55
China	Mining	Huafeng mine, Xinwen, Shandong	Coal	35.865	117.149	2.5	ML	not found	710	Insufficient evidence
Spain	Mining: collapse	Lo Tacón (Torre Pacheco)	zinc-lead ore	37.61701	-0.88828	2.4	MW	1998-05-02	2600	0.83
Switzerland	Tunnel work	MFS Faïdo (Gotthard basetunnel)	Gneiss	46.53959	8.80179	2.4	ML	2006-03-25	500-1000	0.86
Canada	Mining	Fraser, Ontario	not specified in the database	46.66389	-81.33994	2.4	MN	2008-10-16	Not reported	Insufficient evidence
China	Mining	Event No. 26	not specified in the database	35.7	108.88	2.3	ML	2017-01-11	Not reported	Not assessed
USA	Mining	Lompoc diatomite mine, California	not specified in the database	34.60075	-120.45399	2.3	MD	1995-04-05	Not reported	0.3

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
USA	Mining	Florida, New York	not specified in the database	41.36018	-74.36141	2.3	Not reported	2003	Not reported	Insufficient evidence
China	Mining	Gangdong mine, Shuangyashan, Heilongjiang	Coal	46.532	131.309	2.3	ML	not found	Not reported	Insufficient evidence
Sweden	Mining	Dannemora	not specified in the database	60.20395	17.86024	2.27	MD	not found	Not reported	0.86
China	Mining	Qiao tou he mine, Lowde, Hunan	Coal	27.818	111.781	2.2	ML	1974-05-31	Not reported	Insufficient evidence
United Kingdom	Mining	Rotherham (Yorkshire)	Coal	53.42	-1.33	2.2	ML	1988-10-14	1900	Insufficient evidence
China	Mining	Kaiyang mine, Jinzhong, Kaiyang, Guizhou	Phosphorus	27.11063	106.85204	2.2	ML	1990-10-23	Not reported	Insufficient evidence
United Kingdom	Mining	Bargoed Mid Glamorgan (South Wales)	Coal	51.679	-3.26	2.2	ML	1992-08-17	1600	Insufficient evidence
South Africa	Mining	TauTona, Carletonville	Gold	-26.41669	27.42209	2.2	Not reported	2004-12-12	3600	0.55
Canada	Mining	Craig, Ontario	not specified in the database	46.63721	-81.36934	2.2	MN	2007-06-22	Not reported	Insufficient evidence
Poland	Mining	Wujek mine	Coal	50.24483	18.98876	2.2	MW	not found	Not reported	Insufficient evidence
Poland	Mining	Ziemowit mine	Coal	50.12594	19.12888	2.2	MW	not found	Not reported	Insufficient evidence
Japan	Mining: Hydraulic Excavation	Sunagawa mine	Coal	43.46869	141.99076	2.1	ML	1986-01-29	1180	0.89

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
United Kingdom	Mining	Buxton (Derbyshire)	Coal	53.24	-1.79	2.1	ML	1989-09-04	500	0.58
China	Mining	Jinhuagong mine, Datong, Shanxi	Coal	40.11033	113.16221	2.1	ML	not found	Not reported	Insufficient evidence
United Kingdom	Mining	Sunderland (Durham and Northumberland)	Coal	54.85	-1.27	2	ML	1988-05-05	7300	0.55
Netherlands	Mining: collapse	Montfort	Limestone	51.12943	5.94542	2	ML	2002-10-01	Not reported	Insufficient evidence
Czech Republic	Mining	Mayrau mine	Coal	50.16539	14.08306	2	ML	not found	Not reported	0.86
China	Mining	Shuikoushan mine, Hengnan, Hunan	Lead and zinc	26.58535	112.59575	2	ML	not found	Not reported	Insufficient evidence
United Kingdom	Mining	Bolton (Lancashire)	Coal	53.59	-2.37	1.7	ML	1989-03-11	2500	0.55
China	Mining	Shi xia jiang mine, Shaoyang, Hunan	Coal	26.994	110.691	1.6	ML	1991 (December)	Not reported	Insufficient evidence
USA	Dissolution mining	Oxy Geismar Cavern, Napoleon salt dome, Assumption Parish, Louisiana	salt	30.01058	-91.14337	1.6	MW	2012	470	0.55
China	Mining	Dongchuan mine, Yunnan	Copper	26.20225	102.94114	1.5	ML	2021 (January)	Not reported	Not assessed
Netherlands	Dissolution mining	Heiligerlee salt dome	salt	53.14321	7.00731	1.3	ML	2017-11-19	400-1500	Not assessed
United Kingdom	Mining: collapse	Boulby mine, North Yorkshire	salt, potassium salts, polygalite	54.55346	-0.8243	1.2	ML	2019-07-10	1000	0.28

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Finland	Mining	Pyhäsalmi	Zinc and copper	63.65905	26.04817	1.2	MW	not found	Not reported	0.89
USA	Mining	Beatrice, Virginia	Coal	37.20276	-81.98613	1	ML	1974-05-15	Not reported	0.58
USA	Dissolution mining	Dale, New York	salt	42.81937	-78.17313	1	ML	not found	Not reported	0.03
Australia	Mining: rock destruction	Moonee Colliery	Coal	-33.16427	151.62427	0.6	MW	1998	Not reported	Insufficient evidence
USA	Mining: collapse	Springfield Pike Quarry, Pennsylvania	Carbonate rock	40.0133	-79.53927	0.2	MW	2000-02-21	100	Insufficient evidence
Romania	Mining: Controlled collapse	Field II, Ocnele Mari	salt	45.08174	24.31716	0.2	MW	not found	Not reported	0.91
Netherlands	Dissolution mining	Twente shallow salt mines	salt	52.24165	6.82477	0	ML	not found	Not reported	Not assessed
China	Mining	Dagandshan Hydropower Station	not specified in the database	29.4495	102.21764	-0.2	MW	not found	Not reported	0.89
France	Dissolution mining	Arkema-Vauvert	salt	43.6735	4.30447	-0.24	MW	not found	Not reported	0.58
Canada	Tunneling the barrel	Underground Research Laboratory, Manitoba	not specified in the database	50.25314	-95.86482	-1.9	MW	not found	Not reported	0.61
China	Mining: collapse	Rongxing Gypsum Mine, Hubei Province	Gypsum	30.99252	112.25991	Not reported	Not reported	2021-02-16	Not reported	Not assessed
South Africa	Mining: collapse	Ophirton	not specified in the database	-26.22529	28.03437	Not reported	Not reported	1908	Not reported	Insufficient evidence
USA	Mining: collapse	Wilkes-Barre, Pennsylvania	Coal	41.24618	-75.8812	Not reported	Not reported	1954 (February)	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Italy	Mining	Raibl mine, Cave del Predil	not specified in the database	46.44	13.57	Not reported	Not reported	1965	Not reported	Insufficient evidence
China	Tunnelling: rockburst	Dongguashan (Shizishan copper mine), Tongling, Hunan (Roadway construction)	Copper	30.9321	117.78259	Not reported	Not reported	1999 (March)	850	0.55
China	Tunnelling: rockburst	Tianshengqiao II Hydropower Station (Head race tunnel construction)	Carbonate rock	24.95383	105.20404	Not reported	Not reported	1990-12-11	120-600	0.58
Canada	Mining: rockburst	Brunswick No. 12 mine	not specified in the database	47.47387	-65.88902	Not reported	Not reported	not found	Not reported	0.61
Australia	Mining	Queenstown, Tasmania	not specified in the database	-42.06882	145.56913	Not reported	Not reported	not found	Not reported	Insufficient evidence
India	Mining	Chinakuri Colliery	Coal	23.67325	86.86069	Not reported	Not reported	not found	Not reported	0.03
Russia	Mining	Gluboky Mine, Strel'tsovsk	Uranium	69.40019	30.73043	Not reported	Not reported	not found	Not reported	0.55
Canada	Mining: rockburst	Denison mine, Ontario	Uranium	46.49555	-82.60381	Not reported	Not reported	not found	Not reported	0.55
Japan	Mining: rockburst	Miike mine	Coal	33.01375	130.45588	Not reported	Not reported	not found	Not reported	Insufficient evidence
Australia	Mining	Mount Charlotte Mine	Gold	-30.72785	121.47958	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Fuli mine, Hegang, Heilongjiang	Coal	47.27207	130.28372	Not reported	Not reported	not found	400	Insufficient evidence
China	Mining	Didao mine, Jixi, Heilongjiang	Coal	45.35885	130.75349	Not reported	Not reported	not found	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Tiechang mine, Tonghua, Jilin	Coal	41.72826	126.18306	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Hongtoushan mine, Fushun, Liaoning	Copper	41.99672	124.51667	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Gaode mine, Fuxin, Liaoning	Coal	42.01161	121.70745	Not reported	Not reported	not found	Not reported	0.28
China	Mining	Dongliang mine, Fuxin, Liaoning	Coal	41.90973	121.56256	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Guanshan mine, Beipiao, Liaoning	Coal	41.81347	120.78564	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Datai mine, Beijing, Beijing	Coal	39.96903	115.94221	Not reported	Not reported	not found	460	Insufficient evidence
China	Mining	Tongjialiang mine, Datong, Shanxi	Coal	40.00653	113.09717	Not reported	Not reported	not found	240	Insufficient evidence
China	Mining	Meiyukou mine, Datong, Shanxi	Coal	40.02482	113.15107	Not reported	Not reported	not found	250	Insufficient evidence
China	Mining	Yongdingzhuang mine, Datong, Shanxi	Coal	40.01301	113.10379	Not reported	Not reported	not found	250	Insufficient evidence
China	Mining	Bayi mine, Zaozhuang, Shandong	Coal	not found	not found	Not reported	Not reported	not found	400	Insufficient evidence
China	Mining	Chaili mine, Zaozhuang, Shandong	Coal	34.9654	117.03476	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Wumei mine, Hebi, Henan	Coal	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Shier (Shi'er kuang?) mine, Pingdingshan, Henan	Coal	33.75992	113.37422	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Quantai mine, Xuzhou, Jiangsu	Coal	34.32972	117.33166	Not reported	Not reported	not found	590	0.28
China	Mining	Qishan mine, Xuzhou, Jiangsu	Coal	34.33263	117.40477	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Zhangxiaolou mine, Xuzhou, Jiangsu	Coal	34.34176	117.1053	Not reported	Not reported	not found	1025	Insufficient evidence
China	Mining	Zhangji mine, Xuzhou, Jiangsu	Coal	34.35968	117.0143	Not reported	Not reported	not found	575	Insufficient evidence
China	Mining	Leigu mine, Mianyang Beichuan, Sichuan	Coal	31.77874	104.43548	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Tianchi mine, Mianzhu, Sichuan	Coal	31.48595	104.13225	Not reported	Not reported	not found	240	Insufficient evidence
China	Mining	Yanshitai mine, Wansheng district, Nantong, Chongqing	Coal	28.96217	106.92569	Not reported	Not reported	not found	240	Insufficient evidence
China	Mining	Bajing mine, Gaoan, Jiangxi	Coal	28.17177	115.48285	Not reported	Not reported	not found	460	Insufficient evidence
China	Mining	Tungsten ore mine, Jiangxi	Tungsten ore	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Manganese mine, Zunyi, Guizhou	Manganese	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	South manganese mine, Huayuan, Hunan	Manganese	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Manganese mine, Taojiang, Hunan	Manganese	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Phosphorus mine, Yichang, Hubei	Phosphorus	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Yangmuxi mine, Changyang, Yichang, Hubei	Coal	30.46096	110.71898	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Songyi mine, Yichang, Hubei	Coal	30.12965	111.47706	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Gaofeng mine, Dachangjingtian, Guangxi	Metal ores	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Tongkeng mine, Dachangjingtian, Guangxi	Metal ores	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Manganese mine, Dounan, Yunnan	Manganese	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Manganese mine, Heqing, Yunnan	Manganese	not found	not found	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Dongguashan (Shizishan copper mine), Tongling, Hunan	Copper	30.9321	117.78259	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Zhenxing mine, Hegang, Heilongjiang	Coal	47.256	130.274	Not reported	Not reported	not found	400	Insufficient evidence
China	Mining	Yingcheng mine, Shulang, Jilin	Coal	44.151	125.943	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Xian mine, Liaoyuan, Jilin	Coal	42.95	125.162	Not reported	Not reported	not found	340	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	Taixin mine, Liaoyuan, Jilin	Coal	42.962	125.112	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Benxi Niuxintai mine, Shenyang, Liaoning	Coal	41.336	123.919	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Binggou mine, Jianchang county, Liaoning	Coal	40.776	119.769	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Changgouyu/Zhanggouyu mine, Beijing, Beijing	Coal	39.732	115.879	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Muchengjian mine, Beijing, Beijing	Coal	39.938	115.918	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Tangshan mine, Kailuan, Hebei	Coal	39.653	118.198	Not reported	Not reported	not found	580	Insufficient evidence
China	Mining	Guantai mine, Cixian, Hebei	Coal	36.298	114.078	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Xin zhou yao mine, Datong, Shanxi	Coal	40.106	113.304	Not reported	Not reported	not found	250	0.3
China	Mining	Suncun mine, Xinwen, Shandong	Coal	35.883	117.644	Not reported	Not reported	not found	720	0.55
China	Mining	Zhangzhuang mine, Xinwen, Shandong	Coal	35.824	117.752	Not reported	Not reported	not found	509	Insufficient evidence
China	Mining	Pan xi mine, Xinwen, Shandong	Coal	36.125	117.736	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Dongtan mine, Yankuang, Shandong	Coal	35.435	116.883	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Baodian mine, Yankuang, Shandong	Coal	35.284	116.843	Not reported	Not reported	not found	Not reported	Insufficient evidence

