David Wilgenbus, Cedric Faure and Olivier Schick

When the Earth Runbles

A project of risk education for the primary school A teacher's guide



la main à la pâte®



When the Earth Rumbles

Living with risk

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The Original Edition

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Preface

The translation into English and printing of this book "When the Earth Rumbles" is yet another effort by ISTIC to bring current issues that affect our lives closer to the classroom. As the world changes, there is more so the need to discuss with the young the consequences of some of the threats of today. Understanding the nature of natural disasters, how it happens, what consequences it brings to the environment should be a topic that would be of great interest to pupils particularly in areas that are prone to such calamities.

This book contains essential information, explanations, activities and simulations regarding Earth's movements. The book was originally written in French for French teachers and hence many of the examples have been prepared for the French context. It is therefore essential that users of the English version adapt the activities and examples to suit the local situation. The examples given can also be used as a guide for further activities that are relevant to the local contexts. It is ISTIC's hope that the book will be well-used as a resource material and as a source of reference by science teachers.

I must thank David Wilgenbus, Cedric Faure and Olivier Schick, the authors of this book who have prepared the book so meticulously and who have generously allowed ISTIC to translate it into English. This would certainly reach a wider audience. I also wish to thank *La main* à *la pâte* Foundation for sharing with ISTIC this rich resource that will enhance the learning of science in schools. My deep appreciation goes to the Malaysian Ministry of Science, Technology and Innovation for the financial support in printing this book.

Dato' Ir. (Dr) Lee Yee Cheong Chairman, ISTIC Governing Board



In recent years, there has been increasing incidences of natural calamities that have given rise to risks especially to those living within the vicinity. It is therefore essential that the public be given access to the knowledge, understanding and familiarity with such phenomena that have detrimental effects on the lives of people and the world.

Thus the publication of this book *When the Earth Rumbles* in the English language based on the original French book '*Quand la Terre gronde*' by La main à la pâte Foundation is timely and appropriate. The International Science, Technology and Innovation Centre for South-South Cooperation under the auspices of UNESCO (ISTIC) should be also lauded for making available to the Malaysian public this book which has been translated from French into the English Language.

The publication of the book is also another step towards making science education more relevant and appealing to school children as the issues highlighted are pertinent and current. I am confident that students in particular will enjoy reading the many interesting features in this book. I also join in expressing my hope that this book will be well received and utilised by science teachers.

The Ministry of Science, Technology and Innovation is proud to be part of this commendable endeavour by lending support to the publication of this book.

Dato' Dr. Rosli bin Mohamed Secretary-General Ministry of Science, Technology and Innovation



The La main à la pâte Foundation is pleased to present this teaching guide "When the Earth Rumbles," and thank the International Science, Technology and Innovation Centre for South-South Cooperation (ISTIC) for their translation of the original book "Quand la Terre gronde" published in France in 2012.

When the Earth rumbles offers to primary and lower secondary school teachers a complete program for studying natural disasters, particularly volcanoes, earthquakes and tsunamis. This English version will undoubtedly help many children around the world to study, understand, and self-guard from natural hazards.

This project was originally designed for French classes, so it includes global references but also some local French-contextualized references about Earthquakes and volcanoes. These are examples and teachers are encouraged to adapt the corresponding sessions to the context of their country.

May this book contribute to enhance risk education as well as science education of new generations.

David Jasmin, Director of the *La main à la pâte* **Foundation. David Wilgenbus, Project Manager and Supervisor of the** *When the Earth Rumbles* **project.**

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Introduction

Why study natural risks in school?

The demographic explosion and the colonization of new spaces in particular along major river beds and close to the coasts have significantly increased the exposure of populations to natural risks. In addition, the desertification of the countryside and the proliferation of megalopolises, with often ill-tamed urban development have increased the vulnerability of our societies to disaster.

Some recent events with very heavy human and/or financial impact have deeply marked spirits; as examples, let us refer to the 2004 tsunami in Asia, the earthquake in Haiti or the storm Xynthia on the French coast in 2010 and, more recently, the tsunami in Japan in 2011.

In most cases, the number of victims could have been greatly reduced if people had been suitably informed, empowered and prepared. This is why the action plan adopted in 2005 by the United Nations in order to reduce the risks of natural disasters grants a great place to education and awareness campaigns.

ESD and education about risk

Risk education is to teach the children to live with the risks in the most responsible way possible, to give them a culture of risk and an understanding of the hazards and issues, so that they can adopt appropriate behaviors. Although it is an integral part of education for sustainable development (ESD), risk education is still hardly addressed in schools, probably due to lack of resources or training of teachers on this topic.

Existing projects can be categorized into two generally opposing approaches:

• The first approach is action-oriented. It consists of implementing role plays or simulations (similar to fire drills) so that children develop automatic reactions and know how to behave in similar situations to that which was simulated. This approach is naturally focused on local risks which directly affect the child in school (why study volcanic risk in the Paris area, when the school is exposed to flood risk or landslides?)

• The second approach is understanding-oriented. It consists of carrying out scientific activities giving children a knowledge of risk and an understanding of the phenomena involved so that they can determine for themselves the required behaviours. This approach focuses in general on risks which have the advantage of lending themselves well to this type of investigation (it is easier to model, at the primary school, the formation of a volcano rather than the spread of a fire... besides, the volcanoes are in the program, but not forest fires!), whether they are actual risks or not, in the children's surroundings. It should be noted that even if "exotic", certain risks are very present in the imagination of children, because they are very high profile. Media coverage focusing on emotion can easily become anxiety-provoking if it is not accompanied by an effort to understand. The school has a role to play here too. The stance taken by the authors of this book, which is innovative in this sense, is not to oppose these two approaches, but to

propose a coherent educational project which combines the local and global and which focuses either on knowledge and/or actual experience.

The first three sessions offer respectively the study of volcanoes, earthquakes and tsunamis using an essentially scientific approach (but which does not ignore prevention) while the fourth provides a methodological framework intended to facilitate the study of local risk, its perception by the population, and the means by which they can protect themselves.

The primary school and the town hall "hand in hand"

Such a project is essentially multidisciplinary, applying knowledge and skills from sciences, geography, civic instruction (but also from mathematics, new technologies, teaching of languages...). It thus benefits from the versatility of the teacher and primary school programs, which encourage such a cross disciplinary approach.

Another reason why the primary school offers a particularly favorable context for this project is the closeness between the school and the county council on the subject of risk prevention.

It is indeed the mayor who has the legal responsibility to inform his constituents of the risks which exist in his county... and he also in charge of primary schools. Teachers and the municipality may find it very beneficial to work hand in hand in order to meet their legal obligations and their teaching objectives. This approach which can seem natural is not obvious and is only very seldom implemented in practice.

One of the objectives of the project "When the Earth Rumbles" is to provide schools and counties with a common tool and methodology to enable them to work as partners in the prevention of natural risks.

Scientific insight

The definition that I give of a major risk is the threat to man and his direct environment, on its facilities; the threat whose gravity is such that society finds itself absolutely overwhelmed by the immensity of the disaster. Haroun TAZIEFF

> Would it therefore mean that nature must be subject to our laws, and in order to prohibit an earthquake anywhere, we just have to build a city? Jean-Jacques ROUSSEAU

Myths and legends

The choleric manifestations of the earth such as volcanoes or earthquakes have always inspired fear and as well awe in mankind. Ignorance on extent of the impact the catastrophes associated with these natural phenomena have on human societies has led them to be the subject of myths and legends.

On volcanoes

On all the continents and through different ages, volcanoes were regarded as demonstrations of supernatural or divine forces sometimes contributing to ritual practices such as human or animal sacrifices.

The myths are numerous, and varied, but we will mention only a few examples.

In Europe

It is in Roman mythology that the word "volcano" finds its origins. Vulcan, son of Jupiter and Juno, is the Master of fire, of the forge and of volcanoes. Rejected by his mother after his birth because of his unprepossessing appearance, he was raised by Thetis and Eurynome. For some, Vulcan then installed his forging mills in the depths of a crater called Vulcano, located in the Aeolian Islands, in Sicily. Others prefer to locate it under Etna. He wedded Venus, who was as beautiful as he was ugly. Venus despised him and was often unfaithful to him, leading him to terrible rages: the volcanic eruptions.

This character itself is inspired by Greek mythology, according to which Hephaestus had taken refuge with Cyclops in the bowels of the Etna. The volcanic eruptions were associated with his work, forging the weapons of the gods, in particular the lightning of Zeus.

In North America

The Indians who populated Oregon thought that the god of fire resided in Mount Masama and that Mount Shasta was the residence of the god of snow. The rivalry between good (snow) and evil (fire) led to a conflict during which the god of fire was overcome and Mount Masama was decapitated, thus forming the caldera of Crater Lake.

In the Hawaiian archipelago, the legend of the goddess Pele is very famous. A Symbol of youth and beauty, she took refuge under Kilauea following many quarrels with her sister Namakaokahai, goddess of the ocean. At the least contrariety, Pele pours floods of lava and opens the craters by a simple kick of the heel.

The worship to the goddess Pele is still very present among Hawaiians, who see her hair in the spouting fountains of lava and her body in the shape of the lava flows. Many ceremonies continue to be organized in her honor.

In South America

For many peoples of Latin America, volcanoes were sacred places, at the top of which shrines were built and where bodies of sacrificed young girls have been found.

The Aztecs considered the eruptions as a sign of the gods who were protesting against the conquistadors accused of desecrating their sacred places.

In the year 1600, in Peru, the Huaynaputina volcano erupted. Thinking that the volcanoes were connected by galleries, the Indians expected that the nearby volcano Misti would also erupt to drive out the conquistadors. This did not happen, and the absence of reaction from the volcano was interpreted as an acceptance of the Spanish presence. For this reason, the volcano was renamed San Francisco.

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In Oceania

For the Maori people, three large volcanoes lived on North Island, New Zealand. It consisted of Mount Taranaki (also known as the Egmont Volcano), his wife, Ruapehu, and the Tongariro Volcano. A violent argument broke out one day between the two male volcanoes, Taranaki and Tongariro, both in love with Ruapehu. Taranaki lost the battle and fled towards the West, thus creating the Wanganui river.

Today, Ruapehu and Taranaki, always in love, still sometimes send each other plumes of smoke, while Tongariro smokes and burns with anger.

The Maoris avoid settling between the two enemy volcanoes, lest a new quarrel breaks out one day.

In Asia

On the island of Java, it is said that a very long time ago, a couple lived in a village, near Mount Bromo. The couple, unhappy about not having of child, asked the god that resided in the volcano to give them descendents. The god accepted on condition that a child be sacrificed in the crater of the Mount Bromo. They accepted, without thinking too much, and gave birth to twenty-five children, whom they refused to sacrifice as they loved them so much.

So one day Mount Bromo erupted and its volcanic clouds caused many deaths. The man and the woman then remembered their promise and agreed to sacrifice one of the children, the youngest. Thereafter, they made regular offerings to the crater.

Since then, once a year, a ceremony is held on the slopes of the volcano, during which prayers, sacrifices and offerings take place: animals, flowers and money are thrown into the crater.

About earthquakes

Legends concerning earthquakes are much fewer than for volcanoes. We can only speculate on why there this difference:

- A volcano leaves majestic formations after an eruption... and an earthquake leaves nothing (to what, and where to make offerings, in this case?);
- An eruption is a rather long phenomenon and very spectacular, while an earthquake lasts only a few seconds and appears only as tremors;

• The main danger, during an earthquake, is the collapse of buildings. This must have been rare and without great consequences at a time when the population was predominantly rural and widely dispersed.

Japan has, nevertheless, developed legends around earthquakes. One of the most widespread is that the archipelago rests on the back of a giant catfish, named Namazu. It is guarded by the god Kashima Daimyojin, who is the only one able to control it. If the god reduces its attention even slightly, the catfish would seize the opportunity to move in all directions, causing earthquakes and much destruction.

There are many frescoes which tell the history of Namazu and Kashima Daimyojin.

It should be noted that the catfish are indeed very sensitive to the warning signs of an earthquake and that many witness accounts report the strange behavior of this animal in the hours preceding some earthquakes.

Today, the image of the catfish is used in alarms resounding on mobile phones, computers and on television, as well as on some road signs announcing road closures in the event of a major earthquake risk.

About tsunamis

The archipelago of Santorini, also called Thera, is today made up of five distinct islands, located south east of Greece, in the Aegean Sea. It has a natural harbour whose circular form corresponds to a cauldron, the collapse of the central part of a volcano, which erupted and exploded during the Minoan era, around 1500 BC.

This eruption, one of the most important of ancient times, caused a cataclysm in the whole Mediterranean region. The explosion and the collapse of the volcano caused a gigantic tsunami which devastated the Mediterranean coast, destroying the Minoan civilization in Crete.

This catastrophic event was probably the origin of the Atlantis myth. Signs of this legend can be found in Plato'sTimée. Critias, the Young, relates a story that he heard to Socrates:

[...] in the time which followed, there occurred violent earthquakes and cataclysms; during one disastrous day and night which came, [...] the whole population sank into the earth and similarly the Island of Atlantis sank under the sea and disappeared. This is the reason why until today the sea is in this place inaccessible and unexplorable, filled with shallow places of mud that the island deposited when it collapsed.

Planet Earth

A tumultuous birth

The current activity of the Earth is the result of a long and eventful history.

Our planet was born approximately 4.6 billion years ago in the disc of materials which surrounded the forming Sun; a disc in which gases and dust clumped into small rocky bodies. These planetoids, while colliding, blended to finally form an increasingly large body, the Earth. Subjected to an intense meteorite bombardment during tens of million years, the planet heated to over 4,000°C, and was entirely in a liquid state (it was a "ball of magma"). The heaviest elements fell into the center, to form the core, while lightest went up to the surface.

The Earth cooled little by little, and a crust was formed on its surface, blocking the exchange of heat with the outside. As a result, the water vapor contained in the atmosphere condensed suddenly, giving rise to the oceans. The meteorite impacts were increasingly rare... but of sufficient violence to make the whole of the oceans evaporate and to liquefy part of the crust... which reformed until the next impact. This whole process lasted hundreds of millions of years.

An energy imbalance

The Earth of today is, certainly, calmer, but still very active. Under its now cooled surface, it remains very hot, with a core at more than 6,000°C. This heat is produced by natural radioactivity: heavy elements, such as uranium or thorium, disintegrate over the course of time and release great quantities of energy: approximately 20 000 billion watts per year (20 X 10¹² W/year). Among all the modes of heat transfer (conduction, convection, radiation), only convection is effective enough to allow such an amount of energy to circulate. Matter is put in motion in the same way as in a pan, water heated from the bottom goes up to the surface where it cools down before going down again. In the Earth's mantle, matter is solid: these convection movements are therefore very slow, about a few millimeters per year (see frame below).

It is this energy imbalance between a hot heart and a cold surface which makes Earth an active planet, with tectonics, volcanoes... and even an atmosphere and oceans! Indeed, the primary atmosphere of the Earth quickly escaped towards space, because of the weak gravity of our planet. If the Earth is livable, it is because the volcanic activity, by releasing large quantities of gas, has recreated an atmosphere (called "secondary") and still feeds it today. On Mars, where gravity is even weaker and where volcanic activity gradually disappeared (the planet is smaller and less massive than the Earth; it thus contained less radioactive elements), that led to the scarcity of its secondary atmosphere. Today, the Martian atmospheric pressure is so low that it does not even allow water to be liquid. Radioactivity, volcanicity, atmosphere, liquid water, life... all are linked!

A nesting structure

As we have seen above, Earth has experienced an episode of 'differentiation', in which the heavier elements fell into the centre and the lighter elements moved up to the surface. This explains its current nesting structure:

• The core (15% of the volume of the planet)

Mainly made up of iron and nickel, the core is liquid at its periphery but solid at the center, because of the very strong pressure. For this reason one speaks of an internal core and an external core. The external core is very fluid, the liquid iron is at the origin of the Earth's magnetic field which, besides the fact that it directs our compasses, protects us from the high energy particles of solar wind. When the Earth cools down sufficiently, so that its core is entirely solid, it will lose its magnetic field and life as we know it will no longer be possible.

• The mantle (84% of the volume of the planet)

The mantle consists of rocks rich in iron and magnesium. Although solid, it behaves like a viscous liquid if one observes it over long periods of time (see frame). It is the location of important convection movements which are at the origin of plate tectonics and hot points.

• The crust (1% of the volume of planet)

Mainly made up of rocks, granite on the continents, and basalt under the oceans. The Earth's crust is not very thick (30 to 70 km under the continents, 5 to 10 km under the oceans) and is more rigid than the mantle, because it is cooler.



How can a solid flow? Solid, liquid... these concepts are altogether quite relative and depend on the time scale in which one is interested. On the time scale of a human life, the Earth's mantle is solid (it is rock!). Observed on a scale of millions of years,

it can flow like a very viscous liquid (100 million billion times more viscous than water). Approximately 200 million years is needed for a portion of the Earth's mantle to complete a convection cycle.

The words "solid" and "liquid" will be used in this book and in class in reference to a human time scale. Thus, the mantle is solid... but sometimes, locally, it can melt and become liquid (magma: see further, chapter on volcanoes).

Scientists speak about "plastic" mantle to indicate the upper mantle, while the lower mantle is described as "viscous". This change of behavior (solid, then plastic, then viscous) is explained by the increase in the temperature and pressure as we move towards the center of the Earth, as well as by changes in the chemical composition of the rocks.

Moving plates

Convection movements which take place in the mantle cause the lithosphere (upper mantle + crust) to crack into plates, called "tectonic" or "lithospheric" which are in constant movement against each other, with speeds going from 1 to 20 cm per year. This activity is at the origin of the oceanic floor, chains of mountains, volcanic eruptions and earthquakes:

• When two plates move away from each other, the space left between them is filled by magma, hot and liquid, which goes up to the surface. This effusive volcanic eruption (see page 12), is very active, form the so-called



oceanic ridges, causing the renewal of the seabeds. Iceland is one of the rare places where this type of volcanism appears, making it possible to observe it easily.

• When two plates move towards each other, two cases are possible:

- If one of the two plates is denser than the other, it plunges below and sinks deep into the mantle. This phenomenon, called subduction, is at the origin of strong earthquakes and of explosive volcanism (see page 12), for example, in the ring of fire of the Pacific.

- If the two plates are of the same density, they collide with one sliding under the other. The rocks and the sediments are folded and raised, forming mountain chains, such as the Himalayas (at the border of the Eurasian and Indian plates) or the Alps (Eurasian and African plates).

• Finally, some plates may slide sideways, relative to the other, along "faults". These displacements produce very violent earthquakes, such as in California (San Andreas fault between the Pacific and North American plates).

Volcanoes

Volcanism probably the most obvious manifestation of the internal activity of the planet. Each year, there are more than 50 eruptions (air), besides the permanent ones which occur along the oceanic ridges (submarine eruptions).

Subduction volcanoes

How can tectonics generate volcanic eruptions?

When an oceanic plate (made of dense basaltic materials) sinks under a continental plate (made of a little less dense granitic materials), it carries with it the water-rich sediment. As the plate sinks, it is subject to gradually higher temperature and pressure, causing the sediments to release water into the mantle, lowering its temperature and causing it to melt (the melting

point of the mantle drops very quickly when its water concentration increases). The magma formed is therefore less dense than the rest of the mantle, and rises towards the surface thanks to a buoyant upthrust. Along the way, it grows rich in other minerals (in particular silicates) present in the crust, and ends up accumulating, within a few kilometers from the surface, in a tank called "magma chamber".



Hot point volcanoes

Some volcanoes, quite rare (5 % of them), are not located at the borders but inside the plates. They are called "hot point" volcanoes, or intra-plate volcanoes. The mechanism for the formation of magma is very different to the previous case.

In the beginning, a plume of heat in the mantle heats the base of a tectonic plate, and "pierces it" like a blowtorch by cutting through a path towards the surface, where it emerges, forming a volcano. The hot point is fixed... but the plates, on the surface, move. The volcano formed at the base of the hot spot moves away gradually and is eventually cut off from the magma chamber. It dies out, while a new volcano is formed above the hot point.

From one eruption to another, not one, but several volcanoes are formed, along a chain. The best-known example is the archipelago of Hawaii, made up of about fifteen volcanic islands spread out over more than 2,500 km. It is a chain with many records since Kilauea is today the most active volcano in the world (it has been in permanent eruption for nearly 30 years), while



Mauna Loa is the largest: it rises up to 4 206 m and rests on the seabed at - 5 500 m. Its total height exceeds 9 700 meters! The Piton de la Fournais, on Reunion Island, is also a hot point volcano. Today it one of the most active in the world but it is about to die out, since it is already more than 400 km away from its hot point however current reserves of its magma chamber should feed it for another few thousand years.

Start of an eruption

As we saw earlier, magma, accumulates little by little under the surface, in a magma chamber under intense pressure. Once saturation is reached, it walls break down; the pressure then drops suddenly, which makes the water, carbon dioxide and sulphur dioxide dissolved in the magma return to a gaseous state, as bubbles. These bubbles, while rising towards the surface, drag the magma with them: this is the eruption.

Red volcanoes, grey volcanoes

In very fluid magma, gas bubbles circulate easily, and then quickly rise towards surface. The magma, largely free of the gas bubbles, goes up slowly and comes out in the form of fountains and lava flows which glide down the slopes of the volcano, but are not a real danger to the populations, which would have had time to be evacuated. Such an eruption is described as effusive, and such a volcano is called "red volcano", in reference to the color of the lava. The red volcanoes have frequent but weak eruptions. They are hotspot volcanoes or oceanic ridges. The lava, being very fluid, flows over long distances, which gives these volcanoes very spread out shapes (these are known as shield volcanoes).

On the other hand, in very viscous magma, the gas bubbles are slowed down and cannot rise towards surface: they remain "wedged" in the magma, until the pressure becomes too strong

and then violently ejects the magma + gas mixture. There is then a spectacular and extremely dangerous explosion (which can sometimes "decapitate" the volcano as was the case during the eruption of Mount St. Helens in 1980). Volcanic bombs (more or less solidified fragments of rock) as well as clouds of incandescent



ashes are ejected, covering hundreds of square kilometers. These "ashes" are really microscopic shards of rocks fragmented by the bursting of the gas bubbles which they contain... and have nothing to do with ash.

Sometimes, a burning mixture of gas, ashes and rocks, called "volcanic cloud", hurtles down the slopes of the volcano at speeds which can reach 500 km/h and chars everything in its path. Thus Mount Pelée leveled the town of Saint-Pierre, in Martinique, in 1902, killing 28 000 people leaving only 2 survivors.

Other factors can even further increase the impact of such eruptions, in particular the presence of water, whether it is through strong rains during or after the eruption, or snow melted by the heat (many volcanoes are covered with snow or glaciers at their summit). This water mixes with the large quantities of ejected ashes and then causes major mudslides (called "lahars"), which can be devastating. This is what occurred in 1985 in Colombia, during the eruption of the Nevado del Ruiz: several cities, some up to 80 km away, were buried under the mud, killing more than 25,000 people.

Such eruptions are referred to as explosive and such volcanoes are called "grey volcanoes", in reference to the ejected ash. Grey volcanoes, in contrast to red volcanoes, have infrequent but very violent eruptions. These are the volcanoes that are found in subduction zones. The lava, being very viscous, flows over short distances, which gives these volcanoes little spread out forms, with steep slopes. Furthermore, the volcanic cones often present scars of the old explosions, making this type of volcanoes perfectly recognizable.

It should be noted that this classification of the volcanoes into two categories, red/grey, is a little simplistic. It is however sufficient for the primary school. Some "red" volcanoes may, sometimes, experience explosive eruptions. This is the case for example when a column of lava meets a ground water table. The steam which is created suddenly increases the pressure of gases dissolved in the magma, giving an explosive character to the eruption, even with lava which is not very viscous (often the case in the Massif Central).

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The volcanologists commonly define five types of volcanoes, according to the viscosity of their magma and the amount of dissolved gases. From the reddest to the greyest, are the Hawaiian, the Strombolian, the Vulcanian, the Pelée an and Plinian types.

The volcanic risk in France

About a hundred volcanoes in the world are regarded as very dangerous and more than 500 million people are afffected by this risk. In France, the volcanic risk primarily relates to the overseas departments (Guadalupe, Martinique and Réunion) and, to a lesser degree, French Polynesia as well as the Massif Central.

The only catastrophic eruption which occurred in France is that of Mount Pelée (Martinique) in 1902. With more than 28,000 people killed, it is one of the greatest natural disasters of its history, and undoubtedly the worst which has occurred in France since the beginning of the 20th century. For this reason, Mount Pelée is one of the most monitored volcanoes in the world. Another potentially dangerous volcano is the Soufrière (Guadalupe). The last eruption dates back to 1976, but there were no victims.

The piton de la Fournaise (Réunion) erupts almost every year, but its effusive flow does not cause any major material or human damage.

French Polynesia, just like Réunion, is the location of hot point volcanism (effusive and not very dangerous). Besides volcanic islands, many underwater volcanoes can also be found, including the MacDonald volcano, which is no more than 27 meters away from surface and will soon form a new island.

In mainland France, the Massif Central offers great opportunities to observe volcanoes. The



chains of Cantal and of Mount-Dore have been extinct for a long time, but this is not the case for Puys chain, which is made up of a hundred more recent volcanoes. The last eruption dates back to less than 7,000 years (eruption on the Pavin lake in 4,700), but it takes 10 000 years of inactivity for a volcano to be regarded as extinct. This makes volcanologists say that the volcanoes of Auvergne are dormant and could one day erupt. But monitoring stations will make it possible to predict this event several months in advance.

Volcano monitoring

The majority of volcanoes which are considered to be dangerous are monitored thanks to the deployment of many volcano observatories. Scientists are trying to detect precursory signs of eruptions, such as small earthquakes (which betray magma being pushed up), minimal variations (a few millimeters or centimeters) in the geometry of the slopes of the volcano, variations in the temperature of the rivers, the fumaroles, etc.

It is hoped the prediction of eruptions can be made with increasing accuracy.

This monitoring is not enough; it is necessary to also be able to quickly alert the populations and evacuate them (to do this, it is necessary to have identified safe areas through the study of previous eruptions). In 2000, an "International Charter, major spaces and catastrophes" was initiated by the European Space Agency (ESA) and the National Center of Space Studies (CNES). Its founding members, soon joined by other organizations from around the world, are committed

to delivering satellite data to the countries affected by natural or technological catastrophes. This invaluable data is delivered almost in real time, and makes it possible to quickly know the nature of the catastrophe, its extent, the affected areas, and hence to better coordinate relief¹ efforts.

The charter was activated more than 50 times in 2010.

Why live close to the volcanoes?

Volcanic risk has long been known, but this did not prevent people from settling near the volcanoes (the demographic explosion in the 20th century also considerably increased the exposure of populations). It should be said that if volcanoes have a considerable destructive force, they may also prove to be extremely useful.

The volcanic rocks and deposits are very good building materials. Whether they are pumice (insulating, solid, easy to work with...) used in Auvergne for homes, or places of worship or whether they are ashes which, can sometimes be deposited over tens of meters in depth, hardened and then eroded with the passing of years, to offer natural shelters for the construction of truly troglodytic cities, such as those found in Turkey (Cappadoce).

The volcanoes provide a quantity of precious metals (gold, copper, silver, tin...) which are obviously exploited, but also minerals such as calcium, phosphorus or magnesium which enrich the land and make these areas particularly fertile. In Indonesia, up to three rice harvests per year can be made on the slopes of volcanoes, against only one elsewhere. These same minerals make the water around Iceland particularly rich in fish.

In addition to these resources, volcanoes are also important sources of free, clean and renewable energy: thermal springs, and even geothermal power plants, because the large differences in temperature between the sub-soils and the surface can be exploited to produce electricity (as is done on the Bouillante site, close to the Soufrière, in Guadalupe).

Lastly, let us not neglect the income generated by tourism in these areas for outdoor activities (hiking, mountaineering, skiing, paragliding...).

For all these reasons, the volcanic areas remain, despite the risk, very attractive to local populations.

Earthquakes

The Earth is permanently agitated by sudden convulsions, with several million recorded earthquakes each year, the majority of which go unnoticed as they are too weak or occur in uninhabited areas.

Plate against plate

Movements of plates against each other do not happen without collisions: When plates collide they generate intense friction and impose strong pressure on both sides of the boundary between the plates.

Rocks, deep down, then become gradually deformed and the pressure accumulates over many years, even centuries, until the elasticity threshold of the rock is exceeded. That then leads to a sudden rupture during which accumulated energy is suddenly released and spreads in the form of waves, called seismic waves.

^{1.} Several activities suggested in the teaching module call upon data provided by the European Space Agency. We also propose, in bibliography, teaching guidelines to work around this charter and exploit other data in class.

This is the same as when a rubber band is gently stretched until it breaks. An earthquake² is due to the sudden release of accumulated pressure. The longer the accumulation is, the greater the release of energy.

Earthquakes are frequent along faults, but rather rare inside the plates themselves. When they take place, they are less violent and are the result of the movement of some faults, which correspond to a readjustment of pressure at the level of the Earth's crust.

Volcanoes themselves can also be the cause of other earthquakes or micro-earthquakes, created for example by the movement of the lava towards the magma chamber and the surface. Such events are warning of an imminent eruption.

Lastly, some human activities, such as exploitation of underground deposits or nuclear tests, can generate moderate earthquakes.

Seismic waves

Seismic waves are a means for the rock to dissipate energy which has accumulated slowly. They are spread in all directions, towards the surface as well as towards the center of the Earth, forming concentric spheres.

When one moves away from the center, the surface of a sphere grows very quickly (it is proportional to the square of the radius): the released energy is thus more and more "diluted". Therefore the damage caused by a seism decreases very quickly as one moves away from the focus (the place, on the fault, from which the waves originate... or from the epicentre if one looks at what occurs on the surface. The epicentre is a point on the Earth's surface that is directly above the focus (the focus itself is called "hypocentre" by scientists).



On the surface, the seismic waves form concentric circles around the epicentre. Actually, these circles and spheres are not perfect, because the speed of propagation of the seismic waves depends on the nature of the soil and its topography. These speed variations generate amplitude variations, with effects which can be amplified locally, as shown in the figure above. Behind the term "seismic wave" various types of waves can actually be found. So-called volume (or substantive) waves, which propagate inside the Earth, and surface waves.

^{2.} To be precise: the seism corresponds to the sudden release of accumulated energy, while the earthquake is defined by the spread of the waves generated at the time of the seism on the surface. Here, we will employ these terms synonymously.



Almost 2000 years ago, the Chinese found a way to detect earthquakes. Since Zhang Heng, who built the first seismograph (only mechanical, at the time, as seen on sheet 24, on page 201), these instruments have improved and been computerized. The principle is simple: a coil is attached to a suspended arm, isolated from any vibration and buried into a magnet which, is linked to the ground. When the ground shakes, the magnet moves around the coil which senses a variation of the magnetic field. These variations create an electrical current in the coil (proportional to the speed of the ground) which is transmitted to a monitoring centre. The graph obtained is called a seismogram.



As P and S waves do not travel at the same speed, they are not recorded at the same time. These time lags make it possible to calculate the distance from the focus to the measuring station (it is exactly what is done to know the distance which separates us from a storm, by measuring the temporal shift between the flash, which travels at the speed of the light, and the thunder, which travels at the speed of sound). By using time lags measured in various places, the focus can be located, at the intersection of the spheres (the radius of each sphere being the distance between the focus and the station). Since the stations have been computerized, these data are calculated in real time with a high degree of accuracy, because of the great number of stations.



16 Scientific insight

Using earthquakes to know the internal structure of the Earth

When a straw is dipped into a glass of water, it gives the impression that the straw is bent. This illusion comes from the fact that the light does not travel at the same speed in water and in air, and is thus deviated when passing from one medium to another.

In the same way, seismic waves are deviated when they cross different rocky environments. The analysis of the deviation of these waves thus makes it possible to locate discontinuities in the nature of the subsoil, and determine certain physicochemical characteristics of these elements. This is how the internal structure of the Earth can be deduced (the center of which is located at more than 6 000 km from the surface), while at the same time deepest drilling ever carried out has only allowed the exploration of the first 12 kilometers under our feet.

Magnitude, intensity

The oscillations which can be read on the seismograms make it possible to calculate the amplitude of ground movements and, from there, the energy released by the seism.

This quantity is called the magnitude, and is measured on the Richter scale, the name of its inventor. The Richter a scale is 'logarithmic': increasing the magnitude by one degree is equivalent to multiplying the energy released by 32. An earthquake of magnitude 8 therefore releases 32 times more energy than a magnitude 7 earthquake and about 1000 times more than an earthquake of magnitude 6.

Contrary to a generally accepted idea, this scale has no upper limit. In practice, an earthquake of magnitude 9 is exceptional, and the largest earthquake ever detected is the one which struck Chile on May 22nd, 1960, with a magnitude of 9.5. This earthquake corresponds to the rupture of a 1000 km long fault.

This scale is presented in more in detail on sheet 25, page 202.

The magnitude is unique for an earthquake and independent of the place where it is felt. Of course, a large magnitude earthquake is more likely to do damage... but it is not systematic, as other parameters are taken into account: the depth of the focus (the greater it is, the lesser its effects) and dwellings in the area (in dense urban areas or in the desert, the damage is not the same).

For this reason, another measure is used in order to assess the damage caused by an earthquake: intensity. The intensity is measured on the EMS-98 (European Macroseismic Scale 1998) scale, which is a revision of old MSK scale³.

This scale has 12 levels (numbered from I with XII, in Roman numerals as not to confuse them with the magnitude). For an intensity equal to I, the earthquake can only be detected by seismographs, and cannot be felt by humans. Chimneys of homes fall from an intensity equal to V. From IX, the damage is major. At XI, the ruin is almost complete (as shown to us the Haiti earthquake); at XII, the landscapes themselves are modified. In current practice, intensities are no longer distinguished beyond X.

Although an earthquake only has one magnitude, it has several intensities, since this measures the damage in a given place. On a map, places of equal intensity can be connected between them by an isoseismal curve. As seen above, these curves are approximately circular, intensity decreasing when one moves away from the epicenter.

^{3.} The MSK scale is always used; it is the one which is referred to in the teaching module.

Seismic risk in France

If the word "earthquake" is mentioned, one remembers the catastrophe in Haiti in 2010, or in Japan in 2011, such was the distress caused by the images and testimonies of these recent events. So much so that one forgets that Mainland France also experienced significant earthquakes, although their magnitude was much lower than that of the two previous examples. The most intense earthquake in recent history is one which occurred on June 11, 1909, in Provence. Of a magnitude estimated at 6.2 and an intensity equal to IX close to the epicentre, it caused a lot of damage and about fifty victims, without counting the wounded. Due to densification of



housing and equipment, the same earthquake, today, could kill a thousand people and could cost more than 2 billion euros in damages.

However, Metropolitan France, approximately with 20 felt earthquakes each year, is regarded as having an average seismicity compared to other countries around the Mediterranean, the risks concentrated in being the Pyrenees, the Alps, Provence and Alsace. The seismic zoning of the

territory is visible on sheet 26, page 203. The Antilles, on the other hand, are very strongly exposed to seismic risk. In 2007, an earthquake of magnitude 7.4 (against 7.3 for the one that devastated Haiti in 2010) made Martinique shake, fortunately without causing too much damage because the focus was more than 150 km deep. Since then, the inhabitants await the "big one", which will occur some day and will cause much more substantial damage. It is estimated that an earthquake of magnitude 8 would kill 30 000 people, that is to say 7 % of the population of the island, not only because of the vulnerability of constructions (80 % of the schools, for example, are not up to the standards), but also because of the population performed the actions at the time of the earthquake of 2007.

Protect the populations

Each year, several million earthquakes are recorded in the world, including 150 with a magnitude greater than 6 and likely to cause damage.

The danger, during an earthquake, is not the quake itself, but the collapse of the buildings. If it is possible to predict, statistically, the arrival of a major earthquake in a region of the world, it is still impossible to make short-term forecasts which would enable the evacuation of the populations⁴. Therefore, the only solutions that remain are to build resistant buildings, and to make people aware of the actions they should take in the event of an earthquake.

^{4.} Many early warning phenomena are recorded a few minutes to a few days before the earthquakes: such as microearthquakes, abnormal deformations of the ground, even of the electrical currents in the ground, and perhaps even of the electric disturbances in the ionosphere as demonstrated recently by the satellite Demeter launched by the CNES. But the majority of the earthquakes do not show these early warning signs. Above all, such effects occur most often without great earthquakes occurring as a result, and therefore a method of prediction based on their observation might produce too many false alarms.

There are many regulatory texts which set standards of construction according to the geographical area and the type of building. It distinguishes:

Works at normal risk: these are the buildings for which the consequences of an earthquake are limited to their structure itself and to their occupants. They are classified into several categories according to their importance (from the least to the most important):

- Category I: the works whose failure present only a minimal risk for people or the socio-economic activity (example: farm sheds);

- Category II: average risk (example: personal houses);

- Category III: high risk because of the number of people who can be affected (example: schools, buildings, shopping centres);

- Category IV: buildings whose resistance is of primary importance for civil safety (fire stations, hospitals...).

• Works of special risk: these are the facility for which damage resulting from an earthquake could have heavy consequences on a great part of the territory: dams, nuclear power plants...

The basic seismic building codes are:

- At the implementation level:
- seek protection from the risks of landslides (build away from cliff edges...);

- take into account the nature of the soil: on a rigid ground, preference for flexible and slim buildings; on a movable soil, preference for rigid and massive buildings.

- At the design level:
- preference for simple and compact shapes;
- set up horizontal and vertical winds-braces (chaining, see page 206)
- At the realization level:
- use quality materials (reinforced concrete, steel, wood);
- fix the nonstructural elements to prevent falling (hanging lightings, ceilings...).

The preparation of the population is an essential aspect, which requires, on the one hand, an effort at educating (of the children at the school, but also of general public), so that each one is aware of the risk, and, on the other hand, the organization of simulation and evacuation exercises.

Tsunamis

Are all large waves tsunamis?

The use of the word "tsunami" is widespread since the dramatic events of December 2004 which caused over 280 000 deaths in South Asia... but do we really know what it is? What differentiates a tsunami from a tidal wave or from a series of very large waves, as seen for example during strong storms?

The expression "tidal wave" refers to a flood, caused by the sea, the origin of which is a meteorological phenomenon, such as the unfortunate conjunction of a very strong tide and a storm, such as the Xynthia storm which landed on the Vendée and the Charente-Maritime areas in February 2010.

A storm or a strong swell can give rise to impressive waves of several meters in height. On the other hand, the wavelength of these waves is always rather short. This can be seen very clearly on the beach: even when the waves are very strong, they are never far from each other by more

than a few tens of meters (100 meters, to the extreme, during a storm). In other words, when a wave has passed, simply wait a few seconds until the following occurs (this is called the 'period' of the wave).

A tsunami, on the other hand, refers to a series of special waves whose wavelength is very long, about 100 km, away from the coast, and 10 km, near the coast. Between two successive waves, there can easily be 20 minutes or even more.

