1. How do we know about the structure of the Earth? Earthquake waves, rocks, erupted minerals and gases, accurate measurements of the Earth physical fields told us about this. Seismology, petrology and geophysics are amazing sciences that helped scientists, using a microscope or a seismograph, to look both through the hundreds and thousands kilometers of the Earth interior, and through the hundreds of thousands and millions years of the Earth history. They help us to understand how the oceans and the atmosphere were formed, where from the life on the Earth originated and that the Earth's deep interior can pose a threat to the very existence of the life.
2. The museum of Volcanoes " Vulkanarium" tells us about volcanoes, their fascinating and majestic beauty, their unstable character and long life, and those who live near volcanoes and study them

## Source of volcanism in Kamchatka

1. We live on a hot, alive and dynamic planet. Its hot, fluid interior, located under a hard rock sphere, is called lithosphere. Constant movements of the Earth liquid mantle resulted in heterogeneous and mobile character of its lithosphere. It could be rather thin and dense beneath the ocean floor, and very thick and complex beneath the continents.
2. Lithosphere plates slowly and constantly move and collide forming uplands and depressions; they rotate relative to each other; giant jets of hot material, so called plumes, rise from the depths and melt them; ocean plates are formed and subduct under continent plate. This constant tectonic movements form and change the planet's relief, generate earthquakes, create and feed volcanoes.
3. Such distribution of volcanoes on the Earth's surface is **non-random**. Most of them occur on lithosphere plates boundaries, just where ocean plates subduct under continental ones.
4. Kamchatka is located at the junction of not two, but three lithosphere plates. Here the Pacific plate moves towards the Eurasian and North American continental plates. Moreover, the oceanic plate moves towards the shores of Kamchatka faster than in most other places on the planet, at the rate of 7-8 cm per year (compare this data with the 3-4 cm / year speed of humans' nail growth). Extraordinary activity of volcanoes in Kamchatka is associated with these features.
5. There are more than 3000 different volcanic edifices on the peninsula, about 30 of them are considered to be active, and nowadays from 4 to 7 volcanoes erupt every year.

## Active and dormant volcanoes

1. In Russian volcanology, active volcanoes are considered to be volcanoes that erupted during the last 3.5 thousand years, or those that in our time show obvious activity, for example, emit steam.
2. Where did this value, 3.5 thousand years, come from? Half a century hard work to restore the history of volcanic activity has been carried out on Kamchatka. This work was initiated by volcanologists I.V. Melekestsev and O.A. Braitseva. Thanks to their numerous papers and the data of their followers, we know how the Kamchatka volcanoes erupted over the last 10-11 thousand years. There is not any other country in the world that knows the history of its volcanoes so completely and in all the detail. Volcanic ash is the main source of information for researchers. It is erupted hundreds of kilometers away the volcano, falls to the ground and stores in it for thousands of years.
3. These investigations revealed that the Kamchatka volcanoes that have been sleeping over 3500 years will never awake again. Thus, the extinct are Vilyuchunsky and Kozelsky volcanoes, which are clearly seen from Petropavlovsk-Kamchatsky. Bezymianny Volcano awoke from 1500 years of dormancy and burst into a surprisingly large explosion in 1956.

## Types of eruptions

1. An eruption is effusive when lava flows from a crater or a fissure on a slope for weeks or months covering sometimes vast territories or forming large lava flows.
2. When a volcano is producing very viscous and nearly solid lava, which is being slowly squeezed from a magma conduit, this eruption is called extrusive. Such eruption can last for years, even decades, while a volcano keeps growing as a dome several hundred metres high. When a dome collapses, it causes hot avalanches or devastating pyroclastic flows, which rush down the volcano's flanks. This causes the transition from extrusive to explosive eruptive regime.
3. During the explosive eruption a volcano is producing gas jets, ash columns, and volcanic bombs. Such eruption can either become catastrophic, last a few minutes and produce huge volume of material changing landscape, or can last for days and weeks gradually forming cinder cones.
4. Gas eruption. Over the period 2010-2014 Gorely Volcano in Kamchatka was producing a peculiar eruption. A 6x8 m funnel appeared inside the crater and started producing an incandescent gas jet at the rate of more than 270 metres per second. The gas temperature in 2012 was measured to be about 1000 oC; the jet was glowing during daylight hours making the crater rim red-hot. But the volcano did not produce any single ash emission or lava flow. Powerful gas jets have been also observed at Kudryaviy Volcano, the Southern Kuriles.