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Mining	#2 mine, Weishanhu, Shandong	Coal	35.361	116.596	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Qianqiu mine, Yima, Henan	Coal	34.718	111.883	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Yaoqiao mine, Datun, Jiangsu	Coal	34.881	116.912	Not reported	Not reported	not found	610	Insufficient evidence
China	Mining	Kong zhuang mine, Datun, Jiangsu	Coal	34.784	116.954	Not reported	Not reported	not found	550	Insufficient evidence
China	Mining	Wuyi mine, Shanxi	Coal	39.85	114.302	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Nantong mine, Nantong, Chongqing	Coal	28.913	106.769	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Hua gu shan mine, Xinyu, Jiangxi	Coal	27.919	114.979	Not reported	Not reported	not found	Not reported	Insufficient evidence
China	Mining	Fengdouyan, Jiupanshan, Qishuping and Beitou mines, Jiupanshan, Yichang, Hubei	Coal	29.558	114.87	Not reported	Not reported	not found	Not reported	Insufficient evidence
Russia	Mining: collapse	Berezniki-1 Mine	Potassium salts	59.42811	56.75829	Not reported	Not reported	not found	Not reported	0.64
Australia	Mining	Southern Colliery, German Creek	not specified in the database	-22.92952	148.55726	Not reported	Not reported	not found	Not reported	0.28
Chile	Mining	El Teniente	Copper	-34.08811	-70.38792	Not reported	Not reported	1992 (March)	Not reported	0.58
Japan	Mining	Horonai	not specified in the database	43.2225	141.90374	Not reported	Not reported	not found	Not reported	0.86

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
Norway	Tunnelling: rockburst	Road tunnel	not specified in the database	not found	not found	Not reported	Not reported	not found	Not reported	0.28
Sweden	Tunnelling: rockburst	Head race tunnel	not specified in the database	not found	not found	Not reported	Not reported	not found	Not reported	0.58
Switzerland / Italy	Tunnelling: rockburst	Simplon Tunnel	not specified in the database	46.27216	8.0977	Not reported	Not reported	not found	Not reported	0.03
Japan	Tunnelling: rockburst	Shimizu Tunnel	not specified in the database	36.81036	138.98798	Not reported	Not reported	not found	Not reported	0.03
Japan	Tunnelling: rockburst	Kanetsu (Kan-Etsu) Tunnel	not specified in the database	36.81768	138.91056	Not reported	Not reported	not found	Not reported	0.58
Sweden	Tunnelling: rockburst	Forsmark Nuclear Plant (Hydraulic tunnels construction)	not specified in the database	60.40429	18.17112	Not reported	Not reported	not found	Not reported	Insufficient evidence
Sweden	Tunnelling: rockburst	Ritsem Traffic Tunnel	Milonite	67.72226	17.46539	Not reported	Not reported	not found	Not reported	Insufficient evidence
Iraq	Dissolution mining	Mishraq	Sulfur	36.00569	43.29911	Not reported	Not reported	not found	Not reported	0.58
China	Tunnelling: rockburst	Yuzixi I Hydropower Station (Head race tunnel construction)	granodiorite and diorite	31.06271	103.40077	Not reported	Not reported	not found	250-600	0.3
China	Tunnelling: rockburst	Erlangshan Tunnel (Sichuan-Tibet Highway)	Argillite, Marl and Quartzite	29.84701	102.29016	Not reported	Not reported	not found	270-570	0.55
China	Tunnelling: rockburst	Qinling Railway Tunnel	Granite and gneiss	33.33885	105.02792	Not reported	Not reported	not found	>900	0.3
China	Tunnelling: rockburst	Cangling Tunnel (Taizhou-Jiyun Highway)	Tuff	28.75298	120.36634	Not reported	Not reported	not found	800	0.58

Country	Subclass	Project	Raw materials	Project latitude	Project longitude	Max M	Magnitude type	Date of maximum M	Depth, m	E-PIE
China	Tunnelling: rockburst	Pubugou Hydropower Station	Granite	29.20893	102.8381	Not reported	Not reported	not found	Not reported	0.58
China	Tunnelling: rockburst	Jinping II Hydropower Station (Auxiliary tunnel)	Marble	28.24835	101.64454	Not reported	Not reported	not found	2375	0.55
China	Tunnelling: rockburst	Lujialiang Tunnel (Chongqing-Yichang Highway)	not specified in the database	30.01274	108.3623	Not reported	Not reported	not found	Not reported	0.58
Sweden	Mining	Malmberget	Iron ore	67.18675	20.67913	Not reported	Not reported	not found	Not reported	0.58
Australia	Mining	Ridgeway Deep block cave mine	Gold	-33.46686	148.99367	Not reported	Not reported	not found	Not reported	0.03
China	Mining	Puqing Iron Mine	not specified in the database	not found	not found	Not reported	Not reported	2007-04-06	Not reported	Not assessed
Canada	Vibration of the crushing plant	Underground Uranium mine, Saskatchewan	Uranium	not found	not found	Not reported	Not reported	not found	Not reported	Not assessed

13.11B. Worldwide HiQuake mining corpus: distances, series and sources

An empty distance means that the numerical value in the consolidated register is not reported. It cannot be replaced by the distance from the approximate point of the project to itself.

