LIBERA UNIVERSITÀ INTERNAZIONALE DEGLI STUDI SOCIALI

Department of Political Science
Bachelor in Politics, Philosophy and Economics
Chair in Population Environment and Sustainability

THE EFFECTS OF HUMAN ACTIVITIES ON THE EARTH: INDUCED EARTHQUAKES

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Introduction

Earthquakes have always been considered natural events in our societies, causing hundreds of victims every year around the entire world. Nowadays the things are changing, due to the increased request of natural sources and the continuous growth of world's population, more energy and more resources are being required. Our epoch can be perfectly defined with the term "Anthropocene", referring to the influence that human activities have on our planet, basing the evidence on continuous atmospheric, hydrologic, geologic and biospheric alterations. Starting in the 1950s, this process is damaging the earth with a trend that, if not reversed, is going to leave future generations in a hopeless situation. Having been born in this time period we are used to take many of the utilities we have for granted, not knowing that we obtain them through activities like gas storage, mining and underground water extraction. To define these activities as dangerous would be reductive, since nowadays they can be considered the main cause of the trigger of earthquakes. This could seem illogical, but thanks to the great quantity of concrete cases that can be taken as example, my main focus would be to take into light the correlation between these activities and earthquakes, in order to create more consciousness of the destroying power we have on our planet.

Beginning with the differentiation of the different human activities that, both underground and on the surface, are probably causing these induced earthquakes, my thesis will continue explaining the ways in which several countries have faced the problem, so from a political point of view.

Earthquakes have always been part of our societies, since the beginning of our times, but nowadays as never before they are causing suffering among the population. The increase in the total world population has lead to a correspondent increase in the total amount of earthquakes, with a trend that will continue to grow since it is expected that by the 21st century the number of people in the World will be around 10 millions.

An earthquake is a natural and unpredictable event. Caused, for the most part by clashes in some parts of the planet of earthquake blocks, called tectonic plaques. Tectonic plates, in their slow motion against each other, cause a huge clutch with consequent accumulation of elastic energy in the rocks. When the accumulated energy exceeds the critical point of resistance of the rocks, a sudden and massive fracture occurs, which produces a series of elastic waves called seismic waves that propagate on the surface and are felt. This is how an earthquake is made.

The point, inside the earth's crust where the fracture and the seismic event originates is called Ipocentro. Its superficial projection is called the epicenter, which coincides with the place of maximum advertibility and, sometimes effects of the event. The intensity of the earthquake is greater, the greater the fracture that occurs in the affected rocks.

For what concerns seismic activity zones, they are mostly connected with the contact lines of the tectonic plates, point in which there there is less stability. The superficial fractures (of 5/15 km of depth) of the earth's crust are called “faults”, and it is in their vicinity that quarthquakes originate.
That is why the earthquake, while being an absolutely unpredictable and sudden phenomenon, usually occurs with some repetition and frequency in the same areas, those mentioned above.

It has a duration that hardly exceeds the minute. The main event is sometimes preceded by some "warning" shocks, but above all, it is followed by a series of minor "replicas", which are caused by the natural settling of the ground. Seismic events are measured on the base of two distinct criteria: the Magnitude or Richter scale, or the Intensity or Mercalli scale.

The former estimates the value of the energy released by the earthquake (from 1 to 9 degrees); while the second one estimates the degree of perception of people and the effects of shock on material things, taking into account the degree of vulnerability of buildings and human works (1 to 12).
Having introduced this phenomenon, my my objective is to explain the way in which human activities can trigger it through the different activities, ranging from mining to nuclear undergound test.

1.0 Reservoir-induced seismicity

Artificial water reservoirs are one of the main causes of humanly induced earthquakes, with a total amount of more than 70 cases globally identified by scientists. The worst case is without any doubt the 7.9-magnitude Sichuan earthquake of May 2008, which lead to the death of around 80,000 people and has been linked to the construction of the Zipingpu Dam. During the 1980s nine earthquakes occurred in the Indian Peninsula, five of which are though to be caused by reservoirs, leading to huge damages. This phenomenon is better defined as Reservoir-Induced Seismicity (RIS), and is commonly related to the “extra water pressure created in the micro-cracks and fissures in the ground under and near a reservoir. When the pressure of the water in the rocks increases, it acts to lubricate faults which are already under tectonic strain, but are prevented from slipping by the friction of the rock surfaces"[1](Dr. V. P Jauhari).

In the same way as most aspects of seismology, the certain functioning of Reservoir Induced Seismicity are not well understood, moreover it is not possible to predict precisely which dams will induce seismicity or how strong the vibrations are likely to be. Certainly scientific results have shown that its depth is the most important factor, since most of the strongest cases of Reservoir Induced Seismicity have been observed for dams over 100 metres high (International Commission on Large Dams); although the volume of water also plays a significant role in triggering earthquakes. In the research cases of Reservoir Induced Seismicity, the intensity of seismic movements incremented within around 25 kilometres of the reservoir as it was filled. For what concerns the time period in which seismic events can occur, data have shown that it is a transitory phenomenon which will occur either immediately after filling period of the reservoir, or after a certain time delay of few years. Usually if there is a postponement it is due to the permeability of the rock under the reservoir. [2]

We can distinguish between three main effects of reservoir loading relevant to inducing earthquakes. The first one is the elastic stress increase that follows the filling of the reservoir; followed by the increase in pore fluid pressure in saturated rocks (due to the decrease in pore volume caused by compaction) in response to the elastic stress increase and finally pore pressure changes related to fluid migration.

[1] Paper prepared for the World Commission on Dams, Dr. V. P Jauhari

-Kerr, R. and Stone, R. (2009), “ A Human Trigger for the Great Quake of Sichuan?”.

-Gupta, H.K. (2002), “ A review of recent studies of triggered earthquakes by artificial water reservoirs with special emphasis on earthquakes in Koyna, India. National Geophysical Research Institute, Hyderabad 500007, India. Received 15 March 2000, Accepted 29 October 2001, Available online 19 February 2002

[2] Densomre,A.,Ellis, L.M.A. , Li, Y., Zhou, R. ,Hancock, G.S. Richardson, N. (2007) Active tectonics of the Beichuan and Pengguan faults at the eastern margin of the Tibet Plateau.

-P.Talawani, Seismotectonics of the Koyna-Warna area, India, Pure and Applied Geophisics, (1997).

More specifically we can say that water reservoirs are often constructed in seismically active regions, including the Himalayas, Southwest China, Iran, Turkey, and Chile. This is due to the fact that they are usually built in valleys; which in turn exist because of the active erosions that are taking place. Active erosions consecutively imply that there has been a recent uplift, which is created under compressional tectonic force, (reverse or thrust faults). For this reason, many water reservoirs have an active fault dipping under them.

Earthquakes can occur due to either modifications in stress as a result of the pressure of water, or more generally due to the incremented groundwater pore strength lowering the effective force of the rock beneath the reservoir. In order for triggered earthquakes to occur, both these mechanisms need that the area in consideration is already under considerable tectonic stress. The energy that is released in a Reservoir Induced Seismicity seismic event is tectonic strain energy, released too soon due to the reservoir.Water Pore Pressure plays a large part in earthquake activity; it diminishes the ordinary stress within a rock but at the same time not modifying the shear stress. Under any situation, an increment in water pore pressure signifies that a collapse is more likely to be expected. [3]

Pore pressure can increase in two main ways; due to the decrease in pore volume caused by compaction under the weight of the reservoir, this can occur when the reservoir is being filled. Or secondly due to diffusion of reservoir water through permeable rock under the reservoir, while the rate of flow depends on the permeability of the rock, this effect is not instantaneous. The distance from the reservoir is important to determine the time that the increase in pore pressure takes. Years may pass before the pore pressure increments at a profundity of kilometres down the reservoir. Fortunately after stress and pore pressure have fixed at the new values, reservoir induced seismicity is going to terminate. Earthquake hazard are going to return to analogous levels as if the reservoir have never been filled.

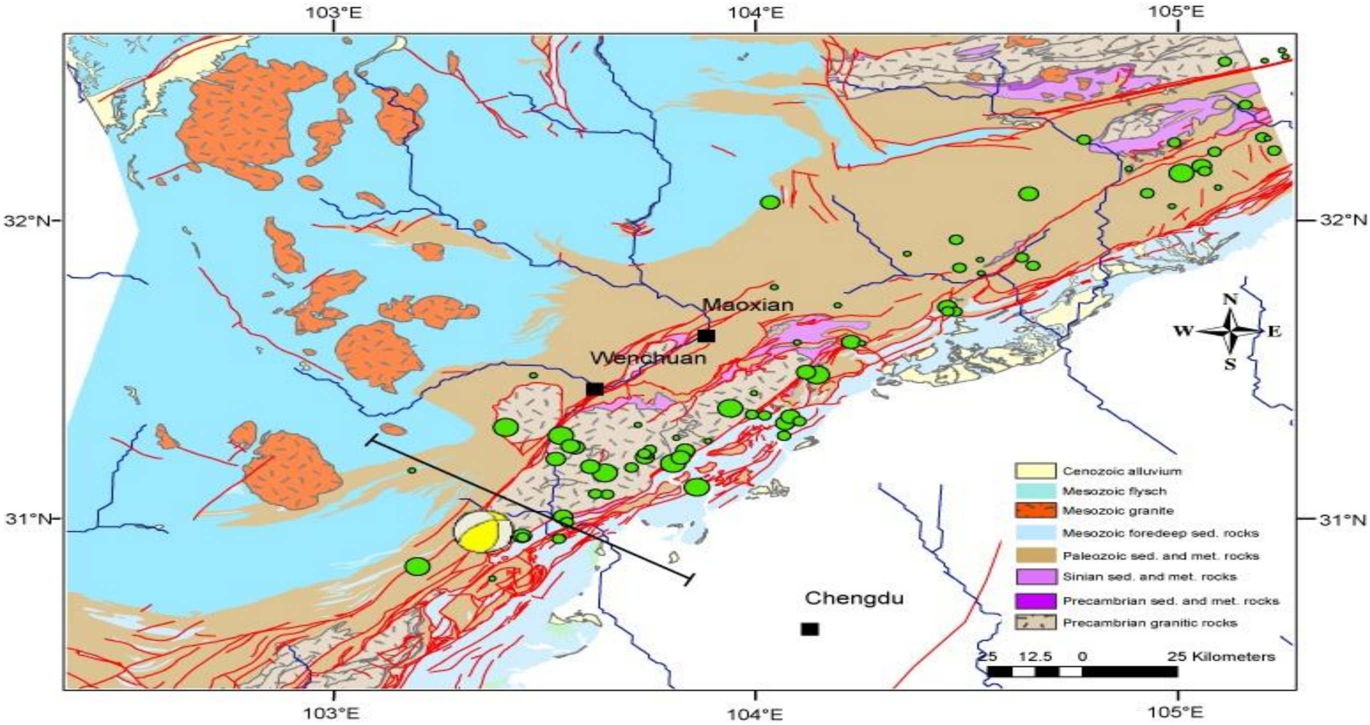
Equally important is the depth of the reservoir-induced earthquake, which usually are not deep, especially those occurring immediately after filling of the reservoir. As seismograph report has shown, the usual depth is one to three kilometres from the surface. Even tough induced earthquakes at reservoirs usually are shallower; some of them that have experienced delayed triggering may be much deeper, perhaps as deep as ten to twenty kilometres. This event can occur also from ten to twenty years after the reservoir has been fulfilled. Prediction of Reservoir induced earthquakes is not easy, while the most important factors to determine it cannot be directly measured; respectively the state of stress of the rock and the rock strength. In the same way the prediction of tectonic non-induced seismic events is most of the time not successful.