## Eruption regimes

1. The steady effusion of lava during an eruption can interchange with explosions. The transition from effusive to explosive eruptive regime can be caused by a magma discharge rate, penetration of water into a magmatic conduit or by change in content of volcanic gas in magma. The scientist from the Institute of Volcanology and Seismology (IVS) FEB RAS, Yu. B. Slyozin, showed that a minor change in magma discharge rate can trigger the transition from effusive to explosive eruptive regime.
2. It is not infrequent that explosions occur periodically, or the activity of explosions or magma eruptions alternate periodically. This results in a layered structure of cinder cones.
3. The scientist from IVS FEB RAS, A.Yu. Ozerov, developed a theory that shows that such intervals in the eruptive regime are caused by groups of bubbles in the volcanic gas, which occur in magma on its way to the surface. The world's largest test installation for simulation of volcanic eruptions was constructed and is used at the Institute of Volcanology and Seismology.

## Types of the volcanoes.

1. Volcanoes are very different, each has its own history and its own life. However, we can distinguish several basic types of volcanic edifices. They depend on the erupting lavas composition and the volcano degree of activity.
2. Shield volcanoes. They are formed by the hottest, flowing basaltic lavas. Easily effusing over long distances, such lavas form flat and vast edifices, called lava shields. The largest volcanoes on the Earth and beyond it are shield volcanoes, it is Mauna Kea Volcano (Hawaii) and Olympus Volcano on the Mars. Gorely Volcano, Ploskiye Sopki in the Klyuchevskoy Group of Volcanoes, and Lavovyi Shish Volcano in Kamchatka could be classified as shield volcanoes.
3. Stratovolcanoes. The lavas of these volcanoes are more viscous, they cannot effuse over long distances and solidify on the volcanic edifice slopes. This change of the eruptive regime from effusive to explosive resulted in the fact that the volcano erupts either volcanic bombs and cinder or thick lava flows on the volcano's slopes. Therefore, stratovolcanoes have layered structure ("stratum" in Latin means "layer") and grow to considerable height.
4. The layers of lava and pyroclastics intersect the cracks (dykes) filled with magma. Dykes can make up to 40% of the volcano volume and strengthen it, protecting from collapse. Ice water and wind, carry pyroclastics from volcanic slopes and expose dykes in the form of tall, narrow and long walls.
5. Solidifying lava in dykes is compressed and cracked in the same manner as drying mud crackles. In this case, fancy platy, columnar or blocky partings are formed. When singular volcanic bombs are cooling we can observe the same phenomenon.
6. Extrusive domes. Viscous, still cooling in magmatic conduit andesitic lava can no longer flow. They are slowly squeezing out of the vents, forming huge domes and spines, short lava tongues (lobes) or peculiar crease structures in the stone lobes or tentacles form. From 1980 to 2015 extrusion dome on Shiveluch Volcano grew by 600 m. Slow growth of the volcanic mountain can be followed by a rapid catastrophic explosion, destroying both the dome and the older edifice of the volcano. Scientists from Lomonosov M.V. Moscow State University A.A. Barmin and O.E. Melnik explained the millionfold magma supply rate during an effusive eruption resulted in explosive catastrophes.
7. Calderas. When there are really colossal volcanic blasts, exposing to the surface more than 10 km3 of magma, the top of the chamber under the volcano collapses and a huge cup-shaped caldera is formed in the place of the volcano. After the catastrophe small volcanic structures (monogenic dome or cones) are formed along the edges of the caldera and in its center the growth of a new volcano can begin. Calderas are widespread in Kamchatka. Active Opal, Gorely, Karymsky Volcanoes are located in calderas. Ilyinsky Volcano is adjoined to the edge of the huge caldera of the Kurile Lake.
8. The most unusual caldera type volcano is Ksudach Volcano. It consists of eight large and comparatively small calderas that have been overlapping each other during the last 40 thousand years. The last eruption of this volcano occurred in 1907. It is resulted in the huge Stubel Crater formation.
9. **Monogenetic cinder cones and domes** These volcanoes erupt only once. Magma comes along a dyke to the surface followed by a several-month-long eruption resulting in formation of a 200 to 300 metres high cone or dome. Then lava in the dyke solidifies, and new lava cannot come through the dyke. A new eruption is only possible if a new dyke will be able to cut through the old one just like it happened in 2012 at Krasny Cone during the New Fissure Tolbachik Eruption (NFTE).
10. **Complex edifices.** Over the period of thousands of years, long-lived volcanoes and volcanic centres can suffer several transitions in eruptive regime or can change a zone of eruptions. This is how complex edifices are formed, such as volcanic ridges, caldera complexes, and volcanoes of Somma-Vesuvian type. These are, for example, the Zhupanovsky and Gamchen Volcanic Ridges, the Karymsky and Kikhpinych Complexes, and Bolshoy Semiachik Group of Volcanoes.
11. Somma-Vesuvius. Avachinsky and Bezymianny Volcanoes have complex edifices. Once, these large volcanoes were destroyed by strong explosions. Avachinsky was destroyed about 30 thousand years ago and Bezymianny was destroyed in 1956. After these events new and younger edifices grew up inside the large explosion craters. Mutnovsky is a unique volcano because it is comprised of four Somma-Vesuvian type volcanoes.
12. Maars Sometimes, at the foot of large volcanoes, one can observe beautiful terminal lakes, located in huge round bowls. These are maars, resulted from **massive explosion**. They can be considered monogenic volcanoes, because, as a rule, such explosions do not occur in one and the same place again.