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Russia	Bachatsky, Kuzbass	Not reported	Not reported	Not reported	Not reported	Emanov et al. (2014)
China	Changning, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2020), Wang et al. (2020c), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Germany	Volkershausen (Ernst Thaelmann/Merkers mine)	Not reported	Not reported	Not reported	Not reported	Alvarez-Garcia et al. (2013), Bennett et al. (1995b), Klose (2007c), Klose (2013), McGarr et al. (2002)
Australia	Newcastle	Not reported	Not reported	Not reported	2 aftershocks	Klose (2007b), Klose (2013)
South Africa	President Brand Mine, Welkom	Not reported	Not reported	Not reported	Not reported	Bennett et al. (1995a), Bennett et al. (1995b), Bowers (1997)
South Africa	Moab Khotsong near Orkney	Not reported	Not reported	Not reported	Not reported	Durrheim (2015a), Voosen (2017)
Australia	Ellalong	Not reported	Not reported	Not reported	Not reported	Jones et al. (1994), Klose (2007c), Klose (2013)
Australia	Maitland	Not reported	Not reported	Not reported	Not reported	Klose (2007c)
Australia	Boolaroo	Not reported	Not reported	Not reported	Not reported	Klose (2007c)
South Africa	Klerksdorp (DRDGold's North West Operations)	Not reported	Not reported	Not reported	Not reported	Durrheim (2010)
USA	Attica, New York	Not reported	Not reported	Not reported	Not reported	Heck and Bodle (1931), Nicholson (1992), Nicholson and Wesson (1992)
Germany	Sunna (Suenna)	Not reported	Not reported	Not reported	Not reported	Klose (2007c), Klose (2013)
South Africa	Welkom	Not reported	Not reported	Not reported	Not reported	Durrheim (2010), Durrheim (2006a; 2006b)
USA	Solvay mine, Wyoming	<5000	Reported upper bound or range	Not reported	Not reported	Bennett et al. (1995a), Bennett et al. (1995b)
USA	Morenci Mine, Arizona	Not reported	Not reported	Not reported	Not reported	Gonzalez-Huizar and Liu (2017)
Russia	Umbozero Mine	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
Germany	Heringen	Not reported	Not reported	Not reported	Not reported	Dahm et al. (2015)
Poland	Lubin mine	Not reported	Not reported	Not reported	Not reported	Gibowicz et al. (1979), Klose (2007c)
South Africa	Hartebeesfontein	Not reported	Not reported	Not reported	Not reported	Klose (2007c)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Australia	Kalgoorlie Super Pit	Not reported	Not reported	Not reported	Not reported	Gibson and Sandiford (2013)
Canada	Wright-Hargreaves mine, Ontario	Not reported	Not reported	Not reported	Not reported	Hedley and Udd (1989)
Canada	Mosaic Company, Yorkton, Saskatchewan	Not reported	Not reported	Not reported	Not reported	Verdon et al. (2016)
France	Le Teil Quarry	Not reported	Not reported	Not reported	Not reported	De Novellis et al. (2020)
China	Changning, Sichuan	Not reported	Not reported	19000	Not reported	Sun et al. (2017), Chen et al. (2023)
South Africa	Free State Goldfield	Not reported	Not reported	Not reported	Not reported	Durrheim (2006a; 2006b)
South Africa	Carletonville	Not reported	Not reported	Not reported	Not reported	Durrheim (2006a; 2006b)
Russia	Solikamsk, Upper Kama	Not reported	Not reported	Not reported	Not reported	Alvarez-Garcia et al. (2013)
Germany	Saale (Halle) (Teutschental mine)	Not reported	Not reported	Not reported	Not reported	Alvarez-Garcia et al. (2013), Grünthal (2014), Teyssoneyre et al. (2002)
Poland	Bełchatów	Not reported	Not reported	Not reported	5	Gibowicz et al. (1981), Wiejacz and Rudziński (2010)
China	Salt mine, Zigong, Sichuan	Not reported	Not reported	Not reported	Not reported	Zhang et al. (1993), Li et al. (2007), Chen et al. (2023), http://mrdata.usgs.gov/mineral-operations/
Germany	Ibbenbüren	Not reported	Not reported	Not reported	Not reported	Gestermann et al. (2015)
Russia	Dnieper–Donets aulacogen	Not reported	Not reported	Not reported	Not reported	Adushkin et al. (2016)
USA	Moss No. 2, Virginia	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
Kazakhstan	Zhezkazgan Deposit (Zlatoyust-Belovskiy Quarry)	Not reported	Not reported	Not reported	Not reported	German (2014), Sokolova et al. (2017)
Russia	Rosvumchorr mine	Not reported	Not reported	Not reported	Not reported	Adushkin (2016)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
South Korea	Korea Airport Pyeonghae Mine, Uljin-gun, Gyeongbuk province	Not reported	Not reported	Not reported	Not reported	Che et al. (2018), Hye Won Lee (personal communication, 2023)
USA	Cacoosing Valley (Sinking Springs), Pennsylvania	Not reported	Not reported	<4500	67 (aftershocks)	Seeber et al. (1998)
Russia	SKRU-2, Ural Mountains	Not reported	Not reported	Not reported	Not reported	Bennett et al. (1995a), Lovchikov (2013)
Australia	Appin, Tower and West Cliff Collieries	Not reported	Not reported	Not reported	Not reported	Clark (2009)
Belarus	Soligorsk (Starobin deposit)	Not reported	Not reported	Not reported	>1000	Paskaleva et al. (2006)
South Africa	Savuka, Carletonville	Not reported	Not reported	Not reported	11224, $-3.4 \leq ML \leq 4.4$	Julià et al. (2009)
Russia	Kachkanar earthquake	Not reported	Not reported	Not reported	Not reported	Adushkin (2016)
China	Yuanfa mine, Lanling County, Shandong Province	Not reported	Not reported	Not reported	Not reported	Ni et al. (2025)
China	Wanzao and Yurong Gypsum Mine, Pingyi County, Shandong Province	Not reported	Not reported	Not reported	7, $1.2 \leq ML \leq 4.0$	Wang et al. (2019), Chen et al. (2023), Ni et al. (2025)
China	Taiji mine, Beipiao, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Chayuan mine, Shizhu, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Russia	Kurgazakskaya Mine	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
China	Louguanshan #4 well, South Bureau, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Russia	Kolyvansky open-pit mine, Gorlovsky Coal Basin	Not reported	Not reported	Not reported	Not reported	Emanov et al. (2020)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
South Korea	Taeyoung EMC, Samcheok city, Gangwon province	Not reported	Not reported	Not reported	Not reported	Che et al. (2018), Hye Won Lee (personal communication, 2023)
China	Weixi mine, Leshan, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Mentougou mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
USA	Willow Creek, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
Poland	Rudna mine	Not reported	Not reported	Not reported	2236 >0.9ML in 2012	Lizurek et al. (2015), Rudziński et al. (2016)
Sweden	Kiruna (Kiirunavaara) mine	Not reported	Not reported	Not reported	Not reported	Dineva and Boskovic (2017), Kozłowska et al. (2020)
Spain	Reocín mine	Not reported	Not reported	Not reported	Not reported	González (2017)
Iran	Sangan mine	Not reported	Not reported	Not reported	140, $1.4 \leq M \leq 4.1$	Mansouri Daneshvar et al. (2018)
Germany	Ruhr area	Not reported	Not reported	Not reported	Not reported	Grünthal (2014)
China	Huachu mine, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Russia	Kirovsky Mine, Khibiny Massif (Kola Peninsula)	Not reported	Not reported	Not reported	Not reported	Eremenko et al. (2009), Klose (2007b), Kremenetskaya and Trjapitsin (1995), Lovchikov (2013)
Russia	Blinovo-Kamensky Mine	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
Canada	Creighton, Ontario	Not reported	Not reported	Not reported	26176, $-2.8 < MW < 0.9$	Vallejos and McKinnon (2011)
France	Lorraine	Not reported	Not reported	Not reported	Not reported	Grünthal (2014)
USA	Buchanan No. 1, Virginia	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
USA	Lynch mine, Kentucky	Not reported	Not reported	Not reported	Not reported	Bennett et al. (1995a)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
South Africa	Western Deep Levels East	Not reported	Not reported	Not reported	1000/day, $-2 \leq ML \leq 4$	Amidzic et al. (1999)
Germany	Saar (Primsmulde), Saarland	174	Reported exact value	Not reported	Not reported	Fritschen (2010), Klose (2013)
South Africa	Kloof	Not reported	Not reported	Not reported	32400	Milev and Spottiswoode (2002)
Canada	Belle Plaine	Not reported	Not reported	Not reported	2	Verdon et al. (2016)
China	Antai Gypsum mine, Shandong Province	Not reported	Not reported	Not reported	Not reported	Ni et al. (2025)
Netherlands	Voerendaal-Kunrade	Not reported	Not reported	Not reported	208, $-0.1 \leq ML \leq 3.9$	Slob et al. (2016), Muntendam-Bos et al. (2022)
Italy	Gran Sasso	Not reported	Not reported	Not reported	Not reported	Bella et al. (1998)
USA	Crandall Canyon, Utah	Not reported	Not reported	Not reported	Not reported	Pechmann et al. (2008)
South Africa	Deelkraal	Not reported	Not reported	Not reported	10000	Milev and Spottiswoode (2002)
South Africa	East Driefontain	Not reported	Not reported	Not reported	3200	Milev and Spottiswoode (2002)
Germany	Peissenberg	Not reported	Not reported	Not reported	Not reported	Grünthal (2014)
China	Wacang/Shimacao/Chenjiapo mines, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
USA	King #4, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
USA	Lynch No. 37, Kentucky	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
China	Wulong mine, Fuxin, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Poland	Bobrek mine	Not reported	Not reported	Not reported	4722	Marcak and Mutke (2013)
Canada	Copper Cliff North, Ontario	Not reported	Not reported	Not reported	Not reported	Vallejos and McKinnon (2011)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Canada	Kidd Creek, Ontario	Not reported	Not reported	Not reported	Not reported	Vallejos and McKinnon (2011)
South Africa	Elandsrand	Not reported	Not reported	Not reported	70000	Milev and Spottiswoode (2002)
Poland	Pstrowski mine	Not reported	Not reported	Not reported	Not reported	Fajklewicz and Jakiel (1989), Marcak and Mutke (2013)
Poland	Mechowice mine	Not reported	Not reported	Not reported	Not reported	Marcak and Mutke (2013)
Poland	Szombierki mine	Not reported	Not reported	Not reported	Not reported	Marcak and Mutke (2013)
Czech Republic	CSA Mine, Ostrava-Karvina Coal Basin	Not reported	Not reported	Not reported	1915, 53 ≥ 2 ML	Holub et al. (2012), Zedník and Pazdírková (2014)
South Africa	East Rand Proprietary Mine (ERPM)	Not reported	Not reported	Not reported	445	Durrheim (2015b), Durrheim and Riemer (2015)
China	Nanshan mine, Hegang, Heilongjiang	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Laohutai mine, Fushun, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Germany	Saar/Lorraine	Not reported	Not reported	Not reported	Not reported	Grünthal (2014)
South Africa	Mponeng	Not reported	Not reported	Not reported	80600	Milev and Spottiswoode (2002)
South Africa	Leeudorn	Not reported	Not reported	Not reported	90000	Milev and Spottiswoode (2002)
China	Event No. 35	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Huaibaoshi mine, Zigui, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Taozhuang mine, Zaozhuang, Shandong	Not reported	Not reported	Not reported	Not reported	Feng (2002), Li et al. (2007), Chen et al. (2023)
USA	Jim Walter Resources, Inc., No. 4, Alabama	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995), Long and Copeland (1989)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Bingshuijing mine, Yingpan, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007)
China	Liu zhi mine, Yingpan, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Wu and Zijian (1996), Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
USA	Soldier Creek, Utah	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
USA	Retsof, New York	Not reported	Not reported	Not reported	Not reported	Alvarez-Garcia et al. (2013), Bennett et al. (1995a)
USA	Genesee, New York	Not reported	Not reported	Not reported	Not reported	Seeber and Armbruster (1994) (unpublished report/proposal to Akzo Salt Inc.) in Seeber et al. (2004)
Russia	Tashtagol Mine	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
China	Shunyuan mine, Zaozhuang, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Russia	Karnasurt Mine	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
Russia	Vorkutinskoe earthquake	Not reported	Not reported	Not reported	Not reported	Adushkin (2016)
China	Shimen Huatou Gypsum mine	Not reported	Not reported	Not reported	Not reported	Tong et al. (2009), Chen et al. (2023)
Australia	Fosterville Gold Mine	Not reported	Not reported	Not reported	10	https://www.bendigoadvertiser.com.au/story/8811062/35-earthquake-shakes-elmore-no-immediate-damage/
USA	Cottonwood, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
Germany	Saar (Dilsburg Ost), Saarland	Not reported	Not reported	Not reported	300 (up to per month)	Fritschen (2010)
Russia	Mine 15-15bis	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
Australia	Olympia Dam	Not reported	Not reported	Not reported	Not reported	Balfour et al. (2014)
USA	Lucky Friday Mine, Idaho	Not reported	Not reported	Not reported	>50 (M>1)	Hsiung et al. (1992)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Kazakhstan	Stepnyak	Not reported	Not reported	Not reported	Not reported	Sokolova et al. (2017)
USA	Olga, West Virginia	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
United Kingdom	North Staffordshire (Stoke on Trent)	Not reported	Not reported	Not reported	Not reported	Westbrook et al. (1980)
USA	Sunnyside #3, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
China	Xujiadong 711 mine, Chenzhou, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	San he jian mine, Xuzhou, Jiangsu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Australia	Cadia	Not reported	Not reported	Not reported	Not reported	Balfour et al. (2014)
Poland	Zofiowka coal mine, Jastrzebie-Zdroj	Not reported	Not reported	Not reported	Not reported	not found
China	Chengzi mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
USA	Wappingers Falls, New York	Not reported	Not reported	Not reported	>100 (aftershocks)	Klose (2013), McGarr et al. (2002), Pomeroy et al. (1976)
USA	Cane (Kane) Creek Mine, Utah	Not reported	Not reported	Not reported	Not reported	Wong and Humphrey (1989), Wong et al. (1996)
USA	Trail Mountain, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002), Arabasz et al. (2005)
Germany	Saar (Primsmulde), Saarland (Roadway construction)	Not reported	Not reported	Not reported	Not reported	Fritschen (2010)
Canada	Garson, Ontario	Not reported	Not reported	Not reported	Not reported	Vallejos and McKinnon (2011)
Canada	Campbell mine, Ontario	Not reported	Not reported	Not reported	Not reported	Hedley and Udd (1989)
China	Huating mine, Pingliang, Gansu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Poland	Centrum mine	Not reported	Not reported	Not reported	Not reported	Marcak and Mutke (2013)
Brazil	Cajati open-pit mine	Not reported	Not reported	Not reported	9, $2.0 \leq MW \leq 3.2$	Assumpção et al. (2025)
China	Event No. 32	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 49	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
United Kingdom	Nottinghamshire	Not reported	Not reported	Not reported	Not reported	Redmayne (1988)
China	Niumasi mine, Shaoyang, Hunan	Not reported	Not reported	Not reported	Not reported	Tong et al. (2003), Li et al. (2007), Chen et al. (2023)
Russia	Mine 14-14bis	Not reported	Not reported	Not reported	Not reported	Lovchikov (2013)
South Korea	Dogye/Backwoon GMC, Samcheok city, Gangwon province	Not reported	Not reported	Not reported	222	Son et al. (2015), Hye Won Lee (personal communication, 2023)
USA	Wauregan Tilcon bedrock quarry, Plainfield, Connecticut	1500	Reported exact value	Not reported	>180	Ebel et al. (2016)
China	Event No. 50	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
Sweden	Grängesberg ore mine	Not reported	Not reported	Not reported	Not reported	Chouhan (1992)
Germany	S-Harz	Not reported	Not reported	Not reported	Not reported	Grünthal (2014)
USA	Star Point #2, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
China	Xifeng Nan shan mine, Lindong, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Bulgaria	Provadia	4500	Reported exact value	8000	95 within first 3 months	Knoll et al. (1996)
China	Qixingjiezhen mine, Lianyuan, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Yueliangtian mine, Panjiang, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Shanjiaocun mine, Panjiang, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Canada	Macassa, Ontario	Not reported	Not reported	Not reported	10351, -1.7<MW<0.7	Vallejos and McKinnon (2011)
China	Mei tan ba mine, Xifenglun, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Tong and Min (2010), Chen et al. (2023)
India	Champion Reef, Kolar Gold field	Not reported	Not reported	Not reported	67	Shivakumar et al. (1996)
China	Event No. 9	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 46	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 51	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 52	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 53	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 55	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 56	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 58	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 59	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
Canada	Cory Mine, Saskatchewan	Not reported	Not reported	Not reported	79	Gendzwill et al. (1982)
USA	Deer Creek, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
USA	Castle Gate #3, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