[3] P. Talawani, S Acree - Earthquake Prediction, 1985 – Springer

1.2 Zipingpu Dam

Talking about concrete examples, the most powerful seismic event thought to have been induced by a reservoir is the devastating earthquake that killed more than 80,000 people in China's Sichuan Province in May 2008, triggered by the Zipingpu Dam.

The Chinese Zipingpu Dam is located 156 meters of distance from the Min River and is near the Longmen Shan fault, the place in which the Tibetan Plateau breaks up with the Eurasian Plate. In less than three years after the filling of the Zipingpu reservoir, the 7.9 magnitude Wenchuan seismic event occurred in the Sichuan Province on May 12, 2008. The result was the death or missing of 88,000 citizens, and the collapse of thousands of constructions. Sixty-nine dams, including the Zipingpu Dam itself, were badly damaged and at a high risk of failure, but the situation could have been worst if they had breached, since millions of more people could have been killed.



The earthquake (yellow ball) occurred along the Longmenshan Fault (red lines), the boundary between the Sichuan Basin (white area in the lower right) and the Tibetan Plateau (blue area in the upper left). (Image courtesy of MIT Department of Earth, Atmospheric, and Planetary Sciences.)

A study of Columbia University's professor, Christian Klose, [4]and a china Earthquake Adrministration in Beijing geophysicist detected an interconnection between the earthquake and the Zipingpu dam. Altough the International Commission on Large Dams didn't accepted their studies , the commission specified that it was "very unlikely" that the earthquake was triggered by the Zipingpu dam, never publishing the seismic findings of the Wenchuan earthquake.

A great number of dams are currently being constructed in earthquake-prone zones such as China's Southwest, Central America, Iran and the Himalayas. Such projects should only proceed if the seismicity

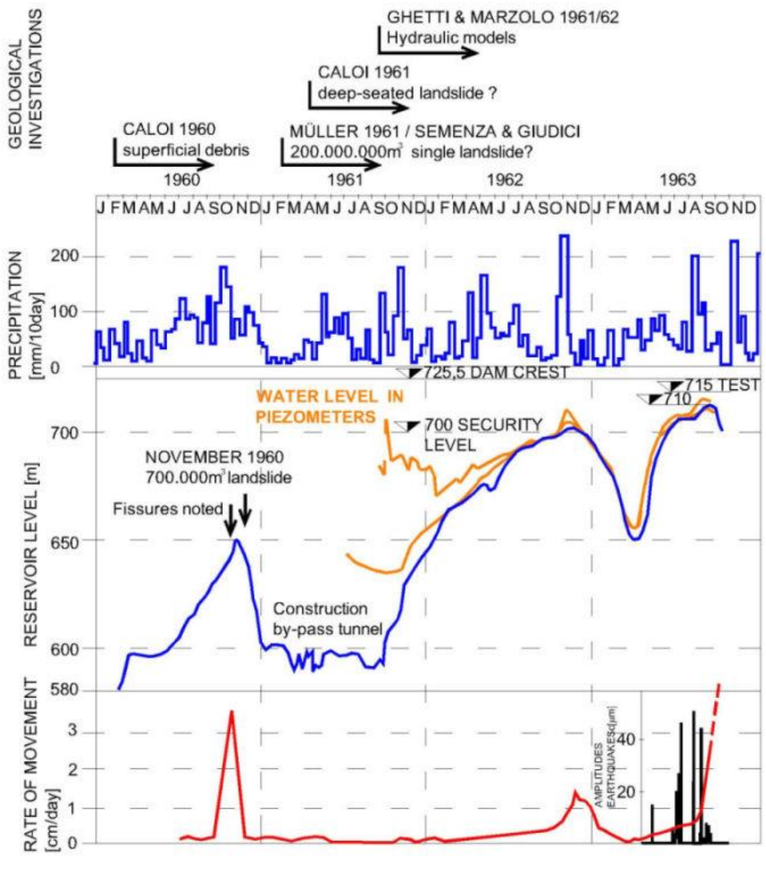
[4] Klose, C.D. (2011) Evidence for Anthropogenic Surface Loading as Trigger Mechanism of the 2008 Wenchuan Earthquake, Environmental Earth Sciences.

around the dam site is continuously monitored, if water levels are not allowed to fluctuate quickly, and if all buildings in the reservoir area are regulated.

The second largest thought reservoir-induced earthquake is the magnitude 6.3 seismic event of 1967, that collided with the village of Koynanagar in Maharashtra, western India. It resulted in the death of around 180 people, leaving thousands of people homeless and injuring 1,500. The earthquake caused panic also in Bombay, 230 kilometres from its epicentre, resulting also in a serious damage of the dam. The epicentre of the earthquake was found near the Koyna Dam or down its reservoir.

1.3 Vajont Dam

In the Italian sphere there is another disaster that is tough to have been induced by a reservoir in 1963, it is the Vajont Dam in the Italian Alps. Concluded in 1960, it was located at the base of the Mount Toc and classified as one of the highest dams in the world, with its height of 261 meters. The seismic activities began since the dam began to be filled, starting also to move unstable rock debris from the mountain into the dam. The Vajont Dam reached its peak at the end of 1960, with a depth of 130 metres and a consequent stop with the seismic events.



Not until it began being filled again, leading to an increment in the vibrations regardless of the engineers and geologists that constructed it, who thought that no problems would have occurred. [5]

Due to the massive quantity of rain that occurred in the reservoir zone in 1963, the dam managed to enlarge leading to a great increase in seismic events during the first days of September of the same year. The disaster happened later on, during the night of the 9 October, due to the huge quantity of rocks that fell off the Mount Toc and directly into the Vajont Dam. In resulted in a wave that overtopped the dam of 110 metres, leading to a complete demolition of the Longarone town and to the killing of a great part of its citizens, totally amounted at 2,600 people.

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[5] Fig.2. Summary of events recorded at the Vajont, modified after MÜLLER 1964 and BELLONI & STEFANI 1992

-Gupta, H.K. (1992), Reservoir-Induced Earthquakes, Elsevier.

2.0 Underground and open-pit mining

When it comes to induced earthquakes, we can definitely affirm that today mining seems to be the principal cause of these kinds of events. While it has been threatening local communities for millennia, it continues to do so on larger and larger scales around the planet as humans contend mineral riches. In the process, deep subsurface mining causes earthquakes: this is no surprise to geologists, who have been documenting the process for a long time. The reason mining causes earthquakes, is due to the large-scale removal of gargantuan quantities of rock and water that creates voids deep underground. This process consecutively stresses underground faults, triggering slippage at the fault interface. As in the case with wastewater injection and Reservoir Induced Seismicity, most of these earthquakes are routinely small (but not all of them).

As introduced above, it is clear that mining induced earthquakes are nowadays well understood, due to the fact that geologists have managed to classify them. It is intuitive that digging and blowing up explosive deep underground, disrupts the natural stress state of the geologic structure: the manner in which the blasting and digging is done defines which category the seismic event falls into. They can differ, as for example in rock bursts(“Rock bursts are the result of brittle fracturing of rock, causing it to and collapse rapidly with violent spalling of rock that is approximately 100 to 200 tonnes, or more”). [6]The void created by material removal changes stress relationships; while under normal conditions, deep rock formations are under a “ confining pressure” from all sides. Although the mining technology operated in underground coalmines generates an extended no pressure area once the rock is removed, the stresses on the remaining rock are still in effect. Moreover while the outer walls of a mine tunnel support the weight of the rock above, in between the walls remains an empty space. A rock burst comes when a wall collapses, which in turn falls down into the excavation with debris under high pressure and enormous force. This process can cause an earthquake, most of the times a noticeable one.

Two factors determine the likelihood of earthquakes in the vicinity of large-scale geoengineering operations: A) geological and tectonic conditions of the earth’s crust, and b) the size and the production plan of the engineering construction or excavation sites. The processes that induce seismic activities include: mass removal or accumulation of material (water or coal), contraction of underground excavations or oil and gas

[6] – Marshak, Stephen (October 2001). Earth: Portrait of a Planet. W. W. Norton & Company.

- Monroe, James S.; Wicander, Reed (1997). The Changing Earth: Exploring Geology and Evolution (2nd ed.). Belmont: West Publishing Company.

- Sprenke, K.F., Stickney, M.C., Dodge, D.A., and Hammond, W.R., 1991, Seismicity and tectonic stress in the Coeur d'Alene Mining District, Bulletin of the Seismological Society of America.

fields, changes in fluid pressure in rock fractures or pores because of water movement or temperature gradients.

Most of the people nowadays are surprised to discover that mining has caused killer earthquakes and landslides in Australia, Canada, Chile, China, Poland, South Africa, Utah and Wyoming. Among the examples there is the process of the gold mining-induced “rockburst” that caused to happen earthquake fatalities in South Africa, which have long been identified as a serious problem. Similarly, mining in the seismically active Andean region regularly triggers small earthquakes that collapse mine structures, damage nearby buildings and kill people.

The first earthquake ever attributed to mining is the one in Germany, 1888, in the Ruhr coal-mining region. As a result the first seismological station was installed in the city of Bochum, 1908, to monitor earthquakes caused by mining. Between the firsts documented earthquakes associated with mining is the one in Germany 1552, in the city of Annaberg, which was the centre of Europe’s major ore mining regions between the fifteenth and the eighteenth century. Also in 1995, a 5.4 quake in the Trona Mining District of south western Wyoming was recorded in the vicinity of five active underground Trona mines. An analysis conducted by University of Utah Seismograph Station suggested that the energy waves generated were not characteristic of a natural earthquake, but were consistent with those associated with an implosion.

Another case is the worst earthquake in Australian history, which was caused by coal mining in and around the black coalfields of Newcastle, NSW. [7]Besides the destructive and costly results beyond the numerical magnitude of this industrial catastrophe, registered only 5.7 on the Ritcher scale, the December 28, 1989 seismic event not far from Sidney killed 13, injured 160 and caused $5 billion in damage. That horrific event was the worst of a series of mining-induced quakes that previously struck the area in the years 1841, 1868, 1925, 1989 and 1994.

In addition to the millions of tons of rock removed over the years, for each ton removed also 150 tons of groundwater have been expelled. Underground water depletion alone can produce major seismic events such as the deadly 2011 event in Lorca, Spain.