## Volcanoes and the atmosphere

1. The Earth is a unique planet. Unlike the other planets in the Solar system, the Earth has a diverse landscape, dynamic climate system, and living beings. This is all thanks to water. Water can take numerous forms (ice, liquid, and vapor) and is capable of transferring energy and matters both on the surface and deep inside the Earth.
2. An active volcano is capable of erupting about 10 to 15 thousand tons of volcanic gases into the atmosphere, and 80% of these gases consist of water. Where did this water in the volcanoes come from? It is contained in rocks that turn into magma in form of crystalline hydrates. Water molecules can be embedded into the structures of molecules of other substances forming strong compounds - crystalline hydrates. Thus, for example, cement solidifies in water, starch is "glued" in rice filled with water, and bread goes stale.
3. Recent scientific investigations in Russia and Europe revealed a water zone in the interior of the Earth at a depth of 450-600 km. This is a real underground ocean several time larger that the World Ocean. But water in this ocean is in a bound state and not in form of vapor or liquid. In addition to juvenile water, basalts that are born inside the mid-oceanic ridges and form the oceanic plate, receive water from the ocean and turn into serpentinites in the presence of water under the effect of high temperature. This water causes the melting of the oceanic plate, which submerges the continental plate, and helps to form magma. As the magma rises to the surface, water is released from the silicates containing it and serves as the driving force for volcanic eruptions.
4. Water, which is released from magma, is called juvenile. It can be distinguished (by isotopic composition) from meteoric water, which participates in the hydrologic cycle. Volcanoes bring to the atmosphere tons of juvenile water that has never been in the atmosphere before, or which was associated with serpentinization more than 200 million years ago. Every cloud of steam that emanates from a volcano is a new cloud in the sky, new water in a stream, new rain over an arid place.
5. It is believed that it was volcanoes that created the modern atmosphere and hydrosphere on the Earth and created a home for all living beings on our planet.