USA	VP No. 3, Virginia	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
China	Xindong mine, Shaoyang, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
USA	Skyline #3, Utah	Not reported	Not reported	Not reported	Not reported	Arabasz et al. (2002)
China	Fangshan mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Wang et al. (2018), Chen et al. (2023)
USA	Mineville, New York	Not reported	Not reported	Not reported	Not reported	Armbruster (1990) (unpublished data) in Seeber et al. (2004)
Poland	Polkowice mine	Not reported	Not reported	Not reported	Not reported	Gibowicz (1998)
Canada	Quirke mine, Ontario	Not reported	Not reported	Not reported	Not reported	Hedley and Udd (1989)
USA	Cleveland, Ohio	Not reported	Not reported	Not reported	Not reported	Nicholson (1992)
USA	Galena mine, Idaho	Not reported	Not reported	Not reported	Not reported	Swanson (1992)
China	Event No. 24	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 41	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 44	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	En kou mine, Lowde, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
USA	Dillsburg, Pennsylvania	Not reported	Not reported	Not reported	600	Kim et al. (2009)
China	Event No. 8	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 18	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 30	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Huayazi mine, Zigui, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Shengli mine, Fushun, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014)
China	Da he bian mine, Shiucheng, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
United Kingdom	Midlothian	Not reported	Not reported	Not reported	Not reported	Turbitt (1988)
China	Niwan mine, Xiangtan, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Benxi Caitun mine, Shenyang, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Event No. 2	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Yuejin mine, Yima, Henan	Not reported	Not reported	Not reported	Not reported	Cao et al. (2023), Li (2025)
China	Baidong mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Sijiaotian mine, Yingpan, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Dizong mine, Yingpan, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Dayong mine, Yingpan, Liuzhi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Canada	Strathcona, Ontario	Not reported	Not reported	Not reported	7	Trifu et al. (1995)
China	Dahuatang mine, Shaoyang, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Doulishan mine, Lowde, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Tong et al. (2009), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Event No. 1	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 21	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 31	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Event No. 45	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
China	Qingshan mine, Lianyuan, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
Spain	San Nicolás (Mieres) and Montsacro (Morcín – Riosa) mines	Not reported	Not reported	Not reported	300	González-Cortina et al. (2008)
Sweden	Zingruvan	Not reported	Not reported	Not reported	5712, $-2.4 \leq MW \leq 2.6$	Nuannin et al. (2005)
China	Pingmeidong mine	Not reported	Not reported	Not reported	Not reported	Li (2014), Chen et al. (2023)
China	Event No. 36	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
USA	Bingham Canyon Mine, Utah	Not reported	Not reported	Not reported	16, $-0.8 \leq Md \leq 2.6$	Pankow et al. (2014)
China	Longfeng mine, Fushun, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Yan guan mine, Zigui, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
France	Gardanne	Not reported	Not reported	Not reported	Not reported	Matrullo et al. (2015)
China	Huafeng mine, Xinwen, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Spain	Lo Tacón (Torre Pacheco)	Not reported	Not reported	Not reported	Not reported	Alvarez-Garcia et al. (2013)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Switzerland	MFS Faido (Gotthard basetunnel)	Not reported	Not reported	200	112	Husen et al. (2012)
Canada	Fraser, Ontario	Not reported	Not reported	Not reported	Not reported	Vallejos and McKinnon (2011)
China	Event No. 26	Not reported	Not reported	Not reported	Not reported	Wang et al. (2025)
USA	Lompoc diatomite mine, California	Not reported	Not reported	Not reported	4	McGarr et al. (2002), Sylvester and Heinemann (1996)
USA	Florida, New York	Not reported	Not reported	Not reported	Not reported	Seeber et al. (2004)
China	Gangdong mine, Shuangyashan, Heilongjiang	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Sweden	Dannemora	Not reported	Not reported	Not reported	1337	Holmgren (2015)
China	Qiao tou he mine, Lowde, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
United Kingdom	Rotherham (Yorkshire)	Not reported	Not reported	Not reported	Not reported	Wilson et al. (2015)
China	Kaiyang mine, Jinzhong, Kaiyang, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
United Kingdom	Bargoed Mid Glamorgan (South Wales)	Not reported	Not reported	Not reported	Not reported	Wilson et al. (2015)
South Africa	TauTona, Carletonville	Not reported	Not reported	Not reported	Not reported	Heesakkers et al. (2005)
Canada	Craig, Ontario	Not reported	Not reported	Not reported	Not reported	Vallejos and McKinnon (2011)
Poland	Wujek mine	Not reported	Not reported	Not reported	Not reported	Gibowicz (1998)
Poland	Ziemowit mine	Not reported	Not reported	Not reported	Not reported	Gibowicz (1998)
Japan	Sunagawa mine	Not reported	Not reported	Not reported	27	Sato et al. (1986) Sato and Fujii (1989)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
United Kingdom	Buxton (Derbyshire)	Not reported	Not reported	Not reported	Not reported	Wilson et al. (2015)
China	Jinhuagong mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
United Kingdom	Sunderland (Durham and Northumberland)	Not reported	Not reported	Not reported	Not reported	Wilson et al. (2015)
Netherlands	Montfort	Not reported	Not reported	Not reported	Not reported	Van Den Eeckhaut et al. (2007)
Czech Republic	Mayrau mine	Not reported	Not reported	Not reported	3090	Číž and Růžek (1997)
China	Shuikoushan mine, Hengnan, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
United Kingdom	Bolton (Lancashire)	Not reported	Not reported	Not reported	Not reported	Wilson et al. (2015)
China	Shi xia jiang mine, Shaoyang, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
USA	Oxy Geismar Cavern, Napoleon salt dome, Assumption Parish, Louisiana	Not reported	Not reported	Not reported	62	Nayak and Dreger (2014)
China	Dongchuan mine, Yunnan	Not reported	Not reported	Not reported	Not reported	Wu et al. (2024)
Netherlands	Heiligerlee salt dome	Not reported	Not reported	Not reported	47, -1.21≤ML≤1.3	Muntendam-Bos et al. (2022)
United Kingdom	Boulby mine, North Yorkshire	Not reported	Not reported	Not reported	Not reported	BGS (2019)
Finland	Pyhäsalmi	Not reported	Not reported	Not reported	8000	Oye and Roth (2005)
USA	Beatrice, Virginia	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
USA	Dale, New York	Not reported	Not reported	Not reported	Not reported	Nicholson (1992), Nicholoso and Wesson (1992)
Australia	Moonee Colliery	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
USA	Springfield Pike Quarry, Pennsylvania	Not reported	Not reported	Not reported	Not reported	Iannacchione and Zelanko (1995)
Romania	Field II, Ocnele Mari	Not reported	Not reported	Not reported	2392	Trifu and Shumila (2010)
Netherlands	Twente shallow salt mines	Not reported	Not reported	Not reported	59, $-2.6 \leq ML \leq 0$	Muntendam-Bos et al. (2022)
China	Dagandshan Hydropower Station	Not reported	Not reported	Not reported	Not reported	Xu et al. (2012), Chen et al. (2023)
France	Arkema-Vauvert	Not reported	Not reported	Not reported	>125000	Godano et al. (2010)
Canada	Underground Research Laboratory, Manitoba	Not reported	Not reported	Not reported	>1500	Gibowicz et al. (1991), McGarr et al. (2002)
China	Rongxing Gypsum Mine, Hubei Province	Not reported	Not reported	Not reported	Not reported	Wang et al. (2024)
South Africa	Ophirton	Not reported	Not reported	Not reported	Not reported	Durrheim (2006a; 2006b)
USA	Wilkes-Barre, Pennsylvania	Not reported	Not reported	Not reported	Not reported	Kim et al. (2009)
Italy	Raibl mine, Cave del Predil	Not reported	Not reported	Not reported	Not reported	Caloi (1970), Braun et al. (2018)
China	Dongguashan (Shizishan copper mine), Tongling, Hunan (Roadway construction)	Not reported	Not reported	Not reported	Not reported	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023), http://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10280443
China	Tianshengqiao II Hydropower Station (Head race tunnel construction)	Not reported	Not reported	4-10	<10	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
Canada	Brunswick No. 12 mine	Not reported	Not reported	Not reported	Not reported	Alcott et al. (1998)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Australia	Queenstown, Tasmania	Not reported	Not reported	Not reported	Not reported	Balfour et al. (2014)
India	Chinakuri Colliery	Not reported	Not reported	Not reported	Not reported	Chouhan (1986)
Russia	Gluboky Mine, Streltsovsk	Not reported	Not reported	Not reported	Not reported	Gilyarov et al. (2014)
Canada	Denison mine, Ontario	Not reported	Not reported	Not reported	Not reported	Hedley and Udd (1989)
Japan	Miike mine	Not reported	Not reported	Not reported	Not reported	Kaneko et al. (1989)
Australia	Mount Charlotte Mine	Not reported	Not reported	Not reported	Not reported	Lee et al. (2006)
China	Fuli mine, Hegang, Heilongjiang	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Didao mine, Jixi, Heilongjiang	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Tiechang mine, Tonghua, Jilin	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Hongtoushan mine, Fushun, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Gaode mine, Fuxin, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Dongliang mine, Fuxin, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Guanshan mine, Beipiao, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Datai mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Tongjialiang mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Meiyukou mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Yongdingzhuang mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Bayi mine, Zaozhuang, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Chaili mine, Zaozhuang, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Wumei mine, Hebi, Henan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Shier (Shi'er kuang?) mine, Pingdingshan, Henan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Quantai mine, Xuzhou, Jiangsu	Not reported	Not reported	Not reported	Not reported	Zhu (1992), Li et al. (2007), Chen et al. (2023)
China	Qishan mine, Xuzhou, Jiangsu	Not reported	Not reported	Not reported	Not reported	Miao et al. (1999), Li et al. (2007), Chen et al. (2023)
China	Zhangxiaolou mine, Xuzhou, Jiangsu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Zhangji mine, Xuzhou, Jiangsu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Yuan et al. (2021), Chen et al. (2023)
China	Leigu mine, Mianyang Beichuan, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Tianchi mine, Mianzhu, Sichuan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Yanshitai mine, Wansheng district, Nantong, Chongqing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Bajing mine, Gaoan, Jiangxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Tungsten ore mine, Jiangxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Manganese mine, Zunyi, Guizhou	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	South manganese mine, Huayuan, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Manganese mine, Taojiang, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Phosphorus mine, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Yangmuxi mine, Changyang, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Songyi mine, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Gaofeng mine, Dachangjingtian, Guangxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Tongkeng mine, Dachangjingtian, Guangxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Manganese mine, Dounan, Yunnan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Manganese mine, Heqing, Yunnan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023)
China	Dongguashan (Shizishan copper mine), Tongling, Hunan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Chen et al. (2023), http://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10280443
China	Zhenxing mine, Hegang, Heilongjiang	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Yingcheng mine, Shulang, Jilin	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Xian mine, Liaoyuan, Jilin	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Taixin mine, Liaoyuan, Jilin	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Benxi Niuxintai mine, Shenyang, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Binggou mine, Jianchang county, Liaoning	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Changgouyu/Zhanggouyu mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Muchengjian mine, Beijing, Beijing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Tangshan mine, Kailuan, Hebei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Guantai mine, Cixian, Hebei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Xin zhou yao mine, Datong, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Suncun mine, Xinwen, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Zhangzhuang mine, Xinwen, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Pan xi mine, Xinwen, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Dongtan mine, Yankuang, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Baodian mine, Yankuang, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	#2 mine, Weishanhu, Shandong	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Qianqiu mine, Yima, Henan	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Wang et al. (2020b), Chen et al. (2023)
China	Yaoqiao mine, Datun, Jiangsu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
China	Kong zhuang mine, Datun, Jiangsu	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Wuyi mine, Shanxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Nantong mine, Nantong, Chongqing	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Hua gu shan mine, Xinyu, Jiangxi	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
China	Fengdouyan, Jiupanshan, Qishuping and Beitou mines, Jiupanshan, Yichang, Hubei	Not reported	Not reported	Not reported	Not reported	Li et al. (2007), Trippi et al. (2014), Chen et al. (2023)
Russia	Berezniki-1 Mine	Not reported	Not reported	Not reported	10000s	Malovichko et al. (2009)
Australia	Southern Colliery, German Creek	Not reported	Not reported	Not reported	152	McKavanagh et al. (1995)
Chile	El Teniente	Not reported	Not reported	Not reported	Not reported	Rojas et al. (2000), Tang et al. (2010), Windsor et al. (2006)
Japan	Horonai	Not reported	Not reported	Not reported	Not reported	Sato and Fujii (1988)
Norway	Road tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Sweden	Head race tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Switzerland / Italy	Simplon Tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Japan	Shimizu Tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Japan	Kanetsu (Kan-Etsu) Tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Sweden	Forsmark Nuclear Plant (Hydraulic tunnels construction)	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Sweden	Ritsem Traffic Tunnel	Not reported	Not reported	Not reported	Not reported	Tang et al. (2010)
Iraq	Mishraq	Not reported	Not reported	Not reported	34	Terashima (1981)
China	Yuzixi I Hydropower Station (Head race tunnel construction)	25	Reported exact value	25	>10	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
China	Erlangshan Tunnel (Sichuan-Tibet Highway)	1000-1500	Reported upper bound or range	Not reported	>200	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
China	Qinling Railway Tunnel	Not reported	Not reported	9-100	43	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
China	Cangling Tunnel (Taizhou-Jiyun Highway)	Not reported	Not reported	8-50	20	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
China	Pubugou Hydropower Station	Not reported	Not reported	6-16	183	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
China	Jinping II Hydropower Station (Auxiliary tunnel)	Not reported	Not reported	Not reported	400	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Ma et al. (2015a), Chen et al. (2023)
China	Lujialiang Tunnel (Chongqing-Yichang Highway)	Not reported	Not reported	Not reported	93	Tian Ma (personal communication, 2016, Tianhuima@dlut.edu.cn), Tang et al. (2010), Chen et al. (2023)
Sweden	Malmberget	Not reported	Not reported	Not reported	Not reported	Wettnen and Martinsson (2014)
Australia	Ridgeway Deep block cave mine	Not reported	Not reported	Not reported	Not reported	Šílený et al. (2013)
China	Puqing Iron Mine	Not reported	Not reported	Not reported	Not reported	Ouyang et al. (2008), Chen et al. (2023)