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7 - CD Klose - Earth and Planetary Science Letters, 2007 – Elsevier

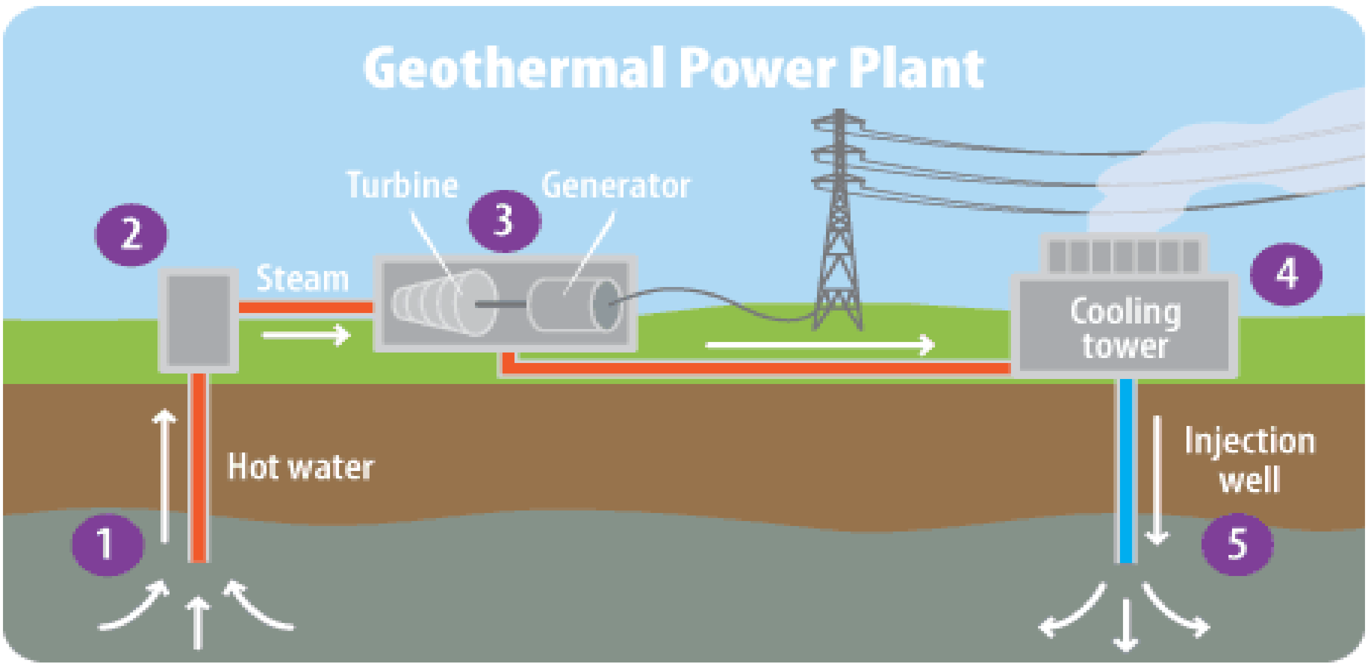
- R. Davies, G Foulger, A Bindley, P Styles - Marine and Petroleum Geology, 2013 – Elsevier

3.0 Geothermal energy

While mining operations has been going on for thousand of years, a new cause of human induced earthquakes can be found in large scale geothermal energy projects, which have emerged relatively recently. Geothermal energy is generally considered to be a far cleaner and more environmentally responsible energy source than fossil fuels.

This technology pumps into the earth's natural underground heat sources, using it to drive steam turbines, which in turn generate electricity. The theory is simple even though it generates small amounts of carbon compared to the ones of fossil fuels. In it most basic forms, geothermal energy can directly exploit easily accessible heat sourced such as hot springs, which are near to the surface. An example is the Italian geothermal power station in Tuscany, which has made out electricity this way for more than a century. Despite these cases, for large scale projects (Enhanced Geothermal Systems or EGS) it is required to break deep into the bedrock (usually several miles) in order to reach the high temperatures required to boil water. Consequently in most of these projects, the ultimate intention is the formation of a deep reservoir containing enough water to generate steam at a commercial level.

Due to the injection of water into the deep well, the extreme temperature differentials with the ones of the well cause the rock to fracture. As a result the greener geo thermal technology involves some of the same processes as oil and gas exploration and mining, causing in the same way some seismic activities.



Not surprisingly the engineers who designed ESG geothermal generating plants fully expected to trigger seismic activities in order to establish underground reservoirs. Thought not part of the original plan, the induced seismic activity helps stimulate the flow of hot water by cracking bedrock and creating new pathways to the surface. The deeper the shaft, the greater the chance that increased levels of seismic activity will reach nearby fault lines, generating an even more powerful earthquake that that caused by the original fracturing. [8]

Certainly the earthquake in Basel, Switzerland, which occurred on December 8, 2008, was triggered by geothermal Explorers International geothermal plant. Although the earthquake measured a moderate 3.4 on the Ritcher scale, it resulted in the damage of buildings and frightening of locals. Furthermore it was followed by more than sixty aftershocks in the following weeks.

Another relevant case is the earliest and most successful geothermal energy projects that have been in operation near California's Salton Sea since 1981. Even though energy production has increased over the years, so has the episode of earthquake swarms. There is no question whether mass quantities of water injected into the well cause the small faults to slip more than normally, while usually the injection of fluids migrates in and around the fault itself and makes slippage more likely. Just as with fracking disposal practices, the wastewater loads up these faults with tension until they shift causing the earth to vibrate. Equivalently the Geysers, the world's largest geothermal project, initiated earthquake swarms from the moment ground was broken in 1975. This area is volcanically active, which is why this geothermal field, heated by a remnant magma chamber is located there in the first place. The earthquake have continued in regular patterns ever since, with quakes of 3.4- 4.0 not uncommon. The USGS monitors there and is able to map incidents of quake clusters, which double during active drilling periods. With a current capacity of 800 MW and growing, the plant continues to raise its injection in rates as the Geysers facility expands. The magnitude and frequency of the events is related to the injection volume as well as the rate at which the injected water alters the stresses in the subsurface.

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[8] - EL Majer, R Baria, M Stark, S Oates, J Bommer, Geothermics, 2007, Elsevier

- L Rybach - Geothermics, 2003 – Elsevier

- Document from United States Geological Survey, https://energy.usgs.gov/GeneralInfo/EnergyNewsroomAll/TabId/770/PID/3941/mcat/3943/TagID/18/TagName/Geothermal/Default.aspx

4.0 Nuclear Activity

In recent years, rumours have circulated following major earthquakes that underground nuclear bombs may have triggered, including the 2003 bam earthquake in Iran and the 2010 Haiti earthquake. Scientific data published in the 20th century suggest that underground explosions induce earthquakes in their vicinity. Seismic technology is mostly associated with the study of earthquakes, but it is also the primary way to identify and detect nuclear explosions.

Underground detonation of explosives, including conventional bombs and nuclear weapons, can be detected like earthquakes. For both earthquakes and explosions strong forces act inside the earth's crust. Energy gets released very rapidly and the result is intensive shaking. The created shock waves, called seismic waves, propagate through the crust until they reach rock boundaries, where one part of these waves bounces off and another part travel through.

Waves that are reflected bounce off the rock surface. Refracted waves travel through surfaces while changing their direction. The waves can travel around the world, but during their journey they constantly lose energy, which leads to a decline of the shacking. Thanks to sensitive seismometers the waves can be detected, while in case of an earthquake the ground starts shaking as part of the crust slide against each other.

During a scenario of an explosion, the initial blast is very powerful, and the shacking of the ground is less severe. These differences make it possible to figure out whether a detected seismic event is an earthquake and peaceful blast or a bomb. Scientists constantly analyse wave patterns that could confirm the one or the other.

Some nations such as North Korea, that are politically isolated from the rest of the world, basically share no scientific data with other nations. [9]Such countries however are encompassed with detector devices in adjacent countries. For example, there are more than 1,000 high- capability stations in china and at least 20 seismic stations in South Korea that continuously listen to activities in North Korea. There is also a large network around the world of hundreds of seismographs. The stations record ground-shaking incidents that can serve to provide evidence of bomb blasts. The underground nuclear weapon tests in North Korea in 2006, 2009 and 2013 were registered with seismographs of the entire world.

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[9] - Kim, W- Y., P.G. Richards (2007) North Korean nuclear test: Seismic discrimination low yield, Eos Transactions American Geophysical Union

- Zhang, M., Wen, L. (2013) High-precision location and yield of North Korea's 2013 nuclear testing, Geophysical Research Letters

4.1 Nuclear Events

Trinity was the name of the first nuclear bomb test, which exploded on July 16, 1945 near Almogordo , New Mexico. This event was the beginning of the nuclear era. Since then only few countries have developed nuclear technology for military purposes, including the United States, former Soviet Union, France; China, United Kingdom, North Korea, India and Pakistan.

Since September 22, 1976, only one violation of the Limited Test Ban Treaty, signed in 1963 by the Soviet Union, the United States and the United Kingdom have occurred and have never been attributed to any country.

The limited test ban Treaty banned nuclear explosions in the atmosphere, in space and under water. Radioactive fallout from these explosions was carried worldwide causing major protests. Physicians and biologists have shown radioactive fallout causes long time genetic damage to life on earth. For example, the fallout from the meltdown of the nuclear reactors in Chernobyl in the former Soviet Union caused major birth defects and leukaemia and thyroid cancer.

In 1974 and 1976 the Limited test Ban Treaty was extended by the Threshold Test Ban treaty and the Peaceful Test Ban treaty. The first banned underground nuclear explosions exceeding and explosive force equivalent to 150 kilotons of TNT (10 times the Hiroshima bomb). A one-kiloton yield is also equivalent to the energy that a magnitude 4 earthquake releases. The second treaty limited nuclear tests to only peaceful purposes.

New treaty negotiations took place in the 1990s in Geneva, Switzerland. However, it took almost two decades after 1976 to open a comprehensive test ban Treaty for signature at the United Nations General Assembly. The treaty was adopted in September 10, 1996. As of 2014, 161 states have ratified the treaty. According to the Comprehensive test Ban Treaty Organization, some states only signed but have not ratified, including China, the United States, Israel, Iran and Egypt. Moreover North Korea, India, Pakistan, Saudi Arabia, Syria and Cuba have not even signed the treaty yet.

After 1945, both nuclear superpowers (the Soviet Union and the United States) created massive research programs responsible for nuclear weapons development.