## "Dry" rivers

1. Dry rivers are common phenomenon for volcanoes. The water in such rivers begins to flow only by 12 o'clock, by evening the riverbed is filled with water running through the night. By morning we can observe only weak streams, or the riverbed is completely dry. This happens every day almost like clockwork during the whole summer.
2. Weak material on slopes and at the foot of the volcano cannot hold melt or rain water, it easily penetrates to dense solid lava flow. By afternoon melting of snowfields or glaciers gives enough water to soak the entire quicksand part of the bottom and after a while the water appears at the surface in the river head. Hour after hour the amount of water increases, streams of water and mud overtake each other, fill the river bed and change it. By the evening the melting decreases, but the amount of accumulated water in the river bed is great and it takes several hours for the water in the river to decline and hide under the ground again.
3. "Dry" river mostly runs under the ground along the impermeable layer. And when this layer appears on the surface, by the site of a river or in the lowland, the river is finally evident as, clean and powerful springs. Such springs could be observed at the foot of almost all volcanoes. Lots of springs resulted from "dry" rivers of the Klyuchevskoy Group of Volcanoes are located on the banks of the Kamchatka River. Klyuchi (Springs) settlement is named after this phenomenon.
4. During the eruptions, powerful and destructive lahars rush along "dry" riverbeds, splashing its banks for 15-30 meters!

## Volcanic lakes

1. Collapsed well-shaped craters are often filled with water. If the volcano shows activity, volcanic gases, containing sulfur oxide, chlorine, fluorine occur in the water. These chemical components turn the water of the crater lake into a mixture of acids.
2. In the late 1960s in the 1970s the water in Troitsky Lake (Maly Semyachik Volcano) was an extremely concentrated mixture of sulfurous, sulfuric, hydrochloric and hydrofluoric acids so that it dissolved a finger-thick steel rod in a several tens of minutes (pH for the solution was less than 0.2). Hydrofluoric acid in this water made it possible to corrode even glass. Volcanologist B.I. Samoylenko had been researching the lake in those years obtained a bottom map and measured the heat flow in the lake. During the water samples transportation he got serious chemical burn.
3. Suspended in water extremely fine particles of sulfur and silicon oxide form an opaque mixture that looks like a soapy solution (a colloid). Colloids tend to scatter light rays, however purple, blue and green lights are diffused intensively than yellow or red ones. A blue-green or blue colour of the colloid against a dark background or at a considerable depth, and a yellowish colour of the colloid in the light or against a light background is associated with the phenomenon called the Tyndall effect. Fantastically bright colouring of opaque water in crater acid lakes is explained by this phenomenon.
4. Observing the "rays" of light in the morning forest or in clouds we deal with the same Tyndall effect, colouring volcanic lakes. But the most interesting is that poetic comparison of the fathomless blue eyes with lakes is of physical nature. The eyes become dark blue or blue not because of their real colour or a pigment, but the effect of Tyndall, in other words the protein particles scattering in uncolored iris of the eye. Look at the noble opal or moonstone, their elusive colour, both yellow and blue, is also the result of the light scattering on the silicon oxide colloid.
5. Finally, the light, diffusing on the air fluctuations gives a blue colour to the blue sky in daytime (Rayleigh scattering) and colours it in purple at dawn and sunset. Thus, the blue colour of the sky, blue eyes and the volcanic lakes blue colour are of the same origin!

