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Anthropogenic seismicity

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PREFACE

The following educational package consists of two parts. The first contains basic information about the topic of the debate.

In the second part you will receive tips on how to directly prepare for the debate, in particular how to prepare arguments supporting or contradicting the following resolution:

In the area of anthropogenic seismic hazard construction of new important infrastructure should be prohibited.

Seismic hazard is usually connected with the devastating earthquakes, which happen on big tectonic boundaries. In this areas people live and designed cities. Mainly because these areas were fertile and had good location in terms of water supply and security. However many of these settlements were raised before danger of tremors from earthquakes were recognized or remembered. During development of civilization the danger of being killed due to an earthquake became vital in cities located near tectonic plate boundaries. On the other hand increase of knowledge and engineering skills allowed to build safe skyscraper buildings in such areas (i.e. Japan, Turkey or Chile). Similar situation occurs with the industrial investments in the field of mining and energy production. Usually mines or power plants are located in remote areas, therefore many of potential hazards are negligible. But during the exploitation cycle, more infrastructure such as houses for employees and other public buildings are constructed, usually before any hazardous accidents happen. When anthropogenic seismicity happens in the old mining area inhabited for a long time it is usually too late for prevention against hazard, houses may be vulnerable for structural damages due to ground shaking as well as the deformation of the surface. It causes economic losses of the companies due to compensation paid for the citizens and loss of society trust in the company's strategy and PR, which usually is based on downplaying of any risks related to the industrial activity. Currently, planning new mining or other seismic hazard related technologies investments companies can take into account the seismic hazard. Should it be obligatory to design the infrastructure accordingly or should any investment in new infrastructure should be banned in the areas of foreseen anthropogenic seismic hazard?

ANTHROPOGENIC SEISMICITY

Important infrastructure – infrastructure vital for society such as schools, hospitals, kindergartens.

Anthropogenic seismicity - seismicity caused by human industrial activity such as mining, oil and natural gas exploitation, water reservoir exploitation etc.

Seismic hazard - is anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking, landslide, liquefaction, tectonic deformation, tsunamis, and seiches.

Magnitude (M) – measure of earthquake size. Logarithmic scale of earthquake size, one magnitude unit means 10 times bigger earthquake.

Read the info cards and try to fulfill the listed tasks below:

1. Find the list of biggest earthquakes in terms of magnitude and human casualties
2. Find the list of the biggest anthropogenic seismic events
3. Compare the lists and try to find if any of the anthropogenic ones are included in the biggest EQ lists
4. Find info about the economic loss due to EQ and compare it with the investments into the mining industry (eg. Gold mining)
5. Find the economic loss values of stopping industrial investments due to seismicity (eg. Basel EQ and geothermal energy plant)

Info card 1	Info card 2
Tragic earthquakes in XXI century **Haiti 2010 M7** Earthquake caused 200 000 casualties and almost complete breakdown of the state. **Japan 2011 M9.1** Earthquake and tsunami caused 20 000 casualties and material loss of about 235 billions USD **Sumatra 2004 M9.1** Earthquake and tsunami with waves up to 30 m height caused 280 000 casualties and material loss of about 15 billions USD	**The biggest anthropogenic seismic events (with casualties)** **Zipingpu (China) M7.9, 2008** Most likely triggered on active fault by water reservoir impoundment, caused 88 000 casualties and material loss of about 150 billions USD **Gazli (Uzbekistan) M7.3, 1976** Operations related to natural gas exploitation and storage caused earthquake, 100 injured, one casualty, large damage of infrastructure in Gazli **Koyna (India) M6.3, 1967,** Earthquake triggered by water reservoir impoundment, caused 200 casualties, several thousands of injured and material loss of about 400 000 USD

Info card 3	Info card 4	Info card 5
The biggest ever recorded earthquakes Chile M9.5, 1960 USA (Alaska) M9.2, 1964 Sumatra (Indonesia) M9.1, 2004 Japan M9.1, 2011	**The biggest anthropogenic seismic events** Zipingpu (Wenchuan China) M7.9, 2008 Gazli (Uzbekistan) M7.3, 1976 Lake Hebgeben (USA) M7.1, 1959 Cerro Prieto (Mexico) M6.6, 1979	**Cost of gold production** Annual cost of gold production in Fosterville gold mine (Australia) is about 159 billions USD (excluding all investment in the mine design and construction, only the operational costs are taken into account).

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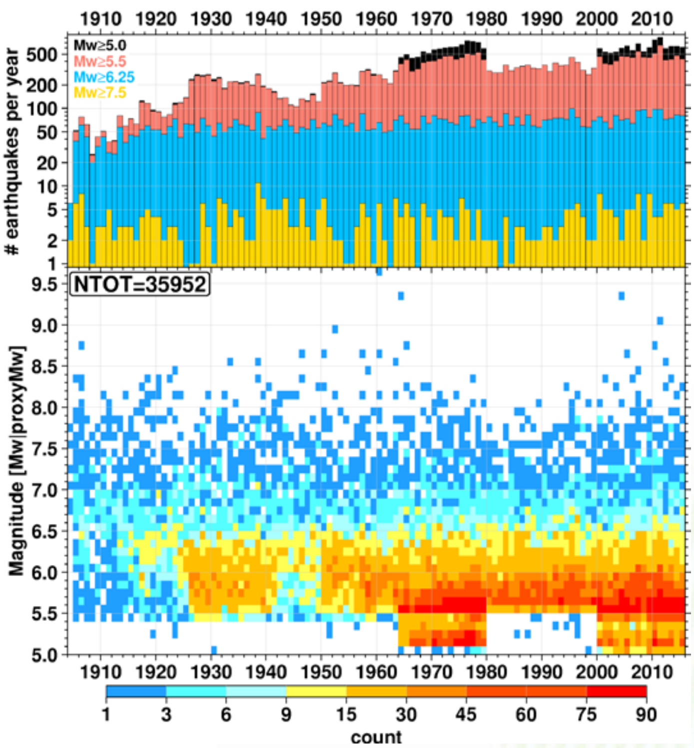
Info card 6

How often tectonic earthquakes occur

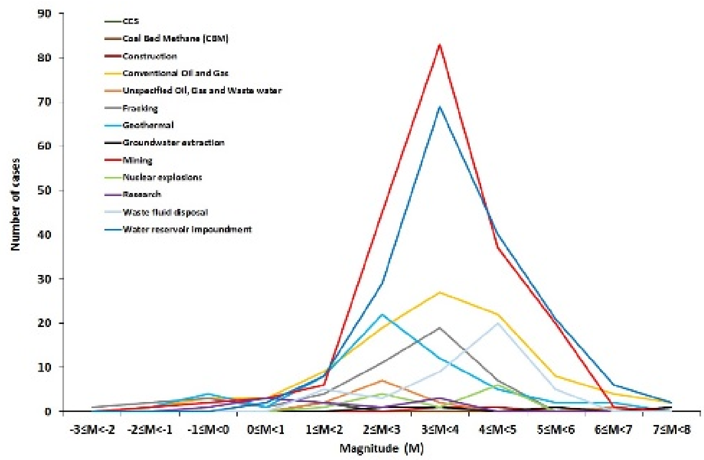
Several hundred earthquakes of magnitude of 5 and greater occur every year. Very strong potentially disastrous events occur up to several every year. (see picture below)



Info card 7

How often anthropogenic sismicity occurs

Less than 50 man-made earthquake of magnitude 5 and greater were ever recorded. Very strong and tragic were several among them in the last 100 years. (see picture below)