Most of the underground nuclear tests have been conducted in the United States at the Nevada Test Site. [10]

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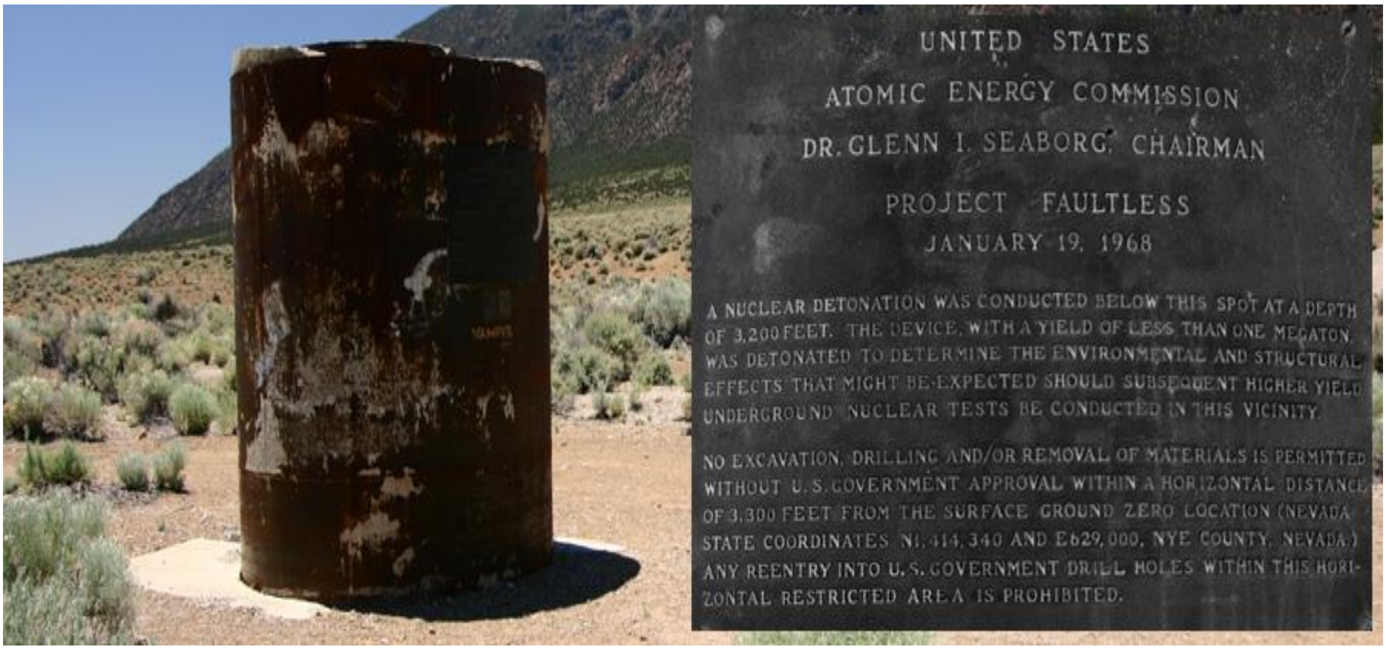
[10] - Hamilton, R.M., Smith, B.E., Fischer, F.G. , Papanek, P.J. (1972) Earthquakes caused by undergound nuclear explosions on Pahute Mesa, Nevada Test Site, Bullettin of the Seismological Society of America.

- Khalturin, V.I., T.G. Rautian, P.G. Richards, Leith, W.S. (2005) A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1995-1990, Science and Global Secutiry.

- Engdahl, E.R. (1972) Seismic effects of the Milrow and Cannikin Nuclear Explosions, Bulletin of the Seismological Society of America.

The available evidence showing the ability to trigger earthquakes by underground explosions includes several nuclear tests and explosions conducted during mining processes. For example, on January 9 1968, the amazing but obscure nuclear test Faultless under Operation Crosstie was conducted somewhere on the Nevada Test Site (as fig 3 shows). The AEC (Atomic Energy Commission) agreed it would have been a splendid idea to put a 1- megaton hydrogen bomb (about 67 times more powerful than the Hiroshima blast) down a 3,200 ft. borehole. They did it on January 19/1968. Several seismic events occurred afterwards, of magnitudes over 7.0 on the Richter scale. The space in the vicinity of the test hole collapsed 12 to 14 feet, entrenching roughly 14 acres. Project faultless was cancelled quickly before the wrong people started asking who fault it were. Although some government " restoration" was attempted, the collapsed area is still visible today. In 1969 the concern came from the public. All six largest thermonuclear explosions that were conducted at the Nevada Test Site triggered damaging earthquakes in California. Following the faultless nuclear test, the rate of earthquakes increased in Northern California (magnitude 3.5 and larger). The thermonuclear yield explosion created a new fault like about 1.5 kilometres away from the detonation point. A seismographic network recorded the seismic waves that were produced by the nearby fault rupture. The yield of the seismic event, however, was much less energetic than that of the nuclear explosion.



The largest nuclear weapon ever detonated, generated substantial seismic activity in the vicinity of ground zero, with earthquakes reaching magnitude levels about of 5. The bomb exploded on October 30, 1961in the atmosphere above Mityushikha Bay of Novaya Zemlya Island. The wave of this mega blast was detected circling the world. This nuclear test, conducted by the Soviet military, was a 50-megaton yield bomb, called Tsar Bomba or king of the bomb. The most powerful soviet underground nuclear explosion was set off on September 12, 1973 in the northern part of the Novaya Zemlya test site.[11]

[11] M. Mackedon, "Project Faultless: Central Nevada's Near Miss as an Atomic Proving Ground", Nevada division of Environmental Protection, 2015.

It had yield of about 4.2 megatons, which is equivalent to a seismic magnitude of almost 7. The yield is equivalent to the total amount of all explosives used during the Second World War, multiplied by ten.

The second most powerful test was conducted in the southern part on October 27, 1973. This explosion had a yield of 3.5 megatons and a similar seismic magnitude of almost 7. [12]Since the threshold Test Ban Treaty in 1974 was established, such mega nuclear tests have been banned. Tests were not allowed exceeding yields of 150 kilotons or a seismic magnitude threshold of 6.

As data shows, consequently to the test Ban Treaty the nuclear tests with a seismic magnitude greater than 6.45 slowed from eleven in the period between 1964 and 1975 to zero in the period between 1976 and 2013.

The largest underground nuclear tests conducted by the U.S. military took place outside the Nevada Test Site. The largest was a 5-megaton yield with the code name Cannikin. It took place on November 6 in 1971. Cannikin had a seismic magnitude of 6.9. The Cannikin test and two smaller nuclear yields were followed by hundreds of small earthquakes with magnitude smaller than 4. As already introduced, a nuclear explosion is a an extremely small and destructive event, it doesn't behave like extraction and injection, that lead to seismic events in a more moderate process, but necessarily to events of brief duration.

Thanks to Geography's professor Gary T. Whiteford, working at the University of New Brunswick, we have a clearer view on the relationship between seismic activities and nuclear testing. The time period of the research conducted goes from before the 1950's when nuclear testing didn't existed to the post period when it had all began. The study showed a correlation: 62.5% of the most dangerous earthquakes happened only a few days after a nuclear test, most of which took place within a day after a huge detonation. The professor, against the US Dept. of Energy that didn't agreed with his studies said: " I have conducted a long-term study of earthquakes, their location, size and frequency throughout the world using seismic data from the last 90 years. Many study indicated a significant disruption in the pattern of large magnitude quakes (6.0 and above) coincides with the advent of nuclear bomb testing".

Since it is not proven that nuclear tests explosions lead to a modification of the balances of the Earth's crust, in the same way it is neither possible to demonstrate they are not modifying the balances in the Earth's crust. Our planet is flexible, in constant mutation, and from a logical point of view it would be more absurd to insist that the thousands of nuclear bombs detonated underground since 1960 didn't' had any effect on the stability of the planet.

- U.S Department of Energy, map of Nuclear Test Sites.

[12] Terrence R. Fehner & F. G. Gosling ,Office of History and Heritage Resources Executive Secretariat,Office of Management, Department of Energy , 2006

5.0 Underground Waste Water Injection and Massive Extraction

Since the 1960s has spread the consciousness between geologists that the injection of large amounts of fluids in the subsoil lead to changes and stresses in the rock formation, that can lead to seismic events. Less intuitively, the extraction of large quantities of fluid from underground is also known to affect pressures within rock formations, and can produce similar results. Underground injection and extraction are both associated with oil and gas exploration, but of the two, it is deployment of deep underground waste injection storage wells that has a significant correlation with earthquakes. Scientific research has demonstrated that the injection of liquids in the subsoil reduces the strength of pre-existing faults, due to the increasing pressure of the fluid.

In the United States, earthquakes have become five times more frequent in the past three years, according to a report issued in July 2013. In the time period between 2010 and 2012, according to the USGS, more than 300 seismic events have been reported of more than 3 of magnitude on the Richter scale. The medium number of earthquakes in this way is about 110 a year, in contrast with the 21 of the years before. This is a tremendous change that might worsen in the following years.[13]

Currently, of all man-made earthquake cause-and-effect scenarios, the one generating the most mainstream discussion is the process called hydro-fracking or " fracking". This is the extraction technology responsible for the opening of vast shale gas deposits in the U.S. to exploitation over the past decade. The increasing number of earthquakes can be associated with an increment in fracking operations. As we will see, these earthquakes are usually small, but not always. The recent USGS studies, officially link "natural" gas drilling with recent seismic events in Arkansas, Alabama, Colorado, Oklahoma, Ohio, Texas, West Virginia and Wyoming. These events have almost always been in the form of earthquake swarms, a series of smallish to middling tremors that occur often, sometimes many times a day.
The future trends are not better, since these earthquakes swarms are expected to worsen. It is a trend not only spread in the United States, but also in other countries like Argentina and South Africa. The town of Blackpool in England can be used as an illustration, since in 2011 increasing tremors lead to the cessation of hydro fracking activities in the zone. Nonetheless due to the grate amount of money at stake, the operations of hydro fracking will restart soon, as the documented events can verify

As previously noted, an important feature in the fracking /earthquake correlation is that is not the first activity that causes directly subsoil destabilization, but it is the disposition of chemicals underground in disposal wells that causes it.

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[13] - W.L. Ellesworth, Injection-Induced Earthquakes, Science, 2013
- J.L. Rubinstein, A.B. Mahani , and facts on wastewater injection, hydraulic fracturing, enhanced oil recovery and induced seismicity, Seismological Research Letters, 2015

The USGS reports and other supporting academic research show that when wastewater disposal occurs near faults and other conditions are right, the chance of earthquakes is greater than when the wells are not here. The odds of triggering a quake increase, for example, if engineers raise the well injection pressure or injection rate. Furthermore the USGS maintains that injection wells can cause earthquakes even if the fault has not shifted in million years. And an even more startling new USGS research report has revealed that when injection wells weaken faults in their vicinity, they are susceptible to triggering by more powerful quakes thousands of miles away. This produces much larger quakes, such as the 2011 event in Prague. This recent revelation promises to re-ignite the debate around fracking.

Fracking technology works through the deposit and injection of water and lubricating chemicals underground, deep under water. The chemical materials that are injected are named fracking fluids. The process works through the fracture of rock formations, with high-pressure techniques, in order to free accumulations of natural gas/methane. The released methane gas should ideally move into storage tanks and through that be at the disposal of citizens' homes and businesses. At the end of the operation the remaining chemicals are taken back as wastewater, composed of the chemicals injected in the subsoil in order to fracture the rocks and of the additional contaminants that has taken once it was underground.

The USA now generates tens of millions of gallons of wastewater from new fracking wells each day, and it all has to go somewhere. Except in states like Pennsylvania, where it may end up anywhere, waste fracking fluids are usually re-injected into deep wells purpose. Drilled for " permanent" storage.
When fracking waste is injected into a disposal well, the additional lubrication and pressure may cause the rock to move and create tremors of varying intensities. In addition, wastewater may migrate in unpredictable directions and over extended time periods. Technically, the actual trigger is increased pore pressure near faults, which may be or may not have been geologically mapped. This reduced frictional resistance and allows elastic energy stored in the surrounding rocks to be released. The cause and effect line is unpredictable, but in the case of many injection wells, the turnaround has often been very fast indeed.

Whether or not a disposal well actually causes earthquakes depends on geologic conditions and the competence of the disposal company. As shown, the tremors are usually small but continuous, with dozens a day in some time periods.

Associated with injection activities, the occurrence of seismic events is surely increasing in the last years. In different situation we can see that seismic events began after the opening of fracking wastewater injection wells, an example is Youngstown, OH, where before the beginning of these operations there had never been any seismic event. In that incident, an injection well operated by D&L Energy was shut down in 2011 by the Ogio Oil & Gas Commission because of proximity to the epicentre of a series of quakes.