This difference is fundamental: a 2 meter tsunami will do much more damage than a swell of 4 meters. To understand this, just look at the mass of displaced water. Imagine a swell of 1 meter high and 10-metre wavelength, which breaks on a 100 meters broad beach... and make the assumption, to simplify, that this wave is in the shape of crenels (it is easier to calculate with the sinusoids!). The volume of water contained in the wave which will break is $1 \times 10 \times 100 = 1000 \text{ m}^3$ Let us replace this swell of one meter by a tsunami of one meter. All is identical, except the wavelength, that amount this time 10 km. The volume of water which breaks on the beach is then $1 \times 10000 \times 100 = 1000000 \text{ m}^3$. This gigantic water mass has a kinetic energy 1000 times greater than in the case of the swell: nothing can resist it.

The fact that a tsunami has a long wavelength has another important consequence: it penetrates



far inland. If the ground is sloping, a wave can flood an area with a dimension comparable to its wavelength. Thus, a "normal" wave (swell... or even storm) will flood the coastline for a few meters or tens of meters... while a

tsunami will do it for several kilometers, thus multiplying the damage.

Speed, height, depth: all is connected!

What makes prevention so difficult, it is the very high speed at which a tsunami is travels: up to 900 km/h offshore (the speed of a plane): one has only very little time. However, on the coast, nobody has ever seen a wave, even a tsunami, approach with a supersonic speed! In fact, the tsunamis break on the coast with a speeds of 30 to 40 km/h.

Why this deceleration?

When a wave travels, it can be slowed down by friction along the bottom, as long as the depth is low compared to its wavelength. For a tsunami, it is always the case (wavelength: 100 km, compared with the average depth of the oceans: 4 km). The speed of such a wave is directly proportional to the depth. Offshore, the tsunami tarvels very quickly... and close to the shore, speed is divided by a factor of 20. The front of the wave slowing down greatly, is caught up by the back of the wave: the length decreases.

Thus, a tsunami with 100 km wavelength offshore will have no more than a 10 km wavelength on the shore.

The result is spectacular: the wavelength decreases... but it still contains as much water! To maintain this quantity, there is no other choice: the wave must increase in height.

The consequence of the tsunami decelerating, is the reduction of its wavelength by a factor 10, which itself mechanically involves an increase in the height of the wave. Here is how a wave of a few centimetres, off the coast, can rise up to several meters near the coast.



This amplification factor depends on the geometry of the seabed. A steep slope "will break" the wave (amplification by a factor 2 only), while a gentle slope will amplify it by a factor 10, maybe more. For example, the tsunami in Sumatra on the 26 December 2004 broke with a height of 35

meter in places, or the equivalent of a building of 10 floors! It was the most serious tsunami in history: 280,000 killed.

This astonishing property of the tsunamis can be found even in the etymology of the word, which means "harbour wave" in Japanese. It is indeed a wave that is not noticeable in the open ocean, but which is greatly amplified as it arrives at the port!

At the origin: an earthquake

To create a tsunami, i.e. a set of waves with a long wavelength, a major disturbance is required. Long, here again, means "long" in comparison to the depth. Throwing a rock in a pond is sufficient to create a tsunami in the pond, but to create a tsunami in the ocean (depth = a few kilometers), a disturbance of very strong magnitude is required.

Generally, tsunamis are created by underwater earthquakes. If the earthquake is of a sufficient magnitude (6.3 minimum) and if its focus is not too deep (< 50 km), then it can deform the sea-bed over a fault which can be several kilometers long. In this case, the column of water above the fault, is set in motion, which forms waves of long wavelength: a tsunami is created. Major underwater ground movements, created for example at the time of a volcanic eruption (sometimes, a whole side of the volcano breaks down into the sea), can have the same effect. Finally, the impact of a meteorite, although this is very unlikely, can also cause a large tsunami.

Recognizing the arrival of a tsunami

The very high speed of a tsunami makes it difficult to alert the population. Even though, since 2004, huge efforts have been made in tsunami detection and the coordination of warning centers, the education of the population is still necessary for prevention.

The arrival of a tsunami is generally preceded by early warning signs which you should learn to recognize:

• withdrawal of the sea: it moves back an unusual distance (by hundreds of meters, even kilometers), in only a few minutes. It is the trough of the wave: be alerted, the crest will arrive soon!

• an earthquake or rumbling noise;

abnormal behavior of the animals (which flee inland)

If one of these phenomena is observed, it is immediately necessary to leave the coast and to take refuge in the hills. A few minutes after, the first wave will arrive... followed by a new withdrawal of the sea... and other waves which will follow one another sometime over several hours.

The tsunami risk in France

Each year there are about 10 tsunamis in the world, including a major one. All the seas are affected.

France is lucky to have the second largest marine domain in the world⁵, after the United States. This considerable economic and geostrategic asset however has its downside, because it makes France particularly concerned by the risk of marine subversion, whether tsunami or tidal waves. Not surprisingly, as with volcanoes or earthquakes, the risk concerns mostly the oversees departments and territories, or DOM-TOM, on the one hand because of their own seismic or volcanic activity, and on the other hand because of their geographical location which makes them vulnerable to tsunamis generated in the Pacific Ocean or the Indian Ocean. The Antilles are particularly threatened.

The coast in mainland France is not necessarily sheltered though, with a risk qualified as "moderate", the most exposed area being the Mediterranean, because several underwater faults run between Algeria and Corsica. Besides, history shows that this risk should not be neglected, since Mainland France has known 4 tsunamis in the past century.

An earthquake with a magnitude of 6 or more off the coast of Algeria (not at all an improbable hypothesis, with regard to seismic activity in the region) would cause, one hour later, a tsunami on the French coast which, far from being as devastating as the tsunami of 2004, would nevertheless lead to major human and material losses. For this reason, a system of detection and alarm is being deployed for the French Mainland coasts, and should be operational at the end of 2012.

Major risks

The last few years have been marked by widely publicized major disasters: the Katrina storm in New Orleans in 2005, the earthquake and tsunami in Southeast Asia in 2009, the monstrous floods in Pakistan, the earthquake in Port-au-Prince in 2010, as well as the recent earthquake and tsunami in Japan in 2011 constitute examples of these events which strike the minds.

While many researchers have worked to classify the risks according to their frequency or their gravity, one of the best definitions of a major risk remains that proposed by Haroun Tazieff, a volcanologist, first to have been nominated to lead, in 1984, the new Secretariat of State for major Risks.

Natural risks	Technological risks
Avalanche Forest fire Flood Landslide Earthquake Marine Subversion (tsunami and tidal wave) Storm Volcanism	Industrial Transport of dangerous materials Dam burst Nuclear power

"The definition that I give of a major risk, is the threat to man and its direct environment, on its installations; the threat whose gravity is such that society finds itself absolutely overwhelmed by the immensity of the disaster."

In France, major risks are divided into two big families, natural risks and technological risks.

^{5.} The French maritime domain covers 11 million km² (including 97 % in the DOM-TOM) and adds up to nearly 38 000 km of coastline!

The heat wave, such as the one in France in 2003, is a natural risk which is not yet commonly integrated into this classification. Depending on the country, other risks can be taken into account, such as for example drought or insects. Lastly, climatic warming is not regarded as a risk per se, but it increases the extent and the frequency of the majority of the natural risks mentioned above, except for the risks related to the internal structure of the planet (volcanism and seism).

Hazard, stake, risk and disaster

In this book, designed to educate students from primary school about natural risks, we voluntarily simplified the concept of risk by not mentioning vulnerability, and by concentrating on two important concepts: risk and stake. This approach seems to be sufficient to understand the concept of risk and especially to transmit this fundamental notion: without issues, there is no risk.

Indeed, an earthquake, even of high magnitude, in the desert, will not have any consequence... while the same event, in an urban area such as Port-au-Prince, is a disaster.

A hazard is the probability that a natural event occurs during a given period. The stakes are composed of the people, the goods, the equipment and the environment threatened by the hazard. The risk is the threat which weighs on the stakes. Danger is a state, risk is its measurement.



Natural risk in France

Even if our country is not the most exposed in the world, the consequences of rare and extreme events can be catastrophic. In addition, global warming must make us anticipate a worsening of all risks linked to the weather over the coming decades.

Below, we quickly scan over the natural risks which exist on the French territory, except for seismic, volcanic and marine subversion (tsunami and tidal wave) risks, which were largely detailed in the previous chapters.

Flood risk

It is the most present risk on the national territory, more than half of the 36 000 municipalities are concerned. Between 1982 and 2010, floods caused more than 200 deaths and generated more than 6 billion euros in damage.

However, all this is not much considering the very large floods of the river Loire in the 19th century or of the river Seine in 1910! Today, such phenomena would affect several hundreds of thousands of people and would cause a major economic crisis.

It is generally considered that there are 4 types of floods :

• Lowland areas floods

The river leaves its minor bed slowly and can flood the lowland area for a relatively long period. The river occupies its average bed and eventually its major bed.

Floods by groundwater levels rising

When the ground is saturated with water, the alluvial groundwater levels mount and a spontaneous flood occurs. This phenomenon particularly relates to low grounds and can last a long time.

• Torrential floods

When intense precipitation falls on a whole water catchment, water concentrates quickly in the river, where brutal and violent floods form near the streams and the rivers.

• The urban storm runoff

The water-proofing of the ground in urban environments (buildings, roads, car parks etc) limit rainfall penetration, which often causes the saturation of the rainwater collection networks. It leads to more or less heavy flows and often rapid flows in the streets.

The "forest fire" risk

Forest fires are disasters which happen in a natural settings of different forest types (forests of leafy trees, conifers or mixed), subforests (bushes, scrublands or moors) or herbaceous (meadows, lawns...).

In France, the South and South-west are the most affected, but the majority of other areas can also be touched, in particular in the West (the Vendée and Brittany).

Fires occur mostly during the summer, but more than a third take place outside this period. Dry vegetation and atmosphere accompanied by low water content of the soils is conducive to fires, including in winter.

With more than fifteen million hectares of woodlands, France is regularly subject to forest fires: there are 15,000 hectares which burn away each year, just in the Mediterranean region.

The majority of fires are caused directly or indirectly by man; for example by a farmer who burns the ground to make it more fertile, by a badly extinguished cigarette, a campfire, not to mention fires started by arsonists. Among natural causes, the most frequent is lightning.

A fire can take various forms according to the characteristics of the vegetation in which it develops.

• Soil Fire

Soil fires burn the organic matter contained in litter, humus or peat bogs. Their spreading speed is low. Although not very intense, they can be very destructive as they attack the underground systems of plants. They can also spread underground, which makes it more difficult to completely extinguish them.

• Surface Fire

Surface fires burn the lower layers of the vegetation, i.e. the higher part of the forest litter, the herbaceous layer and the woody shrubs. They affect the scrubland or the moors. Their spread can be fast when they develop freely and the wind and landscape conditions are favorable.

• Crown Fire

Crown fires burn the higher part of the trees and form a crown of fire. In general they release great quantities of energy and their propagation speed is very high. They are all the more intense and difficult to control when the wind is strong and the vegetation dry.

The risk of "ground movement"

Ground movements include a set of movements, more or less violent, soil or subsoil, natural or man-made.

The volume concerned are between a few cubic centimeters and a few million cubic meters. Movements can be slow (a few millimeters per annum) or very fast (a few hundred meters per day).

These phenomena are often very destructive, because human development is very sensitive to it and the damage caused is often irreversible. There are two main categories of movements:

Slow and continuous movements

- <u>Settlement and subsidence</u>

Some soils can settle as a result of overloads or drying. This phenomenon is the reason for the tipping of the Tower of Pisa.

- The shrinkage-swelling of clays

The variations of the quantity of water in some clay soils produce swellings (wet seasons) and settlement (dry seasons).

- Landslides

They generally occur in situations of high water saturation of the soil. They can mobilize significant volumes of land, which move along a slope.

• Fast and discontinuous movements

- The collapse of underground cavities

Whether they are natural cavities slowly forged by water over several millenia, or underground quarries which have been used for the extraction of ore and building materials, these cavities have a more or less solid roof which, over time, undergoes, strains due to its weight, its age and the infiltration of water, which can suddenly collapse. In 1961, for example, in Clamart, in the Parisian suburbs, more than 8 hectares collapsed causing the death of 21 people.

- Collapses and rock falls

The evolution of cliffs and rocky slopes generates stone and rock falls, and even mass collapses (volume which can reach several million cubic meters).

- Mud and torrential flows

They are characterized by a transport of materials in a more or less fluid form. Mud flows occur on slopes, during heavy rainfall. Torrential flows occur in the streambeds during floods.

- Coastal erosion

This phenomenon can actually be classified into two categories, since it combines a slow erosion of the sandy coasts by the waves and sea currents, and a brutal collapse of the cliffs (Nord-Pas-de-Calais, Normandy, Basque coast). In France, 1,800 km of coast retreat each year by a distance ranging between 50 cm and 1 meter.

"Storm" risk

Storms impact a large part of Europe, and in particular Mainland France. A storm corresponds to the evolution of an atmospheric disturbance, or depression, along which two masses of air of distinct characteristics clash (temperature, moisture). To the winds which can exceed 200 km/h gusts can be added significant rain, risk factors for the population and the human activities. Tornadoes are regarded as a particular type of storm, made conspicuous by a limited lifespan

and the tiny geographical area affected, compared to standard storms. These localized

phenomena can however have devastating effects, considering in particular the strength of the induced winds (maximum speed of about 450 km/h).

Most of the storms affecting France are formed over the Atlantic Ocean, during the months of autumn and winter (known as "winter storm"), progressing at an average speed of about 50 km/h and able to cover a zone of 2,000 km wide. As for tornadoes, they most generally occur during the summer time.

In France, on average fifteen storms each year affect our coasts, of which one to two are particularly powerful. Although this risk relates more specifically to the north-western quarter of the French mainland area and the entire Atlantic front, the storms which occurred in December 1999 have highlighted that no part of the territory is sheltered from the phenomenon. They also showed the extent of the consequences (human, economic, environmental) that the storms are able to have. The storms of the 26, 27 & 28 December 1999 have indeed been the most dramatic of these last decades, with a total of 92 killed and damage estimated at more than 15 billion euros. Their return period was estimated at about 400 to 500 years. In February 2010, the Xynthia storm was accompanied by powerful gusts of wind and waves several meters high. The combination of the storm and a very powerful tide caused the failure of several dams in Charente-Maritime and the Vendée and the death of more than 50 people.

The cyclonic risk

Cyclones are the most powerful climatic phenomena and are each year the cause of very heavy human and economic destruction.

They represent a major risk for the whole of the tropical regions (in particular, for France, the DOM-TOM). However, weather monitoring and information to the population make it possible to considerably limit the number of victims.

The generated financial losses can amount to several tens of billion euros, for example, the Katrina cyclone in New Orleans in 2005. Various terms are used to indicate this phenomenon: typhoon, cyclone, kamikaze, hurricane (this last term being commonly used in the West).

Large scale swirling atmospheric disturbance, due to a major drop on atmospheric pressure, the cyclone draws its energy from the evaporation of sea water and occurs above the hot areas of the oceans. It is characterized by very violent and heavy rains with winds (up to 350 km/h), turning clockwise (in the Southern hemisphere) or in the opposite direction (in the Northern hemisphere). The most violent winds join at the periphery of "the eye of the cyclone", the eye itself being a zone of calm.

"Avalanche" risk

Avalanches are among the least fatal natural disasters (about thirty people have died in France). Major accidents remain exceptional, even if the disaster of February 1999 in Montroc (Haute-Savoie) shows the reality of this risk in France. Carelessness is often the cause of accidents. An avalanche is a rapid movement of a mass of snow on a slope, caused by a rupture of the snow cover. This mass varies from a few tens to several hundreds of thousands of cubic meters, with speeds ranging between 10 km/h and 400 km/h, according to the nature of the snow and the flow conditions.

There are three types of avalanches according to the type of snow and characteristics of the flow.

• The plate avalanche

The plate avalanche, generally generated by the passage of a skier, is due to the bad cohesion between a layer of recent snow, in general brought about by wind, and an older and harder under-layer.

The aerosol avalanche

A heavy accumulation of recent, light and dry (powdery) snow, can lead to avalanches of very great dimensions with a thick cloud of snow (aerosol), progressing at high speed (100 to 400 km/h). Their destructive power is very great. Their journey is fairly straight and they can rise up onto an opposite slope. The blast which accompanies them can cause damage outside of the perimeter of the deposit of the avalanche.

• The wet snow avalanche

When snow becomes denser and wet during melting, in spring or after a rain, it can form avalanches which drag the whole of the snow cover. They move at slow speed (up to 20 km/h) while following the landscape in its low points (corridor, ravine, slope, etc.). Although its path is well known, it can be deviated by an obstacle and generate damage in zones, initially, not exposed.

Prevention of risks

The prevention of natural risks consists in reducing the intensity of some risks and the vulnerability of the stakes so that the human and material costs are bearable to society.

The prevention covers the entire chain of risk and implies many actions, from which it is difficult to choose.

This choice not only depends on the limits of scientific knowledge but also on our social choices:

- What level of safety do we want to have?
- What price are we ready to pay to achieve this level of protection?
- What are the priorities?

Prevention and Risk Management



communication

Teaching insight

We learn well what answers the questions we ask ourselves J.- J. Rousseau

The essence of the reflection is to understand what we did not understand. G. Bachelard
A cross-curricular approach

Risk education has two components which should be distinguished, even if they are complementary:

• The operational component

This component includes the safety of school buildings, the particular security Implementation Plan (PPMS), learning the actions and the exercises/simulations which save.

The operational component is historically the first to have entered the school. Resulting from the methodologies developed by civil engineering and safety/civil protection, this know-how is mastered well and the results are directly related to the time invested and to the amount of finances available.

• The cultural component

We are in the field of school education.

The objectives are to train future citizens to live with risks in the most responsible way possible, and to give pupils and staff of the school a risk culture which will lead them to adhere to the constraints of the operational component of prevention.

This cultural component appeared in the schools later.

Whereas education to sustainable development (ESD) has made a noted entry into the school world, these last few years, (climate change, saving of water or energy, protecting biodiversity, waste sorting... are topics which schools took on), the prevention of risks is not or very little represented there.

However, education on the prevention of the risks is an essential component of the ESD, as shown in the conclusions of the UNESCO world Conference on the ESD⁶ (Bonn 2009), as well as the roadmap of UNESCO for the five years to come⁷.

Within the framework of this project we propose adopting an educational approach inspired by the reflection and the working methods of the ESD, such as were developed in preceding projects of "La main à la pâte" (see bibliography):

multidisciplinary

A comprehensive understanding of the prevention of risks requires both the study of the hazard (Earth sciences) and the study of the stakes (geography or civic education), but also an analysis of the vulnerability (social or economic approach). For that, it is essential to cross the subjects. Risk education is thus at the crossroads of science education (in particular, but not only, environmental), geography, civic education, education to domestic safety, etc.

• "understand in order to act"

It is of no use to oppose theory and practice, knowledge and action, as they are so inseparable. The theory is important in that it allows children to understand the nature of the phenomena concerned, the effects of such or such parameter, why is such or such situation more risky. This understanding then enables them to determine, by themselves (but guided by the teacher, who also validates the results obtained), actions to be performed. These actions, as long as they are the result of reflection, of questioning, of contrasting... are better remembered, and integrated in their behavior, in contrast to when they are simply instructions transmitted by an authority (the teacher, the mayor, the book, etc).

^{6.} http://www.esd-world-conference-2009.org/fr/accueil.html

^{7.} http://unesdoc.unesco.org/images/0018/001891/189145f.pdf

• Global AND local approach

The ESD can lead to studies of global phenomena, which help pupils to understand great social stakes, but it must also make sense in their immediate environment. Pupils can then reinvest their knowledge on phenomena in situ, and assess the effects of actions which they can implement.

In the context of risk education, this corresponds to the work on local risk, to which pupils will bring elements of prevention, in particular for the dissemination of awareness of the risk within the community.

In the project "When the Earth Rumbles", we voluntarily propose various complementary approaches: global/local, centered on the knowledge/centered on the lived experience. Through the various sessions, we invite knowledge and competences resulting from sciences and technology, but also from history, geography, mathematics, TICE or, in a more cross-curricular way, from the mastery of language and civics education.

Science and technology, which constitute the backbone of the project, are developed in conformity with **the principles of** "*La main à la pâte*" (see page 42). In this context the pedagogy of investigation is well established and has been presented in detail in the continuation of this teaching insight.

For the other subjects referred to above, certain elements of this pedagogy remain valid (for example, the emphasis on questioning). In these subjects, the concept of evidence does not necessarily have the same meaning as in science.

We did not seek to adopt a uniform approach throughout the project, an approach which would blur disciplinary specificities. On the contrary, we sought to respect this diversity. This is the reason why we specify, in each session, which the dominant subject is. Sometimes, some abuses of language remain, such as the use of the expression "book of experiments", which takes all its meaning in science but that we kept, for convenience, for the other subjects.

Why study volcanoes, earthquakes or tsunamis?

We could answer "because these sets of themes are in the programs" (that is explicitly true for volcanoes and earthquakes, and implicitly for tsunamis which are one of the possible consequences of the two former ones)... but there are other reasons.

The first, is that a child born in mainland France will not remain there all his life. He will have the opportunity to travel in the DOM-TOM or abroad and could then be directly concerned by one of these phenomena. Very recently (at the time of the tsunami of Sumatra in December 2004), we saw that the education of a child could save lives⁸.

The second reason, is that, contrary to what is often believed, even the mainland is affected by seismic risk (the Pyrenees, the Alps), and by tsunamis (Nice experienced one not so long ago...). For classes in the DOM-TOM, and in particular in the Antilles, the exposure to risk is obvious.

The third reason but not the least, is that these natural disasters are increasingly highly publicized and that the children are frequently confronted by them (television, radio, Internet, children's publications). The emotional aspect is greatly emphasized with little or no understanding, which can be a source of anxiety for the children. Class work allows the child

^{8.} A young English schoolgirl, Tilly Smith, recognized the warning signs of a tsunami (withdrawal of the sea), warned her parents then the director of the hotel, who immediately called for an evacuation of the beach. This simple action saved the lives of a hundred people. Similar stories came to us from Nepal or Japan.

to understand the world in which he lives, to ask the questions why? How? What to do? And thus is not only limited to the reaction of horror caused by the dramatic images which he sees. Volcanoes, earthquakes and tsunamis are closely related, caused by identical geophysical phenomena; and it is for this "conceptual unity" that they have been selected in this project. Their study remains primarily in sciences and in geography.

Why study a local risk?

As mentioned above, the territory is important, because it makes it possible to use the experience lived by the child or his close relations as a basis. This foundation helps to develop what can be called a "conscience of risk".

It is an important stage if the child is to develop adaptive behavior and become responsible. Such work is more related to civics education and geography. Thus the retained approach cannot be directly modeled on the scientific approach of investigation, even if it can be inspired, for example, by always giving great importance to the questions of the child.

One does not preclude the other!

As mentioned above, it is not about opposing the global and the local, nor comprehension with action, but about mixing the two approaches well. We therefore recommend that the teacher who embarks on such a project adopts a "composite" approach, for example:

1. study a choice of geological phenomenon (volcano, earthquake or tsunami). It is the purpose of sessions 1, 2 and 3 of the teaching module. This work will enable, amongst other things, to adopt some specific concepts to education on risk (hazard, stake, etc.);

2. study a local phenomenon. It is the purpose of session 4, which allows the reinvestment of the concepts approached previously in another area, with another risk, nearer to them.

Take ownership of the project "When the Earth Rumbles"

A turn-key project...

This book presents a progression which can be regarded as "turn-key": all the sessions were validated by scientists and educators, then tested in scores of classes with various profiles (rural/urban areas, privileged or not, with inexperienced or experienced teachers...). The description of the sessions is sufficiently precise to allow a teacher, even with little experience of the investigation approach, to know what to do. Each one specifies what is the approximate duration of the activity, what the necessary material is, what questions to start the investigation, what the potential difficulties are, what type of conclusion is expected...

... A project to take ownership of, then to adapt!

In order to take ownership of the module it is initially necessary to become acquainted with it. For this, it is essential to read the various sessions, to carry out the suggested experimental situations and also the other tasks - such as reading the photographic documents, the tables of measurements, the graphs... The indications and comments which appeared sufficient to the authors may not always be for the reader.

A time of reflection and maturation is desirable. This will perhaps involve adaptations according to the pupils or more generally to the context (materials available, experience of the class...). This then opens various options, as the project advances :

- exploit the interests and questions of the pupils, caused by an exchange of arguments, local news, etc;
- take into account unforeseen implementation difficulties, caused by material as well as by the unresponsiveness of the pupils;
- distribute the module across three levels of the cycle, as part of the program for the school stage or because you have a class on several levels;
- choose to develop more than is initially planned, a session within the multidisciplinary framework (the geographical distribution of volcanoes and earthquakes, the graphic representations in mathematics, vocabulary and syntax, etc.).

This necessary adaptation will be advantageous for the teacher and the pupils, without losing sight of the main idea: to allow an understanding of the natural phenomena such as volcanism, earthquakes, tsunamis (as well as some locally-rooted risks), and to know how to react in the event of disaster.

How to implement a scientific investigation approach?

According to the subject of study, the nature of research, the reactions of the pupils, the material and the available time, the sessions of the module "When the Earth Rumbles" can take completely different forms. Nevertheless, it is always about an investigation, which typically involves three phases :

- questioning, initiated by the teacher or the pupils;
- research, which can be documentary, experimental, observational...;
- structuring of the knowledge leading to, in turn, new questioning, new research, etc.

It is not rare however for a session not to contain all of these three phases, but for the latter to be distributed over several sessions which deal with the same problem. For example, for the manufacture of a seismograph, the first meeting is devoted to questions relating to the detection of earthquakes, in other words how to design a seismograph, while the following meeting is dedicated to how to build, how to test, and to do documentary research. The end of the last session makes it possible to replace the various concepts in their context and to structure acquired knowledge.

The purpose of the paragraphs which follow are to specify, using concrete examples from the module "When the Earth Rumbles", the place of the writing and the role of the teacher during the three steps in the investigation approach: questioning, research, structuring of knowledge.

The questioning phase

The questioning is the discussion thread of the module "When the Earth Rumbles".

A problem which the pupils will have to solve will be defined by the diversity of the provided answers, from their confrontation, even from their differences. The difficulty for the teacher is to lead the discussion so the pupils become aware of the problem, of what they seek to know or to show. For that, the teacher encourages communication between the pupils and guides them in their reflection: "And, what would you say? What do you think of it?"

Session 1.1, "the history of the god Vulcan", is a good example. Through the reading of a text about volcanic eruptions associated with the fury of Vulcan, students will be asked to express some of their concepts on this type of natural phenomenon. This confrontation will then make it possible to identify questions which will thereafter guide the investigations of the pupils: "can a volcano wake up? Can an eruption be predicted? How is a volcano formed? Where are volcanoes located? etc."

The formulation of the hypothoses

By relying on his experience and knowledge, the pupil gives accurate or inaccurate explanations. At the time of sessions 2-4, the majority of primary school pupils do not in general have a precise idea of the origins of earthquakes. They may link the origin to a volcanic or weather cause (for example, heat makes the ground crack), or to a human origin (wars/bombs...). It is therefore through the investigation, through a document search or experimentation, that pupils will be able to renounce this idea. The experience comes then, not as an end in itself, but as a necessity for testing the suitability of a hypothesis.

The formulation of concepts or hypotheses by the pupils (what they think they know, what they think they understand and are able to explain a phenomenon) can be made individually or collectively:

• In the written form:

- a captioned drawing, as in the second session about volcanoes when the teacher asks to draw a volcanic eruption corresponding to the proposed text;

- a debated text, as during session 3-1 on tsunamis, during which the pupils, after having observed two photographs (before and after tsunami), must describe and explain what could have happened;

- a list, when the teacher questions the pupils, in sessions 2 and 3, about the required behaviors and actions in the event of a tsunami or an earthquake.

• In an oral exchange, and to take the shape of a collective discussion between the pupils: "what is a natural disaster?", then "what is a natural risk?"

The research phase

During this phase, still guided by the teacher, the pupil is involved in the search for solutions to the problem. It is a matter of testing the selected "hypotheses".

The teacher ensures that the research methods are suggested by the pupils themselves, as they should not be simply following steps. The teacher can sometimes help them, when they are stuck, for example by presenting the available material.

When experimentation is not possible, the documentation research, the modeling and the interview, enable the pupils to validate or reject the previously made hypotheses.

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The "When the Earth Rumbles" module offers a large variety of investigations. Here are a few examples:

• **Experiments:** Why are some volcanic cones steeper than others? How is an earth tremor spread? What is the source of an earth tremor? How to create a wave? (Sessions 1-5, 2-3, 2-5, 3-2)

• **Documentary Research:** Where are volcanoes located? How to be protected from volcanic risk? Where are earthquakes localized? (Sessions 1-4, 1-8, 1-11, 2-4)

• **Modeling:** What is the origin of the volcanic cone? How to build resistant buildings? (Sessions 1-4, 2-10 and 2-11)

• **Construction:** Construction of a model of a volcano. (Session 1-6)

• **Interview:** What risk does my community face? (Session 4-2)

• **Observation:** Visit on the ground to identify the existing risks. (Session 4-3)

It is to be noted that some modeling or documentary studies can be carried out through multimedia animations, for example, when we seek to model various types of volcanic eruptions while varying several parameters (gas pressure, lava viscosity), or when we look at an animation reporting the history of natural disasters. (Sessions 1-4, 2-10 and 2-11)

The structuring of knowledge

We have seen how much questioning holds an essential place throughout the investigation, whether it is the problem, interpreting the result of an experiment, contrasting several points of view... Several back and forth may be required between the questioning and the research, before being able to answer the problem and thus to build new knowledge.

It is at the time of the collective oral phase that the class truly builds a common understanding. Debate holds a paramount place. This pooling should not be seen as a dialogue between pupils and teacher, but as a dialogue among pupils, facilitated by the teacher.

The whole class takes part in the development of a collective written record, to generate consensus and summarize what was learned and understood. This conclusion also makes it possible to take a step away from the activity to start to generalize and conceptualize. The accuracy of the vocabulary becomes central. Thus, for the pupil, the term tectonic plate (geological element) will no longer indicate one continent (geographical element). In the same way, the distinction will be made between magma (mixture of rock in fusion and gas present in the volcanic conduits) and lava (rock in fusion which comes out onto the surface). This collective written record is often in text format, but can be accompanied by other forms of presentation: graphs, diagrams...

The conclusion of the class is a consensus... but that does not mean that it is valid! We can all agree and yet all be wrong! An essential stage in investigation, often forgotten, is the necessary confrontation of the knowledge built in class (our opinion) with the established knowledge (what scientists know). This confrontation is done using books, documents... or even with the teacher who is also custodian of the established knowledge.

In the teaching module "When the Earth Rumbles" standard conclusions at the end of each sequence are presented. They are of course examples (based on tests carried out in class) intended to guide the teacher. It would be however regrettable for these conclusions be used just as they are. We recommend that teachers let their pupils work out their own conclusions, based on the work actually completed in class.

Roles of the teacher

In the process of investigation, where the activity of the pupil is predominant and favoured, the teacher has an essential double role. The teacher is no longer just the one who transmits knowledge, but also the one who helps the pupils to advance towards building knowledge by themselves, and the acquisition of practical and life skills.

To do this, the teacher relies on the knowledge and abilities of the pupils and the progress of the whole class. The teacher is attentive to the general atmosphere as well as to each one's or the groups' pace of work, offers support or raises reflection when that is necessary, decides whether or not to move on to another activity, at moments of refocusing or generalization. For this reason, the teacher is known as the class "tutor".

But he also has another less traditional role, and which appears during some moments of the interactions between teacher and pupil or between pupils. For example, when he questions the proposals of the pupils: "And, in your opinion...", "What do you think of the opinion of your class mates? Do you agree with what has been said?" rather than to judge. Or when the pupils are given opportunities to discuss, to debate, to be referee or moderator. The teacher is the guardian of the observed "facts", of their normality, as an intermediary between "official" science (that of scientists) and the pupils. The teacher also decides about taking into account or not the proposals of the pupils, justifying their treatment and, finally, as an expert or a consultant, decides about the scientific quality of the results of the class's work. For this reason, he is known as "mediator" of the class.

Sciences and mastery of the languages

Oral or written communication is present throughout "When the Earth Rumbles" project. The writing of the experiments, in particular, is an invaluable tool, the use of which deserves to be detailed. Why do the pupils write?

Writing enables them to gain some perspective, to clarify and formulate thoughts in order to make them understood by all. The pupils are not familiar with the steps of investigation and do not write spontaneously. This activity thus requires some training, which will be effective if the pupils understand its use. All writings, in all their various forms (drawings, diagrams, legends, descriptive or explanatory texts), contribute to the construction of learning.

• the pupil writes for himself or herself

Writing allows the pupil to act (specify a device, make choices, plan, pre-empt results), to memorize (keep track of observations, research, readings, reconsider an earlier activity) and to understand (organize, sort, structure, connect previous writings, reformulate collective writings).

• the pupil writes for others

Writing enables the transmission of what has been understood, the questioning of other pupils, and also of people outside of the class (other classes, families...), the explanation of what was done or understood, synthetizing...

The scientific book can be organized into two parts: individual and collective.

The **individual writings** constitute the personal space of the pupil, where he or she writes the first answers to questions, describes the activities which would facilitate answering these questions, notes forecasts, writes reports. These writings can take the shape of texts, but also of diagrams, drawings, graphs... They are used as tools to stimulate reflection and to track actions: for this reason, they are a means for the teacher of tracking progress and the personal journey of each child. It is important that the teacher does not intervene on these personal writings (to correct errors, for example). On the other hand, the teacher will be able to help the child to structure them gradually. Writings with initially little complexity and structure will

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gradually grow through a rich description of the experimental devices (list of the material, protocol, chart or drawing), through the writing of the results and their interpretation, and through conclusions...

• **Collective** writings are the result of a real effort of contrasting ideas and proposals. They then have the status of "validated" writings, and must thus comply with the spelling and syntax rules, and use a specific vocabulary.

Assess the achievements of the pupils

How to assess the knowledge and the skills developed by the pupils during a project like this one? The answer to this question depends above all on the use which will be made of this assessment. Additionally, to answer this concern, each situation suggested at the end of the session was designed primarily as a diagnostic assessment in order to enable the teachers to collect relevant information concerning the capacities of the pupils to mobilize the resources they have, i.e. the elements of knowledge and the procedures that they have. Diagnosis, to allow the teacher to know if the pupils have properly mastered such a concept or such a skill, with the aim of grading them (summative evaluation); and diagnostic from the point of view of teaching support and management (formative evaluation).

The suggested situations are made up of complex situations or problem situations which will, for their resolution, require the pupils to mobilize the resources they have, and so make it possible for teachers to measure the level of mastery of competencies of each one of the pupils. In the assessment on earthquakes, the pupils are led, through various documents, to reason on a specific seismic event, like on an experimental protocol which was not implemented in the class. To solve this problem, the pupils, guided by questions, must mobilize some knowledge on earthquakes, as well as skills in various fields :

• Scientific and technological culture

- To apply a scientific or technological approach.

- To apply an investigative approach: to know how to observe, to question.

- To handle and try out, to form a hypothesis and to test it, to debate, to test several possible solutions.

- To express and use the results of a measurement and of a research using scientific vocabulary in writing or verbally.

• Mastery of language

- READ: Locate explicit information in a text.
- READ: Infer new information (implicit).
- WRITE: Answer a question by using a complete sentence in writing.

• Humanistic Culture

- Have markers relating to time and space.
- Know the main physical geographical features, locate them on maps of various scales.

In the perspective of formative evaluation, the crossing of the information provided by the assessment will allow the teacher to target the possible difficulties of the pupils (difficulties relating exclusively to knowledge, skills or both) and enable the pupils to track their own progress.

Lastly, note that even if pupils are capable of solving a situation that is interesting, it does not make them qualified. Indeed, skill is not about solving a specific situation and particular problem,

but about being able to solve various situations which have common characteristics. If these common characteristics are sufficiently defined and the pupils are assessed through two or three different situations which join these characteristics together, then it will be possible to demonstrate their control and not their competence. This can therefore fall under a process of continuous assessment.

Consequently, to be precise, reliable and useful, a knowledge and competence assessment is advantageously supplemented by the regular observation of the behavior of the pupils, their individual or group work, and of their writing in the experiments book.

Such an assessment, carried out throughout the project, allows adaptation of progress. If the teacher notes that some pupils are stuck on a concept, it will be possible to dedicate a few minutes or a whole sequence to another activity. This will make it possible to approach the concept, which was not understood by some pupils, in a different way, without others getting bored.

The scientific book proves to be an excellent tool for formative assessment, since the pupils use it systematically to write what they think on the subject of study (their ideas, designs, forecasts, suggestions or hypotheses). They clarify by which means they will solve this problem (experimental protocol, for example), give an account of their results, explain, in the form of a conclusion, what they individually understood before working out and writing a collective synthesis with the class.

The observation of the scientific book and the pupils in action thus enables the teacher to assess the abilities and skills expected as a standard:

• Apply a scientific or technological approach.

- Know how to observe, to question;
- Know how to formulate a hypothesis and to test it, put several possible solutions to the test;
- Know how to express and use the results of an experiment, a measurement or a research.

• Civic and social skills:

To be able to communicate and work in a team, to know how to listen, put forward a point of view, negotiate, seek a consensus, achieve a task according to the rules laid down within the group.

Whether it is for summative or formative assessment, it is extremely important that the teacher properly identifies what is expected of the pupils. To assist this, the educational module "When the Earth Rumbles" specifies the notional objectives and the skills practiced for each sequence and presents the conceptual scenario of the whole of the project, page 46 onwards.

*Links with the standard

Taking into consideration the 2008 program, the project "When the Earth Rumbles" allows, through the diversity of its contents and the steps used, the acquisition of knowledge and skills in conformity with standard expectations.

In order to facilitate the comparison of this module (disciplinary and transverse aspects) with the school programs, we present below:

• the list of knowledge and the skills practiced throughout the module, according to the pillars of the standard. The pillars are presented in the order of main points of the project;

• of the extracts of the standard and the personal skills booklet.

Extracts from the standard :

It is about giving pupils the scientific culture necessary for a coherent representation of the world and for the understanding of their daily environment...

Concrete scientific approaches, calling upon the manual skill in particular, help the pupils to understand abstract concepts.

*The links with the standards here refer to the French curriculum, it can however be adopted/adapted to your own particular needs.