The most significant earthquakes related to human activity
M7.9 2008 China (Wenchuan) Very strong and tragic earthquake, which is supposed to be triggered by water reservoir impoundment. There is no agreement between scientist if it was caused by the water level changes or was it purely tectonic origin. It resulted with around 100 000 casualties and lost, 400 000 injured, and material loss of about 150 billion USD **M7.6 1976 Uzbekistan** Operations related to natural gas exploitation and storage caused earthquake, 100 injured, one casualty, large damage of infrastructure in Gazli. Small number of injuries was mainly due to the far distance between human habitats and the location of the earthquake. **M6.3 1967 India** Earthquake triggered by water reservoir impoundment, caused 200 casualties, several thousand injured and material loss of about 400 000 USD. **M2.9 2006 Switzerland** Felt earthquake triggered by the geothermal energy production with use of water injection into the rock formation. No casualties or injured reported, but about 2700 claims about the damage of private properties for about 6.5 million euro. Aftermath of the earthquake was material loss and serious anxiousness of the inhabitants. Seismic hazard analysis results with high possibility of further quakes of similar size during next 30 years, if further operations will be continued. Social anxiety, material loss and possible future earthquakes resulted with closing the investment worth 80 million euro. **Poland** Tens of felt earthquakes induced by underground mining of coal and copper ore. The material loss related to some damage of infrastructure of about several tens of euro. Strong induced earthquake in Bobrek coal mine in 2011 was the latest most significant example. Serious damage of the houses led to evacuation of 215 families. Mining company had to secure the new flats for them. Damages of the houses were very serious leading to demolition of several houses unable to be inhabited. This earthquake was not the only factor of the damage, it was also the long-lasting (almost 100 years) exploitation of the coal seams underneath the city.

The biggest and the most tragic earthquakes in the XXI century

M9.1 2004 Sumatra

Third biggest instrumentally recorded earthquake. The most tragic earthquake in XXI century. Quake and tsunami caused over 200 000 casualties. Damaging tsunami waves reached event to Maledives (2500 km away from epicentre) and Somalia (km away from epicentre). The biggest damages and material loss were in Indonesia, Thailand, Sri Lanka and India. It was second deadliest earthquake since the beginning of XX century. The deadliest was earthquake located in China, 16th December 1920.

M9.1 2011 Japain

Fourth biggest instrumentally recorded earthquake. Earthquake and tsunami caused 20 000 casualties and material loss of about 235 billion USD. Nuclear power plant in Fukishima was damaged. Major failure led to radioactive particles release and contamination of the surroundings and ocean. The nearest zone of 20 km around the plant was closed. Decontamination action is still on going.

M7 Haiti 2010

One of the most tragic natural disasters in XXI century. It caused 200 000 casualties. Damage and human loss led to complete breakdown of the state, it was followed by mass looting, anarchy and cholera epidemy. Without foreign aid, the state of Haiti would not be able to function, not to mention helping the victims. Following the 2010 earthquake and Hurricane Matthew in 2016, aid organizations in 2017 reported that 2.5 million Haitians still need humanitarian aid. Hundred times smaller than Japan 2011 earthquake caused ten times more casualties similar to the Sumatra 2004, which was the biggest in XXI century. Failure to prepare infrastructure, buildings and emergency services for the occurrence of such a large phenomenon, despite the knowledge that it may occur, was a common feature of Sumatra and Haiti cases.

Preparation for the debate

After reading the materials presented, you can proceed to directly prepare the arguments for the debate. Below are a number of questions. Answers to them can be good arguments for discussion. Some of them strongly support the thesis, others will help in refuting it. Some arguments are debatable and can be used by both sides.

Task.

Answer the following questions. Write answers that are also arguments for discussion in the appropriate place in the table (Worksheet No. 1).

Question card 1.	**Question card 2.**
Find the biggest anthropogenic earthquakes. How many casualties did they cause?	Find the biggest anthropogenic earthquakes. How many casualties did they cause?
Question card 3.	**Question card 4.**
How often anthropogenic earthquakes occur?	Does anthropogenic seismicity cause fatalities?
Question card 5.	**Question card 6.**
What are the material losses related to tectonic and anthropogenic seismicity?	Find the biggest earthquakes. Which one of them were anthropogenic earthquakes?
Question card 7.	**Question card 8.**
Can anthropogenic seismicity cause huge material loss?	Can cost and material loss related to anthropogenic hazard be covered by the profit from the industrial activity causing the tremors?
Question card 9.	**Question card 10.**
Does anthropogenic seismicity occur in the areas far from the industrial activities?	Is anthropogenic seismicity more harmful in the areas of low tectonic seismic hazard than tectonic earthquakes?
Question card 11.	**Your own question**
Is it possible to protect the communities from the anthropogenic earthquake damages?	

Division into PROPOSITION and OPPOSITION teams

Task.

You already have arguments that you can use during the discussion. At this stage, you will prepare yourself directly to formulate the argument in accordance with the assigned role and to justify and defend them. Try to predict which counterarguments the opponents will use and prepare your answer. In order to do this, use worksheet No. 2.

Should location of new important infrastructure and human habitats be allowed in the area of anthropogenic seismic hazard?