Country	Project	To the project, m	Distance status	Max. series distance, m	Number of earthquakes	Sources
Canada	Underground Uranium mine, Saskatchewan	Not reported	Not reported	100	Not reported	Castellanos and van der Baan (2013;2015), Barthwal and van der Baan (2020)

13.12. Single annual table: investments

The main series seeks to maintain the indicator of investments in fixed assets. The values of 63 billion for 2017 year and 151 billion for 2022 year are kept separately because they are published with different coverage.

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2006	economic indicators for the full year; seismicity only from 10 October	91.032	488.529	101.65	33.838	181.593	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2007	Full calendar year	115.681	538.408	110.21	39.031	181.660	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2008	Full calendar year	152.887	597.095	110.90	54.731	213.750	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	Not applicable: no alternative value presented

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2009	Full calendar year	110.074	427.520	71.60	32.000	124.286	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2010	Full calendar year	156.518	587.412	137.40	50.000	187.649	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2011	Full calendar year	214.780	732.150	124.64	72.000	245.436	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2012	Full calendar year	267.812	845.268	115.45	94.000	296.683	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2013	Full calendar year	217.711	661.845	78.30	56.000	170.241	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	Not applicable: no alternative value presented

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2014	Full calendar year	230.951	678.324	102.49	44.000	129.232	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2015	Full calendar year	170.470	441.589	65.10	46.000	119.159	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2016	Full calendar year	165.666	404.098	91.51	52.000	126.840	Actual value reported by the regional authorities	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2017	Full calendar year	215.237	486.130	120.30	79.000	178.428	investments in fixed assets of the coal industry; clarification of the industry department published by Interfax	63.000	published regional amount of "investments in the development of the coal industry"; later the industry department clarified 79 billion rubles of investments in fixed assets

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2018	Full calendar year	248.665	522.104	107.40	97.261	204.212	Actual Value, Industry Summary	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2019	Full calendar year	288.407	549.514	105.25	105.000	200.061	Actual value; breakdown disclosed	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2020	Full calendar year	275.045	483.463	87.98	123.500	217.083	regional significance reproduced in educational and scientific material; primary statistical release is required	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2021	Full calendar year	340.022	553.565	114.50	Not reported	Not reported	Open comparable actual value not found; not replaced with planned values	Not applicable: no alternative value presented	Not applicable: no alternative value presented

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2022	Full calendar year	375.379	513.708	92.80	126.200	172.705	investments in fixed assets of coal mining: 126 billion rubles according to Kemerovostat; 126.2 billion follows from the official report on the growth 2023 by 9.1 billion to 135.3 billion	151.000	Sum from industry interviews: companies' investments in production modernization and social programs; more than statistical indicators of investments in fixed assets
2023	Full calendar year	414.429	503.434	98.00	135.300	164.358	investments in fixed assets of coal mining; Kemerovostat and official announcement of the ministry	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2024	Full calendar year	445.344	491.352	97.60	125.500	138.465	Official Industry Page of the Region	Not applicable: no alternative value presented	Not applicable: no alternative value presented
2025	Full calendar year	377.358	377.358	76.80	Not reported	Not reported	Open comparable actual value not found; not replaced with planned values	Not applicable: no alternative value presented	Not applicable: no alternative value presented

Year	Period status	All investment, nominal, RUB billion	All investment, at 2025 prices, RUB billion	Physical volume index, %	Coal, main series, RUB billion	Coal, at 2025 prices, RUB billion	Definition and basis	Other published amount, RUB billion	Why not mixed with the main row
2026	incomplete year: production January–August; seismicity according to 10 October	Not reported	Not reported	Not reported	Not reported	Not reported	Open comparable actual value not found; not replaced with planned values	Not applicable: no alternative value presented	Not applicable: no alternative value presented

13.13. Single annual table: production and physical activity

Year	Kemerovostat production, million tonnes	Operational production, million tonnes	Open-pit, million tonnes	Underground, million tonnes	Associated waste, million tonnes	Overburden, m³	Mine water, m³	Volumes and notes
2006	174.0	not found	91.7	82.3	not found	Not reported	Not reported	Not reported
2007	181.0	not found	97.2	83.8	not found	Not reported	Not reported	Not reported
2008	182.0	not found	103.0	79.0	not found	Not reported	Not reported	three mines were reported; an open annual register of capacities was not found.
2009	178.0	not found	94.5	83.5	not found	Not reported	Not reported	Not reported
2010	178.0	not found	not found	not found	not found	Not reported	Not reported	new open-pit mines and a coal preparation plant; declared production capacity about 8 million tonnes/year
2011	189.0	not found	not found	not found	not found	Not reported	Not reported	Not reported
2012	201.9	not found	not found	not found	not found	Not reported	Not reported	Not reported
2013	198.0	not found	not found	not found	not found	Not reported	Not reported	Not reported

Year	Kemerovostat production, million tonnes	Operational production, million tonnes	Open-pit, million tonnes	Underground, million tonnes	Associated waste, million tonnes	Overburden, m ³	Mine water, m ³	Volumes and notes
2014	208.0	not found	not found	not found	not found	Not reported	Not reported	Not reported
2015	215.0	not found	not found	not found	not found	Not reported	Not reported	Three coal preparation plants with a total capacity of about 7 million tonnes/year were commissioned; this is preparation capacity, not extraction capacity
2016	226.0	not found	not found	not found	not found	Not reported	Not reported	Not reported
2017	240.0	not found	not found	not found	not found	Not reported	Not reported	4 of mining operations: Trudarmeytsky-Yuzhny and Karachiyaksky open-pit mines, Tikhova and Uvalnaya mines; 6.3 million tonnes/year
2018	256.0	255.3	165.8	89.5	not found	Not reported	Not reported	Not reported
2019	248.7	not found	not found	not found	not found	Not reported	Not reported	Uvalnaya coal preparation plant, design processing 5 million tonnes/year; 81% of investments — re-equipment/reconstruction, 19% — new facilities
2020	220.1	220.7	not found	not found	not found	Not reported	Not reported	14 of treatment facilities at coal plants, about 73 million m ³ /year, 1.8 billion rubles; sectoral investments include 5.5 billion rubles for safety

Year	Kemerovostat production, million tonnes	Operational production, million tonnes	Open-pit, million tonnes	Underground, million tonnes	Associated waste, million tonnes	Overburden, m ³	Mine water, m ³	Volumes and notes
2021	239.3	243.1	156.0	87.1	3804.600	Not reported	Not reported	announced commissioning of the 7 November–Novaya mine (4.8 million tonnes/year), the Sibirskaya mine (5 million tonnes/year) and a coal preparation plant (4 million tonnes/year); each commissioning requires separate acceptance verification
2022	223.3	223.6	151.7	71.9	4038.800	Not reported	Not reported	Not reported
2023	211.4	214.2	143.1	71.1	4080.700	Not reported	Not reported	Not reported
2024	193.7	198.4	132.5	65.9	3311.000	Not reported	Not reported	regional page reports 15 new enterprises announced for 2018–2025 without annual layout
2025	191.8	190.7	not found	not found	2189.063	Not reported	Not reported	Not reported
2026	120.6	120.6	81.2	39.4	not found	Not reported	Not reported	Not reported

13.14. Single annual table: seismicity

Year	Entries	M ≥ 3.0	M ≥ 3.5	M ≥ 4.0	Maximum	Episodes	Episodes with max M ≥ 3.0	Source Coverage	Comparability
2006	3	0	0	0	2.94	1	0	Official Regional Annual Catalogue	seismic coverage begins 10 October; year incomplete for seismicity only
2007	1	0	0	0	2.89	1	0	Official Regional Annual Catalogue	not found

Year	Entries	M ≥ 3.0	M ≥ 3.5	M ≥ 4.0	Maximum	Episodes	Episodes with max M ≥ 3.0	Source Coverage	Comparability
2008	3	1	0	0	3.06	1	1	Official Regional Annual Catalogue	not found
2009	3	0	0	0	2.20	0	0	Official Regional Annual Catalogue	not found
2010	2	0	0	0	2.11	0	0	Official Regional Annual Catalogue	not found
2011	0	0	0	0	Not reported	0	0	Official regional catalogue; no events within the boundaries of the region	not found
2012	2	2	2	1	4.30	2	2	Official Regional Annual Catalogue	not found
2013	74	18	8	2	6.10	16	5	Official Regional Annual Catalogue	not found
2014	124	7	1	0	3.60	9	3	Official Regional Annual Catalogue	not found
2015	167	4	1	0	3.70	8	2	Official Regional Annual Catalogue	not found
2016	121	14	8	3	4.68	12	7	Official Regional Annual Catalogue	not found
2017	354	4	1	0	3.54	10	2	Official Regional Annual Catalogue	not found
2018	30	9	4	1	4.00	15	7	Official Regional Annual Catalogue	not found
2019	388	24	13	1	4.10	18	7	Official Regional Annual Catalogue	not found

Year	Entries	M ≥ 3.0	M ≥ 3.5	M ≥ 4.0	Maximum	Episodes	Episodes with max M ≥ 3.0	Source Coverage	Comparability
2020	378	21	8	4	4.90	14	10	Official Regional Annual Catalogue	not found
2021	533	30	7	2	5.60	13	9	Official Regional Annual Catalogue	not found
2022	2514	25	11	2	4.40	3	3	Official Regional Annual Catalogue	catalogue threshold reduced to approximately M ≥ 1.3; the number of all entries is not comparable to neighboring years
2023	107	34	13	4	4.50	27	16	Official Regional Annual Catalogue	the catalogue threshold has been raised to approximately M ≥ 2.4
2024	62	25	7	4	4.60	22	16	operational messages; selection by administrative boundary of the region; verified values may differ	operational cards, not the final reviewed annual catalogue
2025	74	12	7	3	4.20	20	10	operational messages; verified annual catalogue not yet available	operational cards, not the final reviewed annual catalogue
2026	37	14	6	3	4.90	14	11	operational messages; verified annual catalogue not yet available	operational cards, not the final reviewed annual catalogue

13.15. All correlation calculations: coefficients

38 calculations. This is a descriptive test; the coefficients do not prove causality and depend on the coverage of the years and the composition of the catalogue.