		The Skills of cycle 3
The main mathematics elements and scientific and technological culture	Mathematics	 Numbers and calculation Assess order of magnitude of a result Geometry Recognize, describe and name the common shapes and solids Sizes and measurements Use measuring instruments Use common units of measure Organization and data management To see, interpret and build some simple representations: tables, graphs To know how to organize numerical or geometrical information, to justify and appreciate the probability of a result To solve a problem involving a situation of proportionality
	Sciences and Technology	 Apply a scientific or technological approach Apply an investigative approach: to know how to observe, to question. Handle and try out, costruct a hypothesis and test it, debate, test several possible solutions. Express and use the results of a measurement and of a research using scientific vocabulary in writing or verbally. Control knowledge in various scientific fields and mobilize it in different scientific contexts and in everyday activities Sky and earth Volcanoes and earthquakes, the risks to human societies Material States and changes of state Mixtures and solutions Energy Simple examples of sources of energy Living beings in their environment The adaptation of the living beings to the conditions of the environment Technical objects Electric circuits supplied by batteries Levers and scales, balances Mechanical objects, transmission of motion Environment and sustainable development Apply knowledge to understand questions related to the environment and sustainable development and act accordingly
The mastery of language		 Speak Communicate verbally as well as in writing with a suitable and precise vocabulary Speak by respecting the appropriate language level Verbally answer a question using complete sentence. Take part in a dialogue: speak in front of others, to listen to others, formulate and justify a point of view Read Identify the theme of a text Locate explicit information in a text Infer new information (implicit) Carry out research in documentary works (books, multimedia products) Write Answer a question using a complete sentence in writing Write a text of about fifteen lines (account, description, dialogue, poetic text, report) by using knowledge in vocabulary and grammar Vocabulary Understand new words and use them wisely

Mastery of conventional computer and communication techniques	Create, produce, treat, use data • Produce a numerical document: text, image, sound • Use the data-processing tool to present a work Get information • Read a numerical document
Humanistic culture	 Have markers relating to time and space Know the principal geographical, physical and human characteristics of the area where the pupil lives, of France and the European Union, locate them on maps at various scales Understand one or two questions related to the sustainable development and act accordingly Read and speak several languages
Social and civic skills	 Read and use texts, maps, sketches, graphs Show responsible behavior Comply with the rules of life in a group
Autonomy and initiave	 Rely on working methods to be independent Follow simple instructions, independently persevere in all activities Engage in an individual or collective project

Extensions of the project

The sessions suggested in the module "When the Earth Rumbles" does not claim to approach all of the concepts related to the topic of natural risks in an exhaustive way. It is at the crossroads of many disciplinary areas. Everyone has the freedom to go further. Suggested extensions throughout the module, as well as a few examples that follow, make it possible to elaborate a concept by supporting interdisciplinary links, to address another aspect related to the studied topic or to reinvest what is acquired.

• Sciences and technology

- During the construction of a volcano, the pupils can choose to model the two types of volcanic eruptions by preparing different mixtures.

- Observe samples of volcanic rocks (if possible after a field outing) and link them to the corresponding type of volcanic activity.

- Carry out experiments on the means of protection from volcanoes:
 - > Predict the an imminent eruption;
 - How to divert or slow down a lava flow?
- Carry out an experiment allowing the visualization of a seismic wave.

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- Carry out an evacuation simulation in the event of an earthquake.

- Produce a para seismic model of construction integrating the various parameters studied in the teaching module.

- Produce a model on means of protection against tsunamis, such as dams or wave-breaks.

- Study how living beings (animal and vegetation) can adapt to a hostile environment such as volcanoes.

• Humanistic Culture

- Visit to a museum (of arts and trades, for the manufacture of seismographs; dedicated to volcanoes; dedicated to the history of civilizations and natural disasters).

- Establish a link between great natural disasters and historical and/or geographical references.

• Literary references

- Seek myths and legends on the volcanoes, earthquakes or tsunamis.

- Literature Texts can enrich the subject: *Le Démon de la vague* (The Demon of the wave), by Christine Féret-Fleury and Geneviève Lecourtier, tells the story of a village which during each night of full moon is devastated by an enormous wave which was said to contain a demon.

- The bibliography mentions other works of literature by young people that talk about volcanoes, earthquakes or tsunamis.

• Artistic practices and history of arts

- Illustrate a scene showing Vulcan in an angry state, by working on the hot colors and the materials to represent the expressions and attitudes of Vulcan.

- Represent a volcanic eruption through a plastic construction (different materials, hot colors, or in the same way as Sara in her album Volcan).

- Illustrate the various scales relating to earthquakes (MSK and Richter).

• Mathematics

- One of the sessions of the module lends itself to a specific work in mathematics about the calculation of the average and the median. It can be prolonged by one or more mathematical sessions during which the study of new data will lead the pupils to explore these concepts of average and median in more detail.

Documentary Research

- Documentary Research forms an integral part of the investigation step. It is an opportunity to develop reading skills, but also skills related to computer and internet patent.

• Production of writings

- In order to give an account of their work, the pupils can be asked to create posters for an exposition or to produce a small album which will be read to other classes or at home.

Common information and communication techniques

- Use digital tools (e-mail, video conferencing) to communicate with a school located in a zone with a volcanic or seismic risk.

- Create a multimedia production (video, slideshow), by starting from the experiment on the origin of the volcanic cone, which illustrates the formation of the volcanic structure from successive eruptions (chocolate for example).

- Produce a slide show of the activities carried out in class to present the work to other classes or to families.

The 10 principles of "La main à la pâte"

If there is no universal method of teaching sciences, it is interesting to note that all the recent operations to revamp the teaching of sciences in the world are part of a common approach.

This approach regards science not as a set of statements to be learned by heart, but as an activity during which the pupil is in a situation of investigation and where communication (oral and written) is very important. The teacher plays an essential role in helping the children construct their own knowledge.

La main à la pâte formulated ten principles as part of this step. Found in the teaching documentation of its website (www.lamap.fr), are many texts, testimonies and analyses which illustrate and clarify these ten principles.

The 10 principles of "La main à la pâte"

- 1. The children observe an object or a phenomenon in the real tangible world and experiment with it.
- 2. In the course of their investigations, the children use arguments and reasoning, pooling and discussing their ideas and their results, constructing their knowledge, as a purely manual activity is insufficient.
- **3.** The activities suggested to the pupils by the teacher are organized in sessions for a progression of learning. They are linked to official programs and offer pupils a great deal of independence.
- 4. A minimum of two hours per week is devoted to the same theme over several weeks. Continuity of activities and pedagogical methods are ensured throughout school programme.
- 5. Each pupil keeps an experiment book written and updated in his own words.
- 6. The major objective is a progressive ownership, by the pupils, of scientific concepts and procedures, accompanied by a consolidation of oral and written expression.
- 7. Families and/or the neighborhood take part in work done in class.
- 8. Locally, scientific partners (universities, business/engineering schools) support by making their skills available.
- **9.** Locally, teachers' colleges make their pedagogical and didactic experience available to teachers.
- **10**. Teachers can obtain the modules to be implemented, ideas of activities, answers to various questions from the website http://www.lamap.fr. They can also take part in collaborative work by exchanging ideas with colleagues, trainers, scientists

Teaching Module: Class activities

Several possible courses

The project "When the Earth Rumbles" is (deliberately) long, but is not designed to be carried out thoroughly. It is rather an "à la carte" module, which can be browsed in several ways. Here are three suggestions :

1. Study of one or more "geological" natural risk(s)

It is a multi-curricular task which includes a large proportion of science through the study of the volcanoes, earthquakes and tsunamis. The class can study 1, 2 or 3 of these phenomena, depending on the time which can be set for this project. Earthquakes and tsunamis are closely related and are naturally linked (it would be a shame to treat one without the other).

The point, besides including this set of themes in the programs, is to enable an understanding of social phenomena as natural disasters are often shown in the media. In the absence of a reasoned speech and study, this can become a source of anxiety. This is the purpose of the session 1, 2, and 3.

2. Study of a natural "local" risk

It is not a work of science, but rather of civics education and geography, for which we provide the groundwork, a methodology to be tailored to the local context, according to the risk to which the community is exposed (flood, storm, fire, avalanche...). The point is of course to focus on the locality and the daily life of the pupils. This is the purpose of the session 4.

3. "A little of both"

The most interesting way of getting involved in such a project is undoubtedly to mix a little of the two possibilities which are outlined above (study of one of the risks among volcano, earthquake and tsunami, and study of another risk which is more locally focused).

If it is not possible to devote the necessary time to all the sessions among the first three and the 4th session, some choices can be made. For example, to devote 2-3 sessions (the first ones of sequence 4) to the study of a local risk, in order to identify general concepts around major risks (hazards, stakes, risks, disasters)... before going on to study volcanoes, earthquakes and/or tsunamis (the choice can sometimes be dictated by recent news). The same thing can be done in reverse order: start with the study of a geological risk, and reinvest what was learned for the study of a local risk.

Summary table of the Sequences and sessions

Sequence : Volcanoes	
Session	Main Subject
1-1 : Story of the god Vulcan	Language
1-2: What is a volcanic eruption?	Sciences
1-3 : Let us classify the volcanoes of the world	Sciences
1-4 : The origin of the volcanic cone	Sciences
1-5 : Form of the volcano and viscosity of the magma	Sciences
1-6 : The role of gases, construction of a model volcano	Sciences
1-7 : Anatomy of a volcano	Sciences
1-8 : Where are volcanoes located?	Sciences
1-9 : When can it be said that a volcano is extinct?	Mathematics

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1-10 (optional) : How long does an eruption last?	Mathematics	
1-11 : How to be protected from the volcanic risk?	Language	
1-12 : Multimedia summary	Sciences	
Sequence 2: Earthquakes		
Session	Main Subject	
2-1 : What is an earthquake?	Sciences	
2-2 : How to measure the intensity of an earthquake?	Sciences	
2-3 : How does a tremor spread?	Sciences	
2-4 : Where are earthquakes located?	Sciences	
2-5 : What is the origin of the tremor?	Sciences	
2-6 : How to detect an earthquake? Making a seismograph	Sciences	
2-7 : Magnitude and intensity, comparison of the Richter and MSK scales	Sciences	
2-8 : Can earthquakes be predicted?	Geography	
2-9 : What to do in the event of an earthquake?	Sciences	
2-10: How to build resistant buildings? (1)	Sciences	
2-11 : How to build resistant buildings? (2)	Sciences	
Sequence 3: Tsunamis		
Session Main Subject		
Session	Main Subject	
Session 3-1 : What is a tsunami?	Main Subject Geography	
Session3-1 : What is a tsunami?3-2 : How to create a wave?	Main Subject Geography Sciences	
Session3-1 : What is a tsunami?3-2 : How to create a wave?3-3 : Relationship between the speed of a wave and depth of the water	Main Subject Geography Sciences Sciences	
Session3-1 : What is a tsunami?3-2 : How to create a wave?3-3 : Relationship between the speed of a wave and depth of the water3-4 : Multimedia summary	Main Subject Geography Sciences Sciences Sciences	
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Session 3-1 : What is a tsunami? 3-2 : How to create a wave? 3-3 : Relationship between the speed of a wave and depth of the water 3-4 : Multimedia summary 3-5 : How to be protected? Sequence 4: My county in the face of r Session	Main Subject Geography Sciences Sciences Sciences Sciences isks Main Subject	
Session 3-1 : What is a tsunami? 3-2 : How to create a wave? 3-3 : Relationship between the speed of a wave and depth of the water 3-4 : Multimedia summary 3-5 : How to be protected? Sequence 4: My county in the face of r Session 4-1 : What is a major risk?	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesSciencesSciencesSciencesSciencesSciencesSciences	
Session 3-1 : What is a tsunami? 3-2 : How to create a wave? 3-3 : Relationship between the speed of a wave and depth of the water 3-4 : Multimedia summary 3-5 : How to be protected? Sequence 4: My county in the face of r Session 4-1 : What is a major risk? 4-2 : What are the risks in my county?	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesisksMain SubjectSciencesGeography	
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Session 3-1 : What is a tsunami? 3-2 : How to create a wave? 3-3 : Relationship between the speed of a wave and depth of the water 3-4 : Multimedia summary 3-5 : How to be protected? Sequence 4: My county in the face of r Session 4-1 : What is a major risk? 4-2 : What are the risks in my county? 4-3 : Field Outing 4-4 : Visit to a fire station	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesisksMain SubjectSciencesGeographyGeographySciences	
Session3-1 : What is a tsunami?3-2 : How to create a wave?3-3 : Relationship between the speed of a wave and depth of the water3-4 : Multimedia summary3-5 : How to be protected?Sequence 4: My county in the face of rSession4-1 : What is a major risk?4-2 : What are the risks in my county?4-3 : Field Outing4-4 : Visit to a fire station4-5 : My country in the face of risk (assessment)	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesisksMain SubjectSciencesGeographyGeographySciencesGeographySciencesGeography	
Session3-1 : What is a tsunami?3-2 : How to create a wave?3-3 : Relationship between the speed of a wave and depth of the water3-4 : Multimedia summary3-5 : How to be protected?Sequence 4: My county in the face of rSession4-1 : What is a major risk?4-2 : What are the risks in my county?4-3 : Field Outing4-4 : Visit to a fire station4-5 : My country in the face of risk (assessment)4-6 : Survey of parents (preparation of the questionnaire)	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesisksMain SubjectSciencesGeographyGeographySciencesGeographyLanguage	
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Session3-1 : What is a tsunami?3-2 : How to create a wave?3-3 : Relationship between the speed of a wave and depth of the water3-4 : Multimedia summary3-5 : How to be protected? O Sequence 4: My county in the face of r Session4-1 : What is a major risk?4-2 : What are the risks in my county?4-3 : Field Outing4-4 : Visit to a fire station4-5 : My country in the face of risk (assessment)4-6 : Survey of parents (preparation of the questionnaire)4-7 : How is risk perceived? (Analysis of the results)4-8 : Memory of risk	Main SubjectGeographySciencesSciencesSciencesSciencesSciencesisksMain SubjectSciencesGeographyGeographySciencesGeographySciencesGeographySciencesGeographySciencesGeographySciencesGeographyLanguageSciencesGeography	

Conceptual scenario of the project

The teaching ideas and sessions of the module "When the Earth Rumbles" follow a progression for which the "conceptual scenario", expressed in pupil language, can be found.

Note: The 4th session ("My country in the face of risks") is not scientific (but is about prevention and civic education). Thus, it does not give place to a conceptual scenario. In its place, the series of the activities suggested in this session are presented.

"Volcanoes" Session



"Seism" Session



"Tsunamis" Session



Session "My Country in the Face of Risks"



Sequence 1 : Volcanoes

This sequence starts with a little etymology, then with some documentary studies (previous eruptions) leading to a classification of the types of volcanoes (red/grey). Some experimental sequences follow which are intended to understand where the form of the volcanoes come from, what the "engine" of an eruption is, and in what way do red and grey volcanoes differ (role of the viscosity of the lava, role of gases), until they get to a functional model. The study of the location of volcanoes enables the establishment of the link with tectonic plates.

Two sequences (about the duration of the eruptions and the interval between two eruptions) enable the introduction to the basic notions of statistics. Lastly, the sequence ends in recalling behaviors to adopt to be protect themselves from volcanic risk.

Detailed summary:

Session 1-1: Story of the god Vulcan Session 1-2: What is a volcanic eruption? Session 1-3: Let us classify the volcanoes of the world Session 1-4: The origin of the volcanic cone Session 1-5: Form of the volcano and viscosity of the magma Session 1-6: The role of gases, construction of a model of a volcano Session 1-7: Anatomy of a volcano Session 1-8: Where are volcanoes located? Session 1-9: When can it be said that a volcano is extinct? Session 1-10: How long does an eruption last? Session 1-11: How to be protected from the volcanic risk? Session 1-12: multimedia summary Assessment of Sequence 1

Session 1-1: Story of the god Vulcan

duration	45 min
material	For each pupil: • a photocopy of sheet 1 (page 178)
objectives	 Know that the word "volcano" comes from the name of the god Vulcan Collect the pupils illustrations of volcanoes
skills	 Locate explicit information in a text Infer new information (implicit)
main Subject	• Language

Initial question

The teacher asks the pupils, collectively, what mythology is, with the aim of finding a definition for it. The expected answers are of the type "They are stories, legends, that speak about the gods...". The teacher can guide the research by asking them questions: "What is a legend? When were these stories written? Why were they written?"...

This discussion leads to a collective definition, which can be, for example: Mythology includes ancient legends written by the Greeks and the Romans. They invented these stories to explain their beliefs and certain phenomena which they did not understand.

The teacher then distributes a photocopy of sheet 1, describing the history of the god Vulcan, to each pupil. After a phase of individual reading, during which the teacher ensures that the vocabulary does not pose a problem, the pupils are divided into pairs and must answer the following question: "What do you think angers Vulcan? Identify, in the text, the words which make you think so."

Pooling

The teacher organizes a pooling session during which volcanoes are discussed. He then asks the class to explain the differences between what the Romans knew and what we know today about volcanoes. In the event of difficulty, it can then be asked what they think when volcanoes are mentioned.

Inevitably it is not a matter of using the words written in the text of sheet 1, but for the pupils to express themselves spontaneously.

The answers are collected on the black board (eruption, disaster, destruction, lava, magma, mountain, asleep...), taking care to discuss each word in order to identify their various possible meanings (it is sought to collect the definitions of the pupils, not to establish a definition from the class). The disagreements are pointed out (for example on a poster) and will be resolved later.

The teacher encourages oral debate around words of the same family as Vulcan (volcano, volcanology, vulcanology...).

Scientific Note

The terms "volcanologist" and "vulcanologist" are often considered, wrongly, synonyms. Whereas the first is a scientist who studies volcanoes, the second is an engineer who manufactures tires! Vulcanization is a chemical process which consists of injecting rubber with sulfur, to improve the elasticity of the material.

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Grades 3/4 of the Kévin Faix school (the Kremlin-Bicêtre)

The previous written document can then be completed by a text such as:

When there was a volcanic eruption, the Romans were very afraid. As they did not understand this phenomenon, they attributed it to a god: Vulcan. Today, volcanologists study volcanoes; we know more about this phenomenon and no longer need to resort to the anger of the gods to explain it.

Conclusion

The teacher asks the class to give a progress report about "the questions that can be asked about volcanoes". Example of questions: "Can a volcano awake? Can we predict an eruption? How is a volcano formed? Are there volcanoes under water?" (etc.)

These questions are noted on a collective poster, as well as in the experiment books.

Extension

This session can be extended by work in visual arts, for example by asking pupils to illustrate the story of Vulcan, with open instructions such as "represent the heat of the volcano", "represent the anger of the god Vulcan" (work on the materials, the colors, the expressions)...



Grades 3/4 of the Magaly Collee and Anne Clémenson schools (Chambéry)

Session 1-2: What is a volcanic eruption?

duration	1 h 15 min
material	For each pair: • a photocopy of sheet 2 (page 179) or sheet 3 (page 180)
objectives	 Know that a volcano is a point on the surface of the globe, or under the oceans, from which lava comes out during an eruption Know that there are two categories of volcanic eruptions, effusive eruptions ("red" volcanos), calm and with relatively low danger, and the explosive eruptions ("grey" volcanoes) violent and dangerous
skills	 Locate explicit information in a text Infer new information (implicit)
main Subject	Language
vocabulary	• Lava, volcano, bomb, ashes, volcanic cloud, crater, explosive, effusive

Initial question

The teacher recalls the poster created during the previous session and announces that in the next session the class will study what a volcano is.

Research (documentary study)

The pupils are divided into pairs, each pair receiving, either a photocopy of sheet 2 or sheet 3. Each sheet describes two "historical" eruptions, one is effusive, the other explosive (see below for the meaning of these terms), one in France, the other abroad.

The studied eruptions are:

• sheet 2:

- Kilauea (Hawaii: an "effusive" eruption, continuous over nearly 30 years... well before the birth of any of the pupils!)

- Mount Pelée (Martinique: an "explosive" deadly eruption, in 1902)
- sheet 3:
- The piton de la Fournaise (Réunion: an "effusive" eruption takes place almost every year!)
- The Mount Saint Helens (United States, an "explosive" devastating eruption, in 1980)

Initially, the class collectively locates the four volcanoes on world map. Pupils should then highlight the words that describe each volcano's eruption. The vocabulary which poses problem is collectively explained (effusion, precursor, volcanic cloud, lava...). In case of difficulty, the teacher can guide them through questions such as "How did the eruption begin? What came out of the volcano? At what speed did the lava flow? What were the consequences of the eruption?" Finally, the teacher gives the following instruction: "Each one of you must draw one of the two eruptions presented on your sheet. Be as precise as possible: it must be possible to

recognize the eruption that you have drawn. Do not hesitate to go over the text in order to find the characteristics of the volcano or the eruption. You will add a legend on your drawing, with all the words which you highlighted in the text."

Teaching note

This instruction is designed to force the pupils to be as precise as possible. Otherwise, the pupils draw what they know (or think they know) about volcanoes, without any connection with what is described in the text, and all the drawings look like each other (although the eruptions described are very different). A title is not added to this drawing on purpose, as it is supposed to be specific enough for the eruption to be recognized.



Grade 4 of the Michel Fautrel school (Livry-Gargan)

Pooling

The drawings are posted on the black board and are grouped together (drawings of the same eruptions are placed next to each other). To test the fidelity of the drawings to the texts, we start by reading again each text and by writing the visible features of each eruption (what should appear on each drawing) on the blackboard.

Piton de la Fournaise	Mount Saint Helens	Kilauea	Mount Pelée
 Cracks at the top and low altitude Fountains of lava (squirts of lava) Lava flow (lava liquid) 	 Column of smoke Ash and vapor explosion Ash cloud Rock avalanche Steep slopes Volcanic cloud Mudslide 	 Cracks Very liquid lava Fountains of lava Lake of lava Continuous overflowing of lava Gentle slopes 	 Fumaroles and black smoke Ashes Explosions: projection bombs Volcanic cloud

Table created in the Grade 5 class of the Christine Blaisot school (Le Mesnil-Esnard)

The class assesses each drawing by taking into account the shape of the volcano, the presence or absence of liquid lava, ash, flying rocks...

This analysis allows them to group the volcanoes. Two groups can be defined:

• 1st group: weak eruptions, called red or effusive volcanoes (mainly flowing lava): Kilauea and piton de la Fournaise;

• 2nd group: violent eruptions, known as grey or explosive volcanoes (projectiles, ashes, dust, volcanic clouds...): Mount Pelée and Mount Saint Helens.

Then all the elements which had been ignored as they were not visible can be added to the table. (toxic gas, small earthquakes...).

Conclusion - written records

A conclusion made by the class is collectively elaborated (dictated by the pupils). An example of a conclusion : There are two main categories of volcanic eruptions, effusive (red volcanos) and explosive (grey volcanos), more dangerous.

This conclusion is then noted in the scientific book, so is the table made during pooling. The teacher ensures that the various terms used by pupils, or present on the documentary sheets, are collectively defined by the class. Some examples of definition:

• Lava = molten rock which comes out to the surface

• Volcano = location on the surface of the Earth from which sometimes lava comes out, during an eruption (at this stage, we do not seek to know the structure of a volcano: cone, magma chamber, etc.)

- Bomb = Rocky projectile (piece of lava) ejected from a volcano during an eruption
- Ash = very fine powder of volcanic rock
- Volcanic cloud = mixture of hot gases, ashes and rocks which move at high speed

• Crater = opening located at the top or on the sides of the volcano, which releases lava and projections. These definitions are noted in the scientific book.



Multimedia extension

The first multimedia animation created for this project is entitled "Living with risk". It is a cartoon which tells the story of past natural disasters, and the means that men have found to protect themselves. It can be accessed on the project's website (see page 171).



Session 1-3: Let us classify the volcanoes of the world

duration	30 min
material	For each pupil: • a photocopy of sheet 4 (page 181), if possible in color For the class • an enlarged version (or a video projection) of sheet 4
objectives	 To reconsider the classification of the red/grey volcanoes To know that a volcano has a roughly conical shape and that this cone is very spread out (gentle slope) on red volcanos, and steeper and broken on grey volcanoes
skills	 Apply an investigative approach: to know how to observe, to question. Apply knowledge in different scientific contexts
main Subject	Sciences

Initial question

Teaching note

This session can be seen as a consolidation session, even a formative assessment: the classification established previously is reviewed, and is applied to volcanoes, erupting or not, in order to check if it is well mastered by the pupils.

Additionally, this session highlights the link between the shape of a volcano and the type of eruption. This link will be explored in more detail later.

Initial question

The session begins with a reminder of the previously established classification: there are two types of eruptions: effusive and explosive... or, in other words, there are two types of volcanoes, red and the grey.

Scientific notes

• The classification into two types of volcanoes (red/grey) is simplified to the extreme, but seems preferable for this session and the following ones, because it can easily be interpreted by the pupils, in particular through the experimental activities which will follow this session. A finer classification (five types: Hawaiian, Strombolian, Vulcanian, Pelean, Plinian) is addressed in the cartoon "Volcanoes" which we developed with Universcience for this project. It can be accessed on the project's website (see page 171).

• Additionally, some volcanoes can evolve in the long term and gradually go from the "red" type to the "grey" type. This can possibly be mentioned to the pupils in order to nuance the classification, but should not be studied specifically.

The teacher asks the pupils: "In your opinion, what does a red volcano look like, and what does a grey volcano look like?"

This time it is about describing the shape of the volcano "at rest" and not the eruption. This discussion is held collectively, the pupils having few clues enabling them to answer precisely.

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Some clues can be found in the description of their eruptions (see the preceding Session): gentle or steep slopes, decapitated mountain...

Research (documentary study)

The pupils are divided into pairs and receive a photocopy of sheet 4 showing photographs of red or grey volcanoes, erupting or not.

Starting from these photographs, they try to rebuild a classification. Can they recognize the reds and the greys?

The two photographs of the volcanoes erupting are easily recognizable (in one, a cloud of ashes and dust... in the other, a lava flow). The shape of the volcanoes can be guessed (steep slope for the first, gentle for the second) and extrapolated to the other photographs.

If they do not manage to establish this link spontaneously, can they find another criterion for

classification? (For example: steep slope, gentle slope)

Pooling

At the time of pooling, various groups show their classification. It allows them to realize that the morphological features of a volcano "betray" the type of eruption. A red volcano will have a conical form with very gentle slopes, while a grey volcano will have a steeper slopes, and will show the mark of explosions (collapses).

Opposite are the "corrections", with the name and the type of each volcano. Note that one volcano is presented twice, once erupting and once at rest (Mayon). This repetition makes it possible to ensure that the explosive eruption corresponds to a steep slope.



Teaching notes

• Enlargements or a video projection of sheet 4, in color, greatly facilitates this pooling.

• The photographs of volcanoes can also be compared to the drawings produced by the pupils during the previous session.

Conclusion

A volcano has a roughly conical shape. This shape depends on the type of eruption: for the "red" volcanoes, the cone is very spread out and the slope is gentle; for the "grey" volcanoes, the cone is less spread out and the slope is steep; the cone is also more rugged.

Two questions can be asked from this observation:

- Where does this conical shape come from?
- Why are some cones flatter than others?

Scientific Note

The gentle slope of a red volcano is due to very fluid lava, which flows easily, while the steeper slope of a grey volcano is due to more viscous lava, which flows less easily. Viscosity and its influence on the shape of the volcanoes, as well as the origin of the conical shape will be studied in the following session.

Session 1-4: The origin of the volcanic cone

duration	1 h 30 min
material	For each group: • a bent straw or a flexible pipe • a cylindrical container (cup, yoghurt pot) • a piece of cardboard • fine semolina • a drill (to pierce the container) For each pupil: • a photocopy of sheet 5 (page 182)
objectives	• To understand the origin of the volcanic cone (accumulation of materials produced during eruptions)
skills	 Handle and experiment, formulate a hypothesis and test it, debate Express and use the results of a research using scientific vocabulary verbally and in writing Infer new information (implicit)
main Subject	Sciences

Initial question

The teacher reviews the question asked at the end of the previous session: "We have seen that a volcano has a more or less flattened cone shape: how is this cone formed?" The pupils work individually, and note their ideas in their scientific book.

Pooling

The teacher collects the various hypotheses put forth by the pupils. For example:

• the volcano was from a preexisting mountain or from an accumulation of stones carried by the wind;

• the volcanic cone resulted from a deformation of the ground under the effect of a push exerted to the top (confusion with the formation of chain of mountains);

• the volcanic cone was formed gradually, by the accumulation and the cooling of the materials ejected during the eruption.

The teacher encourages the pupils to justify their answers, and asks the rest of the class (is it possible? what do you think? who agrees?).

The third hypothesis is correct, as shown in the rest of this session.

Research (documentary study)

Each pupil receives a photocopy of sheet 5, which describes the formation of the Paricutín volcano (1943, Mexico). This text tells how a Mexican farmer saw a volcano being born on his land,

initially with some fumaroles, then ejections of ashes and stones. It is one of the only volcanoes in the world whose formation has been followed live.

The pupils read this text and seek clues which enable them to answer the question asked at the beginning of session ("How is the volcanic cone formed?").

Pooling

The story of Paricutín shows that the volcanic cone is formed by the accumulation of stones, lava and ashes ejected by the volcano.

The teacher asks the pupils to imagine an experiment to verify that ejected materials form a cone while falling down.

Several possibilities are proposed; the group collectively seeks a material which could be appropriate (it is necessary for it to be solid, but also for it to be able to flow). The pupils propose sand, sugar, semolina (semolina is agreed upon, as there is some in the class)...

In general, the pupils propose two types of experiment:

• in the first, it is enough to release the semolina from a certain height and to observe the shape obtained: it is a cone;

• in the second, it is necessary to make the semolina come out from "below" for better representation of what happens in a real volcano. It is sufficient, for this, to blow into a straw to eject the semolina. This second experiment is described below (the first is not described, but can of course be carried out in class!).

If the pupils do not have ideas, it is sufficient to present the available material to them: very quickly, the second experiment is proposed.

Modeling (by group)







The container is pierced in order to introduce the straw. Warning! It is necessary to drill it "on the side, towards the bottom", but not "under", because otherwise the straw will clog. A hole is made on the card board set on top of it (diameter: 1 cm). The pot is filled to the brim, or almost, with fine semolina. By blowing into the straw, the semolina comes out from the hole on the lid. When falling down on the cardboard, the semolina forms a conical shape (with a "crater" in the middle).



Grade 3-4 class of the Virginia Ligère school (Antony)

Teaching note

A video of this experiment is available on the project's website (see page 171).

The teacher ensures that the pupils properly establish the link between the model and the reality such as it was described in the document (sheet 5, formation of the Paricutín): the semolina represents ashes, dust and the rocks ejected by the volcano, the cup represents the chimney of the volcano...

Conclusion

The story of the Paricutín volcano and the modeling carried out by the pupils both show that a volcanic cone is formed by the accumulation of materials ejected by the volcano.

This conclusion is written collectively, and is noted in the scientific books.

The modeling carried out with the semolina makes it possible to ask the following questions: "In nature, how are these materials ejected? What "blows"?".

In addition, the types of volcanoes highlighted previously raises another question: how to explain that some cones are very spread out, while others are not?

These two questions will guide the next sessions which relate to the role of gases dissolved in the magma, and to the viscosity of the latter. The questions are written on a poster so that they can be referred to again later.

Extension

For some pupils, the use of semolina in the experiment can be a problem (they think of the liquid lava). You can then propose another experiment, which is very enlightening (and very popular!): to build a chocolate volcano.

The introduction of this experiment is very simple, it only requires asking the pupils which material, that they know well, is liquid when it is hot and becomes solid when it cools. Chocolate is immediately proposed.

The experiment can be carried out collectively, by using a plastic pocket or a bag which is pressed to raise the chocolate "from the bottom" (rather than to make it flow by pouring it from the top). Before making a flow, it is necessary to let the previous flow cool down (1 hour in the fridge). It is completely possible to perform the manipulation by letting the flows cool down at room temperature; it is enough to spread it out over two days.

The viscosity of the chocolate can be made to vary by adding more or less water to it. One chocolate bar is required per flow.



Grade 3-4 class of the Virginia Ligère school (Antony)

This experiment does not only allow modeling the formation of a volcano by the accumulation of layers of flows, but also the introduction of the concept of viscosity (see following session). It replicates very well the solidification of lava. On the other hand, it does not explore the role of gases, in contrast to the previous session (where we blew into the straw). This experiment with the chocolate can therfore be added to the first one, but does not replace it. Instead of the chocolate, paraffin wax can also be used.

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Session 1-5: Shape of the volcano and viscosity of the magma

duration	1 h 30 min
material	 the following liquids: water, shampoo, honey these same liquids mixed with semolina other possible liquids (see the session of the activities) a melamine board, possibly pierced for some groups For some groups (see the session of the activities): a stop watch a large syringe
objectives	 Understand that the differences between the shape of the red and grey volcanoes is explained by a difference in the viscosity of the lava (red volcanoes produce a lava that is less viscous than the grey volcanoes) Know that there are more or less viscous liquids (that is, liquids that flow more or less easily)
skills	 Handle and experiment, formulate a hypothesis and test it, discuss Know how to express the results of a research using scientific vocabulary verbally and in writing
main Subject	Sciences
vocabulary	Viscosity

Initial question

The teacher makes a provisional assessment: "We understand the origin of the conical shape of volcano. Among the questions that have been asked, are: "Why are some cones steeper than others?". This question is asked collectively, and gives rise to a discussion in the class. The ideas which most often emerge are:

• The more the volcano emits a great quantity of lava, the steeper its cone.

• The more the lava flows over a long distance, the more the cone is spread out (the less steep it is).

The teacher asks the pupils, collectively, if they can imagine one or more experiments which allow testing these hypotheses. In the event of difficulty, he can guide them in this way:

• 1st assumption: on the basis of the experiment carried out during the previous session, the teacher shows them a cone formed with semolina, and asks them if the cone will be made steeper by adding semolina. He also asks them how to measure this angle (for example, "Chinese hats" can be used). This very simple and very quick experiment can be carried out collectively as a class, or within groups.

• 2nd assumption: the teacher asks them whether they know liquids which flow very easily (such water for example), or with difficulty (such as honey). He then asks them to think about an experiment which could highlight the fact that some liquids flow easily, and others do not. Several experiment are possible (see below). For the second assumption, the teacher presents several liquids of different viscosities (at least: water, shampoo, honey... to which can be added

liquids such as: ketchup, oil, paint, syrup, washing-up liquid, condensed milk...) as well as some of these liquids mixed with semolina. He asks them to classify the liquids according to the ease with which they flow. This classification is noted in the scientific book, and will be compared with the results, at the end of the session.

Research (experimentation)

The pupils are divided into small groups. Each group performs an experiment making it possible to test one or the other of the hypotheses.

The first hypothesis gives rise to an experiment that is very quickly carried out, and makes it possible to note that the angle of the cone always remains the same, whatever the quantity of semolina used. The conclusion is then that the slope of the volcano does not depend on the quantity of lava produced.

The second hypothesis can give rise to several different experiments (which can be carried out successively or by groups):



Grades 3/4 of the Kévin Faix school (the Kremlin-Bicêtre)



Grades 3/4 of the Magaly Collee and Anne Clémenson schools (Chambéry)

• In one experiment a little liquid is poured from the top of a slightly tilted plane (30° for example), and the distance covered by this liquid in a given time (5 seconds for example) is measured. This experiment is not always very conclusive, because some liquids spread on the board but do not really flow. Nevertheless, it is systematically proposed by the children and deserves to be tested.

• In a second experiment (which gives better results), a (fixed) quantity of liquid is poured on to a horizontal surface, and the spreading of this liquid on the surface is observed: which one spreads out the most?



Grades 3/4 of the Magaly Collee and Anne Clémenson schools (Chambéry)



Grades 3/4 of the Kévin Faix school (the Kremlin-Bicêtre)

• In a third experiment, finally, the formation of a volcano is modeled by injecting a liquid through a horizontal surface (pierced) at the bottom. It is the equivalent of the experiment in the previous sessions, but replacing the semolina with the liquid. The liquid is "pushed" upwards using a syringe. Depending on the liquid used, a cone that is more or less spread out will be formed. This experiment is undoubtedly the one which gives the best results, and has the advantage of allowing an immediate conclusion, thanks to its resemblance to a true volcano.

Teaching note

As in any experiment, it is necessary here to vary only one parameter (the nature of the liquid), while all the others are identical, in particular the quantity of the liquid poured. A considerable amount of time will be saved during this session if small "flasks" with the same quantity of the various liquids are prepared in advance for each group.

Scientific note

It is important to take non-porous materials as the surface (horizontal or tilted plane) so as not to allow the liquid to penetrate: it must flow. The same material must be used for the different liquids (variation of only one parameter at any time). A good material: a melamine board (wood covered with a plastic layer).

Pooling

Each group appoints a rapporteur who comes to present their experiment as well as the results obtained to the whole class.

• The first experiment (semolina cone) shows that the angle of a heap does not depend on the quantity of semolina. In the same way, it is not the quantity of lava which explains the shape of the volcanic cones.

• The experiment with the tilted plane shows that some liquids flow less quickly than others: it is said that they are viscous when they flow slowly. Honey is more viscous than shampoo, which in turn is more viscous than water. By adding semolina to honey or to shampoo, the viscosity is further increased.

• The experiment with the horizontal plane shows that the most viscous liquids are also those which spread out the least. It is noticed that the liquids which do not spread out much form a structure which is higher than those which were spread out.

• The experiment with the horizontal plane and the syringe shows that the more viscous liquids give rise to a steeper cone.

The teacher ensures that a parallel is made with the slopes of the volcano: the explosive volcanoes (grey) produce lava that is more viscous than the effusive volcanoes (red).

Conclusion

The class collectively works out a conclusion in the form of a synthesis, for example: lava is said to be viscous when it flows slowly. The red volcanoes emit lava which is less viscous than that of the grey volcanoes. This lava flows more easily, which explains the more "spread out" shape of red volcanoes.

Extension

The extension of the previous session (to produce a chocolate volcano) can just as easily be carried out here, after this session about viscosity. Just ask the pupils if they know of an ingredient which can be more or less viscous according to the temperature (the temperature is a parameter that we were oblivious to in this session , in order to simplify... but can be added without problems; this will make the comparison with lava more "natural"). Chocolate is immediately proposed. Several small volcanoes can be made with chocolates of different levels of viscosity (by changing the temperature and the quantity of water).

Session 1-6: The role of gases, construction of a model volcano

duration	2 hours (in 2 times 1 hour)
material	For the class: • transparent glass • white vinegar • washing up liquid • sodium bicarbonate For each group: • to make the volcanic cone – choice of: earth, papier-mâché or the following material :
objectives	 Know that a volcano has a chimney and a magma chamber. To understand that gas pressure is the principal driver of a volcanic eruption Understand that the higher the gas pressure, the more explosive the eruption
skills	 Handle and experiment, formulate a hypothesis and test it, discuss Know how to express the results of research using scientific vocabulary verbally and in writing Apply knowledge in different scientific contexts
main subject	Sciences
vocabulary	Pressure

Initial question

The teacher reviews previous work: "We have shown that the volcanic cone is formed by the accumulation of the material ejected during the eruption (and that the viscosity of the lava

explained the more or less pronounced spread of this cone). To work our model, we blew into a straw: it was the air that pushed the semolina out."