Photo: G. Lizurek


Photo: Miguel Vera León, Wikimedia Commons

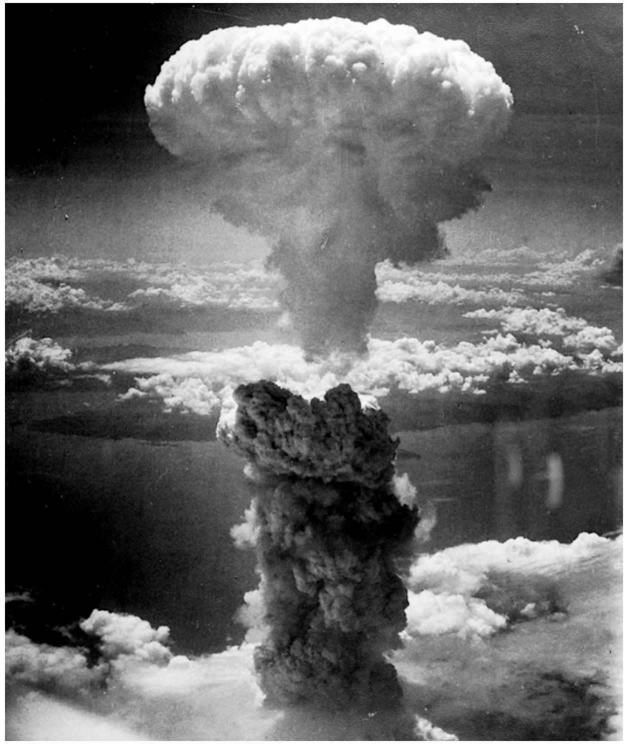


Photo: Library of Congress

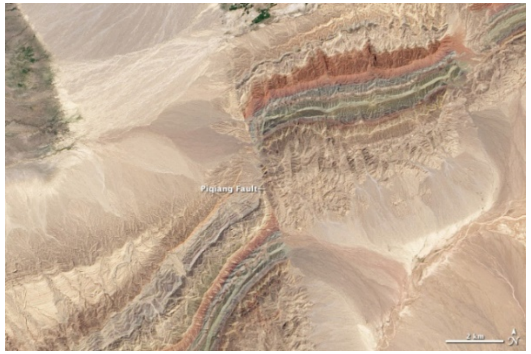
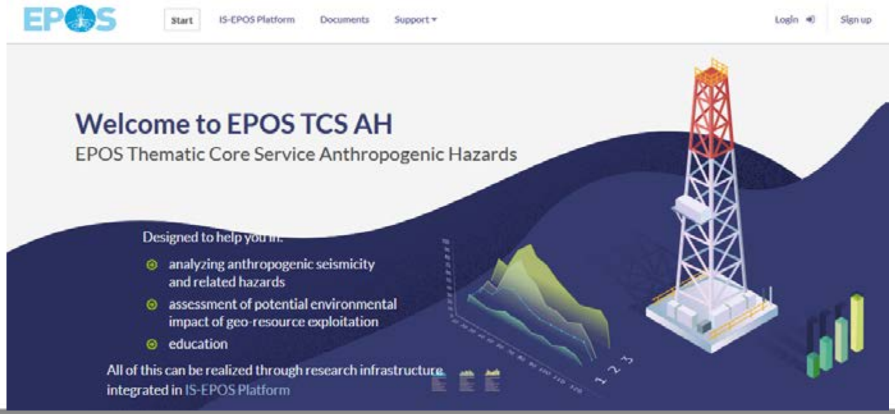
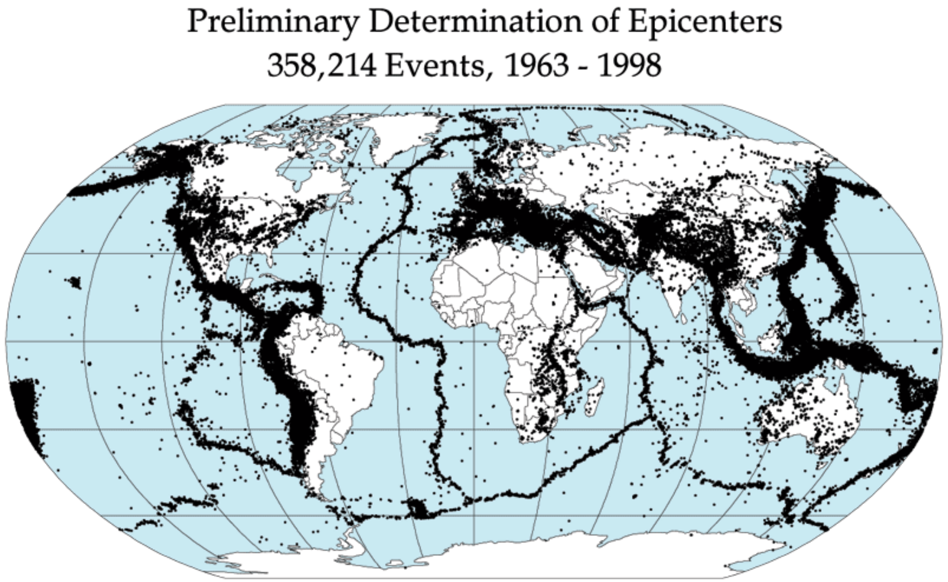
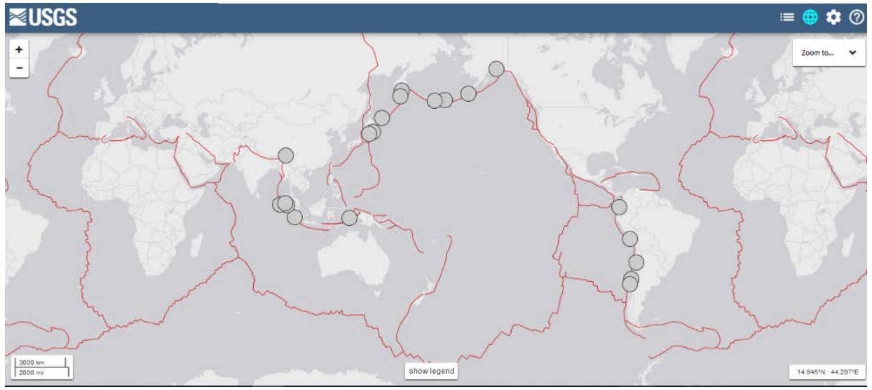


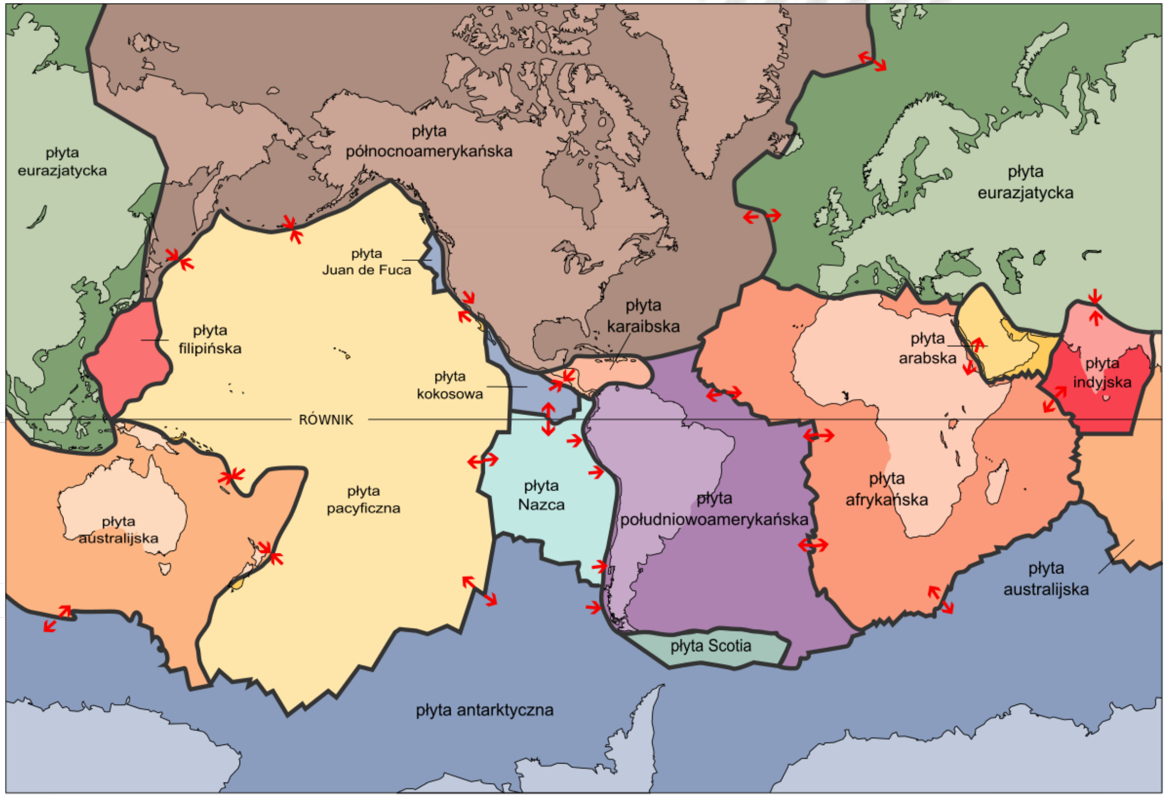
Photo: NASA Earth Observatory images by Robert Simmon and Jesse Allen, using Landsat data from the USGS Earth Explorer



Tectonic earthquakes







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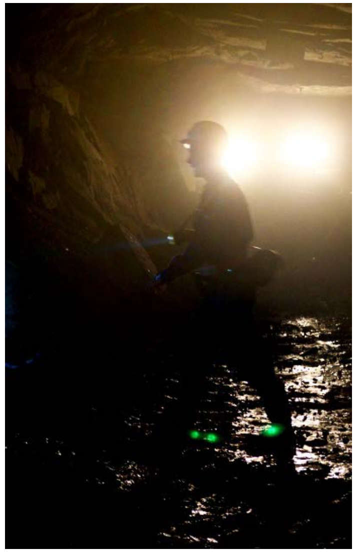
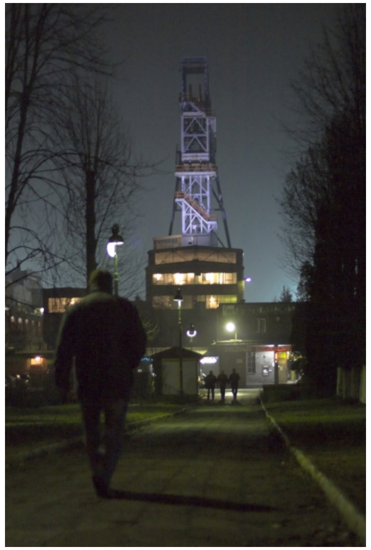
Anthropogenic seismicity

- Man made earthquakes induced or triggered during georesources exploitation, water reservoir impoundment or bomb blasts etc.