X series	Y series	Lag (years)	Filter	n	Spearman's ρ	Pearson's r	Limitation of interpretation
investments in the coal industry, nominal	Annual coal production	0	full years; available investments	18	0.584	0.508	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, nominal	Annual coal production	1	full years; available investments	18	0.368	0.280	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, nominal	Annual coal production	2	full years; available investments	17	0.215	0.113	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, nominal	Annual coal production	3	full years; available investments	16	0.163	0.070	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	0	full years; available investments	18	-0.011	0.002	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	1	full years; available investments	18	-0.039	-0.057	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	2	full years; available investments	17	-0.218	-0.250	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	3	full years; available investments	16	-0.355	-0.332	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue

X series	Y series	Lag (years)	Filter	n	Spearman's ρ	Pearson's r	Limitation of interpretation
Annual coal production	All recorded entries in source coverage	0	full seismic years 2007–2025	19	0.742	0.323	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	All recorded entries in source coverage	1	full seismic years 2007–2025	19	0.806	0.470	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	All recorded entries in source coverage	2	full seismic years 2007–2025	18	0.726	0.307	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	All recorded entries in source coverage	3	full seismic years 2007–2025	17	0.707	0.539	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	All recorded entries in source coverage	0	sensitivity: excluded 2013 and 2022	17	0.748	0.689	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	All recorded entries in source coverage	0	2012–2025; excluded 2013 and 2022	12	0.476	0.522	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	events $M \geq 3.5$	0	full seismic years 2007–2025	19	0.626	0.483	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	events $M \geq 3.5$	1	full seismic years 2007–2025	19	0.783	0.728	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	events $M \geq 3.5$	2	full seismic years 2007–2025	18	0.722	0.723	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue

X series	Y series	Lag (years)	Filter	n	Spearman's ρ	Pearson's r	Limitation of interpretation
Annual coal production	events $M \geq 3.5$	3	full seismic years 2007–2025	17	0.595	0.642	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	events $M \geq 3.5$	0	sensitivity: excluded 2013 and 2022	17	0.676	0.502	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	events $M \geq 3.5$	0	2012–2025; excluded 2013 and 2022	12	0.110	0.102	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	full seismic years 2007–2025	19	0.517	0.308	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	1	full seismic years 2007–2025	19	0.683	0.521	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	2	full seismic years 2007–2025	18	0.802	0.734	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	3	full seismic years 2007–2025	17	0.701	0.645	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	sensitivity: excluded 2013 and 2022	17	0.544	0.327	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	2012–2025; excluded 2013 and 2022	12	-0.274	-0.261	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue

X series	Y series	Lag (years)	Filter	n	Spearman's ρ	Pearson's r	Limitation of interpretation
Annual Production Change	annual change in the number of events $M \geq 3.5$	0	Annual changes; full seismic years	18	-0.088	0.031	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of events $M \geq 3.5$	1	Annual changes; full seismic years	17	0.573	0.447	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of events $M \geq 3.5$	2	Annual changes; full seismic years	16	0.165	0.093	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of events $M \geq 3.5$	3	Annual changes; full seismic years	15	-0.502	-0.399	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	0	Annual changes; full seismic years	18	-0.032	-0.100	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	1	Annual changes; full seismic years	17	0.027	-0.109	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	2	Annual changes; full seismic years	16	0.614	0.648	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	3	Annual changes; full seismic years	15	-0.113	-0.345	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	0	full seismic years; available investments	17	-0.100	-0.096	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue

X series	Y series	Lag (years)	Filter	n	Spearman's ρ	Pearson's r	Limitation of interpretation
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	1	full seismic years; available investments	18	0.117	0.184	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	2	full seismic years; available investments	17	0.178	0.089	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	3	full seismic years; available investments	16	-0.138	-0.146	descriptive checking; no p-value due to small n, autocorrelation, omissions, and changing catalogue

13.16. Correlation calculations: used pairs of years

X series	Y series	Lag	n	Pairs of observations
investments in the coal industry, nominal	Annual coal production	0	18	2006→2006; 2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2022→2022; 2023→2023; 2024→2024
investments in the coal industry, nominal	Annual coal production	1	18	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2022→2023; 2023→2024; 2024→2025
investments in the coal industry, nominal	Annual coal production	2	17	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2022→2024; 2023→2025
investments in the coal industry, nominal	Annual coal production	3	16	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2022→2025
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	0	18	2006→2006; 2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2022→2022; 2023→2023; 2024→2024

X series	Y series	Lag	n	Pairs of observations
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	1	18	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2022→2023; 2023→2024; 2024→2025
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	2	17	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2022→2024; 2023→2025
investments in the coal industry, at 2025 prices (approximation)	Annual coal production	3	16	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2022→2025
Annual coal production	All recorded entries in source coverage	0	19	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2022→2022; 2023→2023; 2024→2024; 2025→2025
Annual coal production	All recorded entries in source coverage	1	19	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2021→2022; 2022→2023; 2023→2024; 2024→2025
Annual coal production	All recorded entries in source coverage	2	18	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2021→2023; 2022→2024; 2023→2025
Annual coal production	All recorded entries in source coverage	3	17	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2021→2024; 2022→2025
Annual coal production	All recorded entries in source coverage	0	17	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025
Annual coal production	All recorded entries in source coverage	0	12	2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025
Annual coal production	events $M \geq 3.5$	0	19	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2022→2022; 2023→2023; 2024→2024; 2025→2025

X series	Y series	Lag	n	Pairs of observations
Annual coal production	events $M \geq 3.5$	1	19	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2021→2022; 2022→2023; 2023→2024; 2024→2025
Annual coal production	events $M \geq 3.5$	2	18	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2021→2023; 2022→2024; 2023→2025
Annual coal production	events $M \geq 3.5$	3	17	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2021→2024; 2022→2025
Annual coal production	events $M \geq 3.5$	0	17	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025
Annual coal production	events $M \geq 3.5$	0	12	2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	19	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2022→2022; 2023→2023; 2024→2024; 2025→2025
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	1	19	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2021→2022; 2022→2023; 2023→2024; 2024→2025
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	2	18	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2021→2023; 2022→2024; 2023→2025
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	3	17	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2021→2024; 2022→2025
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	17	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025

X series	Y series	Lag	n	Pairs of observations
Annual coal production	30-daily episodes with maximum $M \geq 3.0$	0	12	2012→2012; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2023→2023; 2024→2024; 2025→2025
Annual Production Change	annual change in the number of events $M \geq 3.5$	0	18	2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2022→2022; 2023→2023; 2024→2024; 2025→2025
Annual Production Change	annual change in the number of events $M \geq 3.5$	1	17	2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2021→2022; 2022→2023; 2023→2024; 2024→2025
Annual Production Change	annual change in the number of events $M \geq 3.5$	2	16	2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2021→2023; 2022→2024; 2023→2025
Annual Production Change	annual change in the number of events $M \geq 3.5$	3	15	2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2021→2024; 2022→2025
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	0	18	2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2021→2021; 2022→2022; 2023→2023; 2024→2024; 2025→2025
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	1	17	2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2021→2022; 2022→2023; 2023→2024; 2024→2025
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	2	16	2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2021→2023; 2022→2024; 2023→2025
Annual Production Change	annual change in the number of episodes $M \geq 3.0$	3	15	2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2021→2024; 2022→2025
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	0	17	2007→2007; 2008→2008; 2009→2009; 2010→2010; 2011→2011; 2012→2012; 2013→2013; 2014→2014; 2015→2015; 2016→2016; 2017→2017; 2018→2018; 2019→2019; 2020→2020; 2022→2022; 2023→2023; 2024→2024

X series	Y series	Lag	n	Pairs of observations
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	1	18	2006→2007; 2007→2008; 2008→2009; 2009→2010; 2010→2011; 2011→2012; 2012→2013; 2013→2014; 2014→2015; 2015→2016; 2016→2017; 2017→2018; 2018→2019; 2019→2020; 2020→2021; 2022→2023; 2023→2024; 2024→2025
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	2	17	2006→2008; 2007→2009; 2008→2010; 2009→2011; 2010→2012; 2011→2013; 2012→2014; 2013→2015; 2014→2016; 2015→2017; 2016→2018; 2017→2019; 2018→2020; 2019→2021; 2020→2022; 2022→2024; 2023→2025
investments in the coal industry, at 2025 prices (approximation)	events $M \geq 3.5$	3	16	2006→2009; 2007→2010; 2008→2011; 2009→2012; 2010→2013; 2011→2014; 2012→2015; 2013→2016; 2014→2017; 2015→2018; 2016→2019; 2017→2020; 2018→2021; 2019→2022; 2020→2023; 2022→2025

13.17. Sources of the annual economic series

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2006	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	seismic coverage begins 10 October; year incomplete for seismicity only

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2007	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2008	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2009	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2010	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	retrospective table according to Kemerovostat data	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2011	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2012	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2013	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2014	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2015	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Kemerovostat, reproduced in Kommersant	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2016	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Actual value reported by the regional authorities	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2017	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	investments in fixed assets of the coal industry; clarification of the industry department published by Interfax	Regional announcement on investments in the development of the industry	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2018	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Actual Value, Industry Summary	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2019	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Actual value; breakdown disclosed	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found
2020	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	regional significance reproduced in educational and scientific material; primary statistical release is required	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	not found

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2021	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Not reported	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	no comparable actual industry investment value
2022	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	investments in fixed assets of coal mining: 126 billion rubles according to Kemerovostat; 126.2 billion follows from the official report on the growth 2023 by 9.1 billion to 135.3 billion	Industry interviews about companies' investments, including social programs	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	catalogue threshold reduced to approximately $M \geq 1.3$; the number of all entries is not comparable to neighboring years

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2023	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	investments in fixed assets of coal mining; Kemerovostat and official announcement of the ministry	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	the catalogue threshold has been raised to approximately $M \geq 2.4$
2024	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Official Industry Page of the Region	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	operational cards, not the final reviewed annual catalogue

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismicity	Series file	Gap / change of method
2025	Rosstat: investment in fixed assets by constituent entity of the Russian Federation; Roschart mirror	Rosstat: fixed-capital investment volume index; Roschart mirror	Not reported	Not applicable: no alternative value presented	State Report on the State and Environmental Protection of Kuzbass; Kemerovostat Series	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	operational cards, not the final reviewed annual catalogue
2026	Not reported	not found	Not reported	Not applicable: no alternative value presented	Ministry of Coal Industry of Kuzbass, January–August	compiled project catalogue; source yearbooks of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), and operational cards are identified row by row	data/kuzbass-annual-pattern-summary-2006-2026.csv	operational cards, not the final reviewed annual catalogue