Waterfalls

1. Kamchatka is famous for its amount of pure water. There are more than 14 thousand rivers on the peninsula! Rivers flow along volcanic slopes, forming numerous beautiful, reaching tens of meters height waterfalls.
2. Waterfalls are formed on ancient step-shaped gigantic lava flows, composing volcanic edifices. Water easily washes cinder and ash away, and cascades of waterfalls run along solid lava flows

## Volcanoes that created life on Earth

1. We usually associate the volcanic force with death and destruction. Indeed, volcanoes have repeatedly tested the vital capacity of living beings. Incredibly powerful and continuous eruptions 252 and 60 million years ago possibly caused mass extinctions on our planet. Vast lava flows, the Siberian and Deccan Traps, as thick as 2000 m are the memory of those eruptions.
2. But many evidences show that even earlier volcanic activity created the conditions for the advent and development of life on Earth. One of the first volcanologists in Russia, Evgeniy Konstantinovich Markhinin, proposed a new area of research – biovolcanology. It showed that the volcanoes not only created the atmosphere and hydrosphere on our planet, but also helped populate it.
3. Creation of such complex self-organizing structure as a living cell requires unique conditions: large contrasts of chemical and thermodynamic potentials, liquid warm water, rich chemical composition of aqueous solutions and mixtures, periodic electric discharges, minerals with a complex molecular structure, and finally, such a transient state must be maintained for a long period of time – hundreds or maybe thousands of years.
4. All these conditions can be found within volcanoes. Hot springs create large temperature differences and they look like strong and acid saline solution, just like the ancient ocean; the flow with a wide variety of elements and substances flows from shallow magmatic chambers to the surface. Frequent lightning discharges accompany eruptions of ash clouds, and small bubbles may appear on the surface of clays into which hot springs are converted. These bubbles are coacervates, the forerunners of the first cells.
5. Today, in the caldera of Uzon Volcano scientists can observe how living bacteria form stromatoliths - petrified colonies. It is the ancient stromatoliths that allowed paleontologists to reveal that the first living beings appeared on Earth 2.5 billion years ago. On Uzon you can also see how hydrocarbon compounds and even oil are developed.

## Hydrothermal springs and geysers

1. Lots of hot springs, cauldrons, and steam jets are boiling around fire mountains. Such volcanic activity is called hydrothermal and it can last for a long time, even when a volcano has ceased its activity.
2. Hot mineralized acidic water gradually destroys solid lava and pyroclastics turning them into loose altered rocks. Water from black or gray volcanites makes white, yellow or red friable rocks; it grinds them into clays, bright as oil paints: blue, gray, orange or carmine-red. Water infiltrates into the smallest cracks and fills them with opals, quartzites, and gypsum. All these rocks are fragile and rains with snows easily wash them off the slopes of the volcano. Thus, having stopped eruption the volcano begins gradual self-destruction, giving its body to soil, rivers and seas.
3. But hydrothermal activity of a volcano means not only destruction. Hot water transfers an abundance of elements that, when cooled, precipitate in the form of various combinations, and accumulate over hundreds of thousands of years as ores and mineral deposits. Besides, a volcano can offer us various hot springs, healing mud cosmetics, and mineral water.
4. The most striking part of hydrothermal activity is geysers. Jets of steam swirling up to the sky; fountains of unusually large drops sparkling in the sun like pearls; quaint edifices built of geyserite; and finally the ability to erupt "like clockwork ". This is a surprising and shocking phenomenon!
5. How do geysers erupt? Self-organizing periodic eruptions of superheated water can be arranged by creating a deep channel in the earth, such that it could be easily filled with water, and hot steam may enter it. The water at the bottom of the channel will be under great pressure and the boiling temperature will rise. For example, if a channel is as deep as 30 m, water will only boil when it is heated to 130 °C.
6. When steam bubbles come into the cold water from cracks at the bottom of the channel, they instantly collapse, but each bubble contributes into the water heating. Gradually water becomes hotter, steam bubbles rise higher displacing water, and hot but not yet boiling water begins to flow from a geyser.
7. Steam bubbles move unevenly: big bubbles catch up with those that are smaller and push them, clustering them into dense groups. This causes numerous periodically popping bubbles on the surface of the geyser. During volcanic eruptions the same process makes lava to fountain from a crater spattering and producing bombs and lapilli.
8. Hot steam at the bottom of the channel continues to heats the water, and after a while it starts to boil. This process is also accompanied by jittering: a huge bubble of vapor rising through the channel gets into the water with lower temperature and abruptly collapses breaking into many small bubbles. The geyser begins to "breathe", the spout becomes irregular and pulsating, and the water in the geyser looks like boiling, but then it again calms down. When at home we listen to a rattling electric kettle or crackling water in a saucepan, we can hear how small steam bubbles collapse.
9. Finally, the water at the bottom of the channel and in its middle part becomes so hot that the evaporation is inevitable. Soon enough, steam begins to push and raise water to the surface, the temperature of which is as high as 110 or 120 °C. At atmospheric pressure it simply explodes. And this is where the eruption begins! The geyser erupts all the water from the channel, and for a while only steam with rare drops of water are coming out accompanied by a hollow rumble.
10. Soon the geyser calms down and cold water from the river flows into the channel, or it is filled with underground water. The cycle repeats. Both the time of water heating and intervals of eruptions depend on amount of water and steam coming into the geyser and the depth of its channel.
11. Some geysers erupt at regular intervals, some have sporadic nature. This is due to the shape of the channel: if there is a curved section (a traprock) inside the channel, steam that smoothly comes to hot water will cause jittering. Overlapping the jittering caused by the geyser’s eruption will likely make the eruption regime much complicated.
12. The unusually large droplets erupted by the geyser are formed due to a small surface tension of water near the boiling point, which under ordinary conditions, breaks a stream of water inside a fountain into small drops.