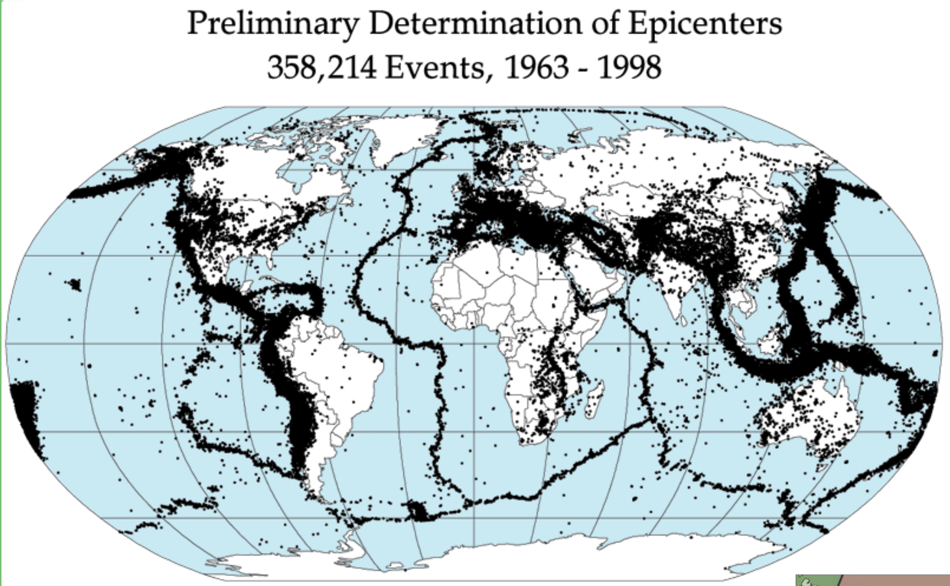





https://inducedearthquakes.org/

https://commons.wikimedia.org/wiki/File:Kopalnia_w%C4%99gla_brunatnego_i_elektrownia_w_Be%C5%82chatowie.jpg

Tectonic earthquakes



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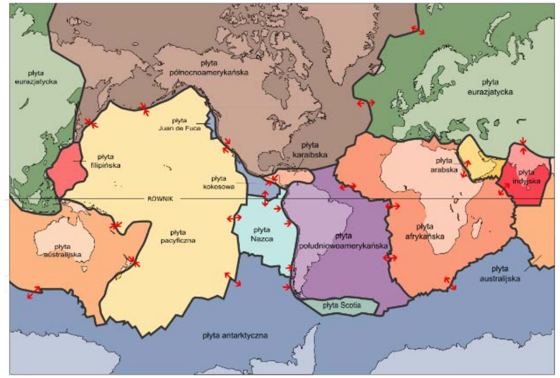

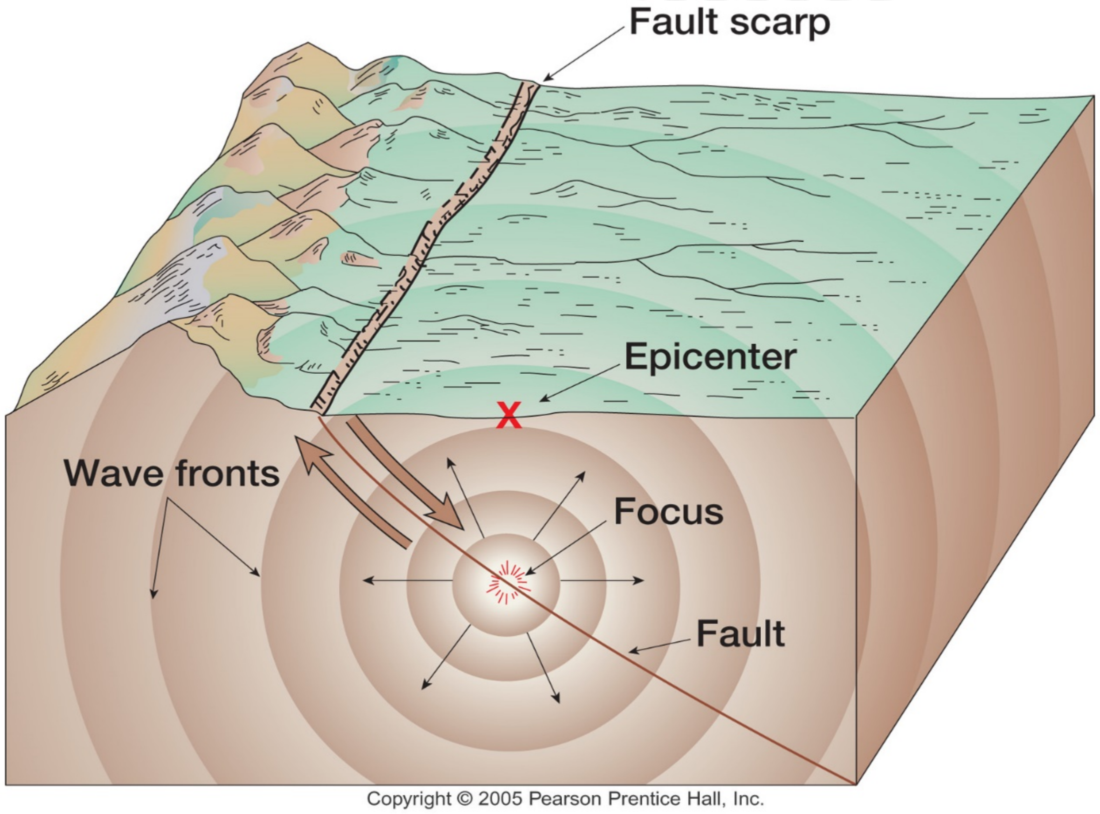

- **Earthquakes are the most tragic natural disasters:**
  - **Sumatra 2004 M9.1 earthquake and tsunami with waves up to 30 m height caused 280 000 casualties and material loss of about 15 billions USD**
  - **Japan 2011 M9.1 earthquake and tsunami caused 20 000 casualties and material loss of about 235 billions USD**
  - **Haiti 2010 M7 earthquake caused 200 000 casualties and almost complete breakdown of the state**

Photo: David Wald, USGS. Public domain
https://www.usgs.gov/media/images/damage-2008-great-sichuan-earthquake-china

Photo: Logan Abassi/UNDP Global
https://commons.wikimedia.org/wiki/File:Haitian_national_palace_earthquake.jpg

Photo: Rob Witter/USGS
https://www.usgs.gov/news/2018-anchorage-earthquake

Oxford Debates for Youths in Science Education

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Examples of anthropogenic seismic events:

- Zipingpu (China) M7.9, 2008, most likely triggered on active fault by water reservoir impoundment, caused 88 000 casualties and material loss of about 150 billions USD
- Gazli (Uzbekistan) M7.3, 1976, operations related to natural gas exploitation and storage caused earthquake, 100 injured, one casualty, large damage of infrastructure in Gazli
- Koyna (India) M6.3, 1967, earthquake triggered by water reservoir impoundment, caused 200 casualties, several thousands injured and material loss of about 400 000 USD