13.18. Economic series sources: addresses

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismic file
2006	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://ecotrends.ru/index.php/eco/article/download/2154/1194	Not applicable: no alternative value presented	https://kuzbasseco.ru/001/1.5..htm	data/kuzbass-annual-pattern-summary-2006-2026.csv
2007	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://ecotrends.ru/index.php/eco/article/download/2154/1194	Not applicable: no alternative value presented	https://kuzbasseco.ru/002/1.5.html	data/kuzbass-annual-pattern-summary-2006-2026.csv
2008	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://ecotrends.ru/index.php/eco/article/download/2154/1194	Not applicable: no alternative value presented	https://kuzbasseco.ru/003/1.5.html	data/kuzbass-annual-pattern-summary-2006-2026.csv
2009	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://ecotrends.ru/index.php/eco/article/download/2154/1194	Not applicable: no alternative value presented	https://kuzbasseco.ru/004/1.5.html	data/kuzbass-annual-pattern-summary-2006-2026.csv
2010	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://ecotrends.ru/index.php/eco/article/download/2154/1194	Not applicable: no alternative value presented	https://kuzbasseco.ru/005/1.5.html	data/kuzbass-annual-pattern-summary-2006-2026.csv
2011	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2025/03/doklad_ecolog_2011_final.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2012	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2018/12/doklad2013.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismic file
2013	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2018/12/doklad2013.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2014	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2015	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2016	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.kommersant.ru/doc/3247750	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2017	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.interfax-russia.ru/siberia/news/kuzbass-v-2019g-nameren-sohranit-investicii-v-osnovnoy-kapital-ugleproma-na-urovne-2018-100-mlrd-rub	https://www.10kanal.ru/news/economy/production/151916.html	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2018	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.mining-portal.ru/publish/kuzbass-podvodit-itogi-2019-goda/	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2019	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.mining-portal.ru/publish/kuzbass-podvodit-itogi-2019-goda/	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2020/09/gosdoclad2019.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismic file
2020	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://xn---ctbbdw9ayagei.xn--p1ai/images/kalekinvv/KonfOIVT/Konfstudkafik1.pdf	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2022/08/doklad_2021.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2021	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	Not reported	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2022/08/doklad_2021.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2022	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://expertsibdv.com/news/investitsii-v-osnovnoy-kapital-kuzbassa-snizilis-pochti-na-10/	https://www.uk42.ru/index.php?id=16866	https://kuzbasseco.ru/wp-content/uploads/2025/02/DOKLAD_2023.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2023	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://mupk42.ru/ru/press-center/news/novosti-ministerstva/zamestitel-ministra-ugolnoy-promyshlennosti-kuzbassa-golova-e-l-dolozhila-parlamentu-kuzbassa-o-rezu/	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2025/02/DOKLAD_2023.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2024	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	https://www.vvk-kuzbass.ru/industries/ugolnaya-promyshlennost/	Not applicable: no alternative value presented	https://kuzbasseco.ru/wp-content/uploads/2025/06/doklad_v2-1.pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv
2025	https://roschart.ru/dataset/invest-sub-2000-2025-investicii-v-osnovnoy-kapital-po-subekt	https://roschart.ru/dataset/din-invest-sub-dinamika-investiciy-v-osnovnoy-kapital-po-sub	Not reported	Not applicable: no alternative value presented	https://42.rosstat.gov.ru/storage/mediabank/Публикация_Кузбасс%20в%202025%20г..pdf	data/kuzbass-annual-pattern-summary-2006-2026.csv

Year	All investments	Comparable prices	Main coal indicator	Differently scoped indicator	Mining	Seismic file
2026	Not reported	not found	Not reported	Not applicable: no alternative value presented	https://mupk42.ru/ru/press-center/news/novosti-ministerstva/osnovnye-pokazateli-ugolnoy-otrasli-dobycha21/	data/kuzbass-annual-pattern-summary-2006-2026.csv

13.19. Source conflicts and open questions

Case	Source A	Data/Statement A	Source B	Data/Statement B	How it was handled
Kuzbass 2008 strong events	Adushkin 2018	three events mb 4.5–4.6 classified as proposed human-induced tectonic	GS RAS normalized annual catalogue	does not reproduce the same strong-event set under the same parameters	saved as a separate source row; without reconciling the source records, the rows are not combined
Bachatsky 2012-02-09	GS RAS annual catalogue	ML 4.3 near 54.27, 86.21	Adushkin/Yakovlev source solutions	mb 4.6 or local M about 3.8 with different coordinates	All solutions and types of magnitude are preserved
Bachatsky 2013-06-18	Emanov local solution	ML 6.1, depth about 4 km	unified/other catalogues	M about 5.1 or mb about 5.8 and alternate depths	ML 6.1 is used only with a scale specified; alternative solutions are preserved
Taldinsky 2021	GS RAS reviewed catalogue	ML 5.6, unified M 5.1, depth 3 km; no causal label	regional authority statement reported by Interfax	natural event with energy accumulated from blasting/mining	classified as disputed/proposed mixed origin; special causal study not found
Krasnobrodsky 2024-09-26	reviewed site-specific catalogue	54.090, 86.48933; depth 0.7 km; ML 4.25	operational notice	54.07, 86.40; M 4.3; no depth/type	The evidence card uses the reviewed values; the preliminary solution is retained for comparison
Kiselevsk 2026-10-10	Altai-Sayan Branch of FRC GS RAS	54.09, 86.54; M 4.9; no depth/type	regional and Kazakhstan solutions	54.16, 86.37 M4.8 and 54.04, 86.47; media depth near 5 km	distances are calculated for each solution; origin remains undetermined
Newcastle 1989	Klose 2007	mining and groundwater removal may have triggered earthquake	Quinn et al. 2008	The inference is not supported by the model and available geological and seismic data	Classified as controversial

Case	Source A	Data/Statement A	Source B	Data/Statement B	How it was handled
Ibbenbüren 1991	German induced-seismicity compilations	ML 4.3, intensity VI	HiQuake 2026 snapshot	ML 4.6; insufficient evidence; citation appears mismatched	value 4.3 is used with reference; database discrepancy revealed
Bełchatów 1979-1980	Gibowicz et al. 1981	five events through May 1980; three largest ML 3.5	later compilations/HiQuake	1980-11-29 event near M4.6-4.66	counted as a later event of the same long series, and not as a value from the original sample of five events
Boolaroo Australia	HiQuake 2026 snapshot	date field 9484	historical literature	No reliable date was found within this check	marked as database error; date not published

13.20. Machine-readable file inventory

A blank row count denotes JSON or another file type for which a line count is not a meaningful content measure.

File	Data rows	Size
eqru-kemerovo-2003-2023.csv	4800	969.1 KB
eqru-kuzbass-bbox-2003-2023-with-ids.csv	4882	985.7 KB
eqru-kuzbass-bbox-2003-2024.csv	4882	508.5 KB
global-coal-key-cases-reviewed.csv	15	6.8 KB
global-coal-proximity-audit.csv	150	20.4 KB
global-hiquake-by-cause.csv	16	0.4 KB
global-hiquake-by-country.csv	84	1.3 KB
global-hiquake-coal-mining.csv	150	42.1 KB
global-hiquake-mining.csv	343	94.7 KB
global-hiquake-mmax-ge5.csv	105	37.4 KB

File	Data rows	Size
global-hiquake-projects-2026-09-24.csv	1385	436.4 KB
global-mining-proximity-audit.csv	343	66.3 KB
global-selected-coal-projects-working.csv	46	6.1 KB
gsras-annual-relevant-sheets-manifest.csv	47	14.8 KB
gsras-annual-source-manifest-2006-2023.csv	42	12.8 KB
gsras-annual-workbook-inventory-2006-2023.csv	357	32.0 KB
gsras-kuzbass-2024-normalized.csv	2024	568.7 KB
hiquake-2026-09-24.csv	1385	436.4 KB
kiselevsk-city-blasts-2006-2026.csv	7180	2120.7 KB
kiselevsk-city-blasts-annual-2006-2026.csv	21	2.3 KB
kiselevsk-city-seismicity-2006-2026.csv	517	165.2 KB
kiselevsk-city-seismicity-annual-2006-2026.csv	21	4.0 KB
kiselevsk-cluster-m25-within-35km-2006-2026.csv	184	32.1 KB
kiselevsk-coal-enterprises-2019-baseline.csv	9	8.6 KB
kiselevsk-event-2026-10-10-all-nearby-quarries.csv	9	1.6 KB
kiselevsk-event-2026-10-10-gem-boundary-distances.csv	8	1.3 KB
kiselevsk-event-2026-10-10-quarry-distances.csv	25	3.9 KB
kiselevsk-osm-mining-and-waste-polygons-2026-10-11.csv	16	4.9 KB
kuzbass-analytical-zone-summary-2006-2026.csv	7	1.3 KB
kuzbass-annual-catalog-summary-2006-2023.csv	18	1.5 KB

File	Data rows	Size
kuzbass-annual-pattern-summary-2006-2026.csv	21	1.7 KB
kuzbass-computational-episodes-2006-2026.csv	206	58.0 KB
kuzbass-core-events-v0.1.csv	32	14.9 KB
kuzbass-core-events-v0.2.csv	42	20.7 KB
kuzbass-detailed-local-series-2007-2020.csv	16103	8882.5 KB
kuzbass-investment-correlation-results.csv	38	20.1 KB
kuzbass-investment-production-seismicity-2006-2026.csv	21	13.5 KB
kuzbass-investment-source-notes.csv	21	23.5 KB
kuzbass-operational-earthquakes-2025-2026.csv	111	38.2 KB
kuzbass-recorded-earthquakes-2006-2026-scope-aware.csv	4977	889.5 KB
kuzbass-regional-blasts-2006-2023.csv	49636	29310.2 KB
kuzbass-regional-earthquakes-2006-2023.csv	7427	4865.3 KB
kuzbass-series-v0.1.csv	14	7.0 KB
kuzbass-series-v0.2.csv	18	9.8 KB
kuzbass-spatial-grid-summary-2006-2023.csv	481	19.8 KB
kuzbass-spatial-patterns-2006-2026.csv	491	41.0 KB
kuzbass-zone-event-assignments-2006-2026.csv	4977	1113.1 KB
seishub-kemerovo-2024-blasts.csv	292	39.2 KB
seishub-kemerovo-2024-earthquakes.csv	62	8.5 KB
seishub-kemerovo-2024.csv	354	47.2 KB

File	Data rows	Size
seishub-kemerovo-2025-2026-blasts.csv	347	46.2 KB
seishub-kemerovo-2025-2026-earthquakes.csv	111	15.0 KB
seishub-kemerovo-2025-2026.csv	458	61.1 KB
seishub-kuzbass-2024-blasts.csv	296	39.5 KB
seishub-kuzbass-2024-failures.json	not found	1.4 KB
seishub-kuzbass-2024.csv	365	48.7 KB
seishub-kuzbass-2025-2026-blasts.csv	355	47.3 KB
seishub-kuzbass-2025-2026-earthquakes.csv	124	16.8 KB
seishub-kuzbass-2025-2026-failures.json	not found	1.7 KB
seishub-kuzbass-2025-2026.csv	479	63.9 KB
source-conflicts-and-open-questions.csv	10	2.3 KB

SECTION 14

Register of sources

International corpus

HiQuake

- **Name:** The Human-Induced Earthquake Database.
 - **Organization:** Durham University/HiQuake Research Group.
 - **Version:** update from 24 September 2026.
 - **Coverage:** 1,385 industrial projects or series that the scientific literature has proposed linking to induced or triggered seismicity.
- **Fields:** country, mechanism, project, coordinates, period of activity and seismicity, number of events (if known), maximum magnitude and its type, depth, distances, project parameters, links and E-PIE.
 - **Limitation:** This is a register of scientifically proposed connections, and not a list of 1,385 indisputably proven cases.

- **Public page:** <https://inducedearthquakes.org/>
- **Local copies:** `sources/HiQuake_2026-09-24.xlsx`, `sources/HiQuake_bibliography_2026-09-24.docx`.
- **Machine-readable export:** `data/hiquake-2026-09-24.csv`.

E-PIE

- Wilkinson M. et al. *The plausibility of claimed induced seismicity*. Scientific Reports 14, 30846 (2024).
- DOI: <https://doi.org/10.1038/s41598-024-81632-3>
- Significance for the work: a consistent preliminary assessment of the strength of the published evidence. The authors emphasize the unequal quality of evidence and the preliminary nature of the assessment.

Global Overview

- Foulger G. R. et al. *Global review of human-induced earthquakes*. Earth-Science Reviews 178 (2018): 438–514.
- DOI: <https://doi.org/10.1016/j.earscirev.2017.07.008>

Kuzbass: catalogues

Database "Earthquakes of Russia" of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS)

- Public Database: <http://eqru.gsras.ru/>
- Upload: 2003–2023, bounding box 52–56° N and 84–89° E.
- Local preliminary result: `sources/eqru-kuzbass-bbox-2003-2024.html`.
- Normalized table with card IDs: `data/eqru-kuzbass-bbox-2003-2023-with-ids.csv`.
- Number of rows: 4,882.
- Limitation: the export contains seismic events of different origins and does not provide a ready-made causal attribution. The bounding box extends beyond the coal basin and includes the entire northern part of the region; it serves as the initial sample, not the final register.