"In reality: is air, or other gases, produced by the volcano?"

The class collectively reviews the description of the eruptions of session 1-2, and it is noted that indeed gases are emitted, and come out from the same place as the lava (the crater). This allows us to question the role of these gases: is it possible that these gases "push" the lava to the outside? In order to allow an experimental investigation, we look at more accessible gases and liquids: "Do you know situations where gases are "mixed" with liquids?"

We speak about carbonated drinks. The teacher asks what happens when a bottle of carbonated drink is shaken before being opened. He asks for details: "What overflows? the gas? the liquid? both?"

Teaching note

- This experiment is futile (all the children know what will occur)... speaking about it without doing it, is enough.
- For this work, we do not need to look further into the concept of dissolving, nor into that of pressure: the empirical knowledge of the pupils is perfectly sufficient.

The discussion makes it possible to agree on the fact that there are bubbles and that these bubbles, once spread on the table (or clothing...), will wet this table. That means that liquid was ejected: the gas is able to move the liquid upwards.

The teacher ensures that all the pupils see the parallel with the volcano: gas is able to push lava outside. A lot of gas is needed to make these tons lava to come out.

Research (experimentation)

The teacher announces that there is a way of making much more bubbles with vinegar and sodium bicarbonate. He prepares an experiment with:

• a cup or transparent glass, filled (approximately ¼ full) with vinegar;

• a cup with 1 tablespoon of sodium bicarbonate.

The experiment is carried out collectively (it is more a demonstration than an experiment): when sodium bicarbonate is poured into the glass of vinegar, the pupils observe what happens: strong degassing (effervescence can be heard), formation of large bubbles... After the first



Grades 3/4 of Virtginie Ligère (Antony)

test, the pupils are questioned on the type of eruption represented; they speak about effusive eruption then reflect on what could make it explosive. "More gas would be needed", "more pressure".

The experiment is then repeated by adding more vinegar, more bicarbonate.

Teaching note

A video of this experiment is available on the project's website (see page 171). If we took a mustard pot instead of a glass, we can add a lid and note that the lid pops up (excitement of the pupils guaranteed).

This experiment makes it possible to show that to make viscous magma come out a lot of gas is needed, and that this involves more explosive eruptions.
Each pupil writes a report, as well as the conclusion developed in common, in their scientific books: "It is the gas contained in the magma which makes it come out."

Scientific note

The gas produced by this reaction is CO_2 ; the same gas contained in carbonated drinks. It is also one of the main gases produced during volcanic eruptions.

The teacher then asks the pupils to use what they have learned to create a model of a volcano. The pupils work in groups, and draw their model in their scientific book.

Constructing a model of the volcano

The various proposals are compared in a table. Here is an example of model. The lava will be produced as in the previous experiment, but inside a bottle. A volcanic cone is built around this bottle (either by piling up earth, papier-mâché... or by making a kind of "modeling dough", as described below).

1 - Making the dough for the volcanic cone

1 kg of flour, 500 g of salt, 4 tablespoons of vegetable oil are mixed in a salad bowl. Separately, 30 cl of water, a little dye or paint are mixed to obtain a green chestnut colour. This coloured water is then added to the previous mixture. The whole thing is then mixed by hand, until the paste obtained is no longer sticky. If, after a few minutes, the paste is still too is sticky, a little flour can be added.

Teaching note

The teacher who wishes to save time can prepare this paste in advance. If it is prepared the day before, it will remain flexible the following day (malleability will be closer to the modeling clay than to salt-paste).
If the cone is made with earth rather than with modeling clay, a little plaster can be mixed with this earth, and moisten it, to make it more solid.



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2 - Making of the volcanic cone

The bottle is placed on a surface which will allow the model to be transported. The dough is molded around the bottle in order to form a cone which is not too steep (if needed, more dough can used, or first make a paper cone, which is then covered with the dough). Only the bottleneck should be visible. The model is ready: it is necessary to let it dry over night before generating the eruption.

The following day: the eruption

The lava should first be prepared: the vinegar must be added last.

50 ml of lukewarm water is mixed with 50 g of sodium bicarbonate. Some drops of red dye as well as 30 ml of washing up liquid is added and mixed gently (without making it foam). Using the funnel, this mixture is poured into the volcano.

When all is ready, 100 ml of vinegar is poured into the volcano: the eruption begins!



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Teaching note

• This session can be enriched and various mixtures compared, thus modeling either effusive or explosive eruptions. To do this, you can exploit two parameters:

- The quantity of washing up liquid (30ml, 60ml, 90 ml): the more the washing up, the more viscous the lava becomes.

- The quantity of sodium bicarbonate (50g, 100g): the more the bicarbonate, the greater the degassing.

• We can also imagine that one of the volcanoes is closed by a stopper, which will pop because of the pressure of gases (especially if too much sodium bicarbonate was put). With a "very fluid lava", there is no time to place the stopper. On the other hand, this can be done with more viscous lava (large quantity of washing up liquid). In this case, there is a prior accumulation of pressure which makes the eruption explosive.

Written record and conclusion



Grade 3-4 class of the Virginia Ligère school (Antony)

The pupils draw their model in the scientific book, and explain how it works.

The teacher ensures that the pupils grasps the relationship between the model and reality properly. The collective discussion makes it possible to conclude that the greater the quantity of gas, the more explosive the eruption. If the conclusion of the previous session is added (about the viscosity of the lava), it can be concluded: An eruption is more explosive the more viscous the lava and the more gas it contains.

This conclusion is written collectively, and is noted in the scientific books.

Teaching note

This session is rich... and long. If there is not enough time to complete the written evidence and the conclusion, that is not an issue; this can be done later during a session which is very short. The diagram of the model which has been produced is then compared to the diagram of a "real" volcano.

Extensions

If possible, study samples of various volcanic rocks. Compare slags and basalts full of cavities (small bubbles contained initially in the magma) with more massive samples (rhyolites, obsidians). The collection of these samples can become the subject of discovery class on the Massif Central for example...

Session 1-7: Anatomy of a volcano

duration	45 minutes
material	
objectives	• Know the anatomy of a volcano: cone, chimney, magma chamber
skills	• Know how to express the results of an experiment, a measurement or research using scientific vocabulary verbally and in writing.
main Subject	Sciences
vocabulary	Magma, magma chamber, chimney

This session is used as an assessment of the structure and the activity of a volcano.

Initial question

The teacher explains that the purpose of the previously produced model was to reproduce an eruption. The class did not seek to represent the interior of the volcano accurately. Individually, the pupils create a diagram of a volcano, as they imagine it.

Pooling

The teacher compiles the various diagrams on the black board, and asks the pupils to compare them (common points and differences). This comparison enables the highlighting of the elements which must be present in the diagram of a volcano (see below).



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The teacher copies the diagram of the model produced during the previous session on the black board and writes, on the side, a volcano, naming its various elements: cone, crater, chimney, magma chamber, magma, lava, ashes...

Once this diagram is finished, the class reviews the steps of an eruption. To make this summary an assessment, the teacher guides the pupils with questions such as:

- Where does the lava come from?
- How does it come out?
- From where does it come out?
- What happens to the lava which has come out?
- How is the volcanic cone formed?
- Etc.

Session 1–8: Where are volcanoes located?

duration	1 hour
material	Choice: • a computer connected to the Internet (1 computer per pair) • or, for the class: a computer + a video projector • or, if there is no computer equipment, for each pair, photocopy of sheets 6 (page 183), 7 (page 184) and 8 (page 185), as well as a world map
objectives	 Know that the earth's crust consists of plates moving against one another, and that the majority of volcanoes are located at the edges of these plates Know that some volcanoes are not located on these lines. These volcanoes are called "hot point" volcanoes. They are red volcanoes Know that there are also underwater volcanoes (consequence of the operation of the ocean ridges)
skills	 Express and use the results of a research using scientific vocabulary verbally and in writing Know the main physical geographical characteristics; locate them on maps of various scales. Read and use maps
main Subject	Sciences

Preliminary teaching notes

This session is based on a multimedia animation, produced by La main à la pâte and Universcience, which can be downloaded from the "pupil" section of the website dedicated to the project (see page 171). This session is very similar to session 2-4 relating to the localization of earthquakes. It can be carried out independently (a pair per computer), or collectively, using a video projector.

- If the pupils are in front of the computer, they will need strong coaching (if not, they "play" with multimedia, without really paying attention, and without learning anything).

- If the session is carried out collectively, it is advisable to facilitate it well, to stop often, to ask the pupils to anticipate ("in your opinion, what is going to happen...") so that they are not passive.

• An alternative is offered (in the form of a documentary study) if the use of multimedia is not possible. The two alternatives are not exclusive.

Implementing and conducting the session

Before starting the multimedia animation, the teacher asks the pupils where the volcanoes are located, and collects their answers. The pupils are divided into small groups, ideally into pairs, each group having a computer at their disposal, with the animation on the screen. The interactive animation is made up of several elements making it possible to visualize:



Animation "The Earth"

- the inner layers of the Earth;
- the tectonic plates (in particular, their displacement since Pangea can be followed);
- the localization of earthquakes on Earth (at this stage of the project, this part can be skipped, and will be studied in sequence 2);
- the location of volcanoes, which they can compare with the line of the tectonic plates.

Pooling and conclusion

After viewing the animation, the pupils share what they have learned:

- The Earth's crust consists of plates moving against each other.
- The majority of volcanoes are found at the edges of these plates: they are grey or red volcanoes.
- However, there also exist volcanoes which are not located on these lines. These volcanoes are called "hot point" volcanoes. They are red volcanoes.

• There also exist underwater volcanoes (consequences of the operation of the oceanic ridges). They are red volcanoes.

Alternative

If this multimedia animation cannot be used in class due to lack of equipment, a similar session can be carried out using maps (sheet 6, sheet 7, sheet 8) as well as a world map. The study of sheet 6 shows that the volcanoes are not distributed everywhere: the majority are on "lines". While reflecting the significance of these lines, graph 2 (sheet 7, which shows the tectonic plates) is introduced... and it can be noted that these lines correspond to the edges between the tectonic plates.



The pupils are then asked to trace the outlines of South America on a world map, then to place this copy on a world map while trying to join South America to Africa. The pupils notice that the two "fit" and formulate a hypothesis explain this. A possible explanation is that these plates move, and that at some point

in time the two continents were only one. The same thing can be done with Arabia and Africa to obtain an identical report and hypotheses.

The teacher then introduces sheet 8, which explains continental drift, and proposes to arrange in order the various stages since Pangea. For convenience, one can start by coloring the continents (in order to better follow them).



aching module

The answer key is given below (quaternary = today):



The session ends in a collective discussion during which the teacher explains the link between the movements of the plates and volcanism.

Session 1–9: When can it be said that a volcano is extinct?

duration	1 hour
material	For each pair: • a photocopy of sheet 9 (page 186)
objectives	A volcano can be active or not. Beyond 10 000 years without eruption, it is said that the volcano is inactive or extinct
skills	 Organization and data management: read, interpret and construct some simple representations: tables, graphs know how to organize numerical or geometrical information, to justify and to assess the likelihood of a result
main Subject	Mathematics

Initial question

The class, has until now, wondered about the various types of volcanic eruptions, as well as about the distribution of the volcanoes. But not all volcanoes are active. Several types of questions are possible:

- Is a volcano always in eruption?
- How long is it between eruptions?
- It is sometimes said that some volcanoes are extinct, or dormant: what does that mean?
- Can the volcanoes of Auvergne erupt?

The pupils responses are noted in he table. Some think that an "extinct" volcano can erupt again; others that an extinct volcano is a volcano which was active but that this activity is definitively finished; others still think that it cannot be known.

The duration which must separate various eruptions is also the subject of a disagreement (1year, 1 century, 1000 years, "it depends on the volcano"...).

Research (documentary study)

The pupils are divided into pairs and receive a photocopy of sheet 9. This document contains the following data:

- Dates of eruption of the Vesuvius, in Italy, in ancient times.
- Dates of the last eruptions of Mount Pelée, in Martinique (see documentary study of Session 1-2).
- Date of the last eruptions of the Chaîne des Puys, in Auvergne.

The instruction given in the document guides them step by step in the analysis of these data.

Teaching notes

• The calculation of the time intervals can be problematic, in particular with some "negative" dates. This difficulty can be solved using a timeline (which can distributed to the pupils or be made by them). After having placed the dates on the timeline, it can be observed that, to calculate the difference between the year - 1660 and year +79, it is initially necessary to calculate the difference between -1660 and 0 (1660 years), and between 0 and 79 (79 years). The total difference is the sum of both: 1660 + 79 = 1739 years. One proceeds in the same way for the difference between - 4700 and today.

• The pupils can also be asked to calculate approximate values, because what is of interest here are the orders of magnitude.

• Other data can also be studied, for example the dates of the eruptions of Etna between ancient times and the 17th century: 252, 812, 1329, 1536, 1610 and 1614. That gives differences of 560, 517, 207, 74 and 4 years.



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Pooling

The teacher collects the results of the pupils, and makes the class discuss them. The first question shows that the interval separating two successive eruptions from Vesuvius can go up to 8 000 years. This means that, even if a volcano did not erupt for centuries or millennia, it can still erupt again.

The second question shows that Mount Pelée has not erupted for a little more than 80 years: it is almost certain that it will erupt again (see previous result). It is also the reason why it is under intense monitoring.

The third question shows that the last eruption noted in the Chaîne des Puys goes back to nearly 7 000 years. Can they erupt again? It is possible (but definitely less certain than for Mount Pelée).

The teacher then explains that, for volcanologists, a volcano is regarded as extinct (i.e. that it will no longer erupt) if its last eruption dates back more than 10 000 years. This criterion is arbitrary (one could have taken 50 000 or 200 000 years!), but practical because compatible with what is known of the last eruptions: it is very rare that two successive eruptions of a volcano are spaced by more than 10 000 years.

In contrast, a volcano which is not extinct is known as "active". It can then be in eruption or "asleep" (i.e. between two eruptions).

The teacher asks the pupils to determine if the volcanoes of the Chaîne des Puys, in Auvergne, can be regarded as extinct or not. The answer is that they are asleep... which means that they could, perhaps, erupt again.

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Scientific note

We did not choose to study "a" volcano from Auvergne in particular, but a chain (Chaîne des Puys). The reason is that, in this area, there are often "mono-eruptive" volcanoes: they only erupt once. But the area remains active: the next eruption takes place a few kilometers further and forms a new volcano.

Conclusion and written records

The class writes a collective conclusion, which could look like:

A volcano is considered to be extinct if it has not had an eruption for the past 10 000 years. If not, it is said that it is asleep... which means that it can erupt again.

Extension

This session can be extended with a documentary research: What volcanoes are in France? Are they extinct (as in the Massif du Cantal or Mount-Gilds on the mainland, or the Piton des Neiges on the Réunion) or active (Chaîne des Puys, and many examples in Martinique, Guadalupe and Reunion)?

Session 1–10: How long does an eruption last?

duration	1 hour
material	For each pair: • a photocopy of sheet 10 (page 187)
objectives	Know that an eruption can last a few hours to several years
skills	 Organization and data management: read, interpret and construct some simple representations: tables, graphs know how to organize numerical or geometrical information, to justify and assess the likelihood of a result
main Subject	Mathematics
vocabulary	Variability, average

Teaching note

This session targets pupils in grade 4, even in college, and is an introduction (very basic) to the "statistical way of thinking in a scientific view of the world"⁹. This view is inseparable from the experimental approach and contributes to the analysis and summary of data from observation.

Very often, children as well as adults have the same instinct when they are confronted with a large amount of data which has to summarized: they calculate a mean value. This average is in general very relevant... but not always. In particular, when the data is very "dispersed", the mean value does not mean much. It is the case here: the mean value of the duration of the volcanic eruptions does not make much sense.

The goal of this session is to see this, and to find an alternative way to answer the question "How long does a volcanic eruption last?" It will be seen that a relevant way to answer it (other that "it depends"!) is: half of the eruptions last less than XXX days. This concept, in statistics, is called the median. This concept is approached, without however naming it nor explaining how it is calculated (fortunately, there is a very simple way to define it, without calculation!).

Initial question

The teacher asks the pupils how long a volcanic eruption lasts. The pupils are invited to read the documents studied in session 1.2 again (sheet 2 and sheet 3). Eruptions of varied durations are found: 9 hours, 26 days, 2 months... and 29 years (this last duration, 29 years, is only indicative: the eruption is still not finished!).

^{9.} This is the subject of a of converging theme of the college. Here, for primary school, it is limited to a "small steps" approach.

Research (documentary study)

The pupils are divided into pairs and receive a photocopy of sheet 10, which lists the eruptions of various volcanoes (and, for some volcanoes, several different eruptions in order to see the variation between volcanoes... but also, for the same volcano, between eruptions).

The instruction, although very simple ("How long does an eruption last?") is not without difficulty. The point of this instruction lies especially in the fact that the pupils must seek how to answer. There are several possible strategies:

- "it depends on the volcanoes";
- "it depends on the volcanoes and the eruptions";
- "the average duration of an eruption is ..." (calculation of the mean);
- "an eruption can last between... and... days";
- etc.

Pooling

The teacher collects the answers of the pupils on the black board. Some perhaps thought of calculating the mean: in this case, the teacher asks why they chose this calculation, and what it means.

He invites the pupils to calculate the mean duration of an eruption, which requires, initially, converting the durations into the same unit. For example, in days. This conversion can be made collectively to save time.

The calculation gives a mean duration of 493 days.

The teacher asks: "How many eruptions have a duration which is close to this mean value?" Only one... all the others are very far from it (by a factor 2, 10, 100 or more!).

Scientific notes

• The calculation of a mean value is very sensitive to the extreme values. Here, the duration of the Kilauea eruption, 29 years, or approximately 10 585 days, completely "pulls" the mean of the 25 data upwards.

• It will be also noted that an extreme value influences the mean all the more when there are few data: generally, it is always preferable to specify how many data the mean was calculated from.

• When the mean is not a value around which many data of the series are, this mean is not a relevant indicator to describe the series. It is preferable to calculate another measure, such as the median, for example. It is the purpose of the following activity.

• The mean, like the median, does not account for the extent of the variability of the data available. It is thus advisable to accompany the mean or the median by an indicator which accounts for variability: there are many choices which can be made to describe a series of numbers, but it is important to give a measurement of "central trend" (median or mean for example) as well as an indicator of variability. The simplest way of speaking about variability consists in giving the smallest and the greatest actual value, and their difference (called range of the series).

The teacher ensures that all the pupils are aware of how little "use" this mean value is. He then asks them how the question can be answered.

If no pupil thinks of answering "we could say that half of the eruptions lasts less than XXX days", the teacher introduces this idea. He or she can say, for example: "Could the eruptions be distributed into two equal groups?"

Research (determination of the median)

To find out the duration which separates eruptions into two groups (half of the eruptions are shorter, the other half are longer), eruptions must first be arranged by their duration (from the shortest to the longest).

The median value is the one which is in the middle of the table. We find: 17 days.

Pooling

The teacher, after collecting the results of the pupils, discusses with them the meaning of this value. That means that half of the studied eruptions are longer than 17 days and the other half are shorter. This information, even if it remains vague, nevertheless makes more sense than the mean value for this type of data.

Teaching notes

Generally, the duration of a volcanic eruption varies from a few hours to a few days.

• Here it is not sought to mathematically define the median (what is not part of the program), but simply to approach this concept intuitively.

• It is preferable not to try to represent the data graphically, because such a graph would suppose logarithmic scales (unless all the data is packed onto one side of the graph, for only one point at the other end), because of the great dispersion in the durations. Such a form of representation is difficult to interpret by pupils of at that level. The table is already sufficient.

Conclusion

The conclusion of this session is two fold:

• when there is a lot of data, it is not always possible to answer with a single number. Sometimes, the mean is a good indication, sometimes it is not.

• the duration of a volcanic eruption is variable. An eruption can last a few hours, a few days, a few months... or even several years.

Extension

This session can be extended by a more systematic exploration of the concepts of mean and median through the study of various data (in all the cases, it is necessary to have the greatest possible amount of data, at least several dozens):

• Case where the mean and the median are virtually identical:

- Measure the distance covered in 10 natural steps by various pupils.

- Ask the pupils to cut a string of "approximately" 20 cm after observing a 20 cm ruler, then to measure the lengths obtained.

- Case where the mean and the median should be different:
 - Measure the time taken by pupils to complete a sudoku grid.
 - Measure the waiting time for a bus, a subway train...

Session 1–11: How to be protected from the volcanic risk?

duration	1 hour
material	Documents (not provided: free research) or Internet connection
objectives	 It is possible to predict volcanic eruptions and to prepare the populations In the event of an eruption, it is necessary to assess the zone at the risk
skills	To carry out the research independently in documents (books, multimedia products)
main Subject	Language

Teaching note

To save time, it is preferable that the teacher has planned to borrow books, magazines or DVD's from the library.

Initial question

The teacher reviews all that was seen previously, in particular the consequences of the eruptions on the population.

He asks the pupils how to be protected from this risk. The collective discussion enables the identification of three quite different areas:

- Can we predict eruptions?
- Can we prevent them, contain them or channel them?
- If an eruption takes place, how to be protected?

Some examples of answers of pupils: "it is necessary to avoid living close to volcanoes", "it is necessary to involve the population", "it is necessary to install sirens", "it is necessary to build dams to stop the lava"... The teacher asks them how to check that these proposals are correct, and the class agrees on the need to research in documents.

Documentary research

The class is divided into several groups, each one having to explore different areas of response by a document research: books, Internet, videos...

During the work on predicting eruptions, information will be sought about volcanic observatories: Who works there? To observe what? Where are these observatories?

It is possible to predict volcanic eruptions, and thus to prepare the populations and to evacuate them if necessary. Scientists take turns 24h/24 in volcanic observatories, and record the vibrations of the ground (an eruption is sometimes preceded by small earth tremors), the flow

and the temperature of the fumaroles (which can change before an eruption), the geometry of the volcano (the walls swell by a few millimeters to a few centimeters before an eruption), degassing, etc. It is sometimes possible to divert the flows (using dikes or bombing), to slow them down (by flooding) and thus to facilitate the evacuation of the population. Very good examples can be found in some villages around Mount Etna...

The third area relates to the plans for civil protection (protection of the populations from volcanic risk). Many examples of PPMS¹⁰ of schools in seismic areas are available online on the site www.planseisme.fr. For example, that of schools of the French Antilles: http://www.planseisme.fr/Guadeloupe-PPMS-et-guide-d-elaboration-de-PCS.html

Finally, one of the essential aspects of protection is the information to the population, they must know when to evacuate, where to go, when to return...

Pooling and conclusion

The results of the various documentary research are shared and summarized in the form of one or more posters.

Que fine on Cas d' ineption ? Peut-on prévoir une emptions? done are gone foredu dongen Se metre à l'ari lat Ecolitor la radio et subre objet :ex journal, télévision omment alter l'indispensable (roline) OB etm les con the english d'éxation (templonet to to at letter to Grade 2/3 class of the Magaly Collee and Anne Clémenson school (Chambéry)

The teacher ensures that the key messages are well understood: "It is possible to predict volcanic eruptions and to prepare the populations. In the event of an eruption, it is necessary to assess the zone at the risk."

This can constitute a conclusion to be noted in the scientific book.

Experimental extension

This session can be prolonged and enriched by an experiment which is very simple to carry out, and which makes it possible to note that the imminent arrival of a volcanic eruption can be predicted:

- Insert a straw into a balloon and cover the balloon with a small pile of sand.
- Blow into the straw to send air into the balloon, then let the air out. When the balloon inflates, the pile of sand becomes deformed and cracks appear on its surface.

^{10.} Particular safety implementation plan.

Sequence 1

This experiment illustrates the fact that magma, while rising and filling the magma chamber, slightly deforms the walls of the volcano. This deformation can be measured, and can be used to anticipate an eruption.

Extension: production of writing

This work on volcanoes can be communicated externally (other classes, families...), in various ways:

• Prepare a slide show about volcanoes, which can be shown, and discussed, with other classes.

• Write articles in the school newspaper. In addition, besides the scientific phenomena and the preventive aspects, it is possible to address some more entertaining topics, for example, food recipes (make a chocolate volcano).

• Organize a "volcano forum" in the form of experimental workshops, in which pupils from the class guide other pupils, or parents ("open" day), in the understanding of some of the concepts studied previously.

Session 1-12: Multimedia assessment

duration	45 min
material	Computer room
objectives	 Understand how changing certain parameters (viscosity of the lava, pressure of gases) enable the production of volcanic eruptions which are more or less effusive or explosive Know some examples of volcanoes throughout the world
skills	 Read a digital document Express the results of research using scientific vocabulary verbally or in writing
main Subject	Sciences

Initial question

This session is based on a multimedia animation, produced by La main à la pâte and Universcience, which can be downloaded from the "pupil" section of the website dedicated to the project (see page 171).



Set up and progress of the session

Animation « Les volcans »

The pupils are divided into small groups, ideally in pairs, each group having a computer at its disposal. The interactive animation takes place in several stages:

• Initially, the pupil can vary two parameters (viscosity of the lava and quantity of dissolved gas), and see to which type of volcano that corresponds to.

• Then, the pupil can trigger and follow the eruption of this volcano, and visualize the damage caused.

At each stage, information is given on the dangerous nature of this type of volcano, the preventive attitudes and the required behaviors in the event of eruption.

Pooling and conclusion

After having used animations, the class reviews what was seen throughout this session and produces a summary poster about the types of volcanoes, their forms, their location, their eruptions, and the means of protection against them. The drafting of this poster also makes it possible to review what was made during the first session (what is known, what is thought to be known... all the words which we think of when we talk about volcanoes), and hence to make a final assessment in the format: "What was learnt? "Are there any outstanding questions?"....



Multimedia extension

The last multimedia animation created for this project is a quiz, with some questions that deal with volcanic eruptions. It can be accessed on the project's website (see page 171).



Assessment of sequence 1

duration	1 hour
material	For each pupil, a photocopy of sheet 11 to 16 (pages 188 to 193)
objectives	Assess knowledge and skills acquired during session 1

We propose to assess knowledge and skills related to the approach of investigation, starting with a questionnaire and documents which refer to an eruption of the Piton de la Fournaise and Pelée mountain.

The competencies assessed are as follows:

- Scientific and technological culture:
- Practice a scientific or technological approach.
- Practice an investigative approach: know how to observe, question.
- Handle and experiment, formulate a hypothesis and test it, debate, test several possible solutions.

- Express the results of a measurement and research using scientific vocabulary verbally or in writing.

• Master knowledge in various scientific fields and apply them in different scientific contexts and activities in everyday life:

- Sky and Earth: volcanoes and earthquakes, risks for human societies.
- Mastery of language.
- READ: Locate explicit information in a text.
- READ: Infer new information (implicit).
- WRITE: Answer a question with a complete written sentence.
- Humanistic culture:
- Read and practice various languages.
- Read and use texts, maps, sketches, graphs.

The assessment protocol is composed of 6 fact sheets available in the appendix (of sheet 11, sheet 16). The pupils have one hour to individually answer the questions.

Step 1

Discovery, reading and understanding the documents

Question 1	Knowledge or skill to be assessed	ltem
READ	Locate explicit information in a text.	1

Handover time: 8 minutes

Say to the pupils:

"Initially, you will read the framed text attentively by yourself. I will then invite you to answer the first question. For that, you must complete the table by specifying the materials produced at the time of the eruption as well as the consequences of the eruption for each volcano."

Teaching note

The teacher can read the text and the questions separately to the pupils who have particular reading difficulties.

Correction and coding: Code 1, Item 1

Name of the volcano	Piton de la Fournaise	Pelée mountain
Materials produced by volcano (lava, ashes, dust, gas,)	very fluid lava	Fumaroles, ash clouds, blocks of lava, ashes, burning clouds
Consequences of the eruption	The pupils refer to destruction of property, evacuation people (and expansion of the island)	The pupils refer to destruction of property and to the human losses Formation of a lava needle

Stage 2

Question 2	Knowledge or skill to be assessed	ltem
Master knowledge in various scientific fields and to apply them in other scientific contexts and in everyday activities	Sky and Earth: volcanoes and earthquakes, the risk for human societies	2

Handover time: 1 minute

Say to the pupils:

"Four sentences are proposed. For each one of them, tick the appropriate box".

Correction and coding:

Code 1

Item 2: • The piton de la Fournaise is a red volcano

- The eruption of the piton de la Fournaise is effusive
- Mount Pelée is a grey volcano
- The eruption of Mount Pelée is explosive

Stage 3

Questions 3 and 4	Knowledge or skill to be assessed	Items
READ	Infer new information (implicit).	3 and 4

Handover time: 4 minutes

Tell the pupils:

"Here are two diagrams. After observing them, complete the sentences in the right-hand column using the names of the two volcanoes quoted in texts 1 and 2: the piton de la Fournaise and Mount Pelée. Then complete the legends for these two diagrams by using information contained in the documents."

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Correction and coding:

Code 1

Item 3: Diagram 1 represents Mount Pelée /diagram 2 represents the Piton de la Fournaise Item 4:



Step 4

Questions 5 and 6	Knowledge or skill to be assessed	ltems
Master knowledge in various scientific fields and apply them in various scientific contexts and in activities of daily living	Sky and Earth: volcanoes and earthquakes, risks for human societies	5 and 7
WRITE	Answering a question with a complete written sentence	6 and 8

Handover time: 3 minutes

Tell the pupils:

"You will now answer questions 5 and 6. For that, you will write a sentence".

Correction and coding:

Code 1

Item 5: The magma is composed of molten rocks and gas Item 7: It is the pressure of gases which pushes the magma during an eruption Items 6 and 8: Writing a correct sentence

Stage 5

Question 7	Knowledge or skill to be assessed	ltem
Practice a scientific or technological approach	Handle and experiment	9

Handover Time: 3 minutes

Tell the pupils:

"A class working on volcanoes decide to carry out the two experiments below to understand what happens during a volcanic eruption. In experiment 1, ketchup is placed in a U-shaped tube. Water is poured in the left section of the tube then an effervescent tablet is added before the left section of the tube is closed with a stopper. The same device is reproduced in experiment 2, but ketchup is replaced by puree.

In order to establish the link between this experiment and a real volcanic eruption, you must specify what the effervescent tablet, ketchup and the puree represent".

Teaching note

Ensure that all the pupils know what an effervescent tablet is.

Correction and coding:

Code 1

Item 9: • Effervescent Tablet = gas contained in the magma

• Ketchup/puree = magma

Stage 6

Question 8	Knowledge or skill to be assessed	ltems
Practice a scientific or technological approach	Handle and experiment	10
WRITE	Answering a question with a complete written sentence	11

Handover Time: 1 minute 30s

Tell the pupils:

"Write a sentence to indicate what the pupils of this class want to test by using ketchup in experiment 1 and puree in experiment 2".

Correction and coding:

Code 1 Item 10: The pupils refer to the viscosity of the magma Item 11: Writing a correct sentence

Stage 7

Question 9	Knowledge or skill to be assessed	ltem
READ	Infer new information (implicit).	12

Handover Time: 2 minutes

Tell the pupils:

"According to you, by using the various information discovered about each volcano, which experiment represents: Mount Pelée / Piton de la Fournaise?"

Correction and coding :

Code 1

- Item 12: Eruption of the Mount Pelée: experiment 2
 - Eruption of the piton de la Fournaise: experiment 1

Stage 8

Question 10	Knowledge or skill to be assessed	ltems
Practice a scientific or technological approach	To formulate a hypothesis and to test it	13
WRITE	Answering a question with a complete written sentence	14

Handover Time: 3 minutes

Tell the pupils:

"What will happen to the ketchup and the puree, when the effervescent tablet starts to act? Write what you think, your hypothesis".

Correction and coding:

Code 1

Item 13: For the 1st point, the proposal of the pupil refers to ketchup and for the 2nd point, the proposal refers to the puree

Item 14: Writing a correct sentence

Stage 9

Question 11	Knowledge or skill to be assessed	ltems
Practice a scientific or technological approach	Know how to observe	15
WRITE	Answering a question with a complete written sentence	16

Handover Time: 2 minutes

Tell the pupils:

"Here are the results of the experiment obtained by the class after a few seconds. Write a sentence to describe what you observe about the ketchup and the puree".

Correction and coding:

Code 1

Item 15: If the pupil refers to ketchup and puree and if a change is observed in the two experiments

Item 16 : Writing a correct sentence

Stage 10

Question 12	Knowledge or skill to be assessed	ltems
Practice a scientific or technological approach	Express the results of a measurement and research using a scientific vocabulary verbally or in writing	17
WRITE	Answering a question with a complete written sentence	18

Handover Time: 3 minutes

Tell the pupils:

«For question 10, you answered by formulating hypotheses, i.e. what you thought was going to happen during the experiment which we are following. Does what you observe in question 11 confirm your hypotheses?

You are not asked to just answer by yes or no, but, to, additionally, specify in a few words why what you observed in question 11 corresponds or not to your hypotheses with regards to the ketchup and the puree.»

Correction and coding:

Code 1

Item 17: If there is an comparison between the results of the experiment (question 11) and the hypotheses suggested (question 10)

Item 18: Writing a correct sentence

Stage 11

Question 13	Knowledge or skill to be assessed	ltem
Practice a scientific or technological approach	Express and use the results of a measurement	19

Handover Time: 2 minutes

The teacher reads the instruction and addresses the questions one after another while leaving time for the pupils to answer between each question. He makes a pupil read the question and the proposals.

Correction and coding:

Code 1 Item 19: If the pupil answered the three proposals correctly a) True b) False c) True

Stage 12

Question 14	Knowledge or skill to be assessed	ltem
Read and practice various languages.	Read and use texts, maps, sketches, graphs.	20

Handover Time: 4 minutes

Tell the pupils:

"Here is a chart on the distribution of volcanoes in the world. Locate on the chart the two volcanoes quoted in the texts: the Piton de la Fournaise and Mount Pelée. From the information which you discovered about these two volcanoes, complete the legend on the chart by indicating if the points and the squares representing the volcanoes correspond to effusive volcanoes or explosive volcanoes".

The teacher ensures that all the pupils have located the two volcanoes. He can then ask a pupil to specify by which symbol the Piton de la Fournaise is represented (point). Then the teacher does the same for the Mount Pelée (square).

Correction and coding:

Code 1

Item 20: • effusive volcanicity explosive volcanicity

Stage 13

Question 15	Knowledge or skill to be assessed	ltem
Mastering knowledge in various scientific fields and applying them in various scientific contexts and in everyday life	Sky and Earth: volcanoes and earthquakes, the risk for human societies	21
WRITE	Answering a question with a complete written sentence	22

Handover time: 1 minute 30s

Tell the pupils:

"Where are the majority of volcanos on our planet located? You will answer by writing a sentence".

Correction and coding:

Code 1

Item 21: The majority of the volcanoes are located at the edges of the tectonic plates Item 22: Writing a correct sentence

Stage 14

Question 16	Knowledge or skill to be assessed	ltem
Mastering knowledge in various scientific fields and applying them in various scientific contexts and in everyday life	Sky and Earth: volcanoes and earthquakes, the risk for human societies	23

Handover time: 3 minutes

Tell the pupils:

"Here is the diagram of a volcano. Complete the legend using the suggested words".»

Correction and coding:

Code 1 Item 23:



Stage 15

Questions 17 and 18	Knowledge or skill to be assessed	ltems
Mastering knowledge in various scientific fields and applying them in various scientific contexts and in everyday life	Sky and Earth: volcanoes and earthquakes, the risk for human societies	24 and 26
WRITE	Answering a question with a complete written sentence	25

Handover time: 3 minutes

Tell the pupils:

"Read only questions 17 and 18 and answer these two questions. You will write a sentence to answer question 17".

Correction and coding:

Code 1

Item 24: The answer can refer to: fertility of the ground, tourism, hydrotherapy, source of heat for houses, metal deposits, materials for the construction of houses, abundance of fish in water close to volcanic zones, sports activities

Item 25: Writing a correct sentence

Item 26: They must listen to the radio to know instructions to be followed and they must prepare a bag containing the bare essentials (identity document, drinking water, radio)



Sequence 2: Earthquakes

This sequence starts with a documentary study which makes it possible to define an earthquake. Starting from the damage observed a scale is introduced (MSK scale, which measures the intensity, i.e. local impact of the damage) then the propagation in concentric circles of the seismic waves is studied (with documents and experiments). The study of the location of earthquakes makes it possible to highlight the tectonic plates and, from there, to get to the cause of the phenomenon. Experimental activities facilitate the study of how the earthquake is created, and how it can be detected. The Richter scale is introduced, in order to measure the energy released by the earthquake (magnitude). Finally, after having referred to the required behaviors in the event of an earthquake, the class finishes this sequence by testing various aspects of earthquake-resistant buildings.

Detailed summary:

- Session 2-1: What is an earthquake?
- Session 2-2: How to measure the intensity of an earthquake?
- Session 2-3: How does a tremor spread?
- Session 2-4: Where are earthquakes located?
- Session 2-5: What is the origin of the shock?
- Session 2-6: How to detect an earthquake? Making a seismograph
- Session 2-7: Magnitude and intensity, comparison of the Richter and MSK scales
- Session 2-8: Can we predict earthquakes?
- Session 2-9: What to do in case of earthquake?
- Session 2-10: How to build resistant buildings? (1)
- Session 2-11: How to build resistant buildings? (2)

Session 2-1: What is an earthquake?

duration	1 hour
material	For each pair: • choice of: a photocopy of sheet 17 (page 194) or sheet 18 (page 195)
objectives	 A seism is an earthquake: it manifests itself by tremors which can cause collapses and landslides The duration of a seism varies from a few seconds to a few minutes A seism can cause a lot of damage and cause many casualties A seism can sometimes cause tsunamis
skills	Locate explicit information in a text. • Infer new information (implicit) • Practice an investigative approach: know how to observe, question.
main Subject	Sciences
vocabulary	Seism, earthquake, tsunami

Initial question

The teacher asks the pupils what they know in connection with seism (while starting to use the vocabulary: seism, earthquake...).

At this stage, it is not sought to define these terms precisely, but only to identify what the pupils know.

Teaching note

• Very often, the pupils use a very precise vocabulary (seism, magnitude, core, plates, tsunami...), which they know because of the strong media coverage of certain events (the earthquake which occurred in Japan in March 2011, for example), but without necessarily mastering the associated concepts. For some, a seism is a quake of the entire Earth, for others, it is a local phenomenon even more rarely associated weather phenomena ("there are waves that can cause hurricanes").

• Generally, the word "plate" used by the pupils indicates in fact a continent.

• For the majority of pupils, an earthquake is a very violent phenomenon, during which the ground opens literally into two (the risk for the population is they fall into the cracks). These erroneous representations will progressively be corrected as this session progresses.

Research (documentary study)

The pupils are divided into pairs, half of them receive a photocopy of sheet 17, and the other half a photocopy of sheet 18. These two sheets include press articles relating to earthquakes which occurred recently, in France or abroad, mild or dramatic depending on their magnitude and the degree of preparation of the populations.