Photo: David Wald, USGS. Public domain
https://www.usgs.gov/media/images/damage-2008-great-sichuan-earthquake-china

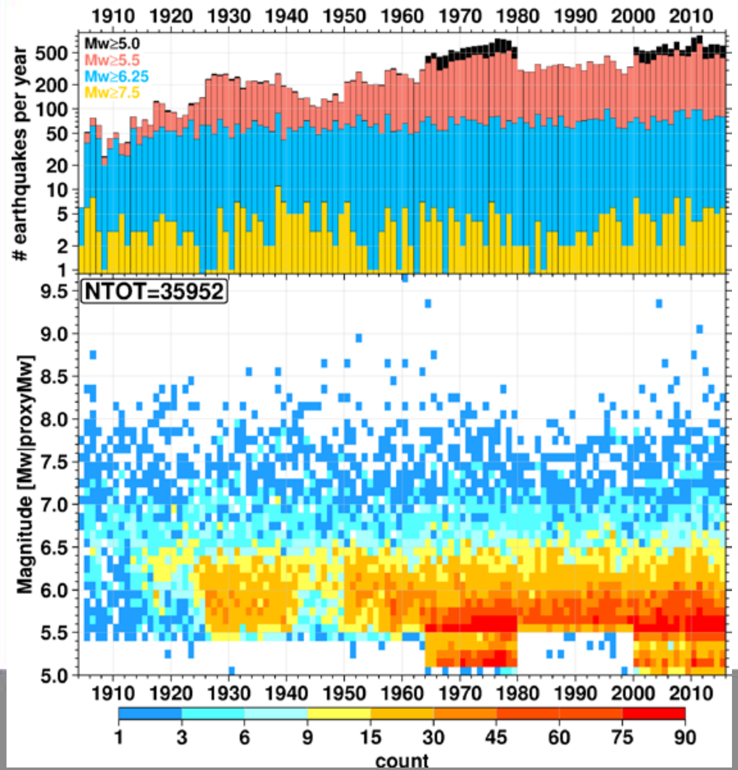
https://upload.wikimedia.org/wikipedia/commons/3/3d/Miaoziping_Bridge_damaged_in_2008_earthquake.jpg

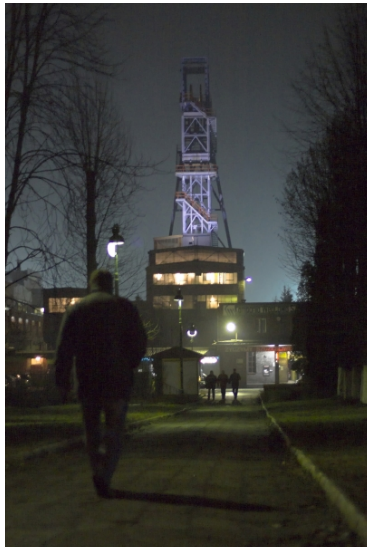
https://upload.wikimedia.org/wikipedia/commons/0/09/Zipingpu_Dam.JPG

https://inducedearthquakes.org/

Tectonic vs anthropogenic seismicity

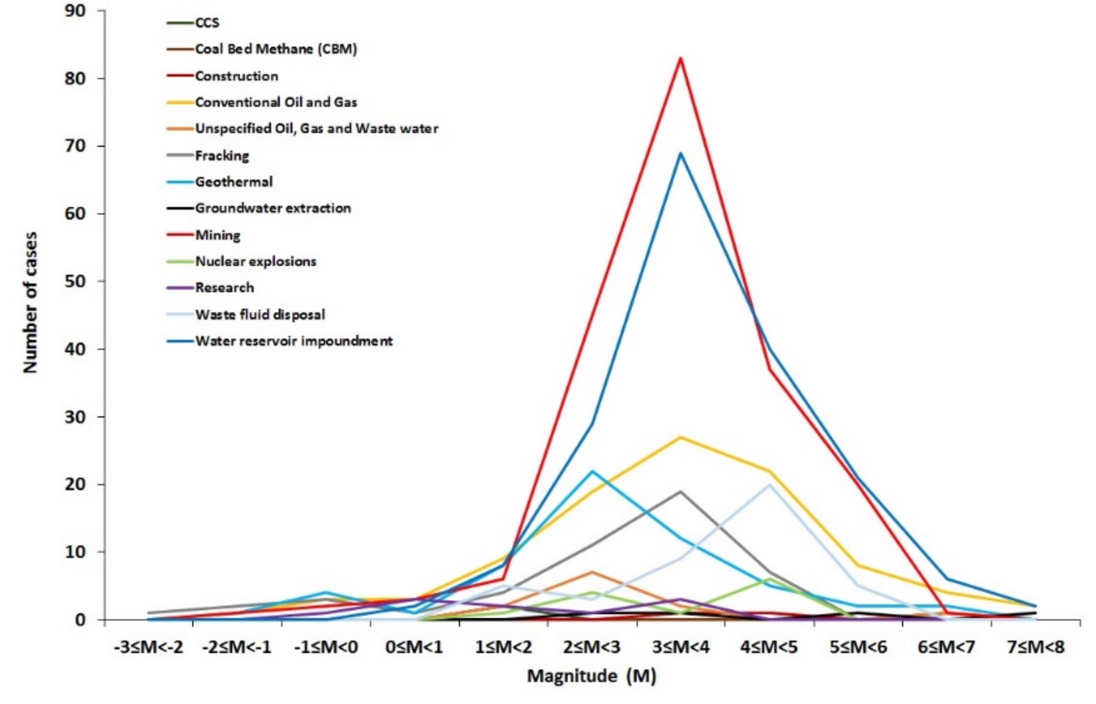
- **Tectonic:**
- Several hundreds of earthquakes with M>5 per year. Maximum several events with casualties annually.





https://inducedearthquakes.org/

- **Anthropogenic:**
- All known anthropogenic seismic events with M>5 were less than 10. Large and tragic events with casualties were several within last hundred years.



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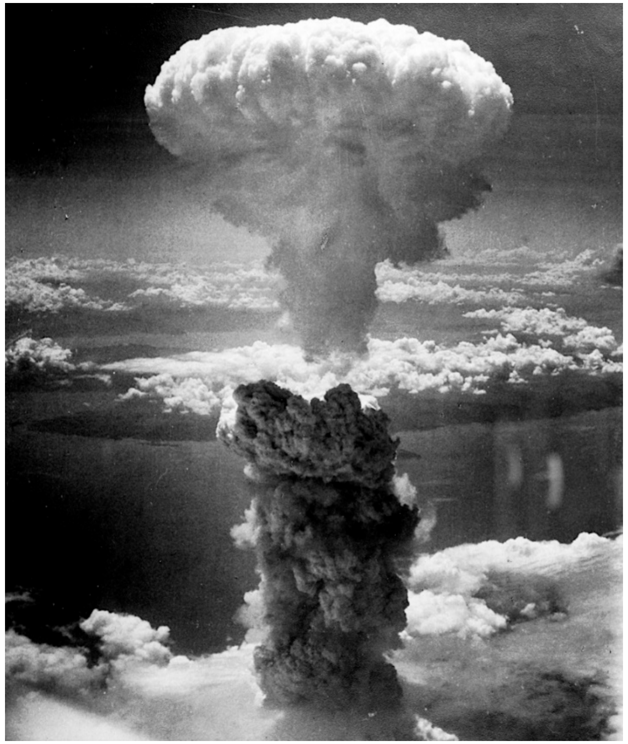
Should location of new important infrastructure and human habitats be allowed in the area of anthropogenic seismic hazard?