## **Volcanic rocks**

1. Abundance of forms of organic compounds is the basis of life on the Earth. It is associated with the fact that it is lots of ways to combine atoms of carbon, oxygen and hydrogen, including such active elements as nitrogen and phosphorus. At that, atoms form rings, chains, lines, spirals and absolutely incogitable complex shapes. Sugars, fats, RNA and DNA and proteins are formed in such a way.
2. Silicon is an element that is also capable of forming a wide variety of forms. Silicon combines with oxygen and forms a stable triangular pyramid-shaped compound (tetrahedron). These tetrahedrons can build different shapes in space: tightly packed crystals, layers and lines, and even very complex structures. Besides, atoms of other elements and water molecules contribute in building of these structures. Thus, a huge family of minerals based on silicon oxide (silicates) is formed.
3. While silicate magma is rising to the surface and even after the eruption, silicates are transforming too, changing their structure, melting and crystallizing, binding or releasing water and admixture. Erupted rocks properties are associated with such transformations, determining the eruption type and the type of the volcano.
4. But the most surprising that scientists have learned by studying tiny crystals of rock-forming minerals to restore the erupted magma history and understand the 5, 10, 50 or 70 km deep earth processes. The science, which opens such an opportunity to us, is called petrology.
5. Olivine is one of the most widely spread minerals in the Earth interior. But it is rather rare at the surface, but for volcanoes, supplying us with this mineral, we would not know the Earth's interior's composition. Pure large olivine crystals are precious, they are called chrysolites. During large events Avachinsky Volcano erupts large assemblages of accumulated in volcanic chamber olivine (olivinites).
6. Different rocks, erupted from volcanoes are called volcanic rocks. Silicon oxide comprises the base (from 40 to 70%), there are also a variety of other minerals: compounds of iron, magnesium, titanium, potassium, aluminum and many other elements.
7. Based on the amount of silicon oxide in the rock we can distinguish basic and acidic volcanic rocks. Typical basic rocks are basalts. The amount of silicon oxide in them is small, but the amount of dense dark-colored mineral is substantial. These are dark, sometimes black dense rocks. They are often contain light crystals of plagioclase and green olivines. Basalts, composing oceanic plates, more than once in the Earth history were erupted at the surface as giant lava flows (trapps).
8. Andesite is a striking example of acid volcanic rock. It is gray heterogeneous rock with light crystals of plagioclase, dark amphiboles and pyroxenes. Andesite type of eruption is resulted in lava domes growth, explosions and calderas formation.