Seismic sensors recorded 109 earthquakes over 2.0 following the opening of he Northstar disposal well, culminating in a magnitude 3.9 quake on December 31 2011. The seismic activity stopped when the well was closed.

The 2010-2011 Arkansas tremors are another conventional explanation of earthquake swarms caused by the injection of wastewater. The area was characterized by an increase of gas drilling since 2008, and since the region was already an almost seismically active one, the operations lead to a situation in which at least dozen earthquakes occurred daily. Finally the the Arkansas Oil and Gas commission managed to cease the activities in that area, and after more than 1300 quakes in the area, they stopped when the wells were closed.[14] However, new seismic events occurred in other parts of Arkansas, beginning in 2012 until 2013, with dozen earthquakes in the area near Morrilton. The logical conclusion is that there is a relationship to two new injection wells drilled in the same area, apparently just outside the boundary of the previous moratorium area.

5.1 Prague Oklahoma Earthquake

An additional catastrophic event has been the Oklahoma earthquake, which occurred in November 2011, with a magnitude of 5.7. The surprise trembler caused serious property damage, including knocking a spire off a five story building, destroying fourteen homes and causing three sections of U.S Route 62 to buckle. The tremors were reported from locations as far away as Illinois, Kansas, Arkansas, Tennessee and Texas.[15]

According to research first published in the journal Geology in March 2013, the Prague earthquake was caused by wastewater injection well that had been operating at an oil well site for 17 years previously. A slight variation of interest in this case was that the “wastewater” was the product of the extraction process at new oil wells; it was being pumped into older oil wells, which had been depleted. For the record, there are more than 10,000 underground injection wells active in Oklahoma. The report described how for the first decade of operation, the brine had been filling underground disposal well spaces from which oil had already been extracted. However, beginning in 2011 the pressure began to escalate until it reached a level ten times greater than previously.

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[14] -United States Environmental Protection Agency, Class I Industrial and Municipal Waste Disposal Wells, 2015.

[15] - Charles Davis & Jonathan M. Fisk (2017): Mitigating Risks From Fracking- Related Earthquakes: Assessing State Regulatory Decisions, Society & Natural Resources

- J. Eaton, Oklahoma Grapples With Earthquake Spike—And Evidence of Industry's Role, National Geographic, 2014.

- A. Kuchment, "Drilling for Earthquakes. Scientists are increasingly confident about the link between earthquakes and oil and gas production, yet regulators are slow to react”, Scientific Americain, 2016.

It was a separate investigation into the Prague earthquake that resulted in even more dramatic findings on the part of the seismic researchers. According to a Columbia University study published in Science July 2013, quakes near flacking disposal sites have been set off by larger earthquakes thousands of miles away. Wastewater injection leaves faults “ critically loaded”, so that even weak seismic waves can set off an earthquake. This phenomenon is understood at this point to be most applicable to long term wastewater wells in places where there is little history of seismic activity. According to the investigation, the Prague, OK earthquake was part of a sequence of events directly linked to an 8.8 earthquake in Maule, Chile on Feb 27, 2010.

In this scenario, the seismic waves from the Chilean quake rippled across the Earth’s crust and set off a 4.1 quake in the Wilzetta oil field near Prague the next day. Tremors continued over time until Nov 6, when, as we have seen, the 5.7 earthquake did some serious damage in the area. The Chilean quake also triggered a 5.3 magnitude earthquake and smaller swarms in Trinidad, CO. The source was a previously unknown fault line that had been compromised by methane extraction wells in the area.

Earthquake swarms have continued in Oklahoma well into 2013 in various locations around the state, which has approximately 6,000 disposal wells in operation.

6.0 State Institutions

As we have seen, the different types of event that are identified as possible causes of induced earthquakes can lead to enormous disasters, with repercussion on the lives of innocent people. Moreover is important to underline the possibility that these kind of event could be triggered not only in territories that are naturally seismic, but also in the aseismic ones, leading to greater damages due to the fact that the population was not prepared for it. Many events have shown the relationships between the installation of this processes and the consequent increase of the seismicity in the area, to this extent we should expect that earthquakes would occur, not thinking of them as a " natural disaster".

The death of innocent people is not to underestimate, and with certainty once the catastrophe has occurred no one could repair the loss of victims. As it is an activity to not underestimate we should expect the state to defend citizen's main rights, not only giving information about the risks that these activities can cause, but also putting bases to prevent them from occurring.

For what concerns the Italian case, no regulations have been made about this argument, even though Italy is a naturally seismic country. The fact that the territory is already strongly affected by natural earthquakes can, on one side complicate the recognition of induced events, but on the other takes us to confront the anthropogenic events with the natural tectonic ones. After the seismic event that occurred in Emilia-Romagna on the 20th of May 2012, for the first time in Italy a commission has been established to study the possible correlation between the earthquake and the activities in the zone. It was named Ichese commission. In the area studied we can find three concessions of exploitation of hydrocarbon, respectively the one of Mirandola, Spilamberto and Recovato, together with the geothermic camp of Casaglia (Ferrara) and the gas storage deposit of Minerbio. Included in the study there is also the project of Rivara, for natural gas storage. The problem of this case is the absence of terms of confrontation for what regards its danger, since is difficult to define in probabilistic terms the functioning of time-induced seismicity. With the stop of geothermal activities the probability of a seismic events is close to zero, while the same cannot be said for natural events. Morover in most cases it is possible to control the evolution of induced seismicity, before it reaches damaging levels through a controlled management of the activity if correctly monitored. In conclusion to the studies the commission has stated that the actual state of knowledge and the interpretation of all the information collected and elaborated, doesn't permit to exclude, but neither to prove the possibility that the actions inherent to the exploitation of hydrocarbons in the Mirandola centre can have contributed to trigger the seismic activity of 2012 in Emilia-Romagna. [16]

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[16] MiSE (2014) - Guidelines for monitoring seismicity, ground deformation and pore pressure in subsurface industrial activities. 2016.

MiSE (2015). Decreto Ministeriale 25 marzo 2015. Aggiornamento del disciplinare tipo in attuazione dell'articolo 38 del Decreto Legge 12 settembre 2014, n. 133, convertito, con modificazioni, dalla legge 11 novembre 2014, n. 164; Roma - May 6, 2015

Even tough the results, they managed to set up new guidelines that are based on the following principles:" 1) monitoring will be evaluated "a posteriori" on the base of its performances; 2) monitoring should be developed and managed by well referenced, preferably public, institutions; 3) the subject which is in charge of monitoring should remain independent of the company which holds the concession; 4) information and data should be public and, possibly, open". These principles have been published in November 2014 and adopted in 2015.

Not less important to mention, due to the increasing public concern of the possibility that different activities that exploit the subsoil and its resources would lead to induced earthquakes, the StoHaz project (Task 7, first year of the project S2) has probably represented one of the first initiatives of Italian research made to fill up the gap of information in this sector. Has emerged, in this sector, the scarce consistence of scientific dates, of consolidated knowledge and of procedures of seismic monitor due to shared protocols. In consequence, StoHaz has the aim of highlight these themes and its more dangerous points, while putting together and making disposable for the public the documentation both at the national and the international level; in order to initiate an effective process of revision and definition of procedures and rules of seismic monitoring. The process was mostly concentrated on gas storage, since the ones concerned with the study had an important direct experience in this field (seismic monitoring of Collalto storage). The final project resumes the principle considerations about the situation of the procedures of monitoring and of the seismic danger due to the subsoil gas storages, giving also some advices for future actions. The considerations of the Comitato di Programma Sismologico highlight the reduced focus of the research only on the typology concerned, on the other way recognizing the importance of the study and the need to enlarge it to other type of activities.

In other cases states have intervened to regulate and try to prevent disastrous catastrophes, the most active countries have been the United States and Holland. [17]

In the United States induced and triggered seismicity began to be taken into consideration in 2011, although the Safe Drinking Water Act (SDWA) of 1974 regulated the underground fluid injection, securing safe drinking water for the public. Different American states have reduced or closed disposal wells due to the increasing seismicity. Both in Ohio and California new laws have been established regarding the regulations for hydraulic fracturing, which requires seismic monitoring for wells within 5 km to known faults and suspension after seismic events of MI>=1 for Ohio and MI>=2.7 for California. [18]

The introduction in Oklahoma of traffic Light Systems in industrial centres that work on wastewater injection, even though there is not a state regulation, detects, locates and characterizes induced seismicity as a way to prevent critical events from happening.

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[17] Site S2on – Induced and Triggered Seismicity, developed by OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale in the field of Task n. 7 of the project S2-Constraining Observation into Seismic Hazard, 2012-2014.

[18] United States Environmental Protection Agency, Safe Drinking Water Act, 1974

The European situation is not quite clear, since the interest in underground activities that generates energy as natural gas storage, hydrocarbon production and shale gas production is great. But European Union Directives on Environmental Impact Assessment (2014/52/EU) doesn't regulate induced seismicity. The main focus of these directives regulates the use of underground resources. Special cases can be shown of European Countries that have developed their own regulations and guidelines, North European Countries are amongst them. The latters are usually characterized by low levels of natural seismicity, but since the high population density of these countries, more superficial earthquakes are likely to lead to damages and to trigger stronger ones, for which the territory would not be prepared.

The first nation to introduce [19]regulations on seismic monitoring was the Netherlands. Since 2003 the Dutch government requires a seismic hazard assessment as part of the license, in order to highlight the expected maximum magnitude of potential seismic events. Due to the regulation if the seismic event's magnitude is superior to what is approved by the regulation, the authorities can interfere. [20]

For what regards the German case, the German Geothermal Association in 2010 published for the first time a regulation on induced seismicity. It was the result of continuous seismic monitoring, liability and insurance coverage. Moreover GtV-BV ensures that monitoring networks are under the control of public entities or of private companies always controlled by public entities. The Earth Physics Research Council (FKPE) that regulates the opinion of the German Geophysical Institutions on induced earthquakes has issued other more specific regulations. General instructions are presented on the way to create a seismic network in order to put together seismic data with industrial data, as well as the need for clear reports and data access. Anyhow these documents don't provide clear regulations of potential decision-making procedures and have not been implemented in any official governmental document. [21]

Folger, P. F., and Tiemann, M. (2016). Human-Induced Earthquakes from Deep-Well Injection: A Brief Overview. Congressional Research Service.

Muntendam-Bos, A.G., J.P.A. Roest and J.A. De Waal, 2015, A guideline for assessing seismic risk induced by gas extraction in the Netherlands, The Leading Edge.

Van Eijs, R., Mulders, M. Nepveu, C.J. Kenter, B. C. Scheffers, 2006, Correlation between hydrocarbon reservoir properties and induced seismicity in the Netherlands, Engineering Geology.

Van Eck, T., Goutbeek, F., Haak, H., and Dost, B. (2006). Seismic hazard due to small-magnitude, shallow-source, induced earthquakes in The Netherlands. Engineering Geology.

In the United Kingdom, "shale gas" has been the main reason in order to constitute a regulation on induced seismicity. This kind of event is mainly carried on the subsoil, creating probable problems not due to the process of fracturing itself but on the quantity of re-injected wastewater underground. The UK Department of Energy and Climate Change claims that "This practice is not likely in the UK and any application would be closely scrutinized" [22]. More strict monitoring operations and protocols of intervention have been suggested, in order to prevent any induced seismicity event.