Photo: G. Lizurek

Photo: Miguel Vera León, Wikimedia Commons



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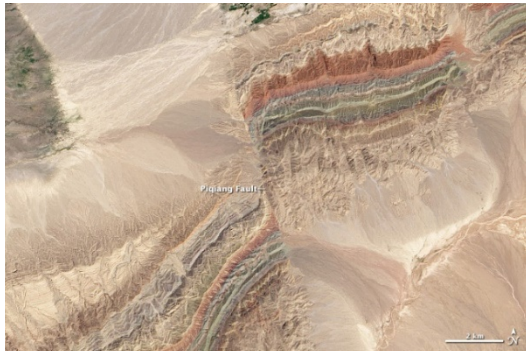
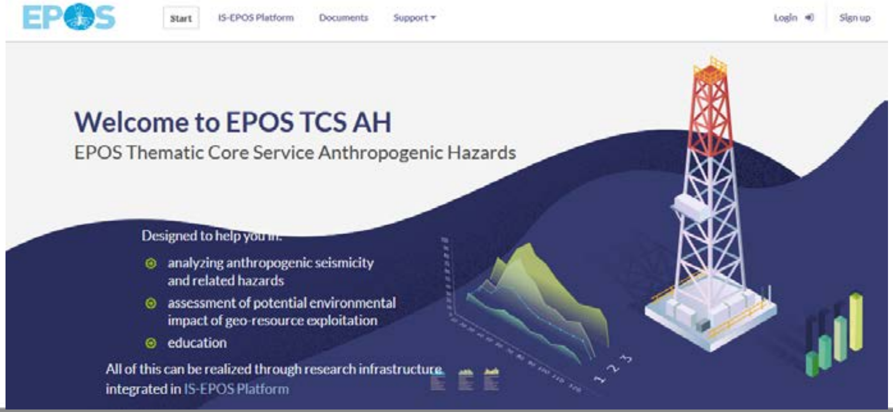


Photo: NASA Earth Observatory images by Robert Simmon and Jesse Allen, using Landsat data from the USGS Earth Explorer



„Anthropogenic seismicity"

Material for teachers

With methodological guidelines, a lesson plan and an answer key to worksheets

The educational package "Anthropogenic seismicity" was developed within "Oxford debates for the education of young people in the field of mathematics and science" project.
It is a key material, facilitating the achievement of primary project goals, including increasing reasoning skills and interest in STEM, which in the future may result in taking up a scientific career.
When preparing students for the debate, one should not neglect the development of such skills as: communication excellence, argumentation or public speaking. Students should improve their ability to persuade effectively, argue properly, reason accordingly and speak out correctly. Composition of texts, using rhetorical means in oral statements, speaking in accordance with the rules of language culture, text interpretation, public speaking and presentation of texts, discussions and negotiations are of equally high importance.
In order to achieve the abovementioned goals, the implementation of thematic educational packages should be preceded by classes dedicated to preparation for debating as such. This can be accomplished in consultation with teachers of other subjects and the class teacher. The development of basic communication skills can be included in the class teacher's work plan, and the prepared lesson plans can be used during regular classes. Auxiliary materials can be found in the following documents:

1. **Warm up practice** – Annex No 2 to National frameworks for implementation of Oxford debates in STEM in school practice (pages 37-39);
   This document includes the following exercises: active listening, public speaking and debating skills.
2. **Lesson plans aimed at general development of debating skills** – Annex No 2 do National frameworks for implementation of Oxford debates in STEM in school practice (pages 40-55).

   This material consists of 7 lesson plans prepared by Dr. Foteini Englezou, president of the Hellenic Institute for Rhetorical and Communication Research. Scenarios are a guide to work. It is not necessary to follow all the lessons. The teacher can decide which scenarios (or their selected fragments) are most useful for working with a specific group of students. The document offers the following lesson plans:

   1. Communication skills
   2. Express your scientific argument, not your opinion
   3. Build a valid scientific argument
   4. Searching for evidence
   5. Enhancing students' linguistic skills
   6. Rebuttal and refutation
   7. Fallacies
3. Methodological Guide for Teachers. ODYSSEY: Oxford Debates for Youths in Science Education

The final stage of preparation for debates based on specific packages is to familiarize students with the principles of debating, described in detail in the abovementioned document.

Anthropogenic seismicity

The " Anthropogenic seismicity " educational package consists of the following elements:
• Multimedia presentation;
• Introductory video based on the presentation: https://youtu.be/LtTDSnm3_c0;
• Educational package " Anthropogenic seismicity " - material for students;
• Worksheets (the same for all packages);
• " Anthropogenic seismicity " - material for the teachers (with answer key).
It is recommended to implement the package during a minimum of three lesson units.

The "Anthropogenic seismicity" package contains a set of materials to prepare and conduct a debate in which students will consider the hazard of anthropogenic seismicity for infrastructure and if it is reasonable to build the new infrastructure in the areas of the seismic hazard caused by the industrial activities. The materials focus on the possible societal and economic consequences of the disastrous events like earthquakes, both natural and anthropogenic.

The package has been prepared to minimize the time needed to search for and select source materials. Students will receive ready-made materials in the form of source texts, tables, charts, described authentic stories, as well as auxiliary questions. On their basis, they develop arguments that can be used in the debate both to support the main thesis and to negate it.

The materials in the described package are intended for students of secondary schools. They can be carried out both during geography lessons, as well as during additional classes on science. Part of the work, consisting in the analysis of materials, preparation and appropriate qualification of arguments, can also be done as homework. Teachers may also consider organisation of a debate in grades 7-8 of primary school. However, it requires proper preparation of students, explaining more difficult terms appearing in the materials.

Lesson 1. What is earthquake?

In the first lesson, students should organize their knowledge about earthquakes and its causes, as well as learn how to protect against such disastrous phenomena's, both through the nature-based measures, as well as through the design and construction of a infrastructure. The pros and cons of both are described in the material for students. During the lesson, the teacher can also use the multimedia presentation prepared by Dr. Grzegorz Lizurek or watch a short movie (presentation with author's comment). The package also includes additional story cards describing some examples of the earthquake effects and its influence on economy. The material for students also include additional exercises, the performance of which will help students gather arguments in the discussion.

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It is recommended that students receive the materials a few days prior to the lesson. This will allow them to get acquainted with the topic of the lesson initially and facilitate active participation in the classroom. A multimedia presentation or a video recorded by the author of the package can be used during the lesson.

Lesson 2. „Should location of new important infrastructure and human habitats be allowed in the area of anthropogenic seismic hazard?" – constructing arguments for and against the resolution

The aim of the second lesson is to formulate as many arguments as possible (both for and against the resolution) that will be used by students during the debate, summarizing the work with the package.

Lesson plan

1. Organizational issues, checking the attendance list, familiarizing with the topic and objectives of the lesson [5 minutes].
2. Preparation of arguments [25 minutes]

The teacher divides the class into teams of two. Each team receives 16 **question cards** available in the educational package (material for students) and 2 copies of worksheet No. 1 (one for each student individually). Based on the questions, students formulate arguments for the presented resolution, against the resolution and those that are debatable and can be used in the discussion by both teams. Students work together, but each student individually completes his/her worksheet. There are examples of selected arguments for worksheet 1 presented in the answer key in this material.

3. Teams: proposition and opposition are formed [10 minutes].

Team selection may be executed in many ways, each of them having both advantages and disadvantages.