## Ashes and sands

1. During explosive eruptions lava is fractionized into fine particles (volcanic ash). These are not just sands, but particles of foamed glass and crystals.
2. Hot ash rises to the several kilometers height. During moderate eruptions emissions of volcanic ash can reach the height of 5 to 8 km and during strong ones the 10 to12 km height. The emission height resulted in the fact that ash cannot fall to the ground for a long time and is carried by winds at a many hundreds and thousands of kilometers distance. Catastrophic eruptions can erupt ash to the 20, 30 and even 40 km height. At that ash plumes are carried within the hemisphere or even the entire atmosphere. Ashes from Kamchatka volcanoes could be found in Alaska, in Greenland ice and in Asia soil.
3. Streams and rivers carry rocks to the sea coasts, sea waves constantly grinds and removes particles of these rocks, carrying loose, light minerals and leaving on the shore dense and hard. The beaches are formed in this way. Most beaches on the Earth are composed of the hardest particles of quartz and the waves slap against white and yellow beaches.
4. The dark-colored minerals (titano-magnetite) are the hardest in the active volcanism areas. Therefore, the sand on Kamchatka is dark gray or black. Sand beaches of Kamchatkan eastern coast are deposits of titanic and iron ores. Titanomagnetite has magnetic properties, using a magnet close to the black Kamchatka sand you can observe an evidence of this.
5. There are olivine beaches with green sand in the Hawaiian Islands and on the island of Reunion in the Indian Ocean. This type of erupted rocks (picrites) contains a lot of olivine phenocrysts. This mineral is also very dense and hard.

## Volcanic minerals and ores

1. Minerals are formed not only in magma. After an eruption and between events a volcano is working as a chemical plant by centuries and millennia. Crystals of various substances and compounds grow during cooling from hot gasses of complex composition. Cooling lava fields and craters become multicolored.
2. Among appearing in this way minerals there are stable minerals, and short-term, dissolving in the air ones. Each eruption can discover new minerals. Researchers from Kamchatka and St. Petersburg discovered, described and named more than forty new, previously unknown minerals! Volcanology is a science full of discoveries!
3. One of the bright discoveries was the detection of diamonds in lavas from Kamchatkan volcanoes. Scientific researcher from the Institute of Volcanology Farid Kutyev discovered black diamond (carbonado) in lavas from Avachinsky Volcano. Later, Leonid Pavlovich Anikin detected nano-particles of diamonds in ashes from the 2009 Koryaksky Volcano eruption. And, finally, he also was lucky to find micro-particles of diamonds (up to 0.7 mm) in the lava flow crust from the 2012-2013 New Fissure Tolbachik Eruption. All this resulted in discovery of the new mechanism of natural diamond formation.
4. Complex post-magmatic processes occur in hydrothermal systems: for thousands of years they accumulate metal ores, contribute to the growth of precious stones **crystals.** Volcanic "heat engine" transfers and concentrates a variety of useful substances, working as a slow but powerful ore mining and processing enterprise.