Detailed catalogue 2024

- Shevkunova E. V. et al. *Catalogue of seismic events of the Altai seismological test site and the area of the Rospadskaya-Koksovaya mine, the Kolyvansky and Krasnobrodsky open-pit mines in 2024*.
- DOI: <https://doi.org/10.35540/gsras.er.2026.1.23>
- Publisher: Geophysical Data Repository of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences.
- Local original: `sources/GS_RAS_2024_Altai_detailed_Kuzbass.xlsx`.
- Normalized table: `data/gsras-kuzbass-2024-normalized.csv`.
- Important property: earthquakes and explosions are classified separately.
- Geographical correction: the Kolyvansky site is in Novosibirsk Oblast. Its lines are preserved for source control, but excluded from the results of the Kemerovo region.

Annual regional catalogues 2006–2023

- **Publisher:** FRC GS RAS, yearbooks of "Earthquakes of Russia", appendices to Altai and Sayan.
- **Local originals:** [sources/gstras-annual-2006-2023/](#).
- **Normalized source series:** [data/kuzbass-regional-earthquakes-2006-2023.csv](#) — 4,806 records within the administrative boundary of Kemerovo Oblast for the complete 2006–2023 calendar years. The exact twenty-year period after 10 October 2006 includes 4,804 of them.
- **Explosions:** [data/kuzbass-regional-blasts-2006-2023.csv](#) - Separate table; the gaps for 2013–2018 reflect the incompleteness of the extracted appendices, not the absence of explosions.
- **Rule:** An entry in an earthquake catalog does not automatically mean human-induced origin. A direct causal label is transferred only where it is in a catalog note or profile work.

Operational cards 2024–2026

- **Source:** Altai-Sayan Branch of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS), public index <https://seishub.ru/> and PDF event cards.
- **2024:** [data/seishub-kemerovo-2024-earthquakes.csv](#) — 62 successfully extracted earthquake cards within the oblast boundary; [data/seishub-kemerovo-2024-blasts.csv](#) — 292 cards of other types, mainly explosions.
- **2025–2026:** [data/seishub-kemerovo-2025-2026-earthquakes.csv](#) — 74 cards for 2025 and 37 from the beginning of 2026 to 10 October inclusive.
- **Unretrieved 2024 cards:** [data/seishub-kuzbass-2024-failures.json](#) — Ten files from the wider coordinate sample could not be retrieved; their administrative location and signal type remain unknown.
- **Limitation:** The operational card provides a preliminary solution and type of signal, but does not always contain depth and magnitude type. It does not replace the reviewed annual catalogue.

Kuzbass research

General observation history

- Yakovlev D. V., Lazarevich T. I., Tsirel S. V. *Natural and human-induced seismic activity in Kuzbass*. Physical and Technical Problems of Mineral Development, 2013.
- Local copy: [sources/yakovlev-2013-natural-induced-kuzbass.pdf](#).
- Use: early observations, Tashtagol, swarms in the fields of Osinniki and Polysaev mines, transition from background to mixed natural–human-induced seismicity.

Bachatsky open-pit mine

- Emanov A. F. et al. *Mining-Induced Seismicity at Open Pit Mines in Kuzbass (Bachatsky earthquake on June 18, 2013)*. Journal of Mining Science, 2014. DOI: <https://doi.org/10.1134/S1062739114020033>
- Emanov A. F. et al. *human-induced Bachatsky earthquake 18.06.2013* Engineering Seismology Issues 43(4), 2016, 34–60. DOI: <https://doi.org/10.21455/VIS2016.4-3>
- Emanov A. F. et al., re-analysis of 2023. DOI: <https://doi.org/10.15372/GiG2023149>

- Local copies: [sources/emanov-2014-bachat-abstract.pdf](#), [sources/emanov-2023-bachat-reanalysis.pdf](#).
- Use: mainshock, depth, mechanism, spatial structure, foreshocks and aftershocks, the basis of human-induced classification.

Regional list of strong events

- Adushkin V. V. *Development of human-induced tectonic seismicity in Kuzbass*. Geology and Geophysics 59(5), 2018, 709–724.
- Local copy: [sources/adushkin-2018-kuzbass.pdf](#).
- Usage: table 15 of proposed human-induced tectonic events $mb \geq 4.5$ for 1962–2016; Bachatsky sequence; events after the flooding of mines.
- Limitation: The author's criterion and classification are preserved as a research position, and not as an automatic consensus of all catalogues.

Kaltan, Alardinskaya and Malinovka

- Temporary seismic network observations 2016–2017: local copy [sources/kaltan-2017-conference.pdf](#).
- Emanov A. F. et al. *Monitoring of seismic activity near the Kaltan open pit and Alardinskaya mine*. Engineering Seismology Issues 46(3), 2019. DOI: <https://doi.org/10.21455/VIS2019.3-1>
- Use: swarm and individual events near the open-pit mine, waste dump and underground workings; separation of spatial clusters.

Studies of the evolution of the Bachatsky and other Kuzbass seismic zones

- Emanov A. F. et al. *Seismic activation during open-pit coal mine development*. DOI: <https://doi.org/10.35540/2686-7907.2020.3.08>
- Emanov A.F. et al. Study of the evolution of induced seismicity at the Bachatsky open-pit mine. DOI: <https://doi.org/10.15372/FPVGN2021080210>
- Use: duration of activation after the mainshock, changes in the geometry of the open-pit mine and comparison of the foci with the workings and dumps.

Taldinsky event 2021

- **Parameters:** The annual catalogue of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences for 2021, entry ASR2107250: ML 5.6, unified M 5.1, depth 3 km, macroseismic data.
- **Public causal formulation:** The regional agency described the event as natural while also stating energy had accumulated as a result of blasting at several coal enterprises; the statement was reported by [Interfax 13 August 2021](#).
- **Status in the study:** Controversial/mixed explanation. No separate open-access study providing a focal-mechanism analysis and rigorous attribution was found in this review.

Site geometry and distance calculation

- **OpenStreetMap:** Broad mapped outline of the open-pit mine used for reproducible minimum distance from the operational epicentre. This is not a legal boundary of the license.
- **Global Energy Monitor:** published polygons of coal mines and open-pit mines; for the Krasnobrodsky facility, a licence/project boundary from the available set was used.
- **Calculation files:** `data/kiselevsk-event-2026-10-10-quarry-distances.csv` , `data/kiselevsk-event-2026-10-10-all-nearby-quarries.csv` , `data/kiselevsk-event-2026-10-10-gem-boundary-distances.csv` and scripts `tools/calculate-event-quarry-distances.mjs` , `tools/calculate-gem-boundary-distances.mjs` .
- **Interpretation rule:** the distance is always indicated together with the original solution of the epicentre and the type of contour. The difference between approximately 1 km and 9.6 km for the event 10 October 2026 is not due to an arithmetic error, but to different object boundaries.

Kiselevsk: Enterprises and city boundaries

- **Official Territory Profile:** "[Health profile of residents of the Kiselevsk Municipal District](#)", p. 55. The data document for 2019 lists nine coal mining operations. It is not a register of individual open-pit excavations or waste dumps.
- **Municipal baseline for 2013:** [Decree of the Kiselevsk administration from 10.06.2013 № 221-n](#), lines 200–225 and 321–326. The document reports on two underground mines and seven open-pit coal mines and names enterprises.
- **Industry description for 2020:** "[Coal of Kuzbass](#)", "[Mining Cities](#)", May–June 2020 issue, entries 131–145. The source called nine enterprises operating open-pit mines; that affiliation is retained as a status published in 2020, not as an unchanged structure in 2026.
- **Municipal boundary used in the analysis:** OpenStreetMap/Nominatim relation 1151241 , screenshot from 11.10.2026: `sources/nominatim-kiselevsk-urban-okrug-2026-10-11.json` .
- **Open cartographic objects:** Inquiry `tools/kiselevsk-mining-objects-2026.overpassql` , result `sources/overpass-kiselevsk-mining-objects-2026-10-11.json` , summary `data/kiselevsk-osm-mining-and-waste-polygons-2026-10-11.csv` . Most polygons do not have a name and status; the set is not an official complete registry.
- **Baseline list of enterprises:** `data/kiselevsk-coal-enterprises-2019-baseline.csv` . The table divides the name of the enterprise, physical object, method of extraction, dated ownership, current status and gaps in the geometry data.
- **Urban seismic dataset:** `tools/build-kiselevsk-city-risk-baseline.mjs` , tables `data/kiselevsk-city-seismicity-2006-2026.csv` , `data/kiselevsk-city-seismicity-annual-2006-2026.csv` , `data/kiselevsk-city-blasts-2006-2026.csv` and `data/kiselevsk-city-blasts-annual-2006-2026.csv` .

International key cases

- **Newcastle, Australia:** Klose, DOI <https://doi.org/10.1016/j.epsl.2007.02.009> - Hypothesis linking mining and groundwater drawdown to the earthquake; Quinn et al., DOI <https://doi.org/10.1016/j.epsl.2007.11.067> — published counter-analysis. Official parameters and consequences were checked with Geoscience Australia.
- **Saarland, Germany, 23 February 2008:** BGR, https://www.seismologie.bgr.de/sdac/erdbeben/big_quakes/germany_080223_deu.html — ML 4.1 , shallow depth and high probability of connection to coal mining; after the event, mining was halted.
- **Bełchatów, Poland:** Gibowicz et al., DOI [https://doi.org/10.1016/0013-7952\(81\)90002-8](https://doi.org/10.1016/0013-7952(81)90002-8) — early series on open-pit mine, load removal and groundwater drawdown.
- **Crandall Canyon, USA:** USGS, <https://www.usgs.gov/publications/characterizing-6-august-2007-crandall-canyon-mine-collapse-alos-palsar-insar> documents a collapse-generated seismic signal rather than an earthquake that caused the accident.
- **Ostrava-Karvina, Czech Republic:** DOI <https://doi.org/10.1016/j.tecto.2006.12.013> — rockbursts and deep mine seismicity.

- **Chinese coal mines:** review, DOI <https://doi.org/10.1016/j.ijrmms.2007.06.002> – large rockbursts and induced seismicity; individual parameters require verification from primary Chinese publications.
- **Machine-readable summary:** [data/global-coal-key-cases-reviewed.csv](#).
- **Limitation:** International cases differ in mechanism, depth, type of extraction and quality of evidence; they cannot be grouped into one causal category by the word "coal" alone.

10 October 2026

- Ministry of Emergency Situations of Russia in the Kemerovo region: [initial report](#) and [clarification as of 10:45](#).
- Primary operational report from the Altai-Sayan Branch of the Federal Research Center, Geophysical Survey of the Russian Academy of Sciences (FRC GS RAS) [asb2026txsirz](#): 00:47:01.75 UTC / 07:47:01.75 local time, 54.09 N, 86.54 E, magnitude 4.9, with no magnitude type specified in the card, estimated intensity 6.2 on the MSK-64 scale, signal type [earthquake](#). The card does not report a depth.
- The solution published by the Kazakhstan National Data Center (NDC): magnitude 5.2, energy class 11.8, 54.04 N, 86.47 E, depth 1 km.
- Mayak's report, published on 10 October 2026 at 08:40: [M 4.8](#), 54.16 N, 86.37 E, time 03:47 Moscow / 07:47 in Kuzbass; the depth and source seismological bulletin are not specified:
https://mayaksbor.ru/news/sreda_obitaniya/v_yugo_zapadnoy_chasti_sibiri_10_oktyabrya_proizoshlo_zemletryasenie/
- The operational feed of the official Main Center for Special Control of Ukraine, checked 11 October 2026: [M 4.8](#), 54.17 N, 86.32 E, displayed time 03:47:06; the time zone and depth are not specified: <https://gcsk.gov.ua/sejsmichnij-monitoring/>
- Alternative EMSC solution: 00:47:09 UTC, [mb 5.1](#), 53.8438 N, 86.1776 E, depth 35 km.
- Official preliminary report on impacts: no casualties or damage were identified, a survey of the housing stock was carried out, enterprises and life support systems were operating normally.
- Working classification: **Origin not yet established.** The differences in coordinates and depth among the solutions are retained in the register.