- Students declare which arguments are closer to their beliefs. The teacher divides the class into teams (each with a similar number of students) in the manner reflecting their convictions.
- The second method assumes a division similar to the one above, with the difference that ultimately the team consisting of the supporters of a given resolution becomes the "opposition" team, while the opponents of the thesis become "proposition" team. The supporters of such a division assume that it teaches the participants of the debate to a greater extent to use arguments supported by facts, and is less based on emotions.
- Alternatively, division into teams can also be done randomly.
- Finally, team selection can also be made by the teacher in a subjective way, ensuring that each team has both leaders and students who require more help, so that both teams have similar "winning potential". In order to save time for division, the teacher can do it at the beginning of the lesson, for example by distributing worksheets printed on sheets of different colours or marked in some other manner.

4. The teacher distributes worksheets number 2 to the students (one for each student) and explains the homework. An example of a filled out worksheet is available in the answer key in this document.

5. Students in each team read prepared arguments in accordance with the assignment to a given group. Each student receives 1 argument, which he/she will develop (as homework) according to the guidelines in worksheet No. 2.
6. Each team also appoints 3 people who will present the arguments prepared by the entire group. Students decide the order of their speeches. During the debate, other team members who are not directly involved in the debate, fill out worksheet No. 3
7. Summary of the lesson, evaluation of students' work [5 minutes].

Lesson 3. Debate

During the final lesson, the teams conduct a debate according to the guidelines contained in the "Methodological Guide ..." It takes 45 minutes in total to conduct a full debate. During the debate, the teacher does not comment on the arguments or indicate the fallacies made by the students on an ongoing basis.

An exercise-based debate should be structured as follows:

1. Opening of the debate by the moderator/chairperson [3 minutes].
2. Initial vote by the audience [2 minutes].
3. 1st Researcher-Debater of the A research-team: Constructive Speech [4 minutes].
4. 1st Researcher-Debater of the B research-team: Constructive Speech [4 minutes].
5. Cross-fire between the researchers-debaters (1) of both research teams [3 minutes].
6. 2nd Researcher-Debater of the A research-team: Rebuttal Speech [4 minutes].
7. 2nd Researcher-Debater of the B research-team: Rebuttal Speech [4 minutes]
8. Cross-fire between the researchers-debaters (2) of both research teams [3 minutes].
9. Preparation time for the Summary and Final Rebuttal by both research teams [2 minutes].
10. 3rd Researcher-Debater of the A research-team: Summary Rebuttal [2 minutes].
11. 3rd Researcher-Debater of the B research-team: Summary Rebuttal [2 minutes].
12. Grand Cross-fire between the researchers-debaters (1 & 2) of both research-teams [3 minutes].
13. 3rd Researcher-Debater of the A research-team: Final Focus Rebuttal [2 minutes].
14. 3rd Researcher-Debater of the B research-team: Final Focus Rebuttal [2 minutes].
15. Final vote by the audience / Short written feedback [3 minutes].
16. Presentation of the results by the moderator [2 minutes].

If the debate takes place during extra-curricular activities, then it is recommended to devote, for example, 90 minutes for this part. This will allow you to prepare the room for the debate, recall the rules, conduct the debate and discuss its course and finally evaluate the work of students.

In terms of classroom conditions, it would be ideal to allocate two adjoining lesson units to the debate. Taking into account the school circumstances, organizational difficulties and the inability to devote too many lessons to content extending the core curriculum, the debate can be conducted in one lesson, while maintaining high discipline in time. In this case, it is recommended that during the next lesson with the class additional 10 minutes are spent discussing the debate, pointing to strengths and mistakes made by the participants of the debate.

In this format, 6 students (3 from each team) actively participate in the debate. The teacher may also appoint a moderator from among the students and a time keeper. The rest of the students will receive worksheet number 3. Their task will be to listen carefully to the debate and to note the opposing team's strengths and areas for improvement, and to justify their choice. Completed worksheet no. 3 may be the basis for issuing a grade for activity in the lesson for students who did not take part in the debate directly, but participated in its preparation and were active observers of its course.

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Worksheet No 1 – answers

The table below contains examples of answers to question cards gathered in the worksheet No. 1. The answers may help to formulate arguments in the debate on the presented resolution.

FOR	„GREY AREA"	AGAINST
Question card 1. *Find the biggest anthropogenic earthquakes. How many casualties did they cause?* Zipingpu (China) M7.9, 2008 - 88 000 casualties, Gazli (Uzbekistan) M7.3 – one casualty, 1976, Koyna (India) M6.3, 1967 - 200 casualties. Overall around 88 000 casualties. *Question card 4.* *Does anthropogenic seismicity cause fatalities?* Yes. In extreme cases fatalities may reach thousands of people. Thus, we should not pose people to additional risk with building infrastructure in areas of anthropogenic seismicity. *Question card 7.* *Can anthropogenic seismicity cause huge material loss?* Yes (see infocard 2 Zipingpu 75 mld USD). Casualties material loss and cost related with damages are too huge to justify construction of new infrastructure in regions of high anthropogenic seismic hazard.	*Question card 2.* *Where can anthropogenic and tectonic earthquakes occur?* Anthropogenic seismicity may occur only in the areas, where people influence on the natural state of the rockmass. Tectonic earthquakes occur in very wide the areas of active tectonic areas such as plate boundaries. *Question card 5.* *What are the material losses related to tectonic and anthropogenic seismicity?* They may be very high in both cases. Closing of geothermal plant in Basel cost was 6.5 million euro. Tectonic earthquakes usually cause much bigger material loss. Cost of the 2011 Japan earthquake and tsunami related damages was 235 billion USD - the highest in history. *Question card 8.* *Can cost and material loss related to anthropogenic hazard be covered by the profit from the industrial activity causing the tremors?*	*Question card 3.* *How often anthropogenic earthquakes occur?* Very rare (see infocard 7). It means that seismic hazard related with anthropogenic seismicity is much lower than from tectonic earthquakes *Question card 6.* *Find the biggest earthquakes. Which one of them were anthropogenic earthquakes?* The biggest earthquakes were: Chile M9.5, 1960, USA (Alaska) M9.2, 1964, Sumatra (Indonesia) M9.1, 2004, Japan M9.1, 2011. The most tragic ones in XXI century were: Sumatra 2004 M9.1 (280 000 casualties), Haiti 2010 M7 (200 000 casualties), Japan 2011 M9.1 (20 000 casualties). None of the above were anthropogenic seismicity. *Question card 9.* *Does anthropogenic seismicity occur in the areas far from the industrial activities?* No. Anthropogenic seismicity occur only in close vicinity of the industrial activity, which cases the

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Question card 10.

Is anthropogenic seismicity more harmful in the areas of low tectonic seismic hazard than tectonic earthquakes?

Yes. Such areas and people living there are less prepared for strong shaking that the ones with significant tectonic seismicity.

Yes, if the earthquake is not as tragic as in case of Zipingpu or Koyna (Infocard 2). Usually cost of the industrial activity and the profit related with it are much bigger than the costs of the damages (Infocard 5 cost of gold production is at least covered by the income from selling the end product). Material loss related to tectonic and the biggest anthropogenic earthquakes are bigger than the cost of the gold production (several billions vs several hundred million USD). Material loss may vary from several millions to several billions of USD (Basel vs Zipingpu). Additionally, it is worth to mention, that anthropogenic seismic hazard may affect also the areas with very low tectonic seismic hazard.

tremors (Infocard 2). Therefore, it is relatively simple to apply safty rules int the design and construction of new infrastructure to lower the hazard.

Question card 11.

Is it possible to protect the communities from the anthropogenic earthquake damages?