Teaching note:

The teacher can provide other documents to support this session (in particular if the class is in a seismic area, local references would be desirable).

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Pooling

After reading these texts, the teacher hosts a collective discussion to achieve an operational definition of a seism: it is an earthquake which appears as tremors that can cause collapses and landslides. A seism is a very short phenomenon (a few seconds to a few minutes), but which can be very violent.

A seism can also create a tsunami: a set of high waves which can cause extensive damage. The documents show that France (including mainland) is subjected to seismic risk. The pooling also allows to pupils realize that the main risk related to a seism (except a tsunami) is the collapse of buildings (and not the ground opening into two as many children think). It can be noted that there some countries are better prepared than others, with appropriate structures.

Scientific note

The seism which occurred in March 2011 in Japan illustrates this aspect well: the seism itself caused very little damage (it was the tsunami which had catastrophic consequences). The

majority of the buildings resisted the tremors well, as shown in this very spectacular video online on the project's website (see page 171), where buildings can be seen swaying... but not collapsing. Viewing this video can be a good continuation of this session.

Conclusion - written records

The class works out a collective conclusion which is noted in the scientific notebooks. Here is an example of conclusion:

At the time of a seism (or earthquake), tremors, very short but which can be very violent, can cause the collapse of buildings. A seism can also cause a tsunami.

The teacher asks the pupils to clarify questions that they have about seism, and collects them on a poster (they will be answered progressively during the sequences that follow).

des seismer Que sont la plagues tectoriques Qu'est l'épicentre Convent la terre tremble Comment construire de la neurstanis Languar y a t-il des mismous Comment mesures la numanie d Seisme Carquer to busines n'ont la memo puesance tancero un reserve est il court

Grade 3/4 class of the Francis Bachelet and Corinne Dauchart school (Rosheim)



Multimedia extension

The first multimedia animation created for this project is entitled "Living with risk". It is a cartoon telling the history of past natural disasters, and the means by which man protected themselves from them. It can be accessed via the project's website (see page 171).



Extension

In addition to the extension mentioned in the previous scientific note (to view a video showing the buildings swaying), this session can be supplemented by exploring the myths and legends surrounding earthquakes: a dragon in China, a catfish in Japan, a tortoise for American Indians...

Session 2-2: How to measure intensity of an earthquake?

duration	1 h 15 min
material	For each group: • a photocopy of sheets 19 to 22 (pages 196 to 199) For the class (optional): • 1 video projector or 1 overhead projector to project sheet 22 • A seism spreading in a concentric way
objectives	 The place where it can be most strongly felt is called "epicentre" The further away from the epicentre, the lesser the damage The damage caused by a seism is measured on the MSK scale. We talk about intensity The intensity of a seism varies from I (unperceivable seism) to XII (catastrophic damages)
skills	 Infer new information (implicit) Know the principal physical geographical characteristics, locate them on maps of different scales
main Subject	Sciences
vocabulary	MSK Scale, intensity, epicentre, concentric

Initial question

The teacher asks some pupils to point out the various effects which can be felt during an earthquake (reminder of the previous session).

Research (documentary study)

The pupils are divided into small groups and receive a photocopy of sheet 19, which describes the damage caused (corresponding to the 12 degrees of the MSK scale), this damage being placed at random. Work consists in placing these effects in the order from the least to the most serious (by cutting out and sticking the items onto sheet 20).



See below, the list, in order, as well as the corresponding MSK intensity:

Intensity MSK	Damage
I.	Residents do not feel anything, the seism is only detected by the more sensitive instruments.
П	Only some people who feel weak vibrations wake up.
ш	The glasses and dishes tinkle, the chandeliers swing.
IV	All the people who are awake strongly feel the tremors
V	All the people who were asleep awake, objects fall
VI	Heavy pieces of furniture move. Many people are afraid. Tiles fall from the roofs.
VII	Some cracks appear in the buildings.
VIII	The buildings suffer extensive damage, chimneys fall.
IX	The most fragile constructions, in particular the houses, collapse. Underground pipes are broken. Roads suffer extensive damage.
X	Bridges and dams collapse. Railway rails are twisted.
XI	General panic. All the buildings, even the most solid, are destroyed.
XII	Cities are razed and landscapes are modified (cracks in the ground, rivers displaced).

Pooling

The class shares various proposals, and reach a consensus. The teacher specifies that this description of the corresponding damage, is a simplified version of an international scale (known as MSK, for "Medvedev, Sponheuer and Karnik", the three people who defined it).

Scientific notes

• In spite of the work completed in the previous sessions, many pupils persist in believing that, at the time of a seism, the ground opens up in two (cracks,...). It is seen here that this is true only for exceptionally intense seism (XII on the MSK scale).

• Do not to confuse this relative scale (which measures the damage in a specific place) with the Richter scale, which measures the "absolute" force of the seism. The first is about intensity, the second, about magnitude. The Richter scale will be studied during session 2-7. So as not to confuse these two scales, the intensity (MSK) is noted in Roman numerals.

• Another scale similar to the MSK scale, but older, also exists: the Mercalli scale. In addition, this MSK scale was recently updated and clarified. The new version is called EMS98 (European macroseismic scale). This is not so well known among the public, so we prefer to use the original version here.

Research (documentary study)

The teacher then explains that the class will now use this scale to see how the same earthquake is felt in different places.

The pupils, divided into small groups, receive a photocopy of sheet 21 and sheet 22. The first document provides, for the same earthquake, various testimonies of residents of various cities, while the second presents these cities on a chart. The earthquake being studied is the one which occurred near Laffrey (Isère) on 11th January 1999.

As a first step, the pupils must determine the intensity of the seism in the different cities (relate the observed damage to the intensity on the MSK scale), then connect the cities in which this seism had the same intensity (plot the isoseismal curves, which will form circles).

Pooling

The rapporteurs of the various groups observe that these isoseismal curves (observed damage) are approximately circular. The teacher asks the pupils what this teaches them about the spread of the earthquake.

Scientific note

In reality, the spread is not perfectly concentric because of the nature of the terrain (more or less movable ground, relief) will locally reinforce or reduce the effects of the earthquake. The circles are therefore distorted. This subtlety seems however unnecessarily complex at primary school: we make it "as if" a seism is spread in a perfectly circular way.

The question then is to find the place where the earthquake was most intense, and to name this place. It is located at the center of the circles. It can be named "center". The teacher explains that actually, it is called the epicentre.

The term "epicentre" is provisionally defined in the following way: it is the place where the earthquake can be most strongly felt (if there is somebody to feel it!). This definition will be modified later (Session 2-5), when the focus will have been defined.

A comparison can be made with what is observed when a stone is thrown into a pond: the waves form concentric circles and are less high





as one moves away from the center.

Here is an outline of these data (the star represents the epicentre of the seism), as well as the corresponding intensities.

It can be very useful, for this pooling, to project sheet 22 onto the board in order to enable one or more pupils to draw the various circles and place the epicentre.

Teaching note: use of the interactive digital Whiteboard

Such a session can easily lend itself to the use of the interactive digital whiteboard (IDW), including at pooling time: the map is displayed on the board, a pupil places the values of the intensities and another draws circles. In particular at the moment of the pooling: the chart is posted on the IDW, a pupil comes to place the values of the intensities and another to trace the circles. The IDW is also used to find the epicentre.

Conclusion

The class works out a conclusion in the form of a summary, for example: A seism spreads in a concentric way. The place where it can be the most strongly felt is called "epicentre". The intensity of a seism can vary from I with XII: this intensity measures the extent of the damage. This conclusion is noted in the scientific notebooks.

Variant

The teacher who wishes to devote more time to the production of writing will be able to adapt this session in the following way (allow 2 hours):

1. Ask the pupils to imagine a scale of perception of the earthquake (in 4 or 5 degrees) and to write the corresponding texts. Example: the earthquake is unperceivable/tremors are felt, but there is no damage, etc.

2. Read sheet 21 and refine as the above definitions needed, and characterize, on this personal scale, the severity of the seism in various places.

3. Make a documentary study, then introduce the MSK scale.

Extensions

In visual arts, the MSK scale can be illustrated: feeling of the residents, damage observed, changes to the landscapes...

Session 2-3: How does a tremor spread?

duration	1 hour
material	For each group: • coloured pasta (or other small objects, light, of similar size and weight, but of different colors) • a mallet • an A3 sheet For the class (optional): • a digital camcorder
objectives	 A seism spreads in a concentric way The further away from the epicentre, the lesser the damage
skills	 Handle and experiment, formulate a hypothesis and test it, debate Express the results of a measurement or research using scientific vocabulary verbally and in writing
main subject	Sciences

Initial question

The class reviews what was seen during the previous session, namely: the vibrations of a seism are spread in concentric circles, and their intensity decreases as one moves away from the center. The teacher asks the pupils to imagine an experiment allowing them to verify this.

Some pupils can propose, for example, throwing an object into the water and to observe the shape of the waves (concentric circles). This experiment can be carried out collectively, but the teacher must ensure that the pupils understand that this is an analogy. He encourages them to carry out an experiment which brings into play vibrations comparable in nature as that of an earthquake. "It would be necessary to vibrate something solid."

Rather easily, the pupils then propose to use their table, and to lay the objects in a circle ("We move the table, which makes the objects fall, we look on which circle the objects fall the most easily.") The question of the shock is discussed: is it necessary to strike the table over or under, or to knock two tables together? The last proposal (knock two tables together) can easily be discarded, because we would not have, in this case, a localised epicentre. To be more realistic (a seism comes from the below), it is then decided create a shock under the table, in the middle.

Teaching note

• If the tables are equipped with boxes below, it is necessary to hit between the box and the table (with the mallet)... or, in the worst case, from the top of the table.

- The mallet blow must be given as precisely as possible in the middle of the circles.
- This experiment can be introduced differently, by showing the pupils the material available, and asking them how to use it to answer the question asked.

• Tip: to colour pasta, just dip them a few seconds in the food dye and quickly dry them in the oven so that they do not soften.

Research (experimentation)

The pupils are divided into groups and carry out their experiment.

For example, they place coloured reference marks (colored pasta, pieces of sugar, dominos...) on the concentric circles (a different color for each circle) plotted on an A3 sheet placed on a table. By giving a blow under the table using a mallet (in the center of the circles, which represents the epicentre), a vibration is created which will be spread in the table. Coloured reference marks are moved (or turned over if they are dominos), and their movement is in all directions: in the plane of the sheet but also



Grade 3/4 class of the Sylvie Vernet school (Lyon)

vertically. The more one moves away from the point of impact, the less the coloured reference marks moved.



Teaching note

• If you have a digital camcorder, you can film the experiment in such a way as to show the vertical displacement of the elements. A video of this manipulation is available on the project's website (see page 171).

• If you hit too hard, all the pasta is ejected and nothing can be seen any more. To properly quantify the effort, it is preferable to use a mallet.

Pooling and conclusion

This experiment shows that a tremor is spread in concentric circles. The more one moves away from the epicentre, the more the vibrations decrease, and the lesser the damage.

This result is noted in the scientific books as a conclusion.

This activity makes it possible to introduce a new question: in reality, what produces the tremor (what plays the part of the mallet blow)?

Session 2-4 : Where are earthquakes located?

duration	1 hour
material	Choice: • computers connected to Internet (1 computer per pair) • or, for the class: a computer + a video projector • or, if there is no computer equipment, for each pair, a photocopy of sheets 7 (page 184), sheet 8 (page 185) and sheet 23 (page 200), as well as a world map
objectives	 The Earth's crust consists of plates moving against each other The majority of the seism can be found at the borders of these plates
skills	 Know the main physical geographical characteristics, locate them on maps of different scales Read and use maps Read a digital document
main subject	Sciences

Preliminary teaching notes

• This sequence is based on a multimedia animation, produced by La main à la pâte and Universcience, which can be downloaded from the "pupil" section of the website dedicated to the project (see page 171).

• This session is very similar to session 1-8 about the location of volcanoes. It can be carried out independently (one pair per screen), or collectively, using a video projector.

- If the pupils are in front of the screen, they will need strong coaching (if not, they "play" with multimedia, without being really attentive, and without learning anything).

- If the sequence is carried out collectively, it is advisable to facilitate it properly, to stop often and ask the pupils to anticipate ("in your opinion, what will occur if...") so that they are not passive.

• An alternative is also proposed (in the form of a documentary study) in the case where the use of multimedia is not possible. The two alternatives are not exclusive.

Initial question

The previous sequence has enabled questioning the origin of a seism: what creates the tremor? The pupils reflect individually and note their hypotheses in their scientific notebooks.

Teaching note

The pupils of the primary school in general do not have a precise idea of the cause of an earthquake. They link the origin to a volcanic or weather cause (for example, heat causes cracks in the ground), or to a human origin (wars/bombs...).

In the likely case where the pupils do not establish a link between the origin of earthquakes and the movements of the tectonic plates, the teacher guides them with another question: do earthquakes take place in particular places?

He then introduces the multimedia animation which will be used to answer this question, as would be done for a documentary research.

Research (multimedia animation)

The pupils are divided into small groups, ideally in pairs, each group having a computer at their disposal, with the animation uploaded onto the screen.

The interactive animation is composed of several elements which make it possible to visualize:

- the inner layers of the Earth;
- tectonic plates (particularly, their displacement since Pangea can be followed);
- location of seisms on Earth, which can be compared with the layout of the plates;
- the location of volcanoes (this part can be skipped, because it was already addressed at the time of session 1).



Animation "Planet Earth"

Pooling

After using the animation, the pupils share what they have learned:

• The earth's crust consists of plates which move against one another (the teacher ensures, if needed using a world map, that the pupils properly understand the difference between plates and continents).

• The majority of seisms can be found at the edges of these plates.

Scientific note

In fact, earthquakes are not exactly on the borders of the plates, but in a widened band (going up to a thousand km) around these borders. At primary school, this nuance does not seem important to us.

Conclusion

The class can (temporarily) conclude that there is perhaps a link between the movements of the plates and the origin of the tremors. The following session will make it possible to, experimentally, check, if this proposal is relevant.

Variant

If this multimedia animation cannot be used in class due to lack of equipment, a similar session can be conducted by using maps (sheet 7, sheet 8, sheet 23), as well as a world map. The study of sheet 23 shows that earthquakes are not distributed everywhere: the majority of the major earthquakes are localized on "lines". While looking at the significance of these lines, the 2nd map is introduced (sheet 7, which shows the tectonic plates)... and it can be noted that these lines correspond to the edges between the tectonic plates.

The pupils are then asked to trace the outlines of South America on a world map, then to place this copy on a world map while trying to join South America to Africa. The pupils notice that the two continents "fit into" each other, they then formulate hypothesis to account for this. A possible explanation is that these plates moved and that at some point in time, the two continents were only one. The same work can be done with Arabia and Africa to get to an identical report and hypothesis.


The teacher then introduces sheet 8, which explains continental drift, and proposes the pupils put the various stages since the Pangea in order. For convenience, one can start by coloring the continents (in order to better follow them).

The answer key is given below (quaternary = today):



The session ends in a collective discussion during which the teacher explains the link between the movements of the plates and the seismic activity.

Session 2-5: What is the origin of the shock?

duration	1 hour
material	For each group: • 2 wooden rafters on which a hook is fixed • sandpaper, rubber bands • iron rods, cubes to be piled up or a small container filled with water • velcro or double-sided sticky tape
objectives	 An earthquake is created by a break or a violent movement of the rock The place where this break or this displacement occurs is called the focus The focus of a seism can be more or less deep (10 to 700 km) The epicentre is located on the surface vertically above the focus
skills	 Handle and experiment, formulate a hypothesis and test it, debate Express the results of a measurement or a research using scientific vocabulary verbally and in writing
main subject	Sciences
vocabulary	Focus

Initial question

The preceding session made it possible to identify a possible cause: movements of the plates against each other.

The teacher asks the pupils if this movement is uninterrupted or is in jolts. He then encourages them to imagine an experiment that would allow them to confirm their hypothesis or not. In the event of difficulty, the teacher can guide them with a question such as: "Can you imagine an experiment in which we pull on a plate to move it, either, in a progressive way, or, in a sudden movement, in jolts?"

The pupils imagine a device which quite easily interferes with the movement of the plate, (for example, velcro or double sided sticky tape under the plate) and thus prevents a gradual shift.

Research (experimentation)

The experiment, produced collectively, or by a group, is rather simple:

• Two wooden rafters are placed (or any other rather heavy object, on which a hook can be fixed) on the table.

• One or more rubber bands are attached to the hooks (depending on their strength) on these rafters, so as to be able to pull them.

• Under one of the rafters, stick on velcro or double sided sticky tape, in order to increase friction with the table.

• A container filled with water, or objects piled up in balance, are placed on the rafters so as to be able to detect the tremor (the objects fall, waves appear in the container...).

When we pull on the rubber band, parallel to the table, both rafters behave differently:

• In one case (weak friction), the rafter moves easily, without jolts, and there is no vibration (the objects placed on top do not fall).

• In the other case (stronger friction), the rubber band initially lengthens without moving the rafter (phase of energy accumulation), then the rafter moves suddenly (phase of rupture which releases the accumulated energy in the form of vibrations). Balanced objects fall.

Scientific note

We can also make the manipulation with only one rafter and vary the support. On a smooth surface (table), there is no jolt because the rafter slips easily, while on a rough surface (concrete, gravel...), the movement is in jolts.



Grade 4 of the Stéphanie Barbosa school (Verniolle)

Pooling and conclusion

The preceding experiment showed that a vibration is created when there is a violent movement of the object in relation to the surface. When the movement is progressive, there is no jolt. The teacher ensures that the pupils properly establish the link between this model and reality. The conclusion can be:

The tectonic plates are moving against each other. When this movement is regular, without jolts, it does not create a seism. But when this movement is constrained for one reason or another, accumulated energy is released violently, by a sudden movement of the two plates, which creates a seism.

The place where this break or this displacement occurs is called the focus. The focus of a seism can be more or less deep (10 to 700 km)

The class then reconsiders the definition of the epicentre established in session 2-3, by explaining that the epicentre is the point, on the surface, which is vertically above the focus. These two definitions, as well as the diagrams of the experiment and the conclusion are noted in the scientific notebook.

Session 2-6: How to detect an earthquake? Making a seismograph

duration	1h 45 min, 2 times
material	For each pupil • a photocopy of sheet 24 (page 201) For each group: • materials necessary to build the seismograph (see examples below)
objectives	The vibrations of the ground can be measured using a seismograph
skills	 Handle and experiment, formulate a hypothesis is and test it, debate Express the results of a measurement or a research using scientific vocabulary verbally and in writing Locate explicit information in a text
main subject	Sciences, technology
vocabulary	Seismograph, seismogram

This meeting takes place in two separate sessions, to allow pupils to gather the materials required:

• 1st part: Design of the seismograph, list of the necessary materials

• 2nd part: Build and test the seismograph, then documentary study

The teacher can lead the two parts one after the other, as long as a lot of material has been planned to answer the very varied needs of pupils.

Initial question

After having reviewed what was seen previously (a seism is created by a violent movement of the tectonic plates, this vibration is propagated and can cause damage), the teacher asks the pupils how a seism can be detected, or, more simply, how one can know that a seism takes place.

He can question them on the senses involved (we feel with the body, we see objects moving or falling, we hear these objects move or vibrate). Pupils then think in small groups about an experimental device to detect an earthquake. It is then a question of designing and manufacturing a seismograph.



Grade 4 class of the Anne-Marie Lebrun school (Bourg-la-Reine)

The pupils must provide a diagram illustrating the operation of their seismograph, as well as the list of the materials necessary to build it.

Teaching notes

• For the moment, the teacher does not specify if it is simply a matter of detecting that an earthquake took place, or if it is also a matter of measuring its "strength", or if it is a matter of keeping a record of it (for example, written). These various aspects will be discussed when the proposals of the various groups are compared.

• In order not to stifle the creativity of the pupils by directing their designs, it is important not to show them the available material (if it has already been gathered but to also explain to them that they have the right to imagine any device, provided that the material can be obtained easily (availability and cost). If some of the proposals are too fanciful or impractical, they will be corrected retrospectively.

Pooling

The various proposals are displayed and compared. The pupils can propose very varied devices. Their common point is that there must always be something mobile (suspended, in balance...) likely to move at the time of a vibration. The simplest devices make it possible to detect that a seism took place, but does not keep a durable record of it. Some barely more complex devices allow to keep a record of it, or to even measure the strength and direction of the oscillation (see examples of designs below).

The materials needed are discussed, if it is not available and cannot be gathered for the next time, the seismograph is modified in order to adapt to the available material.

Build

Each group of pupils receives the material necessary to the realization of their seismograph, builds it and then tests it.

The proposals being very variable from one class to another, and from one group to another, we give some examples of the main designs (balance, magnets, water...), knowing that, for each main one, there are many variations.

Around balance		
Grade 3/4 class of the Francis Bachelet and Corinne Dauchart school (Rosheim)	Objects are placed in balance, and fall when the table is shaken.	

Session 2-6



A bucket is filled with water. Holes are drilled just above the surface of water, all around the bucket. The jolt creates a wave, which makes water enter the holes. Water is collected in containers (a container for each hole). Its direction can even be deduced from the oscillation (by observing, afterwards, which containers are flooded).

Grade 4 class of the Anne-Marie Lebrun school (Bourq-la-Reine)



Using magnets

Two magnets are suspended on two strings, at a distance in such a way that they stick to one another as soon as the table is jolted.

Grade 4 class of the Anne-Marie Lebrun school (Bourg-la-Reine)



Grade 4 class of the Anne-Marie Lebrun school (Bourg-Ia-Reine)

Regarding written records

A felt pen is hung from a hanger and marks a paper sheet. In the event of jolt, a trace in the form of zigzag can be seen. This device can be very easily improved (by ballasting the felt pen so that it is always in contact with the sheet, by using a roll of paper which turns, rather than a sheet...).

Teaching note

Many other devices can be imagined, such as for example:

- an object hanging from a spring (the spring will start to oscillate);
- small bells hanging from a string (which will tinkle);
- The strength of the jolt can also only be measured with balls and perforated boards (with more or less large holes): if the jolt is weak, only the balls resting on a very small hole will fall, if the jolt is strong, all the balls will fall;
- a movable metal rod which when subjected to a jolt, will come into contact with an electric circuit, and complete it (a bulb lights up, a buzzer sounds...).

Documentary study

The teacher distributes sheet 24 describing the first seismograph, invented in China in 132 AD (Han dynasty).

After an individual reading of this sheet, the teacher leads a collective discussion intended to make sure that the pupils properly understand the way this seismograph works. The class can then search for the similarities and differences between this device and those made during this session.

The pierced water bucket is rather similar to the Chinese seismograph, but the disadvantage of water is twofold:

• It does not make noise, as opposed to the metal marbles (hence the seismograph would be checked constantly to see whether it has recorded something).

• It evaporates if we wait a long time, making the seismograph ineffective.

The end of this documentary sheet shows what a modern seismogram (recording carried out by a seismograph) looks like. This part has already been discussed, but will be studied again during the next session.

Written records

Each pupil describes his seismograph in his scientific notebook.

Extension

The class can visit a museum such as "arts & crafts" in order to observe various types of seismographs.

Session 2-7: Magnitude and intensity, comparison of the Richter and MSK scales

duration	1 h 15 min
material	For each pupil: • sheet 24 (page 201), already used in the previous session • a photocopy of sheet 25 (page 202) For the class: • computer room
objectives	 The extent of the vibration created at the focus is measured on the Richter scale. One speaks of magnitude The Richter scale is an open scale, but a seism of a magnitude greater than 10 or higher has never been seen
skills	 Express the results of measurement or research using scientific vocabulary verbally and in writing Read a digital document
main subject	Sciences
vocabulary	Magnitude, Richter scale

Teaching note

This session is used to introduce the Richter scale and as well as to make an interim assessment. For this purpose, the multimedia animation "the earthquakes" is very useful, because it helps to understand the difference between magnitude and intensity.

Initial question

The documentary card used at the time of the previous session shows a particular seismogram (recording of a seismograph), of the seism which occurred in Haiti on 12th January 2010.

The teacher asks the pupils what corresponds to the amplitudes of the recorded oscillations.

They correspond to the amplitude of the jolts themselves, i.e. to the energy released during the seism: a weak earthquake causes weak jolts (and the traces of low amplitude on the seismogram), while a strong earthquake causes big jolts, which appear as strong swings on the seismogram.

The teacher explains that the energy released by an earthquake is called the magnitude... and that it is measured on a different scale than that seen previously: the Richter scale.

Teaching note

Many seismograms are found on the site http://www.edusismo.org The analysis of this seismogram makes it possible to note that a seism gives rise to several jolts. Some are very fast (tight lines, on the left) and others slower: this observation will be useful at the time of Session 2-10.

Documentary research

Each pupil receives a photocopy of sheet 25, which represents the Richter scale and compares the released energy of earthquakes of various magnitudes with other phenomena (explosion of an atomic bomb for example).

Pooling

After a few minutes of reading, the teacher questions the pupils collectively:

- What does the magnitude of an earthquake correspond to?
- Can an earthquake have several magnitudes? (the documents of session 2-1 help us answer that an earthquake only has one magnitude)

The teacher ensures that everyone understands that there is an enormous difference between an earthquake of magnitude N and another of magnitude N+1. A variation of 1 magnitude means a factor 32 in energy; a variation of 2 magnitudes means factor 1000!

For example, the teacher can be interested in magnitude 6, very vivid for the children (the energy released is the same as that of the explosion of the Hiroshima bomb). He asks what corresponds to magnitude 7. The answer is: 32 atomic bombs. He then asks what corresponds to magnitude 8 (answer: $32 \times 32 = 1024$ atomic bombs), then magnitude 9... The teacher ensures that the pupils understand the difference between magnitude (Richter scale), which is absolute and measures the "raw" energy of the earthquake, and intensity (MSK scale), which measures the extent of the damage and depends on the place of observation.

So as not to confuse the two, these two quantities are noted in different ways:

- the magnitude (Richter) is noted in Arabic numerals;
- the intensity (MSK) is noted in Roman numerals.

Multimedia animation: interim assessment

The end of this session is based on a multimedia animation, produced by La main à la pâte and Universcience, which can be downloaded from the "pupil" page of the website dedicated to the project (see page 171).

The pupils are divided into small groups, ideally in pairs, each group having a computer at its disposal, with the animation uploaded onto the screen.

The interactive animation proceeds in several phases:



Animation "The earthquakes"

• Initially, the pupil can vary 3 parameters (depth of the focus, magnitude on the Richter scale and geographical area).

- Then, an earthquake can be started and the damage caused visualized.
- Finally, information is received about the required action in the event of an earthquake.

Teaching note

We can make the pupils understand that an earthquake is never "by itself", but followed by several aftershocks, some arriving a few minutes after the main seism, others several days later. For that, an animation relating to the earthquake which occurred in Japan in March 2011 can be viewed. This earthquake had, over a few weeks, several hundred aftershocks. The site <u>http://www.japanquakemap.com/</u> makes it possible to see the aftershocks scroll (tip: accelerate the course of time). After having viewed the animation, the class goes back to what was seen since the beginning of the session: what a seism is, how it is created and spread, how it is measured...

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Conclusion

The class develops a collective conclusion, which is noted in the scientific notebooks. For example:

An earthquake can be described by two scales. Its magnitude, on the Richter scale, measures the energy it releases. Its intensity, on the MSK scale, measures the local damage.

There are thousands of earthquakes each day. But earthquakes with a magnitude higher than 8 are rare. Beyond 9, they are exceptional.

Session 2-8: Can we predict earthquakes?

duration	1 hour
material	For each group: • documents to be prepared in advance by the teacher (see below) • a photocopy of sheet 26 (page 203)
objectives	We cannot predict earthquakes, but we know the areas at risk
skills	 Express the results of a measurement or a research using scientific vocabulary verbally and in writing Know the various physical geographical features, locate them on maps of different scales
main Subject	geography

Initial question

The teacher asks the class collectively if it is possible to predict when and where an earthquake will take place.

The teacher explains that the answer to the question "when" is negative: the occurrence of an earthquake cannot be predicted.

On the other hand, the class has already seen, during session 2-4, that earthquakes were not located everywhere. The past seismic activity of an area can thus be used to assess future seismic risk.

Documentary research

The teacher gets, via the site www.sisfrance.net, the list of earthquakes recorded in their area. He or she gets in fact two lists. First of all, the list of earthquakes felt by some people (intensity higher than 3), and then that of earthquakes which caused minor damage (intensity higher than 6).



To do this, from the home page of the site <u>www.sisfrance.net</u>, click on an area. On the right a form then appears. The results can be filtered, by ignoring for example all the earthquakes too weak to have had a notable effect (tip: put a minimum intensity of 3.0), and finally confirm. Then do the same thing with another threshold value of intensity (for example, 6.0). See screenshot opposite.

from the home page of the site <u>www.sisfrance.net</u>

A table showing various earthquakes with their corresponding dates is acquired. For example:

• for the region of Ariège, more than one hundred earthquakes with an intensity higher than 3 can be found, but only 5 with an intensity higher than 6;

• Paris has had a dozen earthquakes with an intensity higher than 3, but none with an intensity higher than 4.

Scientific notes

There is a small error on the site www.sisfrance.net: the intensities are noted in Arabic numerals, whereas the rule requires that they be written in Roman numerals so as not to confuse them with magnitude.

The document provides the epicentres... but earthquakes whose epicentre is located in another area can sometimes be felt. The lists are therefore not exhaustive.

The seismic risk in France

The teacher distributes a map of the seismic risk to each pupil (sheet 26), or prints it in an A3 or superior format in order to display it in the classroom¹¹. This document evaluates the current and future risk, while the previous documentary research made it possible to note past disasters.

Teaching note

On the Internet site of the project (page 171) an Excel table can be found which was created by the ministry for Sustainable Development, and gives the seismic zoning of the 36 721 French counties, i.e. the characterization of the risk: very weak, weak, moderate, average, and extreme.

The teacher prompts a collective discussion with the goal of observing that in France all regions experience earthquakes. In the majority of cases, they are very weak earthquakes which do not cause much damage. Certain regions, however, sometimes experience more intense earthquakes, and are regarded as more risky. In particular, regions of the the Pyrenees chain and the Alps, as well as Guadalupe and Martinique.

Written records and conclusion

This observation is noted in the scientific notebook, accompanied by the data on the seismicity of the school's geographical region.

11. The document is available in very high resolution on the project's website

Session 2-9: What to do in case of earthquake?

duration	1 hour
material	For each pupil: • a photocopy of sheet 27 (page 204)
objectives	In the event of earthquake, one can be protected by simple actions
skills	 Formulate an assumption Mobilize knowledge in different scientific contexts Express the results of research using scientific vocabulary verbally and in writing
main subject	Sciences

Initial question

The teacher reviews what was learnt during the previous session (it is not possible to predict the occurrence of an earthquake). He then asks the question: "If one lives in an area at risk, is it still possible to be protected?"

The pupils work in pairs and write their ideas in their scientific notebooks.

Grade 4/5 class of the Francis Bachelet and Corinne Dauchart School (Rosheim)

ouse Evit tue mo est très fort et qu'onne pas sortir, que il gau ller sous une table ou > bureau Loud et solide et maitre un casque)

Pooling

The collective discussion makes it possible to identify two main ideas:

- Buildings (where to build, how to build...).
- The behaviors (before, during, after).

If the first idea (to build to earthquake standards) is not mentioned, we can come back on what had been seen during session 2-1: the main danger (except tsunami), during an earthquake, is the collapse of the buildings. Ideas are recorded separately: they will be the subject of the next two sessions.

The rest of the session is centered on behaviors. The proposals of the pupils are very varied, and sometimes contradictory. Examples:

- get under a table
- take the car and drive far
- take refuge underground (carpark, basement...)
- stand in the corner of a room
- move away from windows
- leave the buildings
- call the emergency services
- take shelter under trees, etc

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Some of these behaviors are suitable, others not. Before going further, the pupils must confront their points of view, while trying to reach a consensus. The teacher takes care that each one clarifies their ideas as much as possible: Is this action to be adopted as prevention (before the earthquake), during the tremor, or after? Why does this seem appropriate?

A particular point can lead to strong disagreements: should emergency services be called? For some pupils, the proposal is obvious, but not others, who highlight the fact that "this poses a problem if everyone calls at the same time".

The point will be settled by the study of sheet 27, that the teacher distributes to the pupils. This sheet shows the actions to be adopted in the event of an earthquake occurring at the school. After a few minutes reading the document, the class collectively discusses its contents. Had we forgotten some actions? Did we make any errors? Which ones? The teacher then asks what should be done if we were surprised by an earthquake outside of school, for example at home, outdoors, or in the car.

Conclusion

The basic actions of protection in the event of earthquake are noted in the scientific notebook:

- From the first tremor:
- If inside: take shelter under a solid piece of furniture (table...) or in a doorway.
- If outside: move away from buildings.
- If in the car: stop, but remain in the vehicle.
- After the first tremor:
- If in a building:
 - > cut off the water gas and electricity (for the adults) supplies if possible;
 - > leave the building.
- In all cases:
 - > do not telephone;
 - > listen to the radio;
 - > go to free common open spaces (park, stadium...).

Extensions

Make a poster similar to the one distributed, but showing the actions to be taken at home (this activity is an application of the concepts seen in this session; can be regarded as a training assessment).
Perform an exercise of the actions to be adopted by simulating an earthquake in the class, for example timing how long it takes to the exit the building after the first tremor.

Session 2-10: How to build resistant buildings? (1)

duration	1 hour
material	For each group: • a thick polystyrene board (at least 4 cm) • "rods" of various lengths, of the same material either: - thick cardboard (for example a large calendar cut out into strips) - wooden rods - small vegetable crate - metal (reglets or threaded rods) (see scientific note in top of the following page) • plasticine
objectives	 Buildings that are resistant to earthquakes can be built The height of a building is not a decisive parameter
skills	 Handle, experiment, formulate a hypothesis and test, debate. Express, use the results of measurement or research by using scientific vocabulary in writing and verbally
main subject	Sciences

Initial question

At the time of the previous session, the class raised the possibility of being protected from earthquakes by building buildings which resist shocks.

Now, the teacher asks students to individually think about the properties that a building should have to withstand earthquakes.

Pooling

The pupils make various proposals:

- Use very solid (hard) or rather flexible materials....
- Build low buildings.
- Place buildings on shock absorbers...

We propose to begin this investigation with the "height" parameter. Because almost all the children (and many of the adults) think, wrongly, that it is preferable to build low buildings.

The class collectively thinks of an experiment which would make it possible to know if the height of a building plays a part in its resistance to seismic shocks.

The pupil can propose simple manipulations, starting from stack piles (kapla, dominos...). The downside of these proposals is that such buildings are not solid: rather than various piled up elements (which can slip easily), a single element would be needed.

For example stems of various heights can be taken, planted vertically on a support which is moved horizontally. The stems which oscillate the most are then looked at.

Scientific note

• The material used for the stems should not be too rigid (if not, there is no oscillation), nor too flexible (if not, the oscillations are too strong and the stems become deformed).

• So that the experiment goes correctly, it is necessary that the stems are firmly fixed to the support!

• Large wooden plinths (60 cm for the smallest, 1 m 60 for the largest) screwed firmly with a large rafter are ideal. But this material being rather expensive, we propose other alternatives which work well (skewers, thin straps of thick board...10, 20, 30 cm high planted in a piece of polystyrene...).

• To give a little mass to each stem, and also for a better visualizing of the oscillations, they can be weighed down by a piece of plasticine.

Research (experimentation)

The pupils are divided into groups and carry out the previously designed experiment (each group can have a different material: wooden or metal stems, cardboard...).





The pupils can be required to initially seek to make the largest stems oscillate, then the shortest. Gradually, they realize that the speed of the oscillation (we do not speak about frequency at primary school) is important: if the board oscillates as slowly as possible, it can be observed that it is the highest stem which oscillates the most. If on the contrary very fast oscillations are caused, it is smallest which will oscillate the most. Progressively, the frequency which enables the intermediate stems to oscillate.

Teaching note

A video of this experiment is available on the project's website (page 170).

Pooling and conclusion

Collectively, it is noted that the speed of the vibration plays an important part. The fast jolts make the smallest stems oscillate, and the slow jolts the highest stems. The class establishes the link with reality and concludes from it that a low building is not inevitably safer than a high building. All depends on the speed of the vibration of the earthquake.

The teacher informs the pupils that in general, an earthquake includes multiple vibrations: certain slow, others faster. This conclusion is noted in the scientific books.

Scientific note

Actually, the high buildings are often more resistant than the houses, because they are conceived to resist violent winds. Their construction being the subject of more studies and monitoring due to more economic than physical reasons.

Bession 2-11: How to build resistant buildings? (2)

duration	1 h 15 min
material	For each pupil: • a photocopy of sheet 28 (page 205) • a photocopy of sheet 29 (page 206) For each group: • tools (boards, cards) • choice: – cubes, rubber bands – sand, a basin, large boxes or wooden rafters, metal stems – glass bottles or drink cans (or any other cylindrical object which rolls well), cubes
objectives	 Buildings which are resistant to earthquakes can be built The chaining of building is effective On movable ground, it is necessary to build deep foundations so that the building resists
skills	 Handle, experiment, formulate a hypothesis and test, debate Express and use the results of measurement or research by using scientific vocabulary in writing and verbally
main subject	Sciences

Initial question

The teacher distributes sheet 28 to each pupil which shows two buildings which have undergone extensive damage following an earthquake. He starts a collective discussion intended to talk about what could happen to each of the two buildings. The first fell to the ground (problem of foundations), while the second broke (problem of cohesion of the building). The teacher then asks the pupils how the buildings can be designed to resist earthquakes better, taking into account the two problems mentioned above. Several ideas take shape, of which the main ones are:

• Build deep foundations if the building is located on loose soil.

• Bind together the various elements of the building in order to prevent the walls from moving against each other (which leads to the collapse of the building). The pupils propose for example to surround the buildings by very solid cables.

• Place the building on a damper system (springs, wheels...).

The class collectively looks at ways of testing these proposals using experiments.

Research (experimentation)

The pupils are divided into several groups. Each group tests only one proposal.

Manipulate the "foundation"

The group working on the foundations takes two identical objects (same size, same mass), each one representing a building, placed on a basin filled with sand (loose soil). These objects can for example be two pieces of wood, or two jam jars (filled with water or sand to weigh them down).

Under one of the two objects, stems which represent foundations are fixed (super glue, nails, screw...). One of the "buildings" thus rests on loose soil, while the other rests on a hard ground (the foundations touch the bottom of the basin).

When the basin is shaken, the building with no foundations sinks into sand.



Grade 5 class of the Stéphanie Barbosa School (Verniolle)

Manipulate the "chaining"

This group can carry out a very simple experiment, with kaplas dominoes, wooden cubes (even larger elements such as boxes of tissues)... and some rubber bands.

Two buildings can be built by piling up these elements. One of the buildings is surrounded by rubber bands (the chaining, or wind-bracing).

When the support is shaken, the building which is not chained breaks down very easily.