In order to control risk management and mitigation the most common practice is the use the so-called traffic light system. It is based on a three stages action plan that rules the extraction and injection of fluids in the subsoil. The first one is the green colour, that states that everything is normal and can be continued as planned, the second one is amber, stating that the agency can proceed with caution, while finally the red colour obliges to stop with the extraction/injection processes.

Nowadays traffic-light systems are managed by experts, precluding the objectivity of the tool in the consideration of possible disasters. Failures happened in the European scenario, Blackpool and Basel are an example. [23]A new system has been developed due to the ineffectiveness of the classic traffic light one, it is the so-called ATLS (Adaptive Traffic Light System), although it not already in function.

The main difference between the two systems is that, since the first generation ones are more static, the second ones are more adaptive, probabilistic and risk-based. [24]

Characteristics as depth and location should be taken into account, even though the most important feature is still the magnitude of the seismic event. Before entering in the alert level, a rigorous study should be made, mostly through the use of refined techniques in order to evaluate microseismicity in relation with ongoing activities. The impact of seismic activities in the area of consideration is also not to underestimate. Ground motion prediction equation (GMPEs) is another necessary aspect is the evaluation of seismic danger caused from induced seismicity.

FKPE (2013). FKPE Recommendations on Seismic Monitoring of Induced Seismicity,

FKPE (2013). Empfehlungen zur Ueberwachung induzierter Seismizitaet - Positionspapier des FKPE.

[22] UK-DECG (2014). Fracking UK shale: understanding earthquake risk. Department of Energy and Climate Change, URN 14D/050.

[23] - Hays, J., Finkel, M. L., Depledge, M., Law, A., and Shonkoff, S. B. (2015). Considerations for the development of shale gas in the United Kingdom. Science of The Total Environment.

- Edwards, B., Kraft, T., Cauzzi, C., Kaestli, P., and Wiemer, S. (2015). Seismic monitoring and analysis of deep geothermal projects in St Gallen and Basel, Switzerland.

[24] Wiemer, S., Kraft, T., Landtwing, D., 2014. Seismic risk. Energy from the Earth: Deep Geothermal as a Resource for the Future?, Paul Scherrer Institute, Villigen.

Better defined as "attenuation" relationships, GMPEs provide a mean of predicting the level of ground shaking and its associated uncertainty at any given site or location, based on an earthquake magnitude, source-to-site distance, local soil conditions, fault mechanism, etc. GMPEs are efficiently used to estimate ground motions for use in both deterministic and probabilistic seismic hazard analyses". [25] Even though the GMPEs are a more accurate method in the area of induced seismicity, it is still a modern field of research.

6.1 Federal Institutions

The country with most federal institutions in the field of control activities related to induced-seismicity is the United States, where we can distinguish four different agencies.

6.1.2 Environmental Protection Agency

The first federal authority is the Environmental Protection Agency (EPA), it is specialised in the preservation of the environment, and through the Underground Injection Control (UIC) plan it manages to control the fluid injection underground for what regards oil and gas goods, in order to preserve drinking water's purity. Since a possible underground tremor could lead to damages not only for the population in the surface, but also for the clean water sources, the ones concerned with the program should be ready with responses. The increasing request for oil and gas generation have lead to an increase of Class II disposal wells, that have been located in zones that are ideal for this kind of activity. As a consequence seismic activities of more that 5.0 of magnitude have been registered in the last period, and in order to prevent consumed water from being negatively affected the UIC National Technical Workgroup (NTW) studied the case. Their response on the case haven't shown any possible contamination of clean waters, taking as example the four states of Arkansas, Ohio, Texas, and West Virginia.

As already exposed, disposal wells are not the only cause of induced seismicity; geothermal, mining activities and water reservoirs are amongst the other causes. The study of humanly induced earthquakes is not new to the UIC institution, having already taken in consideration a study in 1990, made by Wesson and Nicholson on deep well injection.

According to the National Technical Workgroup there are some points that are fundamental for injection-induced seismicity, like "the sufficient pressure build-up from disposal activities" "a pathway allowing the increased pressure to communicate with the fault". A mix of geophysical, reservoir and geology characteristics is the way to address injection-induced seismicity, since there is not a recommendation common to all seismic events.

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[25] Atkinson, G. M. (2015). Ground-Motion Prediction Equation for Small-to-Moderate Events at Short Hypocentral Distances, with Application to Induced-Seismicity Hazards.

The fact that the area in the proximity of a disposal well have not already been subject to seismic events, does not lead to certainty that future tremors will not occur. On the contrary, if seismic events occur after the installation of a disposal well it would be a direct example of induced events. In conclusion we can state that seismic monitoring in disposal wells' vicinity is in function, even though the effectiveness of these systems is not a guarantee. The Environmental Protection Agency can't in this way concretely demonstrate the correlation between disposal wells and induced seismicity, since every case should be taken singularly.

But a model has been established by the NTW, in order to advice UIC institution which strategy of intervention and approach is the more complete. The location status is amongst the most important characteristic; together with monitoring operations it results as a complete approach to minimize and manage induced seismicity.

The addition of petroleum engineering skills has improved the data on the studies of the NTW, giving a deeper analysis to injection-induced seismicity. This type of information could only be obtained with the collaboration of state agencies, industries and engineers companies. In conclusion, the NTW suggests a multidisciplinary approach as the most complete one, in order to manage and control induced seismicity due to disposal wells and reservoirs.

6.1.3 Bureau of Land Management

For what regards the production of gas and oil, the main body that regulates this field in the United States is the Bureau of Land Management. It is a federal entity established in 1946, even though it was present since the Independence of America, when the nation achieved new lands. The main role of the BLM is to control the exploration, production and development of gas and oil activities, giving leases in order to concede property rights on the sources in consideration. Its regulation of extraction for federal and tribunal lands is in 43 CFR Part 3160 (Onshore Oil and Gas Operations). For what regards the responsibility in case of damage, the BLM would be the owner of the area in the surface; while for construction permissions of disposable wells the main responsible body is the EPA.

Geothermal wells have a different regulation; the main act is the "Geothermal Steam Act" (43 CFR) ; that gives the Bureau of Land Management the jurisdiction over geothermal resources in federal areas, which are in turn controlled by the Departments of Agriculture and Interior. In these situations the Bureau of Land Management regulates and approves the improvement of geothermal resources.

6.1.4 U.S. Forest Service

The management of on earth resources, especially of forests is regulated by the U.S. Forest Service. The US Forest Servic is an agency of the United States Department of Agriculture that manages the country's "Forests" and national prawns for a total area of 780,000 kilometers square. It works so much in the field of research and development of forest ecosystems as well as of other natural resources.

In collaboration with the Department of the Interior, as in the case of the Bureau of Land Management, the United States Forest Service has the responsibility of the surface in case of activities of injection. The related impacts and facilities on the area in consideration are always under their jurisdiction, even though in the management of the resources in these events, it has to take NEPA's regulations (National Environmental Policy Act) in consideration. Currently the permission of fluid injection activities, as already introduced, is controlled by the Bureau of Land Management, state agencies or the EPA.

6.1.5 United States Geological Survey

Finally in the United States sphere of federal institutions we find the USGS (United States geological Survey). The United States Geological Survey (USGS) is a US government scientific agency. USGS scientists study the US territory, its natural resources, and the natural hazards that threaten it. The body is divided into departments dealing with four major scientific disciplines, biology, geography, geology and hydrology. It is an operating and research organization with no legal powers (it has no regulatory responsibilities) that carries out research on objective environmental facts. Its main objective is to provide scientific data on the Earth, in order to diminish the risks caused by natural events, and to protect biologic and mineral capitals, in order to improve the United States's citizens life's quality. In the entire world scene its uniqueness is due to the fact that it is the only federal agency with the task of register and catalog earthquakes occurring all over the world, and in consequence is one of the main bodies concerned with the sutdy of induced seismicity.

The Earthquake Hazards Program has been developed, a substantial point for the multiagency National Earthquake Hazards Reduction Program and of the National Information Center (NEIC). The former has the function of incrementing the earthquake resilience by the population, by giving knowledge and tools. While the latter is focused on giving complete informations about the earthquake, raning from the size to the geographic area, in order to inform state agencies, experts and citizens.
The Advanced National Seismic System (ANSS) is the body through which the United States Geological Survey manages to monitor and report seismic events, moreover having installed around threehundred monitoring apparatus, the USGS is enhancing it methods of control.

6.2 Castor Project

Thanks to the State Intervention through federal institutions ,the Castor project in the Spanish scene of induced seismicity haven't reched its peak causing more dagames than it had already done.

The Castor project has transformed an old submarine petroleum field, located 21km from the Spanish coast and 1800m deep, into a gas reservoir that could cover up to three months for a possible shortage of this product , due to consumption peaks or breakdown problems in the supply system.

The problem is that it now appears that the Castor project is the cause of over a thousand earthquakes that took place off the Spanish since last September and precisely in Vinaròs. This case has so far been the focus of public attention, but now the issue seems to have come to a turning point , becoming a real battle that seeks against the extractive industry and the environmentalists.

We are facing a situation that has few precedents, and that as with many other researches around the world, also Iberian scientists and geologists have found a causal relationship between gas injection in the Subsoil and the hundreds of seismic events recorded in the storage center area at Castor.[26]

This is explained by Alvaro Gonzalez of the Department of Science and the Earth within the University of Zaragoza, who reports that the earthquakes caused by this type of practice usually don't exceed magnitude 3, while in the Castor wells a magnitude has been reached Of 4.3 on the Richter scale.

In addition, both the Instituto Geográfico Nacional (IGN) and the Instituto Geológico y Minero de España (IGME), in the study published on the Geophysical Journal International, have come to the same conclusion: gas injection causes earthquakes.

Multinationals do not take into account the risks that the ecosystem runs with such operations, ignoring them for a mere economic gain.

This project has been the subject of controversy since its announcement by José Luis Rodriguez Zapatero, Socialist government in 2007, the project has been "weak" since the beginning because of an insufficient environmental impact statement (DIA) provided by Spanish company Escal UGS to the Ministry of the Environment.

At this point it is an abandon of responsibility, since the Spanish ACS group holding 60% of the concession has announced its intention to leave the project due to insolvent problems, but intending to recover its estimated investment between 1.4 and 1 , 8 billion euros.

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[26] -Environmental Project Atlas, Castor Project Gas off-shore storage in Vinaròs, Spain, 2014.

-Castor Project, Engeneering Process website. (http://www.proyectocastor.com)

-B. Gaite, A Ugalde, A. Villasenor ,E Blanch - Improving the location of induced earthquakes associated with an underground gas storage in the Gulf of Valencia (Spain),2016, Elsevier

Mariano Rajoy's conservative government, on the other hand, does not want to take responsibility for the previous government and insists on accelerating the investigation on this project to determine its responsibilities.

The supply of gas to the Costa Dorada and the Costa Azzahar at this point is on the high seas, but in any case first of all comes the security of a territory and of those who live there. Choices must take place in the direction of the common good with that forethought of which the human being still lacks, believing that only the personal satisfaction is important, without realizing the scope of which the human is part.

It is important that a correlation emerges between the earthquakes and the ongoing drilling that are made to capture energy resources through which there is a real war on the part of power groups that want to emanate this planet.

Even though it seems like a battle that has unprecedentes, this battle must be fought beyond the end result that has never been taken into account, bearing in mind that it is important not to become complicit with these obstructions.