Yes, to some extent. If we take a look on the fatality numbers from tectonic earthquakes the better prepared country the lower number of the casualties (see Japan 2011 vs Haiti 2010). Technology and safety procedures to mitigate the hazard are available for tectonic earthquakes, they can be adopted to the anthropogenic seismicity cases.

Worksheet No 2 – examples of arguments

<table>
<tr><th>Argument with reasoning</th><th>Foreseen rebuttals of the other group</th><th>Answers to rebuttals</th></tr>
<tr>
<td rowspan="4">(Claim)
Construction of new infrastructure in the areas of anthropogenic seismic hazard should be banned

(Warrant)
Large earthquakes are extremely dangerous causing fatalities and catastrophic damage of infrastructure. It doesn’t matter if they are tectonic or anthropogenic origin. Human settlements should avoid locations with high anthropogenic seismic hazard.

(Evidence)
The largest anthropogenic seismic events are catastrophic i.e. Zipingpu (China) M7.9, 2008 - caused 88 000 fatalities.

(Impact)
When there will be no new infrastructure such as houses and other public service buildings in the area of seismic hazard, the hazard of death due to anthropogenic seismicity will be significantly lowered.</td>
<td rowspan="2">Very large and damaging anthropogenic earthquakes are very rare, much less often than in case of tectonic earthquakes. Therefore, the hazard posed by the anthropogenic seismicity is significantly lower. Tectonic earthquakes of magnitude 5 and larger is several hundred per year, while anthropogenic seismic events of similar size were less than 50 in the last two centuries. It would be more reasonable to build the new infrastructure taking it into account than to give up any construction in such areas.</td>
<td>Despite the knowledge of the limited areas posed into anthropogenic seismic hazard precise forecast of the damaging earthquake occurence is immposible. It doesn’t help to decrease the hazard.</td>
</tr>
<tr>
<td>Damages caused by anthropogenic seismicity are more socially harmfull in the areas of low natural seismicity, than similar earthquakes can cause in the areas of moderate or high natural seismic activity. It is mainly due to the higher security standards in the areas of high seismic hazard. Therefore new infrastructure build as usual in low natural seismicity may be dangerous. It is safer to not build new infrastructure in such areas.</td>
</tr>
<tr>
<td rowspan="2">Anthropogenic seismicity occurs only in the limited space around the industrial activity, which is influencing the natural rockmass state. In contrast, tectonic events occur in very wide areas around the tectonic boundaries, which makes it difficult to assess the hazard of such events. Taking above into account it is much easier to plan and mitigate possible danger in very limited areas of anthropogenic seismicity using the technology and knowledge of the tectonic seismic hazard assessment.</td>
<td>We can’t fully protect society against the earthquakes. Well prepared for large earthquake countries, such as Japan can only reduce number of fatalities, but can’t fully protect from them inhabitants of the seismic areas.</td>
</tr>
<tr>
<td>Despite the rare occurrence of the catastrophic anthropogenic earthquakes, they cause huge costs and casualties. Zipingpu earthquake caused 75 billion USD of material loss, closing the Basel geothermal plant due to anthropogenic seismicity caused 6.5 million EUR. Human casualties and material loss doesn’t justify construction of new infrastructure in the areas of high anthropogenic seismic hazard.</td>
</tr>
</table>

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<table>
<tr><th>Argument with reasoning</th><th>Predicted rebuttals of opposite team</th><th>Answers to rebuttals</th></tr>
<tr>
<td rowspan="4">(Claim)

Construction of new infrastructure in the areas of anthropogenic seismic hazard should be allowed.

(Warrant)
Earthquakes are a deadly thread for people, but it doesn't stop us to build new infrastructure in the areas of high tectonic earthquake hazard. Therefore similar approach should be applied in the areas of anthropogenic seismicity.

(Evidence)
Highly developed engineering allows to build infrastructure, which will minimize the danger of injury or death during an earthquakes. Such technology is implemented in USA, Chile or Japan, where large earthquakes occurred. New infrastructure is designed and build there to lower the vulnerability to the earthquake effects and making people safer in such areas.

(Impact)
New infrastructure designed according to the construction codes of the seismic hazard areas will make people safer.</td>
<td rowspan="2">Anthropogenic seismicity can occur in areas with no tectonic seismicity reported in the past. It may cause large damages and casualties. Such case was in Basel, where unexpected earthquake caused by the geothermal plant caused material loss and significant social anxiety. It caused closing the geothermal plant investment and many insurance claims.</td>
<td>Anthropogenic seismic events are usually small or moderate. Tragic Zipingpu and Koyna earthquakes are exceptions not the common events. Closing of the geothermal power plant in Basel cost 6.5 million EUR, while costs related to tectonic earthquakes damage are much higher. Japan 2011 earthquake and tsunami caused 235 billion USD material loss. It means that it is much easier and cheaper to take into account at the stage of design of the new infrastructure costs of anthropogenic seismic event damages, than large tectonic ones. However, technology to mitigate vulnerability of building exposed to earthquake is used in the areas of high tectonic earthquake activity. They can be used in case of anthropogenic seismicity as well, when adjusted to the possible seismic hazard.</td>
</tr>
<tr><td>Material loss caused by anthropogenic seismicity can be covered from income generated by the industrial activity inducing seismicity in case of usual magnitude of these events. But except the very large earthquakes such as Zipingpu and Koyna cases.</td></tr>
<tr>
<td rowspan="2">Areas of the largest anthropogenic seismic events may be completely unprepared for such hazard in contrast to the areas of constant seismic risk in highly active tectonic regions. Moreover, the strongest of the anthropogenic earthquakes can be as large as the large tectonic ones, which may cause similar catastrophic damages.</td>
<td>Catastrophic anthropogenic earthquakes are very rare. Tectonic earthquakes of magnitude 5 and higher are much more often – several hundred per year, while anthropogenic events of similar size were less than 50 ever recorded. It means that such events shouldn't be very dangerous for any new infrastructure designed with knowledge and technology adapter to such seismicity.</td>
</tr>
<tr><td>Anthropogenic seismicity can occur only in very limited area, where industrial activity causing the tremors is taking place, while tectonic earthquakes occur in large areas along the tectonic boundaries. This limitation of the occurrence area in anthropogenic seismicity makes the design and construction of the new infrastructure easier. It also limits the costs and simplify the safety protocols.</td></tr>
</table>

Worksheet no. 1

The educational package contains a set of questions to help prepare arguments for discussion on the resolution. On their basis, prepare a set of arguments and group them into those that are clearly in favor of the resolution, against the thesis, and those arguments that can be used by both teams. Write them down in the appropriate parts of the table.

FOR	„GREY AREA"	AGAINST

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Worksheet no. 2

Based on the materials provided by the teacher, prepare arguments for discussion. One group of students prepares arguments supporting the resolution, the other one - opposing arguments. Use the proposed template.

ARGUMENT 1.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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ARGUMENT 2.

Argument with reasoning	Foreseen rebuttals of the other group	Answers to rebuttals

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Worksheet no. 3

Name and surname:……………………………………… Class………… Team: proposition/opposition

During the debate, hear and observe carefully the speeches of the debates from the other team. Then, evaluate which speech convinced you the most and which areas of your opponents' speech should be improved.

1. In terms of **argumentation (**e.g. the quality of the arguments presented, credibility of the data and scientific evidence) in the rival team I was most convinced by the speaker No. ....

Reason:

………

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2. In terms of **the style of presentation and communication with the audience** (e.g. confident, persuasive, authentic and dynamic posture, moderate gestures, assertive voice variety, good eye contact with the audience, use of moderate humor, friendly and professional approach to all participants, effective use of body language) in the rival team I was most convinced by the speaker No. ....

Reason:

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Indicate the element of the rival team's performance that requires improvement. Justify your answer.

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Reason:

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