Grade 5 class of the Stéphanie Barbosa School (Verniolle)

One can test various types of chaining (horizontal, vertical, transverse...).

Manipulate the "shock absorbers"

The pupils propose various types of devices to insulate the building from the seismic shock: shock absorbers, wheels... These proposals could be tested if the material needed is available. An easy experiment is to place buildings on a support which itself is placed on cylinders (bottles for example). When a jolt is triggered, the support moves as a whole, and the buildings vibrate less than if they were placed directly on the ground.



Grade 4 class of the Helene Gaillard School (Paris)

Teaching note

Videos of these experiments are available on the project's website (page 171).

Pooling and conclusion

After having organized the pooling of the results of the various experiments, the teacher distributes sheet 29 to the pupils, which describes some elementary rules of earthquake resistant construction.

Scientific note

This document is not intended to be exhaustive, but only to identify the parameters which are most important and which, moreover, can be tested experimentally in primary school.

Then he reviews the first session, during which the pupils had noticed that an earthquake of the same magnitude could have completely different effects depending on the context (earthquake-resistant buildings, preparation of the population, etc.).

The class writes a collective summary which is noted in the scientific books.

Extensions

Produce a model of earthquake-resistant building reviewing all the studied parameters Learn about the types of constructions around the school, as well as the school itself, if one lives in a seismic region.

Study the solutions adopted in various countries to guard from seismic risk, in particular to discover other principles of earthquake-resistant construction (materials, the shape of the buildings...).



Multimedia extension

The last multimedia animation created for this project is a quiz, where some questions deal with seismic risk. It can be accessed on the project's website (see page 171).



Assessment of sequence 2

duration	1 hour
material	For each pupil: • a photocopy of sheets 30 to 33 (pages 207 to 210) • a sheet of tracing paper • a stapler (to fasten the sheet of tracing paper to sheet 30)
objectives	Assess the knowledge and skills acquired during session 2

We propose to assess certain knowledge and skills related to the step of investigation starting from a questionnaire and documents referring to the earthquake of Loma Prieta, which occurred on the 17th October 1989 in the San Francisco Bay in California.

The assessed competencies are as follows:

- Scientific and technological culture:
- Practice a scientific or technological approach.
- Practice an approach of investigation: know how to observe, question.
- Manipulate and experiment, formulate a hypothesis and test it, debate, put several possible solutions to the test.

• Express and use the results of a measurement and research by using scientific vocabulary in writing or verbally.

• Master knowledge in various scientific fields and apply them in different scientific contexts and in daily activities:

- Sky and the Earth: volcanoes and earthquakes, risks for human societies.
- Mastery of language.
- READ: Locate explicit information in a text.
- READ: Infer new information (implicit).
- WRITE: Answer a question with a complete sentence in writing.
- Humanistic culture:
- Have benchmarks within time and space.
- Know the main physical geographical features, spot them on maps at different scales.

The assessment protocol is composed of 5 fact sheets available in appendix (from sheet 30 to sheet 33). The pupils have one hour to individually answer the questions.

Step 1

Question 1	Knowledge or skills to be assessed	ltem
Have benchmarks within time and of space.	Know the main features physical geographical, locate them on maps at various scales	1

Discovery and reading of the documents

Time: 6 minutes

Say to the pupils:

"Initially, you will carefully read the framed text alone*. I then invite you to answer the first question. For that, I will distribute a sheet of tracing paper which you will need to answer this question."

*As an aside the teacher can read the text and the questions to the pupils who have particular reading difficulties.

Correction and coding:

Code 1 Item 1: If one of the rivers appears in blue, the fault in red and if the arrows are well represented.

Stage 2



Comprehension of text

Questions 2, 3, 4 and 5	Knowledge or skills to be assessed	ltems
READ	Infer new information (implicit).	4
	Locate explicit information in a text.	6
WRITE	Answer a question with a complete sentence in writing.	5,7
Master knowledge in various scientific fields and apply them in context of daily activities	Sky and the Earth: volcanoes and earthquakes, risks for human societies.	2, 3

Time: 5 minutes

Say to the pupils:

"By using the documents, you will now answer questions 2, 3, 4 and 5."

Correction and coding:

Code 1 Item 2: Magnitude of the earthquake Item 3: A seismograph/a seismometer Item 4: The epicentre is the place where an earthquake can be felt most strongly Item 5: Writing a correct sentence Item 6: 16 kilometers Item 7: Writing a correct sentence

Stage 3

Question 6	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Formulate an assumption	8
WRITE	Answer a question with a complete sentence in writing.	9

Time: 3 minutes

Say to the pupils:

"The color code of document 1 indicates the level of intensity of the damage caused by this earthquake. According to you, why is the damage greater in the area of Santa Cruz than in the areas of San Francisco and Oakland?"

Correction and coding:

Code 1

Item 8: The assumption refers to the earthquake and the damage caused. A proposal which does not refer to the propagation of waves is therefore acceptable Item 9: Writing a correct sentence

Stage 4

Question 7	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Manipulate and experiment	10
Master knowledge in various scientific fields and apply them in context of daily activities	Sky and the Earth: volcanoes and earthquakes, risks for human societies.	11

Time: 3 minutes

Say to the pupils:

"Here is the experiment conducted by a class that is working on earthquakes. The pupils decide to overturn a large plastic crate on a table. They lay small heaps of wet sand on top, aligning them and spacing them. Then, using a mallet, a pupil gives a great blow on a point of the crate. To properly understand the relationship between this experiment and what can occur in reality, answer the four questions."

Correction and coding:

Code 1

Items 10 and 11: If the four answers are given

- Shock on the crate = the earthquake
- Impact point = the focus
- Sand heap = houses/buildings
- Turned over crate = surface of the ground

Stage 5

Question 8	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Formulate an assumption	12
WRITE	Answer a question with a complete sentence in writing.	13

Time: 2 minutes

Say to the pupils:

"What will happen to the sand heaps when a blow is given to the crate? Write a sentence to write what you think, your assumption."

Correction and coding:

Code 1

Item 12: The assumption refers to the sand heaps Item 13: Writing a correct sentence

Stage 6

Question 9	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Know how to observe	14
WRITE	Answer a question with a complete sentence in writing.	15

Time: 2 minutes

Say to the pupils:

"Here are the results of the experiment obtained by the class. Write a sentence to say what you observe about the sand heaps."

Correction and coding:

Code 1

Item 14: If the pupil refers to the sand heaps and if a change is noted Item 15: Writing a correct sentence

Stage 7

Question 10	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Express and use the results of measurement and of research using scientific vocabulary in writing or verbally	16
WRITE	Answer a question with a complete sentence in writing.	17

Time: 3 minutes

Say to the pupils:

"On question 8, you answered by formulating a hypothesis, i.e. what you thought was going to happen during the experiment which we are following. Does what you observe on question 9 confirm your assumptions?

You are not asked to answer with just yes or no, but, in addition, to specify in a few words why what you observe in question 9 corresponds to your hypothesis or not regarding the sand heaps."

Correction and coding:

Code 1

Item 16: If there is a comparison between the results of the experiment (question 9) and the suggested hypothesis (question 8)

Item 17: Writing a correct sentence

Stage 8

Question 11	Knowledge or skills to be assessed	ltem
Practice a scientific or technological approach.	Express and use the results of an experiment	18

Time: 2 minutes

The teacher reads the instruction and addresses the questions one after the other while leaving time between each question for the pupils to answer. He makes the pupils read the question and the proposals.

Correction and coding:

Code 1 Item 18: If the pupil answered the three proposals correctly

- a) True
- b) False
- c) True

Stage 9

Question 12	Knowledge or skills to be assessed	ltems
Master knowledge in various scientific fields and apply them in the context of daily activities	Sky and the Earth: volcanoes and earthquakes, risks for human societies.	19
WRITE	Answer a question with a complete sentence in writing.	20

Time: 2 minutes

Say to the pupils :

"In the experiment, the earthquake is caused by the blow from a mallet. Write a sentence to explain what creates an earthquake in reality."

Correction and coding:

Code 1

Item 19: An earthquake is created by a break or a violent movement of the rock Item 20: Writing a correct sentence

Stage 10

Question 13	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach.	Debate	21
WRITE	Answer a question with a complete sentence in writing.	22

Time: 3 minutes

Say to the pupils:

"Explain in what way this experience helps you to understand what occurred during the earthquake of Loma Prieta."

Correction and coding:

Code 1

Item 2: The answer refers to the fact that at the time of an earthquake, vibrations are created and that these are spread (in a concentric way). That explains the fact that the earthquake was felt in Santa Cruz as well as in San Francisco and Oakland

The answer can also refer to the decrease of the vibrations when moving away from the epicentre and to explain why the earthquake was strongly felt in Santa Cruz and a little less in San Francisco and Oakland (see document 1)

Item 22: Writing a correct sentence

Stage 11

Questions 14 and 15	Knowledge or skills to be assessed	ltems
Master knowledge in various scientific fields and apply them in the context of daily activities	Sky and the Earth: volcanoes and earthquakes, risks for human societies.	23, 24
WRITE	Answer a question with a complete sentence in writing.	25

Time: 3 minutes

Say to the pupils:

"We have seen that an earthquake can cause a lot of damage. To be protected, it is necessary to know how to react in the event of an earthquake. Questions 14 and 15 treat the actions and behaviors in the event of an earthquake. Answer these two questions."

Correction and coding:

Code 1

Item 23: I take shelter under a solid piece of furniture while waiting for the end of the quake Item 24: The answer refers to the fact that one should not use the telephone at the time of an earthquake. The telephone lines must remain free for the emergency services Item 25: Writing a correct sentence Sequence 3: Tsunamis

This short sequence¹² starts with a documentary study allowing a definition of a tsunami. Several experimental sequences and a multimedia animation follow. They enable the understanding of the different mechanisms which give rise to waves and why a tsunami slows down and grows in amplitude when approaching the coast. The class then studies the location of tsunamis to know the zones at the risk (in particular on the French coast) and the behaviors to be taken.

Detailed summary: Session 3-1: What is a tsunami? Session 3-2: How to create a wave Session 3-3: Relationship between the speed of a wave and the depth of the water Session 3-4: Multimedia assessment Session 3-5: How to be protected?

Assessment of sequence 3

12. We advise to start with the study of earthquakes (all or part of session 2), before studying tsunamis.

Session 3-1: What is a tsunami?

duration	1 hour
materials	For each pupil: • a photocopy of sheet 34 (page 211) • a photocopy of sheet 35 (page 212) • a world map For the class: • (optional): a video projector
objectives	 A tsunami is a series of tall waves which break onto the coasts A tsunami causes a lot of damage close to the coasts
skills	 Know the main physical geographical features, spot them on maps of different scales. Read and use maps Practice an approach of investigation: know how to observe, question. Express and use the results of research using scientific vocabulary verbally and in writing Locate explicit information in a text Infer new information (implicit).
main subject	Geography
vocabulary	Flood, tidal wave, tsunami, to break

Triggering situation

The teacher distributes a photocopy of sheet 34, which shows two satellite images, before and after the arrival of the tsunami in Indonesia in 2004, to each pupil.

If there is a video projector, this card can be projected in color¹³.

The pupils must individually describe what they see and then describe what could occur.

Teaching notes

• The SERTI site offers many high quality documents, the cartographies of the satellite SPOT, and relating to many natural disasters (reference maps, maps of impacts...): <u>http://sertit.u-strasbg.fr/</u> (click on "fast cartography service")

• Another possible triggering situation (closer in time than the 2004 tsunami), is the tsunami which has occurred in Japan in March 2011. A very beautiful animation, on this site, enables the comparison of the before and after images (move the cursor from left to right to see the evolution): <u>http://www.nytimes.com/interactive/2011/03/13/world/asia/satellite-photos-japan-before-and-after-tsunami.html</u>

^{13.} The documentary sheets are available in colour on the project's website (see page 174).

Pooling

The teacher collects the responses of pupils in a table. He ensures that each one explains the meaning of the vocabulary that they use: flood, tidal wave, tsunami. The teacher asks some questions to make the pupils express themselves on an early explanation of the phenomenon: What's this? How could the sea rise? Some pupils have had experiences of tides and can think that it is a "normal" daily phenomenon. The affected areas are shown below:



Grade 5 class of Anne-Marie Lebrun School (Bourg-Ia-Reine)



Teaching note

Because of the media coverage of the tsunami of March 2011 (Japan), the pupils have acquired a specific vocabulary (tsunami, magnitude, epicentre)... but do not understand their meaning. At this stage, they very often confuse a tsunami and a storm.

Research (documentary study)

The teacher distributes a second document (sheet 35), which consists of a testimony and an article reporting the arrival of the tsunami which struck Asia on the 26th December 2004, and its consequences.

The work initially consists of a free reading of the text, then the pupils are invited to highlight the difficult words.

Teaching note

The tsunami of 2004 was particularly deadly. Many testimonies (texts, photographs and videos) are available on the Internet. A selection of these videos are online on the project's website (see page 171).

Pooling and conclusion

The teacher asks some pupils to comment on their reading of this document. What have they learned? Are there words which they did not understand?

What happened exactly?

He then hosts a collective discussion aimed at characterizing the phenomenon described. The teacher ensures that the following points are mentioned:

• A tsunami originates in a specific location, but can have effects on a large scale and touch very distant coasts.

• Offshore, a tsunami is not noticeable (this aspect will be reviewed in session 3-4).

• A tsunami propagates very quickly, which makes it very difficult to alert the population (the speed of propagation will be studied in session 3-3, we will not go into detail here).

The class discusses the devastating effects of the tsunami, and writes a definition of

this phenomenon. An example of definition can be: A tsunami is a series of high waves which break onto coasts. A tsunami causes great damage along the coast: floods, destruction, casualties...

The teacher then encourages the pupils to express the questions which they have in connection with tsunamis (example of questions: what is the difference between a tsunami and a tidal wave? in which direction does the wave move? why does the wave slow down when approaching the coast? etc). These questions are noted on a poster on which the answers will progressively be proposed during the sessions that follow.

(a) Guelle est la différence entre un naz-de-morrée et un trunami? (2) Pouquei les migues wont moins wite en se nagrochant des côtés? (3) Comment les vagues font pour grandu an se naggradiant des col 4) Dans qualle direction so deplacent voques à partir de l miento

If the question of the origin of the tsunamis was not asked, the teacher asks it: how can such waves be formed?

Grade 3/4/5 of the Marc Rudeau School (Serres-sur-Arget)

Scientific notes

Tsunami or tidal wave? The term "tidal wave" is no longer used by scientists today, because it is too vague: it used to refer, not only to floods due to very strong tides, but also to storms or other weather phenomena. The term tsunami refers to a wave (known as "of significance"... which has a long wavelength, see notes below) which is almost invisible offshore but becomes higher and breaks on the coast, causing a lot of damage. The causes of a tsunami are generally an underwater earthquake or a major land slide (created, for example, by the collapse of part of a volcano which falls into the ocean, during an eruption).

• Tsunami or storm? What basically distinguishes a tsunami from a large swell (created during a storm... or on a surf spot), is the wavelength... i.e. the distance between two peaks or two troughs of the wave. You can also talk about the period of the wave (time between the arrival of two peaks or two troughs).

- A very large swell has a period of approximately 10 seconds or, in other words, a wavelength of a few tens of meters (100 meters for a storm). The surge of this wave carries a "small" amount of water. This water thus penetrates a distance roughly equal to its wavelength on the ground (if the ground is flat)... a few tens of meters.

- A tsunami has a 20 minute period, or a wavelength of 10 km. The quantity of water contained in the wave is thus gigantic. Nothing can stop this water when it breaks. It will penetrate over a distance of several kilometers on the ground.



Multimedia extension

The first multimedia animation created for this project is entitled "Living with risk". It is a cartoon telling the history of past natural disasters, and the means by which men protected themselves. It can be accessed on the project's website (see page 171).



Session 3-2: How to create a wave

duration	1 hour
material	For each group: • water • mops • a basin or an aquarium (wide if possible) • small objects (table tennis balls for example) For the class: • a silicone mould (or a large aluminium food tray)
objectives	 A tsunami can be caused by an earthquake, a volcanic eruption or a large landslide into the sea A tsunami is not an isolated wave, but a set of waves
skills	 Handle, experiment, formulate a hypothesis and test, debate Express and use the results of research using scientific vocabulary verbally and in writing Test several possible solutions
main subject	Sciences

Scientific notes

• To create a tsunami, a disturbance with dimension comparable to the depth of water is needed. In relation to the dimensions of the ocean, it should be a disturbance of the order of one kilometer. An undersea earthquake of magnitude > 6.5 creates a vertical deformation several tens of cm (even several meters)... extended over a distance of several kilometers: this dimension being comparable, even higher, than the depth of the ocean, this causes a tsunami. Major land movements (underwater, or following a volcanic eruption) can have the same effect.

• It is difficult to model a tsunami with precision using small experimental devices. Admittedly (see above), the disturbance must be of the same order of magnitude as the depth... But to throw a stone into an aquarium is not enough. A tsunami is a massive wave which moves the whole of the liquid, and not only its surface. To create a tsunami in an aquarium, it is necessary that the container be long enough (a few meters) to make it possible for to generate a massive wave. A tray of a few tens of centimeters does not create a tsunami... but only a "surface" wave, similar to the swell. It is not a problem in this session ... but it limits the relevance of the analogies which can be made (see, in particular, the two following sessions).

Initial question

The teacher points out the questioning resulting from the previous session and explains that before understanding how to create a tsunami, we should try to understand how to create a wave.

This question is very easy and can quickly be dealt with by the whole class, the pupils being accustomed to creating waves (swimming pool, bath...). Several mechanisms can be mentioned, such as for example:

- Drop an object into water
- Remove an object out of water
- Make movements in water
- Blow on the surface of water
- Shake the container...

Research (experimentation)

The pupils, divided into groups, carry out some experiments to create waves, according to mechanisms identified above.

If possible, it is preferable to carry out these experiments outside (water splash...).

In order to make the experiment more interesting, the pupils can be asked to find, for each mechanism, a means of measuring the speed of the waves, or a means of creating, several times in a row, identical waves. The pupils must also observe the shape of the waves created. To encourage this, they can be asked, beforehand, to draw the waves which they will obtain (and to compare these drawings with those obtained after the manipulations).

• Drop an object into water:

- Manipulate the mass of the object or the drop height (it is preferable "to release rather" than "to launch" the object, in order not to have another parameter which is difficult to control to take into account: the strength with which it was launched).

- Concentric Waves.

- Remove an object from water (a ball for example)
- Ditto.
- Make movements in water:
- Manipulate the size of the moving object, the amplitude and the speed of the movements.
- "Linear waves" can be obtained
- Blow on the surface of the water:
- Manipulate the "strength" of the breath (several people can blow).

- Warning! Do not put an electrical appliance (hair drier, ventilator...) in contact: with water, it is dangerous!

- "Linear waves" can be obtained if everyone blows in the same direction
- Shake the container:
- Manipulate the number of jolts, their amplitude, their direction, etc.

- "Linear waves" which are very easy to follow can be obtained by tilting the container then putting it down (it is ideal to measure speeds).



Grade 5 class of Anne-Marie Lebrun School (Bourg-la-Reine)

Teaching note

Such an activity can easily encourage the pupils to be distracted, especially if the work seems insignificant. Hence the interest of before-after drawings (which require them to observe) and the measurement of the speed (which obliges them to, among other things, not make too big waves, otherwise they will no longer see anything).

Pooling

The pooling allows pupils to link these experiments to waves that can be observed in nature:

• The first observation is that we never create ONE wave... but several.

The role of the wind is mentioned as the cause of waves in large areas (lakes, seas, oceans).

• The experiment with dropping an object shows that the larger the object, the higher the waves created are.

• The teacher makes brief summary of what has been seen so far: "We saw that waves could be created by falling objects, the movement of air, or movements in the water. According to you, what can create a tsunami?"

The objective is to note that two phenomena can be at the origin: the fall of a body (very massive, like a piece of mountain, following a landslide or a volcanic eruption) or a violent displacement of rocks (underwater earthquake, modifying the ocean floor). The idea that the earthquake is a precursor to a tsunami emerges without difficulty, because of the documentary study carried out during the previous session. On the other hand, we do not know yet how an earthquake can cause a tsunami.

The experiment below makes it possible to model the phenomenon.

Scientific note

The impact of a meteorite, even if it is far from probable, can also cause a large tsunami. The impact which took place 65 million years ago in Mexico (Yucatan) created a mega-tsunami which flooded all of North America. The North-American dinosaurs died by drowning!

Teaching note

It is possible that some pupils cannot differentiate between a "normal" wave (created by the wind on the sea) and a tsunami (created by a landslide or an earthquake), or that they are not convinced of the part played by the wind on the oceans. The teacher can then bring back several weather bulletins. It is noted that each time the sea is agitated, there are violent winds offshore.

Research (experimentation)

To model the formation of a tsunami following an underwater earthquake (which modifies the geometry of the ocean floor), it is necessary to use a container for which the shape can be modified. A silicone cake pan (or an aluminium food tray) is perfect for that.

The class carries out the experiment collectively. After pouring water in the mould (and having waited until the water is still) a pupil delivers a small blow to the lower part (for that, place the container on a pierced table, or between two tables). The bottom becomes deformed, generating a wave.

Conclusion

A conclusion is written collectively and noted in the scientific notebooks. Example of conclusion: When the seabed is modified (by an underwater earthquake) or when a great mass falls in the ocean (at the time of a volcanic eruption or a landslide), a tsunami can be created.

Teaching module

Session 3-3: Relationship between the speed of a wave and the depth of the water

duration	2 hours
material	For each group: • water • a rectangular container (as large and broad as possible; minimum height: 10 cm) • a stop watch for the class: • computer connected to the internet, or photocopies sheet 36 (page 213)
objectives	 The greater the depth, the faster the waves spread A tsunami advances very quickly offshore (approximately 900 km/h) and slows down on approaching the coasts (30-40 km/h)
skills	 Manipulate, experiment, formulate a hypothesis and test it, debate Express and use the results of a measurement or research using scientific vocabulary verbally and in writing Test several possible solutions Read, interpret and build some simple representations: tables, graphs Know how to organize numerical information, justify and assess the likelihood of an outcome
main subject	Sciences

Initial question

The teacher asks the class to review the testimonies studied during session 3-1, by focusing on the speed of the waves.

At what speed were the waves travelling?

The pupils highlight a contradiction: the first testimony seems to say that the waves broke on the coast at 40 km/h, while the article speaks of a much greater speed (800 km/h: the speed of a plane!) offshore.

Pooling

The teacher draws a diagram on the black board, like that on following page, on which he writes the speeds mentioned above.

The teacher then collectively asks the pupils why these waves slowed down. Two assumptions emerge in general:

• depth ("while arriving close to the coast, there is less water, then the wave is obstructed and slows down");

• a loss of momentum ("when one moves away from the epicentre, the wave loses its momentum and slows down").

The pupils must then find a means of testing these two hypotheses. For the first one, it is a

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question of designing an experiment which makes it possible to see whether the depth of the water plays a part in the speed of propagation of the waves. For the second, it would be necessary, for example, to look at the evolution the speed of a tsunami when it moves away from the epicentre, but while going offshore rather than towards the coast (we come back to it at the end of the session).

Research (experimentation)

The pupils are divided by groups and test the role of depth.

A possible experiment consists in taking a large flat container in which a little water is poured (a few millimetres).

Waves are created and their speed is measured. To do this, just follow and measure the time it takes to make a few trips (always the same number), because this wave will be reflected on the walls.

This experiment is repeated with 0.5 cm of water, then with 1 cm, 2 cm, 4 cm, etc

Scientific notes

Preferably use a rectangular container (pan or something similar and deeper if possible), first tilt the container then put it back down: a linear wave, which is easy to follow and measure, is thus generated in this container. With a circular wave, it is much more difficult.
A video of this experiment is available on the project's website (page 171).

Several measurements are necessary for each depth (in order to avoid possible errors). It can be useful to prepare a table in advance, that the pupils will just have to fill, in order to save time.

Depth	Journey time		Average of the journey time
0.5 cm	Measure 1		
	Measure 2		
	Measure 3		
1 cm	Measure 1		
	Measure 2		
	Measure 3		
• • •			

The teacher asks the pupils to write these measurements on a chart, and distributes graph paper. The class collectively discusses the choice of axes and scales. One can either place all the points on the graph, or to decide to place only one value for each depth. In this case, the teacher asks which value to place and, if the pupils do not know, proposes to calculate the mean value of the measurements, and to place only the mean on the graph.



Grade 5 class of Anne-Marie Lebrun School (Bourg-la-Reine)

Teaching note

This part of the session (calculation of the averages, chart) is more akin to a mathematical work. You can go even further in this direction and calculate speed, in km/h, of the produced waves (allow ½ hour more in the duration of the sequence). This calculation is difficult, even for a class of grade 5. A way to get there is to: 1/ calculate the distance covered in 1 second (in cm)

2/ convert this distance into km (which gives us a speed in km/s)

3/ multiply by 3 600 to obtain the speed in km/h $\,$

The more the depth increases, the more the travel time decreases, which means that the speed increases.

Pooling

Each group names a representative who comes to present the results of their experiment. The report is: the greater the depth of the water, the faster the waves spread.

Research (documentary study)

The second hypothesis mentioned above (a tsunami slows down because it "loses its momentum") is easy to refute. You can do this by studying the spread of a tsunami on a large scale, either by viewing a video (on line on the project, website: see page 171), or by using sheet 36, which shows the progression of a tsunami throughout the Indian and Pacific Oceans. This activity can be carried out collectively or in groups.

In both cases (video or document), it can be noted that a tsunami does not slow down offshore... it slows down only when it approaches the coast. It is therefore the depth that plays a role, and not the distance from the epicenter.

Conclusion

A tsunami spreads very quickly offshore and slows down when approaching the coast because the depth decreases.

Scientific notes

• The fact that the speed of a wave depends on the depth is not specific to tsunamis. It is the case for any wave, provided that the depth is small compared to the wavelength of the wave. For a tsunami (wavelength: 10 km or more), it is always the case, even offshore. For a wave of "normal" swell (wavelength: a few meters or tens of meters), this phenomenon appears only when very close to the coast, when the depth is very low.

• The deceleration of a tsunami when approaching the coast involves a reduction in its wavelength, which goes from a few hundred kilometers, offshore, to a few tens of kilometers, near the coast. This factor of 10 or more, has a consequence on the wave height: the height increases in proportion. A tsunami offshore, is a mere 1 metre high wave... but this wave can easily measure 10 meters onshore!

• In spite of the reduction in the speed of the tsunami when it approaches the coast, the period of the wave remains constant. Approximately twenty minutes separate two successive waves.
Session 3-4: Multimedia assessment

duration	1 hour
material	 Computer room (optional): experimental alternative: 1 large aquarium 1 digital video camera
objectives	 A tsunami increases in height when it approaches a coast (as the depth decreases, the height of the wave increases) Sometimes (but not always), the arrival of the tsunami is preceded by a phase of withdrawal of the sea. Such a withdrawal must be interpreted as a sign of danger
skills	 Read a digital document Express and use the results of research using scientific vocabulary verbally and in writing
main subject	Sciences

This session is based on a multimedia animation, produced by *La main* à *la pâte* and Universcience, which can be downloaded from the "pupil" section of the website dedicated to the project (see page 171). You can also carry out this study in the form of an experimental sequence, as long as there is the necessary equipment (see the alternative suggested at the end of the session).

Foreword

The teacher requires the class to review one of the testimonies read in session 3-1, in particular the sentence about the fishermen offshore: those who were at sea, far from the coast, noticed nothing. He explains to the pupils (or asks them to research) the etymology of the word "tsunami". This name comes from two Japanese words: "wave" and "port". A tsunami indicates a group of waves which hit the port but which cannot be seen offshore.

The teacher requires an explanation of this phenomenon. Because of the similarity of this issue with that of the previous session, the pupils do not find it difficult to imagine that the depth of the water can also play a part in the height of the wave.

The pupils propose an experimental device to test this hypothesis. It is developed collectively. The teacher then explains that the experiment is difficult to implement (but nothing prevents the testing, of course!), and offers, for this reason, to carry it out "virtually", via a multimedia animation.

Set up and progress of the session

The pupils are divided into small groups, ideally in pairs, each group having a computer at their disposal, with the animation uploaded onto the screen. The interactive animation proceeds in several phases: - Initially, the pupil visualizes how a wave is created, spreads, and amplifies when the depth decreases.

- Then, he follows the appearance of a tsunami (generated by an underwater earthquake) and receives information on the action to be taken.

The teacher asks the pupils to properly observe what happens on approaching the coast: it is seen that the wave slows down (see previous session), but also that it is straightens out. It can



Animation « Les tsunamis »

also be noted that the wave is preceded by a "hollow", similar to the withdrawal of the sea mentioned in the testimony of session 3-1.

Scientific note

• The withdrawal of the sea before the arrival of the tsunami does not always happen but it is common. When the seabed is deformed (which causes the tsunami), one side is raised, and the other is lowered. When it is close to the epicentre, if the coast is on the lowered side, the trough of the wave arrives first: there is a very large withdrawal of the sea. If the coast is on the raised side... then a withdrawal is not observed. When it is far from the epicentre, on the other hand, a withdrawal can be observed, but it is weaker.

• This withdrawal of the sea cannot be confused with a downward tide: whereas the tide takes several hours to recede, the withdrawal heralding the tsunami takes only a few minutes.

The teacher can tell the story of Tilly Smith, a young girl of 11 years, on holiday in Phuket in December 2004, who saw the sea withdrawing rapidly and warned her family as well as the emergency services of the imminent arrival of a tsunami (she had studied this phenomenon a few weeks earlier in class). The beach was evacuated just in time, saving the life of tens of people.

Conclusion

The class writes a collective conclusion, for example: As the depth of the water decreases, the height of wave increases. Often, the arrival of the tsunami is preceded by a phase of withdrawal of the sea. Such a withdrawal must be interpreted as a sign of danger.

Experimental alternative

The study of the relation between the depth of water and the height of wave can be done in an experimental way... but it requires a large transparent container (larger than the aquariums which are in general available in schools. One meter long is the minimum...). You will also need a digital camcorder because the effect to be measured (change in wave height) is small, and the phenomenon is too fast to be seen.

For these two reasons, we propose this experiment in the form of an alternative... but few classes will be actually able to implement it.

The session begins with the same question as described at the beginning, but the experiment is completed collectively.

To simulate the approach towards the coast, it is sufficient to tilt the container, which has the consequence of having one side of the container deeper than the other side.

A wave is generated by withdrawing an object which was put beforehand into water, and the propagation of the wave is filmed. Colouring the water makes this observation easier. Moreover, on the two sides of the tray, two small pieces of wood are placed, which will allow, by the persistence of a wet trace, to see the maximum height reached by the wave.



On the left, where the depth is lower (because of the slope of the tray), the height of the wave is greater than on the right. This effect is not very pronounced, because of the small size of the container. The longer the container is, the better it works. Ideally, an aquarium of several meters long would be needed to properly model a tsunami.

Ilus la profondeur de l'eau diminue plus la parteur de la vaigne augmente

Grade 3/4/5 of the Marc Rudeau School (Serres-sur-Arget)

It is essential to be able to film the experiment and review the film in slow motion, or even frame by frame. This makes it possible to note the height variation of the wave, and also its deceleration.

Session 3-5: How to be protected?

duration	1 hour
material	For each pupil: • a photocopy of sheet 37 (page 214)
objectives	 Tsunamis are not located in any particular place: all coasts can experience them A tsunami can be predicted when a triggering event has been detected (earthquake, volcanic eruption, landslide), but only some hours in advance In the event of tsunami, one needs: to take shelter on higher ground (hills, buildings), stay there several hours (several waves), bring water, bring a radio
skills	 Formulate a hypothesis, debate Apply knowledge in different scientific contexts
main subject	Sciences

Initial question

The teacher asks the pupils where, according to them, the tsunami hazard zones are. Of course, they are the coastal areas... and more specifically those located in seismic areas (see session 2-8). However, as we saw that a tsunami can be spread over thousands of kilometers, it can easily be imagined that even the non-seismic areas can be affected by tsunamis created elsewhere.

The teacher distributes a photocopy of sheet 37 to each group of pupils, presenting tsunamis which have recently occurred on the French coasts.

He hosts a collective discussion with the goal of noting that in France, some tsunamis can be expected, in general of low magnitude. Certain areas, however, are more exposed (Reunion, Guadalupe, Martinique), because of their seismic activity or volcanic and their insular nature. The only French territory with a tsunami Specialized Emergency Plan (PSS) is French Polynesia. This report is noted in the scientific notebook.

Teaching note

Just like for earthquakes, there are two scales, one of magnitude, the other of intensity, to quantify the 'strength' of a tsunami (directly connected to the height of the wave reaching the coast), or its severity in terms of damage and human casualties. These scales are little known, compared with the Richter or MSK for earthquakes, and do not seem essential to us for a primary school project.

The teacher then asks the question: "If you live in an area at risk, how can you be protected?" The pupils work in pairs and write their ideas in their scientific notebooks.

Pooling

The collective discussion makes it possible to identify three main tracks:

- Recognize the warning signs of a tsunami.
- How to behave (before, during, after).
- Build appropriate structures (dams, buildings on high ground...).

Recognize the warning signs already mentioned previously:

- An underwater or coastal earth tremor (see session 2).
- Observe a fast withdrawal of the sea (much faster than a downward tide).

It is necessary to keep informed in various ways (radio, public announcements), or to observe the animal behaviors (massive flight of birds, escape of domestic or wild animals ...).



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The action to be taken in the event of tsunami is collectively discussed: What should be done? Why is this a good (or bad) idea?

• If at sea (on a boat): it is beneficial to navigate away from the coast, because the effect of the tsunami focuses on the coast.

• If on the ground, it is necessary go to higher ground not to be submerged: hills, roofs of the buildings...

• And it is necessary to stay there several hours (the tsunami is composed of several waves, which will arrive every 10 to 30 minutes: the first is often not the strongest!).

• Bring water and a radio (with batteries, obviously).

Teaching notes

• The emergency concept is differently perceived among the pupils: for some, it is very important to carry money, precious objects, identity papers, while for others, it is more important to leave quickly. This debate can be animated by comparing this situation with another one that the pupils know well (because the school organizes fire drills several times a year): fire alarm. In the event of a fire alarm, everyone leaves, immediately, leaving their stuff.

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• Another point on which it can be difficult to obtain a consensus is the need to call the emergency services. For some, it is essential, while for others, it is to be avoided because it will cause a problem if everyone calls at the same time, and also "the emergency services have other things to do than to be on the telephone".

• Some pupils can make fanciful proposals on the way in which one can be protected from a tsunami (carry life jackets, remain at home by closing the doors...), showing that they have difficulty picturing the violence of a tsunami. In this case some videos from the project's website (see page 171) can be projected. Although these videos have been selected so as not to show shocking images (corpses), they are sufficiently striking so that the scope of the damage can be imagined well.

Written evidence and conclusion

The class then makes a collective illustrated poster on the way of to be protected from a tsunami.



Multimedia extension

The last multimedia animation created for this project is a quiz, where some questions deal with tsunamis. It can be accessed on the project's website (see page 171).



Assessment of sequence 3

duration	1 hour
material	For each pupil, a photocopy of sheets 38 to 42 (pages 215 to 219)
objectives	Assess the knowledge and skills acquired during session 3

We propose to assess knowledge and skills related to the investigation approach from a questionnaire and documents which refer to the phenomenon of tsunamis as well as to the relationship between the height of the wave and the depth of the water.

The assessed competencies are as follows:

- Scientific and technological culture:
- Practice a scientific or technological approach.
- Practice an investigative approach: know how to observe, question.

- Manipulate and experiment, formulate a hypothesis and test it, debate, put several possible solutions to the test.

- Express and use the results of measurement and research using scientific vocabulary verbally or in writing.

- Master knowledge in various scientific fields and apply them in different scientific contexts and in daily activities:

- Sky and the Earth: volcanoes and earthquakes, risks for human societies; the movement of the moon around the Earth.

- Mastery of language.
- READ: Locate explicit information in a text.
- READ: Infer new information (implicit).
- WRITE: Answer a question with a complete sentence in writing.
- WRITE: Write a text of about fifteen lines by using knowledge in vocabulary and grammar.

The assessment protocol is composed of 5 fact sheets available in the appendix (from sheet 38 to sheet 42). The pupils have one hour to individually answer the questions.

Stage 1

Discovery, reading and understanding documents.

Question 1	Knowledge or skills to be assessed	ltem
READ	Locate explicit information in a text.	1

Time: 6 minutes

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Say to the pupils:

"Initially, you will carefully read the framed text by yourself*. I then invite you to answer the first question. To do this, you must give three different answers. You will write a single response per line." *The teacher can read the text and the questions for pupils who have particular reading difficulties.

Correction and coding:

Code 1 Item 1: The three answers given: The wind An earthquake A landslide/the fall of a cliff or part of a volcano or a mountain

Stage 2

Question 2	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach	Formulate a hypothesis and test it, debate	2
WRITE	Write a text of about fifteen lines using knowledge in vocabulary and grammar	3

Time: 8 minutes

Say to the pupils:

"In the previous question, you identified three possible causes for the formation of a wave. For each one of them, you must imagine an experiment that will show that it is the source of the formation of the waves. For that, you must describe and produce a diagram for each of these experiments."

Correction and coding:

Code 1

Item 2: The experiments suggested by the pupil are consistent with the answers provided to the question 1

Item 3: The 15 lines are not a criterion, on the other hand the produced text should be coherent with the experiments suggested by the pupil. For this skill, it is the syntactic correction which is taken into account and not the mastery of scientific knowledge

Stage 3

Question 3	Knowledge or skills to be assessed	ltems
READ	Infer new information (implicit).	4
WRITE	Answer a question with a complete sentence in writing.	5

Time: 2 minutes

Say to the pupils:

"In the text, it is written: upon approaching the coast, the wave is slowed down and then starts to rise. According to you, why is the wave higher when it reaches the coast? You will answer by writing a sentence."

Correction and coding:

Code 1

Item 4: The height of the wave is greater upon approaching the coast because the depth of water decreases (the wave, slowed down, "rises") Item 5: Writing a correct sentence

Stage 4

Question 4	Knowledge or skills to be assessed	ltem
Mastering knowledge in various scientific fields and applying them in different scientific contexts and activities in daily life	Sky and Earth	6

Time: 4 minutes

Say to the pupils:

"Here are, at random, the various stages of the formation of a tsunami. Give a title to each one of them then arrange them in order."

Correction and coding:

Code 1

Item 6:

Titles A = earthquake; B = withdrawal of the sea; C = coast in a normal state; D = surge (arrival of the wave on the coast); E = spread of the tsunami Stages in the order: C, A, E, B, D

Stage 5

Question 5	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach	Manipulate and experiment, test a hypothesis	7
WRITE	Answer a question with a complete written sentence	8

Time: 4 minutes

Say to the pupils:

"A class that is working on tsunamis has read in a text documentary that the waves are highest upon approaching the coast. A pupil of this class decides to carry out the following experiment. He uses a large aquarium filled with water in which the coast will be represented by a slope made out of gravel. Then the pupil uses an object immersed in water to create a wave by withdrawing it from the aquarium. During this experiment, the pupil wants to observe the height of the wave. For that, he places paper strips on the right and left-hand side of the walls of the container.