7.0 Considerations

Having seen the various methods through which humans can trigger earthquakes, nowadays it is important to understeand not only how to prevent them, but also what is the principal cause behind this process.
It is mainly the enormous increase in consumption, in the continuous growth of the population and in the progress of living standards which requires continuous energetical power.

Accomodating more than seven million people, our planet is going to run out of forces, since due to the trends the number of human beings will still be growing in the following years, reaching sproportionate levels.
This will cause continuous shortages, considering that 100 years ago the number of people on our planet was 4 times less, amounting at 1.5 million in 1900. Earth's carrying capacities, defined as "the maximum number of a species an environment can support indefinitely. Every species has a carrying capacity, even humans. However, it is very difficult for ecologists to calculate human carrying capacity. Humans are a complex species. We do not reproduce, consume resources, and interact with our living environment uniformly. Carrying capacity estimates involve making predictions about future trends in demography, resource availability, technological advances and economic development". [27] Theories about carrying capacities vary, since many believe the maximum capacity is of ten million, while others believe we already surpassed the limit.

Future generations will be the most affected by the future earth's shortages. Biodegradation and resource depletion will be the direct sources of the decreasing carrying capacity, while technological innovations could reverse this trend. Since the velocity of depletion of natural resources is the direct effect of growth rate, it would be justifiable to define it as the main the increase in population as the main cause of induced seismic events. Geoengeneering activities, ranging from geothermal activity to mining are the result of the increasing demand by society, leading to modifications on the earth's crust.

Even thought the increased development of our societies in the last decades, nowadays we can still find many differences in the trend of consumption between different countries.
Society's main division is currently between developed and developing countries, and since the formers are composed of only the five percent of the total world's population, its consumption of energy resources is around the thirteen percent. On the other side, in developing countries the thirteen percent of the population consumes only the five percent of energy capital annually. Following the fact that developing countries are incrementing their living standards, with the aim to reach the same levels of developed countries, the problem is the quantity of natural resources that will be needed to support this situation.

A first illustration of the increased request of natural resources is given by the production of coal and oil. The total consumption in 2010 amounted at 7,238 million tons, due to the data of the International Energy Agency (IEA), identifying China as the primary consumer, followed by United States and India. This shows a direct relation in the possibility of the increase in future induced earthquakes, since following this trend, more coal and oil activity center will be implemented.

Mining is a further potential damage for our societies, since it is an example of the increased request of natural resources after the Industrial Revolution, with the first mining center opened in Germany in 968 A. d. An activity that has been functioning for more than 1,000 years, producing more than 30 million tons of material. Compared with the Chuquicamata center in Chile, which have produced the same total amount of copper in only 90 years, the increasing technological advancement is leading to levels of production never reached before. The triggering of the improvements is also due to the Cold War, which asked for new technologies. Induced seismicity is only one of the many negative externalities that our planet is facing.

In conclusion, failing to deal with human caused natural disasters, constitutes not only failing to protect future generations but inflicting adversity on them by making their circumstances more difficult and dangerous as they would have been without these already existing human activities affecting the subsoil, and more difficult and dangerous than circumstances are now for us. If the current seismic activities were a natural occurring problem and we did nothing to deal with it, we would leave future generations facing a problem that was only as severe when we bequeathed it as when we inherited it. We would have failed to provide protection-done nothing to make their lives less dangerous.

Failing to deal with our negative activities on worlds' subsoil is not like that, because most of these activities are not naturally occurring. Political choices to not stop these economic based interests are causing or triggering earthquakes. At some time in the earth's history, earthquakes has occurred naturally, but many countries' seismic activities happening now are, as the scientists say, anthropogenic: people are causing them, by the increasing exploitation of natural resources. Human activities are undermining the environmental conditions to which human beings have successfully adapted, making the environmental conditions for future generations more threatening for them than the present conditions are for us.

To continue doing nothing of concrete to induced seismicity and simply continuing to " close an eye" on several activities that could cause extremely damaging events, is making thousands of people's lives at risk. Persisting with the activities that endanger the population, thereby creating serious phenomenal events that could lead to the death of many people, is not merely to decline to provide protection. It is to inflict danger, and to inflict it on people who are vulnerable to us and to whom we are invulnerable.

Conclusion

Having seen all the brutal consequences that we are causing to our planet should make us open our eyes. Not only because of the lack of control we have on it, but also because if a change doesn’t happen today, the situation is going to be irreversible. As induced seismicity, also climate change and water insufficiency are already showing the power they have on our daily lives, and considering that following this trend things can only get worse, I would not even imagine the conditions of the planet 100 years from now. Future generations are not only going to live in a dangerous situation, but also loose all the little things we now take for granted, all the achievements of our previous generations, all the beauty that mother nature has given to us, the trees, the animals, everything will be gone. But the happy thing is that we can stop it. Having seen all the advancements that humans managed to create, showing our superior capacities, making up unimaginable things, is now time to take a step forward, or all of that we have created will be gone.

It is without any doubt not simple to change from a day to the other all that habits we are used to, but by cooperating and by considering new alternatives, healthier both for us and for our planet, we can still have faith. The power is all in our hands, in the choices we take everyday.

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Riassunto in italiano

I terremoti sono sempre stati considerati eventi naturali nella nostra società, causando centinaia di vittime ogni anno in tutto il mondo. Oggi le cose stanno cambiando, a causa della crescente richiesta di fonti naturali e della continua crescita della popolazione mondiale, è necessario un aumento di energie e risorse. La nostra epoca può essere perfettamente definita con il termine "Antropocene", riferendosi all'influenza che le attività umane hanno sul nostro pianeta, basando le prove su continue alterazioni atmosferiche, idrologiche, geologiche e litosferiche. Dal 1950, questo processo sta danneggiando la terra con una tendenza che, se non invertita, lascerà le generazioni future in una situazione senza speranza. Nascendo in questo periodo siamo abituati a prendere molte delle comodità di cui usufruiamo ogni giorno per scontato, senza considerare il fatto che per ottenerli sfruttiamo attività come lo stoccaggio di gas, l'estrazione mineraria e l'estrazione dell'acqua sotterranea. Definire queste attività pericolose sarebbe riduttivo, poiché oggi possono essere considerate la causa principale dell'iniziamento di movimenti sotterranei.

La sismicità indotta si riferisce a terremoti tipicamente minori e tremori che vengono causati dall'attività umana attraverso l'alterazione dele caratteristiche della crosta terrestre. La sismicità indotta è generalmente di scarsa intensità. Alcune aree hanno regolarmente più terremoti, come l'impianto geotermico The Geysers in California, dove sono stati registrati due eventi M4 e 15 eventi M3 ogni anno dal 2004 al 2009.
I risultati delle continue ricerche pluriennali sui terremoti indotti dall'Associazione Geologica degli Stati Uniti (USGS) pubblicati nel 2015 hanno suggerito che la maggior parte dei terremoti rilevanti in Oklahoma, come l'evento sismico di magnitudo 5,7 di El Reno (1952), potrebbero essere stati indotti da una profonda iniezione di rifiuti acquiferi da parte dell'industria petrolifera.
Un' altra potenziale causa della sismicità indotta può essere l'iniezione di anidride carbonica durante la in fase di stoccaggio di carbonio, che mira a catturare l'anidride carbonica rilasciata dalla produzione di combustibili fossili o altre fonti nella crosta terrestre come mezzo attraverso il quale mitigare i cambiamenti climatici. Questo effetto è stato osservato sia in Oklahoma che in Saskatchewan. Sebbene le pratiche sicure e le tecnologie esistenti possano essere utilizzate per ridurre il rischio di sismicità indotta a causa dell'iniezione di anidride carbonica, il rischio rimane significativo in caso di stoccaggi di grandi dimensioni.
Le conseguenze della sismicità indotta potrebbero compromettere i guasti preesistenti nella crosta terrestre e, allo stesso modo compromettere l'integrità delle guarnizioni nelle zone di stoccaggio.
Il rischio sismico causato dalla sismicità indotta può essere valutato utilizzando tecniche analoghe a quelle utilizzate per la sismicità naturale, pur non rappresentando una sismicità stazionaria. In seguito, una valutazione del rischio può essere eseguita tenendo conto del pericolo sismico e della vulnerabilità degli elementi esposti a rischio (es. La popolazione locale e lo stock degli edifici). Infine, il rischio può, almeno teoricamente, essere mitigato, sia mediante modifiche al rischio in se, che attraverso una riduzione all'esposizione o alla vulnerabilità.

Sono molteplici i modi in cui può essere verificato un evento di sismicità indotta. Negli ultimi anni alcune tecnologie energetiche sia di iniezione che di estrazione di fluidi terrestri, come quella di petrolio, gas e lo sviluppo di energia geotermica sono stati considerati o sospettati di essere la causa motrice di questo tipo di eventi. Alcune tecnologie energetiche portano alla produzione di rifiuti che possono essere gestiti mediante lo smaltimento o immagazzinamento in zone in profondità nel sottosuolo. Un esempio può essere l'acqua di scarto prodotta da petrolio e gas, insieme all'anidride carbonica creata mediante una varietà di processi industriali, il quale allo stesso modo può essere gestita attraverso l'iniezione sotterranea.

Bacini artificiali

La quantità d'acqua che è iniettata in bacini artificiali altera lo stress presente in fratture preesistenti. In questo tipo di serbatoi il peso della colonna d'acqua può modificare in modo significativo lo stress su un difetto già esistente o la frattura sottostante aumentando la tensione totale attraverso il carico diretto o diminuendo lo stress effettivo attraverso l'aumento della pressione dei pori acquiferi. Questo improvviso cambiamento di stress può portare ad un movimento improvviso lungo il guasto o la frattura, causando un terremoto. Gli eventi sismici indotti dai bacini possono essere relativamente potenti rispetto ad altre forme di sismicità indotta. Sebbene la comprensione dell'attività sismica indotta dal serbatoio sia molto limitata, è stato notato il fatto che la sismicità sembra verificarsi su dighe con altezze superiori a 100 metri. La pressione supplementare dell'acqua creata dai grandi serbatoi è la spiegazione più accettabile per l’attivazione di attività sismiche. Per quanto riguarda il lasso di tempo in cui un terremoto può verificarsi, una volta riempiti i bacini, eventi sismici possono avvenire immediatamente o con un lieve ritardo.

Sin dalla fase iniziale di riempimento della diga del Vajont in Italia, sono stati registrati shock sismici. Il punto critico è arrivato dopo la riempitura della diga nel 1963, causando una scossa sismica conseguita da una frana ed un’inondazione massiccia che ha portato alla morte di circa 2.000 persone. Dopo lo svuotamento, l’attività sismica è andata riducendosi, fino ad arrivare a livelli quasi inesistenti.

Un altro possibile esempio è il terremoto del Sichuan del 2008, il quale ha causato circa 68.000 morti. Diversi studi scientifici hanno evidenziato potenziali correlazioni tra il riempimento della diga di Zipingpu e l’evento sismico.

Estrazione Mineraria

L'estrazione mineraria lascia vuoti che generalmente alterano l'equilibrio delle forze nella roccia, molte volte causandone la rottura. Questi vuoti possono crollare producendo onde sismiche e in alcuni casi riattivare i guasti esistenti causando terremoti minori. Allo stesso modo il crollo di caverne naturali potrebbe produrre un evento sismico locale sostanzialmente identico.