**Earthquakes**

1. Observing the sun shadow **at different seasons** of the year and in different parts of the world, ancient people could already understand that they live on the round Earth. Even more, they managed to estimate its size. Now we know that the Earth consists of layers, outside there is a solid crust, liquid mantle and outer (molten) core are at a more deeper layer, and a solid inner core is in the center. But how do people know all this? Yet people can neither observe nor drill a well to a thousands of kilometers depth!
2. An earthquake is not only a disaster, a natural catastrophe or a frightening natural phenomenon. Earthquakes gave the opportunity to "see right through" the Earth, to the very center of it! Geophysicists record seismic waves not only in the epicenter of the event, but all over the world, these seismic waves, "illuminating" the inner part of the Earth give us the opportunity to have a kind of the Earth's interior picture. In the same way, using ultrasound future parents have the opportunity to get acquainted with their yet unborn baby.
3. Earthquakes investigations contributed much to our knowledge on tectonic plates and volcanic processes nature. Besides, seismic signals evidence of processes beneath the Earth's surface: tectonic plates motions and future eruptions build-up. Rising to the surface magma makes its way in the hard and brittle crust, causing it to fracture. This produces small, but very frequent earthquakes. Such earthquakes themselves, the increase of their magnitude, and the earthquakes' foci displacement towards the surface evidence of the near future volcanic eruption.
4. Volcanic seismicity investigations learned us to predict several volcanoes eruptions. In 1975, the researchers from the Institute of Volcanology managed to make a month prior the beginning prediction of the Great Fissure Tolbachik Eruption. The 2010 eruption of Kizimen Volcano, which had been silent for more than 80 years, also was not surprising. Researchers have been developing new forecasting technologies and methods, including not only seismology, but also geodesy (measurements for volcanic edifices deformation), detecting compositional changes in volcanic gases.
5. It is possible to predict volcanic eruptions, although this task is far from complete solution. But forecasting of tectonic earthquakes, associated with tectonic plates movements, is near-impossible task to solve. It is only possible to talk about an earthquake probability in one or another region and in the next year or five years. But to specify the time, the place and the magnitude of the future earthquake is impossible.
6. There are early warning systems alerting on the already occurred earthquake. Seismic waves quickly travel in the Earth's interior and surface with the first kilometers per second velocity, but, nevertheless, not faster than a radio signal. This means that a seismometer located in the epicenter of a distant earthquake can transmit data on the already occurred earthquake 7 - 10 seconds prior to destructive waves arrival to the large city.

## Types of seismic waves (Иллюстрация).

1. Primary waves (P-waves) are the fastest waves propagating both in solid and liquid media (magma, outer core).
2. Secondary waves (S-waves) are slower than P-waves, but more important that they do not propagate in liquid media and are reflected from margins, separating melt and solid rocks.
3. Surface waves are resulted from seismic waves contacts with the Earth's surface. They cause the most destructions during an earthquake.

## Tsunami

1. The ocean is great, but actually on a planet's scale it's just a shallow water reservoir and waves of a planetary scale can travel along it. These are tsunami waves.
2. What is the difference between tsunami waves and giant storm waves? Strong winds can create 15 and 25 meters height waves in the ocean. These waves are impressive, but do not do harm. People ride waves and like to make photos against them. However, 8-10 meters tsunami waves are already considered destructive, and 15-25 meters are catastrophic!
3. These waves differ significantly by their energy. The strong wind wave velocity is 20 m / s, the tsunami wave velocity is 200 m / s (700 km / h)! The length of the wind wave (the distance between the crests) reaches 500 m, the tsunami wavelength is hundreds of kilometers! Even with a very strong wind, the first tens of meters of water come in motion, in tsunami wave the whole 3-4 kilometers thickness of the ocean moves! The tsunami wave at enormous rate carries a tremendous amount of water.
4. As a result, wind waves destroy and fill only the foreshore (the first hundreds of meters from the water), and tsunami waves 20 meters high can travel for more than 10 kilometers deep into the land! When such a wave arrives the sea turns into a fast, free-moving, unstoppable river.
5. Now we share emotions, events and impressions by photos. They amaze us, surprise, please or shock, moreover, they can tell and explain, they can make us to plunge into thought or carry the most subtle feelings through time and distance.
6. In our exposition, we told you about volcanoes and their lives with the help of photography. Sure, you also share your impressions of Kamchatka with their help. But the first photographic pictures of Kamchatka appeared quite recently. Even in the beginning of the 20th century, the image of Kamchatka was almost unknown beyond its borders. A glimpse of the wonders and beauty of this land could only be given by emotional stories or drawings.
7. In 1908-1910 the Imperial Russian Geographical Society have organized the largest complex expedition, initiated by the Russian philanthropist Fyodor Pavlovich Ryabushinsky. Geologists, botanists and zoologists, meteorologists and ethnographers took part in the expedition. Most of the materials, obtained in the expedition were carefully processed and studied, they are stored in the archives of world famous institutions. However some of photographic plates were lost for decades. Fortuinately