The drawing which he made on the scientific notebook is shown.

In this experiment, the pupil chooses to test a parameter which is likely to act on the height of the wave. You will write a sentence to say what this parameter is."

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Correction and coding:

Code 1

Item 7: The parameter tested in the experiment is the depth of water, it is modified when the wave arrives at the slope made out of gravel to model the coast Item 8: Item 5: Writing a correct sentence

Stage 6

Question 6	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach	Manipulate and experiment, test a hypothesis	9
WRITE	Answer a question with a complete written sentence	10

Time: 3 minutes

Say to the pupils:

"What will happen when the pupil takes the object out of the water? You will write a sentence to say what you think you will observe (your hypothesis) for the wave and for the paper strips."

Correction and coding:

Code 1

Item 9: For the 1st point, the proposal of the pupil refers to the wave/the movement of the water, and for the second point the proposal refers to the strips of paper Item 10: Item 5: Writing a correct sentence

Stage 7

Question 7	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach	Know how to observe	11
WRITE	Answer a question with a complete written sentence	12

Time: 3 minutes

Say to the pupils:

"At the end of the experiment, the pupil drew his observations in the scientific notebook and stuck the strips of paper. Write a sentence to say what you observe about the wave and the paper strips."

Correction and coding:

Code 1

Item 11:

For the wave: the pupil refers to the spread of the wave in the two directions of the aquarium and/or to the height of the highest wave on the end where the gravel is located

For the witnesses: the pupil observes a difference in the height of the wave on the two paper strips

Item 12: Writing a correct sentence

Stage 8

Question 8	Knowledge or skills to be assessed	ltems
Practice a scientific or technological approach	Express and use the results of measurement and research using scientific vocabulary verbally or in writing	13
WRITE	Answer a question with a complete written sentence	14

Time: 3 minutes

Say to the pupils:

"On question 6, you answered by formulating a hypothesis, i.e. what you thought was going to happen during the experiment performed by the pupil. Does what you observed in question 7 confirm your hypothesis?

You are not asked to answer by just yes or no, but, in addition, to specify in a few words whether what you observed in question 7 corresponds to your hypotheses or not regarding the wave and its mark on paper."

Correction and coding:

Code 1

Item 13: If there is a comparison between the results of the experiment (question 7) and the suggested hypothesis (question 6)

Item 14: Writing a correct sentence

Stage 9

Question 9	Knowledge or skills to be assessed	ltem
Practice a scientific or technological approach	Express and use the results of an experiment	15

Time: 2 minutes

The teacher reads the instruction and addresses the questions one after the other while giving the pupils time to answer between each question.

He makes the pupils read the questions and the proposals.

Correction and coding :

Code 1

Item 15: If the pupil answered the three proposals correctly

a) False

b) True

c) I can't tell (indeed, it is not possible to deduce this conclusion from the preceding experiment)

Stage 10

Questions 10, 11 and 12	Knowledge or skills to be assessed	ltems
Mastering knowledge in various scientific fields and applying them in different scientific contexts and activities in daily life	Sky and Earth	16, 18, 20
WRITE	Answer a question in a complete written sentence	17, 19, 21

Time: 6 minutes

Say to the pupils:

"You will now read only questions 10, 11 and 12. You will write a sentence to answer each one of these questions."

Correction and coding:

Code 1

Item 16: The fast withdrawal of the sea precedes the arrival of the tsunami. Such a withdrawal must be interpreted as a sign of danger

Item 18: People may have confused this withdrawal of the sea with a tide. However, the withdrawal announcing a tsunami happens in a few minutes whereas the tide takes several hours.

Item 20: In the event of tsunami alarm or of a fast withdrawal of the sea, it is necessary to go to higher ground so as not to be in danger (to climb on the top of a hill, on the roof of buildings) It is necessary to wait several hours, because the tsunami is composed of several waves, and to bring water and a radio

Items 17, 19, 21: Writing a correct sentence

Sequence 4: My county in the face of risks

This sequence was produced with the assistance of the association "Prevention 2000". It is based on the "Memo' Risks" methodology, pilot scheme of UNESCO, and "Good Practice 2010" for the United Nations (UN-ISDR).

Foreword

This sequence is intended for the study of a local risk, a priori, other than volcanoes, earthquakes or tsunamis (which we have already previously worked on): flood, forest fire, landslide, avalanche, cyclone, storm... The choice of the risk studied depends on the territory in which the school is located. If the area is not affected by any natural risk (rare case), then this sequence does not need to take place.

The project relates to natural risks... and not major risks in general (which include the technological risks). For a justification of this choice, read the teaching note at the beginning of session 4-1.

In addition to the risk itself, we will be interested in the way in which the inhabitants of the county perceive it.

Preliminary work for the teacher

For a start, the teacher must take note of the natural risks which exist in the area of the school, and choose one of them in particular, which will be studied in this sequence. A few weeks in advance, the teacher must make contact with the town hall (elected or technical departments), because several sessions will require the assistance of a qualified person. A standard letter is appended (sheet 43, page 220). The experience gained in the project "Memo' Risks" shows that, very often, the town hall is pleased to take part in such a project, just like the local press (in particular the county newspaper).

Nevertheless, if no one at the town hall can accompany the class, it will be possible to contact local associations, the prefectural services, the catchment manager, etc.

Memo

Summarized here are the various stages of this session, in order to facilitate its preparation.

Session	Heading	Date	Action
		1 month before starting	 Identify the risks in the county Identify the elected official and/or the technician in charge of major risks Send the letter (sheet 43)
		15 days before starting	 Confirm the choice of technical risk services Identify the iconography available in the town hall Get maps of the county Discuss, with the elected official, the evaluation of the investigation within the county (with the parents, publication in the newspaper of the city)
1	What is a major risk?		 Send the authorization form to get parents permission Confirm the attendance of the technical services for session 4-2
2	What are risks in my county?		 Inform the local press about the field trip Contact the fire station
3	Field trip		- Confirm the appointment with the fire station
4	Visit to a fire station		
5	Interim assessment		 Set the date for the final session with the elected official (known as "presentation of results" session) Establish contact for the report(s) in connection with the technical services
6	Survey of parents (development questionnaire)		 Confirm the reporting appointment(s) Distribute the survey to the parents of the pupils
7	How is risk perceived? (examination of the survey)		Invitation to the presentation of results: – parents of pupils – school principal – elected official and technical services – Education officials – persons asked to report – local press
8	Memory of the risk		
9	Prepare for the presentation		 Provide refreshments and decoration for the official presentation of results Send the invitations for the presentation of results
10	Presentation		

• Session 4-1: What is a major risk?

duration	1 hour
material	For each pupil, a photocopy of: • sheet 44 (page 221) • sheet 45 (page 222)
objectives	Know that a major risk is characterized by its rarity, violence and impact on a large scale, on people, goods or the environment
skills	Apply knowledge to understand questions related to environment and sustainable development, and act accordingly
main subject	Sciences
vocabulary	Hazard, stake, risk, disaster

Initial question

The teacher asks the pupils, collectively, to list all the natural disasters (or natural risks... that will be specified during the session) that they can think of. Here is the exhaustive list (according to categories specified by the Ministry for Sustainable Development), accompanied by remarks and examples which will be useful in the discussion with pupils.

Volcanic eruption	e.g.: mount Pelée in Martinique in 1902 (28 000 dead) or the Icelandic volcano Eyjafjöll in 2010 (economic stakes: civil aviation)	
Earthquake	Earth has on average a quake every 30 seconds; the majority are not felt e.g.: Haiti in 2010 (more than 200 000 victims) or Japan in 2011 (few or no direct victims of the earthquake)	
Tsunami	Flooding caused by a phenomenon such as: earthquakes, landslides, rock falls or meteorite e.g.: Sumatra 2004 (280 000 dead) or Japan 2011 (30 000 dead)	
Tidal wave	Flooding caused by a weather phenomenon: storm, cyclone e.g.: New-Orleans 2005 (Katrina) or the Vendée 2011 (Xynthia)	
Flood	The most widespread catastrophe in the world e.g.: Pakistan 2010 (20 million displaced people) or France, Var 2010 (25 deaths)	
Avalanche	30 to 40 deaths every year in France; carelessness is often the cause of deaths	

Cyclone/hurricane/ typhoon (same phenomenon which have different names depending on which area of the world)	The winds can exceed 250 km/h and the depression can cover a territory of several hundred km ² . Cyclones, like storms, are a given, each year, the name chosen by a scientific institute, alternates female and male names (Chris, Chantal, Cristobal, Claudette e.g.: Katrina (the 2005 USA)	
Storm	Winds greater than 90 km/h, and up to more than 200 km/h e.g.: Lothar and Martin (France 1999), Xynthia (France 2010)	
Tornado	Very localized and very violent phenomena, the winds can exceed 400 km/h e.g.: 2011 USA, several hundred tornadoes and more than 300 deaths	
Forest fires	A very common risk, often due to imprudence or mischief 22,000 ha burned on average each year in France	
Ground movement (underground cavity, rock fall, landslide very diverse and current phenomena)	The landslides include a set of movements, more or less violent, of the ground or underground, of natural or from human activity. The volume concerned is between a few cubic meters and a few million cubic meters. Displacement can be slow (a few millimeters per annum) or very rapid (some hundreds of meters per day)	

Teaching note

The concept of major risk is broader than that of natural risk, since it also includes the technological risk (examples: nuclear risk, dam rupture, transport of dangerous goods...).

The technological risks often require knowledge which is beyond that of primary school (nuclear, chemical...), and impartial information is more difficult to obtain as this information often comes from the owners themselves, or from "anti" organizations. Such subjects of study can then easily become polemic and cause anxiety for young children. For all these reasons, we prefer to restrict ourselves to natural risks in this project.

However, if technological risks are mentioned by the pupils, they must be taken into account. For example, we can propose to classify the various risks in two categories (to be defined by the pupils, but probably natural/technological).

Research (documentary study)

The teacher distributes sheet 44 (page 221) and the pupils must respond individually to the questions. This document shows two situations where the same natural phenomenon (such as a landslide) can have consequences on populations or not. In one case, we will speak of major risk, but not in the other.

Pooling

The collective discussion highlights the fact that a natural phenomenon, even violent and spectacular, is not necessarily a major risk.

The teacher then introduces the specific vocabulary:

• The natural phenomenon (for example, a cliff which threatens to collapse) is called a "hazard" (we look up words in the same family, such as "random", which include the notion of chance)

• People, environment or goods (equipment...) which are threatened are called "stakes" (a comparison can be made with sporting vocabulary: the stakes, are what can be lost or gained).

• "Major risk" is the contrast of a risk with its stakes. If there is no stake, there is no risk; for example, an earthquake in the desert does not threaten anybody.

• When the risk occurs, we then speak of "natural disaster".

The class develops as a definition of what a major natural hazard with emphasis on the following characteristics: rarity (it is not something that happens every day, but in exceptional cases), violence (impact on a large scale, speed...) and severity (for man, the environment or property). We can also write the definition that Haroun Tazieff gave: "The definition that I give of the major risk, is the threat to man and his direct environment, on its facilities, the threat that the gravity is such that society is absolutely overwhelmed by the immensity of the disaster."

The teacher distributes a second documentary sheet (sheet 45, page 222) to each pupil. This sheet presents various situations, for which the risk and the stakes must be determined, and if it is a major risk or not.

This work can be done collectively, the teacher ensuring the correct use of the previously defined vocabulary.

Situation	Aléa	Enjeux	S'agit-II d'un risque majeur ?
Children .	e" Esuption Volcanique	Les habitants environment maisons-usine	QUÍ
	incendie	le pekit engant habitation	man
Const.	innondition	Les habitations Les habitations L'asime	QU;
6	feu de gêret	Leo habitationo Pienvissonement	wi
Id and	accident	Le petit emgant	mon

Grade 5 class of the Pascale Cros School (Foix)

Conclusion and Written Records

The conclusion of the session is the definition of major risk established above. It is noted in the scientific notebook and is accompanied by the documentary sheets completed by the pupils.

Teaching note

The "scientific" concept of risk is a probability concept. The risk is the component of the hazard (probability that the event occurs, for a particular intensity) and vulnerability (foreseeable damage, effects of the risk on the stakes). Here, at primary school, risk will only be defined as the intersection between the risk and the stakes, without dwelling on calculations of probability.

• Session 4-2: What are the risks in my county?

duration	1 hour
material	
objectives	 Know the risk (or one of the main risks) to which the county is exposed Meet a member of municipal technical services, in charge of the prevention of risks
skills	 Know the main physical and human geographical characteristics of area where the pupil lives Apply knowledge to understand questions related to the environment and to sustainable development, and act accordingly
main subject	Geography

This session is dependent on the presence of an external speaker, if possible a member of the municipal technical services.

This person briefly presents the risks to which the county is exposed and then explains to the

pupils in detail the risk which was previously identified and chosen in consultation with the teacher.

During this session, the pupils will address questions to this speaker, regarding the nature of the risk, its gravity (in what way is it a major risk?), its frequency, stakes and geographical areas concerned, actions to be taken, etc. Preferably, these questions will have been prepared in advance by the teacher and the pupils.



Grade 5 class of the Pascale Cros School (Foix)

Teaching note: Care will have to be taken not to be distracted by questions about all the risks, but to keep the natural risk selected as the main discussion thread.

The information is noted in the scientific notebook. It will be reviewed again later to prepare for the final presentation of results.

At the end of this session, the teacher announces to the pupils that they will go on a school trip in order to see how this risk in the city is manifested.

The pupils have been instructed not to tell their parents (for now) what they did during this session (nor during the following trip)... because they will have to find out later if their parents are well informed and conscious of the risk, and if they know the stakeholders concerned as well as the actions to be taken.

Session 4-3: Field trip

duration	1 hour
material	For each group: • digital camera • map of the city
objectives	 Know the risk (or one of the main risks) to which the county is exposed Meet a member of municipal technical services, in charge of risk prevention
skills	 Apply knowledge to understand questions related to the environment and sustainable development, and act accordingly Know the main physical and human geographical characteristics of the area where the pupil live, locate them on maps of different scales Read and use texts, maps, sketches, graphics
main subject	Geography

This very important session will allow to the pupils to identify the risk which the county faces. It needs to be guided by a member of the technical services of the town hall (if possible, the same one who came to present the risk in the previous session).



Grade 5 class of the Jean - François Ortemann School School (Vendôme, risk = flood)

The pupils, in practical terms, discover in the field, how the risk is manifested: what the zones concerned are, what traces remain of past natural disasters, what to do to limit the impact of future events... The class write a mini-report (notes, photographs)... and can also invite a journalist from the local press (municipal newspaper...), who are often very interested in this kind of intervention, because it shows the civic and citizen dimension of the work performed in schools, and the co-operation of the municipality.





Classe de CM2 de Pascale Cros (Foix, risk = landslide)

Teaching notes

• In the event of a media involvement, it is advisable to respect the right to privacy, by asking for parental consent beforehand.

• If the teacher proposes to make a "risk map" (extension of session 4-5), it will be advisable to ask the pupils to identify and locate the stakes encountered during the trip on the city map.

• It is better to choose the "pupil photographers" before the trip. This will simplify the problem of transferring the photographs to the class computer (provide the necessary cables), and, also, the children are likely to concentrate more on handling the camera and picture taking than on the comments of the guide.

• Session 4-4: Visit to a fire station

duration	1 hour
material	Digital camera
objectives	 Meet one of the major players in crisis management: the fireman Know what behaviors to adopt in the event of a natural disaster
skills	• Apply knowledge to understand questions related to the environment and sustainable development, and act accordingly
main subject	Geography

During this session, the class visits a fire station. This second trip is complementary to the previous one.

In addition to the fact that it is very motivating for primary school pupils, it enables the understanding of how a natural disaster is managed, when it occurs, and what the right actions to be taken are. It also allows them to learn about the profession.



The teacher will have to be careful to explain to the firemen that this visit has a special purpose (it is not only about knowing what a fireman does on a daily basis), it is about understanding how the firemen intervene in a particular case (example: flood, if it is the risk chosen as subject of studies): which stakes are the most at threat, how to help sick people, people with reduced mobility or are very old, how the alarm is raised, etc.

In this case as well, the trip is preceded by some class work class during which questions that will be asked to the firemen are listed.

Grade 3/4 of the Nathalie Caissial School (Nancy)

Session 4-5: My county in the face of risk (assessment)

duration	1h 30 m
material	• Pictures and notes taken during the two class trips (field/station)
objectives	Make an assessment on the natural risk studied
skills	 Apply knowledge to understand questions related to the environment and sustainable development, and to act accordingly Know the main geographical, physical and human characteristics of the area where the pupils live, locate them on maps of different scales Read and use texts, maps, sketches, graphics Write a text of about fifteen lines (report) using knowledge in vocabulary and grammar.
main subject	Geography

Pooling

Back in class, after the involvement of a member of the municipal team and two school trips (to the field and fire station), it is time make an assessment of the known risk in the county.

Les risques naturels	Aléa, Risque el Enieu
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scrunt haite le ville. Aléa (riegan nuturol)	IN DAL
the elsis set for issues (pri post Airon anticet) . Par exemple , the petit pergen qui que avec un brigget, thou as not fields est Antendie et l'enjou est le petit pargan.	

Proposal (before correction) of the grade 5 class of the Jean-François Ortemann School (Vendôme)

The class produces one or more posters on which are noted:

- What the risks are (hazard, stakes).
- How it is manifested in the territory.
- What the authorities do to protect the population.

• How a possible natural disaster would be handled (collectively), and what are the actions to be adopted (individually).

These posters are first done in small groups (each group working on only one poster), then discussed, illustrated and finalized as a whole class. The concepts of hazard, stake and risk are revised.

The posters will be later shown during the presentation of the results of the investigation.

The teacher then explains to the pupils that they are now well informed about risk... but that it is perhaps not the case for everyone, including adults. To find out, we will conduct a survey with a questionnaire to parents of pupils.

Extension

Draw the risk map.

Take a map of the city, locate the school, and point out all the zones in which the risk can spread (easily flooded zone for example). Around the school, in a zone affected by the risk, the stakes are defined: all that is likely to be affected: inhabitants, public services, trade and other economic activity, equipment. This work can be performed using layers: a layer with the plan of the city, another with the risk, and the last with the stakes. The superposition of the layers gives a view of the risk on the county.

Session 4-6: Parent survey (Preparation of the questionnaire)

duration	1 hour
material	A computer (with word processing or spreadsheet)
objectives	Prepare the questionnaire which will serve as a support for the investigation
skills	Write a text of about fifteen lines using knowledge in vocabulary and grammar
main subject	Language

Initial question

The teacher explains that an important aspect in the prevention of risks is informing the inhabitants. For this reason, it should be known if the population is conscious of the risk, and if they know how to protect themselves.

The teacher explains why an investigation will be carried out on the adults. As a priority, the parents of pupils in the class... but also, why not, parents of other pupils in the school.

Teaching note

This investigation allows work on language (prepare a questionnaire, prepare a summary), in mathematics (compile and analyze data), as well as in civic education (communicate results to the elected officials, to parents...).

Research

The children are divided into small groups and must prepare a list of 5 questions to include in the questionnaire.

Previously, the teacher explained why these questions must be "closed questions" (they do not answer as they like). It must be multiple choice questions, or questions to which the answer is either "yes", "no" or "I do not know".

The questions relates only to the risk studied, and on the perception that the adults have of local risk rather than on their "scientific" knowledge.

To guide and direct the reflection, the teacher can propose a first question, for example: "Do you know if the county has ever experienced a natural disaster (of the type that was studied)?" or "Do you think that this risk is serious/not serious? frequent/not frequent?"...

Pooling

Each group dictates its questions to the teacher, who makes the whole class discuss them. The difficulty lies in having to limit the number of questions, to avoid having too much data to analyze.

Teaching note

If the questionnaire is addressed to the parents of the pupils in the class, it can contain a dozen questions. If it needs to be disseminated more widely (all parents of the school, for example), then it must be restricted to 5-6 questions.

The teacher ensures that the formulation of the questions is correct and allows, indeed, a closed answer. He supervises the collective completion of the questionnaire.

Below, is an example of questionnaire used for the "flood" risk (caution, it is only an example: the questionnaire must be designed by the class!)¹⁴.

Questionnaire answered by:	Date:	
Do you know who is in charge of informing you about flood	risk? yes 🗌 no 🗌	
Is it: The town hall The general council The region The prefecture The local press Local associations The ministry for Sustainable Development?		
Do you know what the communal information document on	major risk (DICRiM) contains? yes 🗌 no 🗌	
Do you think that your city can be flooded? yes	no 🗌 do not know 🗌	
Do you know if this has already occurred in the past?	yes 🗌 no 🗌	
Do you think you are better protected today than yesterday	? yes□ no□ do not know□	
Do you think that your road can be flooded; several times a year a once a year a once a year a once a century a even less than that a		
Does that worry you? much 🗌 a little 🗌 not at all 🗌		
Do you remember having received information on this subject	ct? yes 🗌 no 🗌	
Would you wish to receive more information on this subject	? yes 🗌 no 🗌	
Do you know ways to protect yourself?	yes 🗌 no 🗌	
Is your basement converted?	yes 🗌 no 🗌 do not know 🗌	
When an alarm sounds, should we: collect the children from school \Box ask someone near to the school to collect the children \Box telephone the school to know what to do \Box remain at work or at home?		

Clean draft

The teacher can draft the questionnaire in a clean version (word processing or spreadsheet), or ask some pupils to do it (plan for an additional half hour).

^{14.} Other examples of questionnaires can be found on the site www.memorisks.org

Session 4-7: How is risk perceived? (analysis of the survey)

duration	1 h 30 m
material	For the class: • completed questionnaires • (optional): a computer with spreadsheet • a poster
objectives	Compile and interpret the results of the survey on the perception of risk by the residents
skills	 Express and use the results of a research using scientific vocabulary verbally or in writing Apply knowledge to understand questions related to the environment and sustainable development, and act accordingly
main subject	Sciences

Pooling

The analysis of the survey is done collectively. Because of the amount of data collected, we advise the teacher to proceed, not sheet by sheet, but question by question (for example: "Raise your hand, those who have a "yes" answer to question 1").

Thus, the results gradually appear in the table. It can later be put on a spreadsheet, or directly entered by the teacher or the pupils. This is not mandatory, since the treatment that is made of the data is elementary: it is limited to counting the number of "yes" or "no" answers... and, eventually, to calculate percentages (extension into mathematics).

Written records and conclusion

The results are noted in the scientific note book, and the class interprets them collectively.

Are our parents (or neighbors...) aware of the risks? Do they know who is responsible for their protection? Do they know the means implemented to prevent this risk? Do they know what to do in the event of a natural disaster?

According to the nature of the risk, and reality (was there a natural disaster recently?), the results can be very varied.

Teaching note

The written evidence must be as complete and precise as possible, because they will be used, later, to prepare a poster for the presentation of results sequence.

The memory of past events is essential to understanding present risks; the testimony of the elders often constitute a wealth of information. It is the purpose of the following session.

Session 4-8: Memory of risk

duration	1 hour
material	For the class: • a digital camera • a dictaphone or a camcorder
objectives	Question a person with a memory of a natural disaster which had occurred in the county
skills	Apply knowledge to understand questions related to the environment and to sustainable development, and act accordingly
main subject	Geography

Teaching note

This session, interesting if only for its intergeneration dialogue, becomes essential if no natural disaster has been recorded in the recent past. The population could then have forgotten what the risks are, and how to act. The memory of the "elders" is then very instructive.

The teacher can ask for support from the town hall which sometimes have a good idea of the people to be contacted.

If the last manifestation of the risk is too long ago to have any hope of collecting the memory of the event, substitute reports can be suggested by the town hall (community policeman, a major player in prevention...).

Preparation

A few days before, the teacher speaks to the pupils about the possibility of interviewing people who have witnessed such disasters in the past. The question then will arise about knowing who to talk to. The possibilities are many: grandparents or great-grandparents of the pupils, residents of the old folks home, etc. The important thing is that the people live in the county (or lived there at the time of the event).

The class therefore has identified one or more persons to be interviewed, and has prepared some questions.

Interview

On D-day, this person is invited to come and talk about their experience to the class. The pupils question them about the memory they have of this event. If the interview is relevant, one witness is enough; if some grey areas remain, several witnesses can be interviewed.

The interview leads to recordings and photographs, which will be used during the final presentation of results (following session).

• Session 4-9: Preparation for the presentation of results of the investigation

duration	1 hour
material	
objectives	Prepare the presentation of results of the investigation (questionnaire, interviews, visits)
skills	 Write a text of about fifteen lines (report) using skills and knowledge in vocabulary and grammar Apply knowledge to understand questions related to the environment and sustainable development and act accordingly Use information technology to present the work
main subject	Language

Teaching note

The presentation of results (including this preparation sequence) constitutes the collective assessment of this session.

The investigation carried out on the risk in the county comprises several elements:

- A report of the site visit.
- A report on the visit to the fire station.
- The interpreted questionnaire of the parents of pupils.

• One or more interview(s) of witnesses of past disasters (or someone who acts on risk prevention).

- The posters previously produced.
- Option: a mapping of the risk in the county.

All these elements must now be formatted in order to be communicated in a coherent way.

The presentation of results will not only be addressed to the parents who were interviewed, but also to the various people concerned with local risk management. They must therefore also present at the same time the purpose, the methodology and the results.

The principal objective of this presentation of results is not to explain the risk in itself, but rather the way in which this risk is perceived by the population.

All the supporting evidence is allowed: posters, slide shows, photographs, videos... A work in visual arts can enrich this summary.

Teaching note

During the presentation of results, the products of the pupils will be communicated to the parents, the representatives of the town hall, etc. This presentation of results must be as attractive as possible, in form, but what about the content? Is it necessary to correct the ideas of the pupils or to leave them just as they are? Originality, and the recognized benefit (in particular by UNESCO) of the "Memo' Risks" methodology is based on the contribution of the young people for the preventive information of the population. For this reason, it is important that the presentation of the risk (hazards, stakes, preventive devices set up...) by the pupils is validated, at least by the teacher, and if possible by the person who has come to present this risk in class.

On the other hand, the investigative work completed by the pupils with their parents, or with the elders, can be communicated "as is", with the interpretations which reached consensus in the class. These interpretations, even if awkward, are the children's work and thus are of interest.

(Assessment of sequence 4: Presentation of results

duration	1 hour
material	
objectives	Communicate the results of the investigation carried out in the county, about the perception of risk which its inhabitants have
skills	 Express ideas verbally as well as in writing using suitable and specific vocabulary Speak respecting the appropriate language level
main subject	Language

The presentation of results of the investigation, prepared during the last part of this session, is the assessment because it offers the opportunity to the pupils to apply the knowledge obtained throughout this project.

It cannot be done over school time, in that as it is done in the presence of parents (one evening, one Saturday morning, etc). This presentation of results can be a very friendly meeting between the education stakeholders, the elected officials, the parents and the children.

It is important to give a publicity to this citizen work, and to invite the greatest possible number people for this presentation of results:

• Parents of pupils:

- At least, those who were interviewed... and if possible other parents from the school.

• A representative of the town hall (preferably the mayor, or an elected official):

- They come to comment on the investigation, to explain what the town hall does in terms of prevention of the studied risk, and to answer the questions of the parents who are also voters and towards whom they have a duty to inform.

- If the county is subjected to major risks other than that studied by the class, the representative can mention them briefly.

• The school principal:

- In the same way as the representative of the town hall, the principal has the responsibility (and the legal obligation) of the installation of the PPMS in the establishment.

- He presents the PPMS and answers the questions of the parents about safety in the school.

• Members of the education authorities:

- The inspector of academy or the team in charge of risks: the "hygiene and safety inspector", the "major educational risks coordinator" as well as the "ESD coordinator".

- The district inspector.

• The local press

The presentation of results is done by the pupils, who exhibit the work they have completed (interviewing of parents, and others...), not with the aim of giving a talk about risk itself, but about the way in which the inhabitants of the county perceive it.

Then, the various speakers comment on this investigation, answer the parents' questions and present the preventive actions implemented (by the town hall, the school, etc).



Grade 5 class of the Jean-François Ortemann School (Vendôme)

An Internet site dedicated to the project

To acompany the class project

The project "When the Earth Rumbles" has its own website intended to accompany its implementation in class.



http://www.quand-la-terre-gronde.fr

The site allows classes to communicate, exchange and help each other, thanks to many collaborative tools. Each class can attest to the progress of their work on a blog, put their work online, whether they are text or multimedia (image galleries, videos...), consult and comment on the work of other classes...

A forum allows the teachers to question their colleagues and the scientific and teaching consultants of the project, and thus to find help and assistance in the implementation of this work. Finally, an interactive map makes it possible to come into contact (twinning, visits, correspondence...) with other classes registered in the project, near home, or more distant (it is not rare that the projects of La main à la pâte are implemented in classes in other countries, whether they are French schools or local schools).

Teacher space

The space dedicated to teachers enables them to be informed about this project and to register. This registration allows them to access, in addition to the collaborative functions described above, the complete scientific and teaching documents:

• the teaching module is completely online;

• the documents to be used in class can be downloaded (and projected or printed for a better quality than a photocopy);

• many videos are available to supplement the paper documents (testimonies, experiments...). These videos are accessible within each sequence and have the same number as the sequences in which they are mentioned.

Multimedia animations (pupil space)

In this space, the pupils can freely access 6 multimedia animations specifically produced for this project by La main à la pâte and the Cité des sciences et de l'industrie.

They can be used by children from 8 to 12 years as a complement to the teaching module, but also independently.


Bibliography

Scientific resources

• Volcans du monde, seismes et tsunamis, Jacques-Marie Bardintzeff, Orphie editions, 2010. Clearly and well illustrated, this book answers all the questions about volcanoes, earthquakes, tsunamis.

• Les Tremblements de terre en France. Hier, aujord'hui, demain, Jerome Lambert, BRGM, 1997. Through one surprising trip to the past, this book seeks to explain the mechanisms of earthquakes, their effects, and how to be protected.

• *Peut-on prevoir les tsunamis?*, Helene Hébert and François Schindelé, editions Le Pommier, October 2011. This book explains, in a precise and concise way, what a tsunami is and how to respond to the risk.

Teaching resources

http://www.edusismo.org

Many documentary and teaching resources to study earthquakes in school.

http://www.memorisks.org

Memo' Risks is a project intended to educate pupils, and their families on major risks. The site offers class testimonies which can be extremely useful when studying the risk present on one's county.

http://www.disasterscharter.org

Dedicated to the international charter "Space and major disasters", this site offers among other things, a teaching file for primary school and college regarding the use of space imagery in this context (produced by the ESA).

Documentary resources

• http://macommune.prim.net

This site of the ministry for Ecology gives, for each county, the list of the decrees on natural disasters and the preventive measures taken by the local authorities.

• <u>http://www.sisfrance.net</u> and <u>http://www.tsunamis.fr</u>

These two sites, developed by the ministry for Ecology, refers to earthquakes and tsunamis which have hit the French territory throughout History.

http://www.prevention2000.org

The association Prévention 2000 proposes teaching resources for various types of major risk.

• http://sertit.u-strasbg.fr

The SERTIT proposes a cartography service of very good quality, updated constantly, which makes it possible to work on natural disasters using satellite images. The data is classified by date and type of disaster.

Children's literature

• Les Catastrophes naturelles, Pierre Koelher, Fleurus editions, 2007.

This work draws an objective picture of the natural disasters which threaten our planet and explains them in an accessible way.

• Volcans, Sara, editions Thierry Magnier, 2002.

A wordless cartoon signed by Sara, in a unique graphic style. Always playing with cut papers, Sara tells, in this cardboard album, the story of a volcano, seemingly quiet, which suddenly erupts, spitting out red balls of fire.

• *Nuit sur l'Etna,* Fabian Gregoire, L'École des Loisirs, 2005.

Silvia's grandmother lives in a house located on a slope of Etna, the frightening Sicilian volcano. To live on the slopes of a volcano present advantages when vegetables are cultivated, as they grow in a particularly fertile ground. But if the volcano awakes, the risks are great, for vegetables as well as for the men. But Etna sleeps with only one eye closed (or a crater).

• Tremblements de terre, Leïla Haddad and Vincent Jagerschmidt, Milan jeunesse, 2007.

Plate tectonics, Earth tremor, Richter scale... Earthquakes fascinate almost as much as they terrify. There are several kinds of earthquakes. With real and often spectacular examples, this book teaches how to differentiate, understand the phenomena which cause the earthquakes and assess their consequences.

• *Le Demon de la vague,* collective, Flammarion-Père Castor, 2005.

A Vietnamese tale telling the story of a village at the edge of the water, which during each night of the full moon is devastated by an enormous wave which is said to shelter a demon.

• Les Volcans et leurs eruptions, Jacques-Marie Bardintzeff, Le Pommier, "Les minipommes", 2010. In 64 pages, discover what a volcano is, what causes an eruption, when the eruptions occur, how many active volcanos still exist... also what the work of a volcanologist is.

Thanks

The teaching guide "When the Earth Rumbles" is the result of a collaboration between the *La* main à *la* pâte team, teachers, trainers, educational specialists and scientists.

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Appendices : Documentary sheets

The pages which follow contain the documents to be photocopied for the various sessions of the teaching module, with the associated instructions. These "sheets" are also available in color on the project's website (see page 174), in order to be downloaded, printed or projected rather than photocopied.

Sheet 1 - Session 1-1

The story of Vulcan

According to Roman mythology, Jupiter, the king of the gods, married his sister Juno. They had a son by the name of Vulcan, who was so ugly that he was driven out from the sky by his mother and was obliged to hide underground. He was very gifted in working metal, he installed immense forging mills under Mount Etna and, with the assistance of Cyclops, manufactured Hercules' invincible armour, Neptune's trident, Jupiter's lightning, as well as many weapons and jewels for the other gods and goddesses.

He thus became the god of fire and metal and was recognized by all. Vulcan, ugliest of all the gods, deformed and lame, received in marriage Venus, the most beautiful of the goddesses. She did not care for such a husband and was often unfaithful. This caused Vulcan to go into terrible rages, causing violent explosions of the Etna, sending large flaming jets and clouds of hot ashes into the air, and pouring out torrents of molten rocks.

Nowadays, Vulcan is the patron of blacksmiths.

Kilauea (Hawaii: an eruption that has been going on for nearly 30 years!)

Kilauea is a volcano located on the island of Hawaii, in the Pacific Ocean. It is regarded as the most active volcano in the world. Its last great eruption started in 1983, and is still not finished!

In January 1983, cracks opened on the sides of the volcano, letting very liquid lava escape. A few months later, a lake of lava was formed and, for 3 years, there was an imposing spectacle of fountains of lava going up to hundreds of meters high.

Gradually, these fountains stopped, and were replaced by a continuous overflowing of lava. This lava formed rivers which flow at 50 km/h along the gentle slopes of the volcano, and into the ocean. Since 1989, most of the lava flows are via underground tunnels, but, from time to time, it flows on the surface.

When it arrives in the ocean, the lava, until then heated to more than 1 000 °C, cools suddenly and forms large blocks. This new rock, formed over the ocean, gradually increases the size of the island of Hawaii. Since the beginning of the eruption, the island has increased by 220 hectares, while the lava covered more than 110 km² of ground, destroying hundreds of buildings. Fortunately, the population had time to be warned and are not in great danger.

Mount Pelée (Martinique: a fatal eruption in 1902)

The Mount Pelée is the only active volcano of the island of Martinique, sadly known for causing the death of 29 000 people during its eruption on the 25th April 1902.

Yet there were warning signs! Two months earlier, in February, some fumaroles had appeared at the top, but nobody was worried because it had happened often in the past without announcing an eruption.

On the 23rd April, some ashes fell from the volcano, and low rumblings were heard. On 25th April, an explosion projected many bombs (rock projectiles) and let an immense cloud of ashes escape, without causing a lot of damage. In the days which followed, ashes covered the surroundings of Saint-Pierre, but nobody worried! The curious even went and climbed the steep slopes of the volcano to observe it more closely. From the 2nd to the 7th May, violent explosions resounded in the city and could be heard up to the Guadalupe, 150 km away! A plume of black smoke rose from the volcano. The inhabitants started to worry, boats did not dare approach the port.

It was on 8th May that the drama started. At 8:02, a volcanic cloud, formed of ashes, burning dust and gases (heated at more than 1000 °C!), descended the slopes of the volcano at more than 500 km/h. In one minute, the whole city was submerged and consumed. Twenty-eight thousand people died instantly. Only two people survived: Louis-Auguste Cyparis, a prisoner sheltered between the walls of his underground dungeon (who was still seriously burned), and Leon Compère-Léandre, a shoe-maker who lived outside the city.

The eruption of Mount Pelée lasted several months, with new explosions and new volcanic clouds, killing 1000 more people in Morne-Rouge, 6 km from the already devastated town of Saint-Pierre.

It was the most serious volcanic disaster of the 20th century. This volcano will surely awake again, that is why it is today one of the most monitored and the most studied volcanoes in the world.

The piton de la Fournaise (Réunion: an eruption almost every year!)

The piton de la Fournaise, located on the island of the Réunion, in the Indian Ocean, is the most active French volcano: it erupts approximately once a year! However, it is not the most dangerous, because these eruptions are rather "quiet".

In April 2007, the piton de la Fournaise had a particularly intense eruption. For several months, some cracks had appeared at the top, causing mini-earthquakes and lava to escape. On 2nd April, at 10 o'clock in the morning, the eruption itself began with a crack which appeared at low altitude, emitting spectacular fountains of lava: the melted rock, at very high temperature (more than 1000 °C), was ejected more than 100 meters high.

The inhabitants of the village of Tremblet feared that the lava would flow towards them, but were quickly reassured: the flow took another direction (a few days later, they were evacuated in preparation for a new flow, but, yet again, it was a false alarm). This extremely fluid lava descended the slopes of the volcano and advanced sometimes at 60 km/h.

The highway (RN2) was cut off for over more than 1 km... covered in places by 40 meter thick lava. Upon reaching the ocean, the lava solidified and formed a platform of more than 200 m wide, thus increasing the island of the Reunion by 45 hectares.

The eruption, which continued until the 28th April, did cause any deaths, only some casualties, in particular teenagers hospitalized because of toxic gases emitted by the volcano.

Mount Saint Helens (United States, an devastating eruption in 1980)

Mount Saint Helens, in the United States, was called "the mountain of fire" by the Indians. It had a devastating explosion on 18th May 1980.

After more than a century of inactivity, on 27th March 1980, Mount Saint Helens awoke: a column of smoke escaped from the top. A small crater was formed, some explosions of ashes and vapour started on 22nd April, while small earthquakes were recorded. This phenomenon, which was repeated over several days, attracted the curious, while at the same time the authorities ordered evacuation. About sixty people, wanting at all costs to closely observe the birth of a new eruption, paid for it with their lives.