Pozzi di scarico

L'iniezione di liquidi nei pozzi di smaltimento rifiuti, più comunemente nello smaltimento di acqua prodotta da pozzi di petrolio e gas naturale, è nota per aver causato terremoti. L'acqua salina è solitamente iniettata in pozzi di smaltimento di acqua salata. Il conseguente aumento della pressione dei pori sottomarini può provocare movimenti lungo le faglie, causando terremoti.

Uno dei primi esempi noti è quello dell'Arsenal Rocky Mountain, a nord-est di Denver. Nel 1961, le acque di scarico furono iniettate in strati profondi, causando successivamente una serie di terremoti.
Il terremoto in Oklahoma, nelle vicinanze di Praga di magnitudo 5.8 si è verificato dopo 20 anni di iniezione di acque reflue in profonde formazioni porose a pressioni e saturazione crescenti. Il 3 settembre 2016, un terremoto ancora più forte con un'ampiezza di 5,8 si è verificato nei pressi di Pawnee, in Oklahoma, seguito da nove scosse di magnitudine tra 2,6 e 3,6 entro 3 ore e mezza. La potenza dei tremori ha portato alla ricezione in luoghi relativamente lontani come Memphis, Tennessee e Gilbert, Arizona.
I risultati della ricerca multilaterale in corso svolta dall'Associazione Geologica degli Stati Uniti (USGS) sui terremoti indotti, pubblicati nel 2015, hanno suggerito che la maggior parte dei grandi terremoti in Oklahoma, come il terremoto del magnitudo 5,5 El Reno del 1952, potrebbero essere stati causati da una profonda iniezione di rifiuti acquiferi da parte delle industrie petrolifere. Tuttavia, prima dell'aprile 2015, la posizione del Geological Survey in Oklahoma sosteneva che il terremoto avvenuto era probabilmente stato causato da cause naturali, e non dalla re iniezione di rifiuti di scarto. Questo è stato solamente uno dei tanti terremoti che hanno colpito la regione negli ultimi anni, essendo stato dimostrato l'aumento, dal 2009, da 1o 2 terremoti all'anno fino a 1o 2 terremoti al giorno. Solamente il 21 aprile 2015, l'Oklahoma Geological Survey ha pubblicato una dichiarazione invertendo la sua posizione sui terremoti indotti in Oklahoma; dichiarando la possibile correlazione tra gli eventi sismici e le iniezioni di acqua nei pozzi di scarico.

Attività Nucleari

Negli ultimi anni le voci si sono diffuse dopo i grandi terremoti che potrebbero essere stati causati dall'esplosione di bombe nucleari sotterranee, tra cui il terremoto del 2003 in Iran e quello di Haiti del 2010.

I dati scientifici pubblicati nel XX secolo suggeriscono che le esplosioni sotterranee provocano terremoti nelle loro vicinanze.
Poiché la tecnologia sismica è per lo più associata allo studio dei terremoti naturali, alla stessa maniera è anche il modo principale in cui vengono identificate e rilevate esplosioni nucleari sotterranee.
La detonazione sotterranea di esplosivi, comprese le bombe convenzionali e le armi nucleari, può essere rilevata come i terremoti. Per entrambi i terremoti e le esplosioni forze forti agiscono all'interno della crosta terrestre; l'energia viene rilasciata molto rapidamente ed il risultato è incredibilmente intenso. Le onde d'urto create, chiamate onde sismiche, si propagano attraverso la crosta fino a raggiungere i limiti delle rocce, dove una parte di queste onde rimbalza e un'altra parte le attraversa.
Le onde possono viaggiare in tutto il mondo, ma durante il loro viaggio perdono costantemente energia, con un conseguente declino di potenza sismica.

Energia geotermica

I sistemi geotermici avanzati (EGS), sono un nuovo tipo di tecnologia di potenza geotermica che non richiede risorse naturali convettive idrotermali, e sono perlopiù noti per essere associati alla sismicità indotta. EGS implica il pompaggio di fluidi a pressione per migliorare o creare la permeabilità attraverso l'uso di tecniche di frattura idraulica. La roccia secca e calda (HDR) EGS crea attivamente risorse geotermiche attraverso la stimolazione idraulica. Secondo le proprietà della roccia, della pressione di iniezione e del volume del fluido, la roccia può reagire attraverso diverse rotture.

I sistemi HDR ed EGS sono attualmente in fase di testazione e sviluppo in Soultz-sous-Forêts (Francia), Desert Peak e Geysers (U.S.), Landau (Germania) e Paralana e Cooper Basin (Australia). Gli eventi di sismicità indotti nel campo geotermico di Geysers, in California sono fortemente correlati ai dati di iniezione, allo stesso modo il sito di test a Basilea, in Svizzera, è stato portato alla chiusura a causa di rilevazioni di eventi sismici indotti.

Come abbiamo visto, i diversi tipi di eventi che possono causare terremoti indotti possono portare a disastri enormi, con una conseguente perdita di centinaia di persone. Inoltre è importante sottolineare la possibilità che questi tipi di eventi possano essere attivati non solo in territori che sono naturalmente sismici, ma anche in quelli asismici, portando a maggiori danni dovuti al fatto che la popolazione non ha adottato le giuste misure di previsione.
Molti fenomeni hanno mostrato il rapporto tra l'installazione di questi processi e il conseguente aumento di sismicità nell'area, portando in questo modo alla consapevolezza di possibili eventi sismici, non identificandoli come "disastri naturali". La morte di persone innocenti non deve essere sottovalutata, e senza dubbio una volta che la catastrofe si è verificata non vi è nessun modo per riparare la perdita di vite.

Poiché è un'attività da non sottovalutare, dovremmo aspettarci che lo sia lo stato in primis a difendere i diritti della popolazione, non solo attraverso la conoscenza di tali potenziali cause, ma anche adottando misure per la prevenzione degli stessi.

Per quanto riguarda il caso italiano, non è stata adottata alcuna regolamentazione su questo argomento, pur considerando l’alto livello sismico in Italia. Il fatto che il territorio sia già fortemente influenzato dai terremoti naturali può, da un lato complicare il riconoscimento degli eventi indotti, ma dall'altro ci permette di relazione gli eventi antropici a quelli naturali tettonici. Dopo l'evento sismico che si è verificato in Emilia-Romagna il 20 maggio 2012, per la prima volta in Italia è stata istituita una commissione per studiare la possibile correlazione tra il terremoto e le attività della zona, denominata “commissione Ichese”. Nella zona studiata si possono trovare tre differenti concessioni di sfruttamento di idrocarburi, rispettivamente quello di Mirandola, Spilamberto e Recovato, insieme al campo geotermico di Casaglia (Ferrara) e del deposito di gas di Minerbio. Presente nello studio vi è anche il progetto di Rivara, per quanto riguarda lo stoccaggio di gas naturale. Il risultato finale degli studi ha portato la commissione ad affermare che lo stato attuale di conoscenza e d’interpretazione di tutte le informazioni raccolte ed elaborate non consentono di escludere, ma neanche di dimostrare la possibilità che le azioni inerenti allo sfruttamento di idrocarburi nel centro di Mirandola hanno contribuito ad innescare l'attività sismica del 2012 in Emilia-Romagna.

Negli Stati Uniti la sismicità indotta e quella innescata hanno cominciato ad essere presi in considerazione nel 2011, anche se la legge sulla sicurezza delle acque potabili (SDWA) del 1974 ha regolato l'iniezione del fluido sotterraneo, garantendo la consumazione di acqua potabile controllata per il pubblico. Diversi Stati americani hanno ridotto o chiuso i pozzi di smaltimento a causa della crescente sismicità. Sia in Ohio sia in California sono state stabilite nuove leggi di regolazione della fratturazione idraulica, la quale richiede un monitoraggio sismico nei pozzi entro 5 km da difetti conosciuti e la sospensione dopo eventi sismici di MI> = 1 per Ohio e MI> = 2.7 per la California.

Per quanto riguarda la situazione Europea, possiamo definirla non ancora chiara, poiché l'interesse per le attività sotterranee che genera energia, come immagazzinamento di gas naturale, produzione di idrocarburi e produzione di gas di scisto è non indifferente. Oltretutto, le direttive dell'Unione Europea sulla valutazione dell'impatto ambientale (2014/52 / UE) non disciplina la sismicità indotta. L'obiettivo principale di queste direttive è l'utilizzo delle risorse sotterranee. Possono essere presentati casi particolari di Paesi europei che hanno sviluppato le proprie normative e linee guida, tra la quale sono presenti i paesi del Nord Europa. Gli ultimi sono di solito caratterizzati da bassi livelli di sismicità naturale, ma siccome l'elevata densità di popolazione, i terremoti superficiali possono causare danni e innescarne di più forti, per la quale il territorio non sarebbe preparato.
La prima nazione a introdurre regolamenti sul monitoraggio sismico è stata i Paesi Bassi.

Sin dal 2003 il governo olandese ha iniziato a richiedere una valutazione di pericolo sismico al momento di assegnazione della licenza, al fine di evidenziare la potenza massima prevista dei probabili eventi sismici. A causa della norma se l'evento sismico è superiore a quello approvato dal regolamento, le autorità possono intervenire per evitare conseguenti danneggiamenti.

In Germania la situazione è differente, poiché l'Associazione Geotermica tedesca nel 2010 ha pubblicato per la prima volta un regolamento sulla sismicità indotta. È stato il risultato di un monitoraggio sismico continuo, di responsabilità e copertura assicurativa. Inoltre il Consiglio di ricerca sulla fisicità della terra (FKPE), che regola l'opinione delle istituzioni geofisiche tedesche sui terremoti indotti, ha emesso successive normative più specifiche. Sono state presentate istruzioni generali sul modo di creare una rete sismica per affiancare dati sismici a dati industriali, e la necessità di relazioni più chiare per l'accesso ai dati. Pur essendo di forte impatto, i documenti non forniscono una chiara regola sulle potenziali procedure decisionali, in quanto perlopiù non sono mai state inserite in documenti governativo ufficiali.

Per quanto riguarda gli enti pubblici, paese con il maggior numero di istituzioni federali nel campo delle attività di controllo relative alla indotta-sismicità è gli Stati Uniti, potendo distinguere quattro diverse agenzie; relativamente "Environmental Protection Agency", "Bureau of Land Management", "U.S. Forest Service" e la "United States Geological Survey".

Le brutali conseguenze che stiamo causando al nostro pianeta dovrebbero farci aprire gli occhi; non solo per il mancato controllo che abbiamo su di esso, ma anche perché se non si verificherà nel breve periodo un totale cambiamento, la situazione sarà irreversibile. Come la sismicità indotta, anche il cambiamento climatico e la diminuzione delle risorse idriche stanno già mostrando il potere che hanno sulla nostra vita quotidiana. Considerando il fatto che che seguendo questa tendenza le cose potranno solo peggiorare, le condizioni del nostro pianeta da qui a 100 anni saranno disastrose. Le generazioni future non solo vivranno in una situazione pericolosa, ma non saranno in grado di ammirare tutte le piccole cose che la nostra generazione prende per scontato, tutti i risultati raggiunti delle generazioni precedenti, la bellezza che madre la natura ci ha donato, andrà tutto perso. Fortunatamente un'inversione di marcia è ancora possibile, se solo le cose cambiassero veramente, ci sarebbe ancora speranza per un futuro migliore.