On the 18th May 1980, at 8:32, Mount Saint Helens erupted violently. Within a few seconds, the whole northern side of the volcano exploded in an enormous ash cloud. A rock avalanche descended the steep slopes at nearly 250 km/h. The volcano was decapitated: its altitude went from 2 950 meters to 2 549 meters in an instant, leaving an immense crater in the shape of a horseshoe.

The quantity of ashes was such that cities located within 150 km of the volcano were plunged into darkness. Millions of trees laid on the ground, knocked down by the shock wave (in places, the winds exceeded 1000 km/h!) and carbonized by the pyroclastic surge formed from the volcanic ashes, dust and burning gases. In addition, the intense heat released by the eruption dissolved snow present at the top of the volcano. This water, mixed with ash, caused large mudslides, the lahars, which completed the destruction.

The eruption, which lasted 9 hours, was very spectacular but had caused only a few deaths, because of the evacuation measures which had been taken.



Sheet 5 - Session 1-4

Birth of a volcano: Paricutin

Dioniso Pulido was a Mexican peasant, owner of a field located not far from the village of Paricutín, approximately 320 kilometers to the west of Mexico City.

One fine summer day in 1942, while he was cultivating corn, he discovered a large hole with a depth of one and a half metres in his field. In spite of the surprise, Dioniso did not worry and continued his activity.

Dioniso continued to work his fields until the 20th February 1943, when, after having heard rumblings coming from the ground, he saw a long crack of a few tens of meters letting ash escape in the middle of his furrows. The inhabitants of the village close to San Juan Parangaricutiro had also felt these rumblings as well as small earthquakes.

Upon arriving in his field the next morning, Dioniso Pulido discovered a cone of ten meters high. A few hours later, after many explosions, the cone measured nearly 30 meters in height and lava started to run out of this new volcano which had just been born, to which was given the name of the nearby village: Paricutin.

During the following days, the volcano continued to grow: 106 meters in one week, 148 meters in one month, 190 meters in three months, to reach 336 meters at the end of one year.

During this time, Paricutin ejected ashes and lava flows.

In July 1944, one of which destroyed the village of San Juan Parangaricutiro by covering all the houses. Only part of the church was spared. The people were evacuated, including in September 1944, when the village of Paricutin was buried by the ashes and lava.





The eruptions continued for eight more years. In March 1952, after nine years of eruption, the Paricutin cone measured 424 meters.

Sheet 6 - Session 1-8

Instructions: This map shows currently active volcanoes on Earth. How are they distributed?





Sheet 8 - Session 1-8

Instructions:

The Earth's crust is divided into plates which move against each other. 270 million years ago, all the continents were one "supercontinent" called Pangea. Since then, these continents slowly "drifted" apart (at a speed of a few centimetres a year).

The drawings below represent the Earth at different times: -270 million years, -200 million years, -135 million years, -65 million year (time of the disappearance of the dinosaurs) and today. They are placed in random order: arrange them in the right order!



Sheet 9 - Session 1-9

Instructions:

1. Observe the great eruptions of Vesuvius from ancient times. Calculate how much time has elapsed between two successive eruptions.

2. Observe the last eruptions of Mount Pelée (Martinique).

- Calculate how much time has elapsed between two successive eruptions.
- How long has it been since the volcano erupted?
- Could it awake?
- 3. Observe the last eruptions of the chaîne des Puys (Auvergne).
- Calculate how much time has elapsed between two successive eruptions.
- How long has it been since the last eruption?
- Could there be eruptions in Auvergne again?

Name of the volcano	Date of eruption
	- 16 000
	- 14 000
Vesuvius (Italy)	- 6000
	- 1660
	79 (destruction of Pompéi)
	1792
Maunt Daláa a (Martiniaua)	1851
Mount Pelee e (Martinique)	1902
	1929
	– 7700 (puy de Dôme)
Chaîna das Duus (Auvenanc)	– 7200 (puy Pariou)
Chaine des Puys (Auvergne)	- 6300 (puys of la Vache et Lassolas)
	– 4700 (lake Pavin)

Sheet 10 - Session 1-10

Instructions:

• How long does a volcanic eruption last?

• How can you answer this question?

Name of the volcano	Date of eruption	Duration of the eruption
	9 December 2010	15 hours
	14 October 2010	17 days
	14 December 2009	7 hours
	30 March 2007	26 days
	30 August 2006	125 days
	30 May 2003	226 days
Piton de la Fournaise (Reunion)	7 November 1963	15 days
	27 August 1992	28 days
	3 February 1981	92 days
	11 March 1959	149 days
	6 July 1955	254 days
	29 Aril 1917	1 days
	14 July 1787	58 days
Etna (Italy)	1991-1993	473 days
	1983	132 days
Mount Pelée (Martinique)	8 May 1902	2 months
Voguvius (Italy)	1631	11 hours
	79	19 hours
Laki (Iceland)	1783	245 days
Tambora (Indonesia)	1815	7 days
Krakatoa (Indonesia)	1883	23 hours
Santa Maria (Guatemala)	1902	35 hours
Pinatubo (Philippines)	1991	9 hours
Mount St. Helens (United States)	1980	9 hours
Kilauea (United States)	1983	29 years (not finished yet)

Sheet 11 - Assessment of sequence 1 (part 1)

Text 1: Story of the eruption of the Piton de la Fournaise

On the night of the 24th to the 25th March 1977, after a 5 month rest, a crack opened at an altitude 2000 m. A small quantity of very fluid lava was emitted in the form of projections, then the activity stopped.

On 5th April, a new crack appeared following a large explosion and fountains of lava spouted up to 20 m high. On 8th April, a very large fluid lava flow escaped through a 500 m long crack and descended the slopes of the volcano. 800 people of a threatened village were evacuated. On 9th of April, a large flood of lava descended in the direction of the village of Piton-Sainte-Rose and 2 500 people were evacuated. The next morning, the river of lava reached the sea. Flows advanced into the sea and the island increased by 30 000 m².

On 13th April, explosions announced the opening of a new crack through which a very large lava flow escaped. About twenty houses of Piton-Sainte-Rose were destroyed, and the church was damaged.

On the 16th of April, the emission of lava stopped, the piton de la Fournaise calmed down until the next eruption.

From Maurice Kraft, "La Fournaise"

Text 2: Story of an eruption of Mount Pelée

In February 1902, fumaroles appeared at the top of the mountain. On 25th April, following an explosion, an enormous cloud of ashes escaped from a crater close to the top. The surroundings of the village of Saint-Pierre were covered with a grayish powder.

On 2nd May, violent explosions awoke the city. Above the volcano an enormous ash cloud went up several kilometers. On 7th May, incandescent blocks of very viscous lava were projected from the crater and ash falls increased.

The following day, a volcanic cloud descended the slope of Mount Pelée at a speed of 500 km/h and destroyed Saint-Pierre. The 28 000 inhabitants were instantaneously killed.

From the 20th to the 26th May, a less intense volcanic cloud occurred and at the level of the crater the formation of a rocky cone of approximately 100 meters in height could be observed. This cone continued to grow reaching 400 meters on 31st May: it was a genuine needle. A few days later, a volcanic cloud destroyed the needle and, on the 30th August, a new much more intense volcanic cloud devastated all in its passage and killed 1000 inhabitants of Morne-Rouge, a village located at 6 km of Saint-Pierre.

Other ash clouds occurred during the remainder of the year 1902. In mid-October, a new solidified needle was formed in the crater.

According to Research, July-August 1987

1.	Complete	the table	from th	e two	texts	that	you	just read.	
----	----------	-----------	---------	-------	-------	------	-----	------------	--

Name of the volcano	Piton de	la Fournaise	M	ount Pelé	ée		
Materials issued by the volcano (lava, ashes, dust, gas,)							
Consequences of the eruption							
				ltem 1	0	1	9
2. For each following sent	ence, tick the i	right answer.					
The piton de la Fournaise i	s a volcano	🖵 red	🖵 grey				
The eruption of the piton de	e la Fournaise is	effusive	• explosive				
Mount Pelée is a volcano		🗅 red	🖵 grey				
The eruption of Mount Pel	é e is	effusive	explosive				
				ltem 2	0	1	9



Sheet 13 - Assessment of sequence 1 (part 3)

7. A class that was working on volcanoes decided to carry out the two experiments below to understand what happens during a volcanic eruption. In experiment 1, ketchup is placed in a U-shaped tube. Water is poured into the left arm of the tube then an effervescent tablet is added before closing the left arm of the tube with a stopper. The same device is reproduced in experiment 2, but the ketchup is replaced by mash.



Experiment 2



In order to establish the link between this experiment and a true volc	anic erupt	ion,	spe	cify:
 What the effervescent tablet represents: What ketchup and the mash represent: 	ltem 9	0	1	9
8. Specify what the pupils of this class want to test by using ketchup in mash in experiment 2. (Write a sentence)	the exper	imer	nt 1 a	and
	Item 10	0	1	9
	Item 11	0	1	9
 9. Which experiment represents The eruption of Mount Pelée: The eruption of the piton de la Fournaise: 	Item 12	0	1	9
 10. What will it happen to the ketchup and the mash, when the effert to act? Write what you think (your hypothesis). (Write a sentence) For the ketchup: 	vescent ta	blet	beg	jins
• For the mash:				
	Item 13	0	1	9
	Item 14	0	1	9

Sheet 14 - Assessment of sequence 1 (par	rt 4)
11. Here are the results of the experiments after a few seconds:	
Experiment 1 Experim	nent 2
What do you observe? (Writes a sentence)	
• writhregalos to the ketchup, in experiment i:	Itom 15 0 1 0
	Item 15 0 1 9
• With regards to the mash, in experiment 2	
 12. Are these observations in agreement with your hypothesis for q Explain your answer by writing a sentence? 13. Starting with your observations at the end of the experiment ar in the first two documents, we propose three conclusions. For each this conclusion is: "true", "false" or impossible to make ("I cannot know appropriate box. 	Item 17019Item 18019Item 18019Ind the information read one of them, indicate if pow"). Each time, tick the
 a) When the lava is very viscous, it flows with great difficulty. When of the volcano, it can then form a needle of lava. This conclusion is true This conclusion is false I cannot know 	en it leaves the chimney
 b) An explosive eruption as that of Mount Pelée is characterized by This conclusion is true This conclusion is false I cannot know 	a very fluid lava.
 c) In an effusive eruption like that of the piton de la Fournaise, the down the slopes of the volcano. This conclusion is true This conclusion is false I cannot know 	e lava is fluid and flows Item 19 0 1 9



Sheet 16 - Assessment of sequence 1 (part 6)

17. In spite of the risk that the volcanoes represent, some people live near them. Give two possible reasons that may explain their choice. (*Write a sentence*)

	ltem 24	0	1	9
	ltem 25	0	1	9
18. How should people react in the event of volcanic eruption?				
Tick the right answers.				
□ They must listen to the radio know the instructions to be followed.				
They must telephone the members of their family to know how the	y are doin	g.		
They should prepare their suitcases with as many items as possible	so that t	hey	are	not
destroyed by the eruption.				
They must plan a suitcase containing the bare essential (identity	docume	nt, o	drinl	king
water radio Jamp dust protection masks)		· ·		
water, radio, lamp, dust protection masks).	Item 26	0	1	9

Sheet 17 - Session 2-1

Instructions: Read the documents below and answer the following questions:

- How long does an earthquake last?
- What are the consequences of an earthquake?
- What are the major dangers for the population?

MONTHLY REPORT

EMERGENCY IN HAITI

Haiti devastated by an earthquake



A TERRIBLE

CATASTROPHE

The Haitian cities most

affected by the earthquake of

January 12th are the capital Port-au-Prince, Jacmel and

Experts estimate that up to 75% of the capital will have to be

Hundreds of thousands of

Haitians were killed or wounded

following the earthquake (see article opposite). In total, 113 people were extricated still alive from the ruins by foreign rescue

January

Port-au-Prince has experienced

about 50 aftershocks (weaker earthquakes) within the space of

two weeks. These aftershocks are difficult for the population to

12th.

Léogâne.

rebuilt.

teams.

endure

On January 12th, an earthquake shook Haiti, one of the world's poorest countries.

On January 12th, the earth shock violently at Port – au one of the world's poorest countries. This country is located in the west of the island of Hispaniola in the Caribbean Sea (between South and North America).

The magnitude (strength of this earthquake was measured at 7.3 on a scale called the Richter scale which is graduated from 1 to 9). When there is an earthquake, the shocks are felt strongest at the epicentre (the place located above the point the earthquake started). In Haiti, the epicentre was located 15 km from the capital, Port-au-Prince.

One third of the city's buildings collapsed after the earthquake. Other Haitian towns were affected. About 90% of the buildings in Léogâne (a city located 30 km southwest of Port-au-Prince) were destroyed. Estimates for the number of casualites range from 170,000 to 200,000 killed and more than



250,000 injured. As everything is in ruins, more than one and a half million people are homeless.



paru le : Vendredi 1 Avril 2005 journaliste : Y. Pigenet expert : E. Jeanvoine

Earthquake – resistant buildings

During an earthquake, it is mainly the collapse of buildings which causes the most victims. By understanding the behaviour of buildings during an earthquake we learn how to construct edifices which do not collapse – a task being carried out since 1968 by the Mechanical Seismic Studies Laboratory (CEA Saclay).

On October 17th 1989, California suffered the effects of an earthquake of a magnitude equivalent to that recorded in Armenia a year before. However, the consequences of the two catastrophes were different. There were actually 72 fatalities in California as against more than 25,000 in Armenia. The generalisation of paraseismic buildings in San Francisco and their quasi-absence in Armenia largely explain this considerable difference in human death tolls.

Sheet 18 - Session 2-1

Instructions: Read the documents below and answer the following questions:

- How long does an earthquake last?
- What are the consequences of an earthquake?
- What are the major dangers for the population?

Japan hit hard



A very powerful earthquake hit Japan, causing a tsunami which swept away everything in its path in the northeast of the country. The Pacific Ocean area is on the highest alert. It was the middle of the afternoon in Japan, and the early hours of the morning in France. The earth started to shake violently for more than two minutes, an eternity. The tremor was the most violent ever experienced in Japan for more than 140 years. It was measured at 9.0 on

the Richter scale. Although Tokyo appears to have resisted the tremors well, several cities on the country's east coast were submerged by waves more than 10 meters high in the following hours. The earthquake, located underwater at 300 km off the coasts, caused an enormous tsunami

The earthquake, located underwater at 300 km off the coasts, caused an enormous tsunami (tidal wave). Striking images of waves hitting the coasts and carrying off everything in their path were

Striking images or waves nitting the coasts and carrying on everything in their path were broadcast on television, showing the scale of the catastrophe. By 3.30 p.m., the number of casualties was 285 dead and 350 missing, according to figures

By 3.30 p.m., the number of casualties was 285 dead and 350 missing, according to figures released by the police. This casualty figures are probably going to rise. In the coming hours, the tsunami is forecast to hit the coasts of several other countries from

In the coming hours, the tsunam is forecast to nit the coasts of several other countries from Indonesia to South America, as well as Australia, which has issued warnings for the evacuation of people from the coastal areas.

Annecy still a-tremble

During the early hours of Monday, Haute-Savoie (France) suffered a 5.2 magnitude earth tremor, one of the strongest in the region in more than 30 years. The earthquake, which occurred at 2.13 a.m., was felt as far away as Grenoble, Besançon, Belfort and Lyon. The epicenter was located at about thirty kilometers to the northeast of Annecy. Aftershocks have been recorded and more may occur.



In Annecy and the surrounding area, in addition to a lightly injured man, there is a lot of material damage – collapsed chimneys, broken glass, damaged cars and vehicles.

	Sheet 19 - Session 2-2
Ins ear	tructions: Arrange in order (from least to the most serious) the effects that an thquake can have.
~	Some cracks appear on the buildings.
	All those who are asleep awake, objects fall.
	The windows and the tableware shake, the chandeliers swing.
	Only a few people awake who feel some weak vibrations.
	The inhabitants do not feel anything. The seism is detected only by the most sensitive instruments.
	Cities are razed and landscapes modified (cracks in the ground, rivers displaced).
-	Buildings sustain serious damage. Chimneys fall.
	Everyone who is awake strongly feels the tremors.
	General panic. All constructions, even the most solid, are destroyed.
-	The most fragile constructions, in particular the houses, collapse. Underground pipes are broken. Roads sustain serious damage.
	Bridges and dams collapse. Railway lines are twisted.
-	Heavy pieces of furniture move. Many people are afraid. Tiles fall from the roofs.

	Sheet 20 - Session 2-2
Intensity measured on MSK scale	Damage
I.	
II	
Ш	
IV	
V	
VI	
VII	
VIII	
IX	
X	
XI	
XII	
L	

Sheet 21 - Session 2-2

Instructions: An earthquake occurred close to Laffrey (Isère) on 11th January 1999. The following day, the inhabitants of various counties were asked about what they had felt.

• Read various testimonies and determine the intensity of the earthquake in each county (by using the MSK scale table).

• Place these intensities on the map on the following sheet, and link the counties where the earthquake had the same intensity.

- The curves drawn are called "isoseismal" curves. Which form do they have?
- According to you, where was the earthquake most intensely felt?

In Saint-Martin-d'Hères

"The jolt awoke me, but not my wife. It was especially the shaking of the windows that I noticed. I really wonder what happened... "

The observations were same in the neighbourhood (Saint-Martin-D'Uriage, Seyssinet-Pariset), in some counties more towards the south (Château-Bernard, Corrençon-in-Vercors and Villard-de-Lans), in the area of La Mure (La Mure, Nantes-in-Rattier), in Monestier-de-Clermont and in the massif of Taillefer (Livet-et-Gavet, Ornon, Oulles).

In Méaudre

"I was already awake and lying in my bed, when I heard a very deafening noise, as occurs when snow falls from the roof. I also felt a very faint swaying. At the time, I did not think of an earthquake. It is only by listening to the radio in the morning that I put the two together..." Some people had similar experiences at Engins, Sassenage, Sainte-Agnès, Allemont, Le Perrier and Valbonnais.

In Champagnier

"I was not yet in bed. I was in the kitchen when suddenly there was a deafening noise and the door which leads to the sitting room opened. The chandelier started to swing and the radio fell. I immediately understood that it was an earthquake because, when I was a kid, in the early Sixties, several had been felt and that had marked me. That awoke my wife and my kids who believed that it was me who had made all this row..." The observations were same in Jarrie, Séchilienne, Vaulnaveys-le-Bas, Vif, as well as at La Motte-d'Aveillans and Monteynard.

A Sappey-en-Chartreuse

Nobody felt the earthquake.

At Saint-George-de-Commiers

"We really had the jitters! In the village, there are quite a few who emerged from their homes to see what was happening. It made a terrible noise like a gunshot, very deafening. Everything shook. At home, the cupboard in the room fell and there were small cracks on a wall which I had just redone. My neighbor, up the road, found, on the bed covers, small pieces of plaster which had fallen from the ceiling..."

The observations were the same in Champ-sur-Drac and Notre-Dame-de-Commiers.

Source: François Thouvenot, of the seismological Network of the Alps, based on an investigation carried out by the French seismological central Office.





Sheet 24 - Session 2-6

The invention of the seismograph

From year the 92 AD to year 126 AD, China experienced a number of earthquakes which caused a lot of damage and deaths. In 132 AD, the Chinese mathematician and philosopher Zhang Heng invented an instrument intended to detect earthquakes and to allow him to study them. Zhang Heng had built the first seismograph.





This instrument resembles a large bronze vase with a diameter of 1.83 m. On the upper part, on the outside, eight dragons each hold a ball in their mouth. They are oriented in the eight main cardinal directions (North, South, East, West, Northwest, Northeast, Southwest and Southeast). Under each dragon head is a bronze frog with its mouth open.

How does this seismograph function?

During an earthquake, a pendulum inside the vase begins to oscillate and pushes a lever which causes the mouth of one of the dragon heads to open: this dragon releases its copper ball. The ball then falls into the frog directly below.

The sound produced by the metal ball indicates that a vibration has taken place... and the dragon which lost its ball indicates the direction of propagation of the seismic wave. However, this seismograph does not to determine the distance nor the intensity of the earthquake.

In 138 AD, Zhang Heng's seismograph is said to have detected, from the town of Luoyang where the instrument was located, the earthquake which destroyed the town of Longxi, 500 km away.

And now?

Today, throughout world, scientists use electronic seismographs which record the vibrations on a computer. The recordings enable the calculation of the energy released by the earthquakes (its "magnitude") and, if several recordings are made at different places, combining them can locate the earthquake very precisely.







Sheet 27 - Session 2-9



The Individual Development Plan Security Provides for the organization of a Crisis



at the first tremor take refuge under a table



to protect the head and neck, stay away from windows



hold the legs of the table if it moves





protect yourself in a corner of a room after the quake, evacuate the building or in a doorway without panicking



move away from the building, taking care to avoid falling objects



An adult makes the roll call at zone of regrouping





no telephone calls, leave the lines free for disaster relief





follow instructions, listen to the radio



Sheet 28 - Session 2-11

Instruction:

- What could have happened to these buildings?
- Did they suffer the same kind of damage?
- How to build more resistant buildings?





Sheet 29 - Session 2-11

Earthquake resistant constructions

The difficulty in predicting earthquakes with certainty has led architects to build new buildings which can resist them. This type of construction is called "earthquake-resistant construction" and must meet a set of rules called "seismic standards". The severity of these standards depends on the level of seismic risk in the zone where one wishes to build.

The buildings are built of reinforced concrete, with a system of "chaining" (or "wind-bracing"), which prevents the movement of the walls... and thus the collapse.



It is important that the building rests on a stable ground, so as not to sink, or even rock, in the event of earthquake. Sometimes, it is necessary to build deep foundations to find stable ground.





The shape of the buildings must be as simple and as compact as possible, in order to avoid asymmetries that could amplify the shock. It is also necessary to avoid building flexible ground floors (or even higher floors), because they are particularly sensitive areas.



Building with flexible ground floor (Izmit, Turkey, 1999)



The Loma Prieta earthquake occurred on October 17, 1989 in the San Francisco Bay in California. This very strong earthquake (6.9 on the Richter scale) caused a lot of damage and killed 63 people. Its epicenter was located near Loma Prieta Peak in the mountains, about 16 km northeast of the city of Santa Cruz, where the earthquake was strongly felt. The earthquake was also felt in San Francisco and Oakland. This was due to the activity of the San Andreas fault, a break that separates the American plate to the East and the Pacific plate to the West, which slide against each other.



The San Andreas fault

1. The photo of the San Andreas fault shows a fault as well as two rivers. Place a sheet of tracing paper on this photograph. Draw the river in blue and the fault in red. Indicate with arrows the direction in which the blocks moved relative to each other.

Item 1 0 1 9

Sheet 31 - Assessment of sequence 2 (part	2)			
2. In the text, it is said that "this earthquake was very strong (6.9 on the Ric this value "6.9" represent? (<i>Tick the correct answer</i>)	hter scale)."WI	hat o	does
 Intensity of the earthquake Imagnitude of the earthquake 	ltem 2	0	1	9
3. What is the name of the instrument used to measure this value?	11 2		1	
4. What does the word "epicentre" in the text mean? (<i>Writes a sentence</i>)	Item 3	0		9
	ltem 4	0	1	9
	ltem 5	0	1	9
How far away from the city of Santa Cruz is the epicentre located?	ltem 6	0	1	9
(write a sentence)	Item 7	0	1	9
Francisco and Oakland? (<i>Write a sentence</i>)		area		Sall
	Item 8	0	1	9
	item 9	0	I	9
 7. A class that worked on earthquakes decided to carry out the following to do this, the pupils flip over a large plastic crate on a table. They put small heaps of wet sand on top, aligning and spacing them out. Then, using a mallet, a pupil gives a strong blow on a point of the crate. In order to establish the link between this experiment and a real earthquake, specify: What does the blow to the crate correspond to? 	experiment and f	nt: lipped	over	crate
• What does the point of impact correspond to?	Item 10	0	1	9
• what do the heaps of sand correspond to?	Item 11	0	1	9
 What does the hipped over create correspond to? 8. What will happen to the heaps of sand when a blow is delivered to the think (your hypothesis). (<i>Write a sentence</i>) 	crate? Wr	ite v	vhat	you
	Item 12	0	1	9
	Item 13	0	1	9

 9. Here is the result after the blow is delivered: What do you observe with regards to the heaps of sand? (Write a sentence) Item 14 0 1 9 Item 15 0 1 9 Item 15 0 1 9 Item 16 0 1 9 Item 17 0 1 9 Item 18 conclusion is the end of the experiment, we propose three conclusions. For each one of them, indicate if this conclusion is: "true", "false" or impossible to make ("I cannot know"). Each time, tick the appropriate box. a) An earthquake produces vibrations which are spread This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations I his conclusion is false I cannot know
Item 14 0 1 9 Item 15 0 1 9 Item 15 0 1 9 Item 15 0 1 9 Item 16 0 1 9 Item 16 0 1 9 Item 16 0 1 9 Item 17 1 9 1 Item 17 1 9 1 Item 18 Item 18 1 1 Itextractitexthe appropriate box. 1
Item 15 0 1 9 10. Are these observations in agreement with your hypothesis for question 8? Explain your answer by writing a sentence. Item 16 0 1 9 Item 16 0 1 9 Item 17 1 9 1 </td
 10. Are these observations in agreement with your hypothesis for question 8? Explain your answer by writing a sentence. Item 16 0 1 9 Item 17 0 1 9 11. From your observations at the end of the experiment, we propose three conclusions. For each one of them, indicate if this conclusion is: "true", "false" or impossible to make ("I cannot know"). Each time, tick the appropriate box. a) An earthquake produces vibrations which are spread This conclusion is true This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations This conclusion is false I cannot know
Item 16 0 1 9 Item 17 1 9 1 Item 17 1 1 1 Item 17 1 9 1 Item 17 1 1 1 Item 17 1 1 1 Item 17 1 1 1
Item 17 0 1 9 11. From your observations at the end of the experiment, we propose three conclusions. For each one of them, indicate if this conclusion is: "true", "false" or impossible to make ("I cannot know"). Each time, tick the appropriate box. a) An earthquake produces vibrations which are spread This conclusion is true This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations This conclusion is true This conclusion is true I cannot know b) The more we move away from the epicentre, the more intense the vibrations I this conclusion is true I this conclusion is false
 11. From your observations at the end of the experiment, we propose three conclusions. For each one of them, indicate if this conclusion is: "true", "false" or impossible to make ("I cannot know"). Each time, tick the appropriate box. a) An earthquake produces vibrations which are spread This conclusion is true This conclusion is false I cannot know b) The more we move away from the epicentre, the more intense the vibrations This conclusion is true This conclusion is true I cannot know b) The more we move away from the epicentre, the more intense the vibrations I his conclusion is true I his conclusion is true
 c) The more we move away from the epicentre, the lesser the damage This conclusion is true This conclusion is false I cannot know
12. In the experiment, the earthquake is caused by a mallet blow. Write a sentence to explain what creates an earthquake in reality.
Item 19 0 1 9
Item 20 0 1 9
13. In what way does this experiment imitate the Loma Prieta earthquake, which was felt in the towns of Santa Cruz, San Francisco and Oakland? (<i>Write a sentence</i>)
Item 21 0 1 9
Item 22 0 1 9
Sheet 33 - Assessment of sequence 2 (part 4)

14. Do you know what you should do if a similar earthquake occurred in your town, when you are at home? Check the appropriate box.

Item 23 0 1 9

□ I should climb onto the roof of the house.

 \Box I should shelter under a solid piece of furniture while waiting for the end of the quake. \Box I should approach the window to see at what is happening outside

□ I should approach the window to see at what is happening outside.

15. The illustration opposite represents the behavior of a person at the time of an earthquake. Explain in what way this behavior is not suitable. (*Write a sentence*)

A Card and a				
AND				
A REAL	 			9
	 Item 24	0	1	9
A BY	Item 25	0	1	9

Sheet 34 - Session 3-1

Instruction: These images show the same area (Banda Aceh, Sumatra), taken at two different times. What happened? What were the most affected areas? Where could refugees be accommodated?



Testimony of Imane, on holiday in Sri Lanka on 26th December 2004

On Sunday morning, at 9:25 exactly, my aunt knocked very hard at my door and yelled: "Run! The sea is submerging the hotel!" Within a short time, the hotel was flooded. There was no noise, no warning sign, no alarm. A few minutes after, the water withdrew and the staff of the hotel started to clean up.

We went onto the terrace, and the sea was very far, it was unreal. Then the sea rose up, very quickly, even higher. In one minute, water had flooded everything and devastated everything up to the 2nd floor. Then the sea withdrew again and, 20 minutes later, a third wave arrived, even higher. We were lucky to be in elevated area. All those who were outside died. The sea went up too quickly to be able to flee. I've heard that the waves arrived at 40 km/h!



Withdrawal of the sea before the arrival of the third wave of the tsunami of the 26/12/2004.

Review of the tsunami of the December 26, 2004 (Planet science, 17/01/2005)

At the last count of the disaster that struck South Asia, the earthquake and the tidal wave which followed it in the Indian Ocean: at least 280 000 victims...

On the 26th December 2004, at 0:58 universal time (7:58 standard time), the American geological Institute detected an earthquake of exceptional magnitude in the Indian Ocean, 9 on the Richter scale. Its epicentre was located off the coast of the island of Sumatra, 250 km south-south-east of the town of Banda Aceh.

Very fast waves (500 to 800 km/h), but relatively low, were formed on the surface of the ocean. For many boats sailing on the open sea, the phenomenon went completely unnoticed. It is only on approaching the coast that the tsunami was formed: the height of the waves increased suddenly, reaching up to 15 m in some areas. According to last assessments, the number of deaths or missing exceeds 280 000.

Eleven countries around the Indian Ocean were affected by the tidal wave. At 1:38 UT, the first waves struck the coast of Sumatra and, a little after that, Malaysia.

One hour later, Thailand, Burma and Sri Lanka were struck as well and, around 3:28 UT, the tsunami reached the coasts of the north of India and those of Bangladesh.



Sheet 36 - Session 3-3

Instruction: The document below shows the propagation of the tsunami created on October 24, 2008 by an earthquake of magnitude 9.2 in Japan. The indications in white (2 hr, 4 hr...) are the number hours that had passed from the moment when the tsunami was created.

• Would you say that a tsunami is a local phenomenon or that it concerns a wide area?

• Did the tsunami slow down while crossing the Pacific Ocean?

• Some people think that a tsunami slows down while moving out to sea, as if it lost its momentum. What do you think?



Sheet 37 - Session 3-5

The French coast (mainland, DOM-TOM) is regularly hit by tsunamis. Since the 18th century, about sixty have been counted, example:

Department or territory	Date	Damage	Name
New Caledonia	1 April 2007	Severe damage	Earthquake of Guadalcanal
Guadeloupe	20 May 2006	Without damage	Eruption of la Soufrière Hills of Montserrat
Reunion	26 December 2004	Severe damage	Earthquake of Banda Aceh (Sumatra)
The Alpes-Maritimes	16 October 1979	Moderate damage	Underwater landslide (Nice, bay of Angels)
Charente-Maritime	7 September 1972	Without damage	Earthquake of Oléron
Var	15 June 1909	Without damage	Coast of Provence and coast of the Var department (Marseilles, Toulon)
Martinique	20 May 1902	Moderate damage	Mount Pelée: lahar from the Carbet river
Gard	20 August 1890	Light damage	The Grau-du-Roi
Bouches du Rhône	23 February 1887	Moderate damage	Earthquake in the Italian Riviera
Pas-de-Calais et Seine-Maritime	5 June 1858	Light damage	Normandy, Kent, strait of Calais
Hérault	17, July 1841	Light damage	Bay of Sète (the port)
Manche	24 January 1838	Light damage	Bay of Cherbourg (the port)

Source: BRGM (www.tsunamis.fr)



Sheet 38 - Assessment of sequence 3 (part 1)

Tsunamis

During storms or hurricanes, it is the wind that produces waves on the surface of the water. On the other hand, during a tsunami, the movement comes from the ocean floor, in general because of a major underwater earthquake. A tsunami takes the form of a succession of waves which advance, at the surface, at the speed of a plane: between 500 and 900 km/h. At sea, the people in boats do not feel anything at all, whereas the waves, when arriving at the coast, will cause extensive damage. Upon approaching the coast, the waves are slowed down to 30 km/h and gain height. Depending on the size of the tsunami, this height generally varies between 5m and 10m, but it can reach up to between 30m and 40 m.

Giant waves, or mega-tsunamis, even more devastating than those created by underwater earthquakes, can be caused by some large landslides, as for example the fall of a cliff or part of a volcano or a mountain. Thus, a wave of 500 m high was created during the collapse of a cliff in bay of Lituya, in Alaska, in July 1958.

1. Using the document, give three possible causes for the formation of a wave.

a.	
b.	
c	

2. For each of these cases, imagine an experiment which can show what is at the origin of the formation of waves. Describe and produce a diagram of each of these experiments.

ltem 2	0	1	9
ltem 3	0	1	9

0 1

Item 1

9

	Description	Diagram
a		
b		
с		

Sheet 39 - Assessment of sequence 3 (part 2)

3. In the text, it is written: "upon approaching the coast, the wave is slowed down and then starts rising". According to you, why is the wave higher when it reaches the coast? (*Write a sentence.*)

ltem 4	0	1	9
ltem 5	0	1	9

4. Here are, not in the right order, the various stages of the formation of a tsunami. Give a title to each one of them then put them in order.





Sheet 41 - Assessment of sequence 3 (part	4)			
7. At the end of the experiment, the pupil drew the observations in the set stuck the strips of paper in the book. Image: mark on left paper strip (without gravel)	mark of paper s (with g	n right trip ravel)	000	and
What do you observe? (Write a sentence)				
• For the wave:				
• For the paper strips:				
	ltem 11	0	1	9
	ltem 12	0	1	9
8. Are these observations in agreement with your hypothesis for question Explain your answer by writing a sentence.	16?			
·	Item 13	0	1	9
	Item 14	0		9
 9. From your observations at the end of the experiment we propose three one of them, indicate if this conclusion is: "true ", "false" or impossible to m For each one, tick the appropriate box. a) The greater the depth of water, the greater the increase in the heigh This conclusion is true This conclusion is false I cannot know b) The height of a tsunami increases upon approaching the coast This conclusion is false I cannot know c) A tsunami slows down when approaching the coasts This conclusion is true This conclusion is true a) This conclusion is true b) The height of a tsunami increases upon approaching the coast 	e conclusi nake ("I ca ht of the	ons. nnot	For t kno re	each ow").

10. A group of people are on holiday at a beach. They observe the sea withdrawing suddenly, very quickly. What does this fast withdrawal of the sea mean? (*Write a sentence*)

				,,
	ltem 16	0	1	9
	Item 17	0	1	9
11. These people, not having ever known a tsunami, do not worry and to go and collect shells. Which other marine phenomenon may have this withdrawal of the sea with? (<i>Write a sentence</i>)	d take the they peop	opp ble c	ortu onf	unity used
	ltem 18	0	1	9
	Item 19	0	1	9
12. What advice could you give to these people in the event of a ts fast withdrawal of the sea? (<i>Write a sentence</i>)	unami alar Item 20	m oi	r of	new 9
	Item 21	0	1	9

Sheet 43 - Session 4-1

Standard letter to send to the town hall

An editable version is available on the site Internet-project (www.quand-la-terre-gronde.fr).

(Depending on the size of the county, it will be sent to the mayor or the municipal technical services.)

Dear Sir

I am a teacher at the [name of school] school located at [address of school] and I would like to set up an educational project about natural risks, and in particular around [choice of risk studied] risk to which our county is exposed.

This project comprises a big part of civics education, we wish to study, in addition to the nature of the risk itself, the the zones of the county which are concerned, what the preventive provisions implemented by the municipal services are, and what the perception of the risk by the inhabitants of the county are. We will alternate studies in class, field trips and surveys conducted among the residents.

We would like to work with the town hall in this project, in several ways:

• to invite, to the class, a member of the technical services who will present the nature of the risk;

• to organize a field trip, accompanied by this same person, who will help us identify this risk and show us the areas impacted in the past as well as the measures set up;

• finally, we would like to invite an elected official to the final presentation of results of the survey which we will have carried out among the residents of the county. This presentation of results will take place in the presence of the parents of pupils, and will be an opportunity to present the actions implemented for risk management (in particular the communal Plan of safeguard, PPMS, as well as the particular safety Plan of the school, PPMS) and to answer the questions of the residents.

Being aware of the complementary nature of our missions to inform pupils and the inhabitants of the county about the risks, I think that a common approach will give the project greater meaning.

Thank you in advance for the attention which you will afford to our activity.

Yours sincerely,

Sheet 44 - Session 4-1

Exercise:

1. Observe the dwellings which are close to the cliff. What risk do they face? Why do the inhabitants take the risk? Does it impact many people? 2. Observe the second cliff. What can happen? What consequences will that have?



Sheet 45 - Session 4-1

Exercise: Specify, for each situation, what the hazard is, what the stakes are, and if it is a major risk or not.

Situation	Hazard	Stakes	ls it a major risk?

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An innovative project concerning education for sustainable development (ESD)

The demographic explosion and the colonization of new areas have considerably increased the exposure of populations to natural risks. The proliferation of megalopolises often with poorly controlled planning has simultaneously increased the vulnerability of our societies to disasters.

Although still little represented, risk education is an indisputable component of education for sustainable development. It consists of teaching children to live with risks as responsibly as possible and to impart a risk culture and an understanding of factors and issues that they may adopt appropriate behavior.

A turnkey project

The aim of this pedagogical guide is to introduce Cycle 3 pupils to natural risks and their prevention through a multidisciplinary process that includes a large portion of the sciences and espouses the educational philosophy of La main à la pâte.

It may concern the risks associated with volcanoes, earthquakes or tsunamis, which are phenomena that are given a lot of coverage in the media but are little studied in school. It may also be a question of risks that are more localized (floods, storms, forest fires, etc.) and are therefore a fortiori more localized in the pupils' daily lives. The two approaches are complementary.

The project comprises:

- A class activities module (4 independent sequences + documentary sheets to be used in class);
- Pedagogical and scientific perspectives for the teachers;
- Skills assessment for each of the sequences provided.

A dedicated website (www.quand-la-terre-gronde.fr) contains several additional documentary resources.

Authors :

David Wilgenbus (coordinator) is a member of the La main à la pâte team and coordinates the production of educational resources and their distribution to teachers.

Cedric Faure is a primary school teacher and educator who is the director of the *La main à la pâte* pilot center in Pamiers (Ariège).

Olivier Schick is the head of Prévention 2000 and an expert in risk prevention.

la main à la pâte®

Launched in 1996 by Georges Charpak, winner of the Nobel Prize for Physics, with the support of the Academy of Sciences and the Ministry of National Education, the purpose of La main à la pâte is to promote quality teaching of the sciences and technology in primary school: http://lamap.fr

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