VOLCANISM: HISTORICAL AND HUMAN PERSPECTIVES

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Summary

Volcanism is a powerful manifestation of Earth's endogenous activity. Lava flow, explosive eruptions, tremendous pyroclastic deposits radically change the relief and landscape of the planet. Volcanism plays the great role in the origin, distribution and existence of the biosphere on the Earth. It relates to number of huge natural catastrophes along with earthquakes and tsunami. In this topic there are descriptions of prominent disastrous eruptions in the history of humanity. The main methods of counteraction to eruptions, mainly to lava flow, are characterized. It is considered also the methods of prediction of volcanic eruptions. In conclusion significant creative role of volcanic processes for practical life of people is shown.

The geophysical observational data and primarily those on the heat flows on the Earth's surface and in the deep bore-holes indicate a considerable heating of the Earth's interior. At a certain depth, the temperature of melting of deep matter, or rocks, usually produces a silicate melt; i.e., magma, which in favorable conditions rises to the surface. This phenomenon is called volcanism. If in the course of its rise, the magma stops at a certain depth and crystallizes by natural cooling, then the phenomenon is called intrusive volcanism. If the magma, by rising, emerges onto the surface, then it is called the extrusive, or the effusive volcanism. The site of the magma outflow onto the surface is called the volcano. The process itself of the outflow of magma onto the surface is called eruption, whereas the poured out magma is called lava. Besides the lava melt, the gases usually also reach the surface. The chemical composition of the magma and gases, the volumetric relationship between them, the rate of the rise of the "magma-gas" system determine the character and type of eruption ranging from the quiescent flow of magma (the Hawaiian type, after A. Lacroix) to highly explosive eruptions (the Katmaian type, after A. Lacroix, the Plinian, Katmaian, Bandaian types, the Krakatau type, which are called after the historical catastrophic eruptions of the corresponding volcanoes). In fact, these extremely energy-capacious and volumetric volcanic eruptions essentially affect, in the first place, the conditions and environment of the human habitat.

1. Volcanoes as rebuilders of landscape

In the course of the history of the Earth, the intensity and scale of volcanic manifestations have been irregular and cyclic. The causes of active volcanism were likewise different. The observations of other planets of the Solar System and of their satellites, such as Mars, Venus, Jupiter, the Moon, Io, etc., have shown that all of them have experienced the stage of intensive volcanism with eruption of colossal volumes of basalt lava. At the earlier stages of formation of these planets, an important factor in the initiation of eruptions was the collision of young planets with large celestial bodies, such as meteorites and asteroids, which inflicted deep chasms by shock craters from which the magma flowed onto the surface. To a certain extent, probably, the initial basalt crust of the planets was thus formed on the Earth as well. Gigantic ring structures that were discovered on ancient platforms are now considered to be the evidence of this early bombardment of the Earth.

The massive effusions of basalt, which formed vast fields of basalt many kilometers thick, the so-called plateau basalts (flood basalts), or traps, are observed at different stages of the geological history of the Earth. Such are the Proterozoic traps of the Voronezh crystalline massif, the Paleozoic traps of Eastern Siberia, the Mesozoic plateau basalts of Kara in South Africa, of Parana basin in South America, the Cenozoic basalts of the Deccan plateau on the Indian ancient platform, of the Columbia plateau in the Cordilleras of North America. By covering the dissected relief, the trap flows smoothed out its surface, whereas the exogenetic processes built up the tremendous beds of the crust of weathering and of the soil. The rivers cut deep valleys through the thick basalt beds thus forming canyons with numerous waterfalls. The different stability of basaltic beds at river erosion complicated and weakened by tectonic fractures leads to forming of latter. Among these waterfalls are the well-known Iguacu on the Iguacu River in Brazil, the Victoria waterfall on the Zambezi River (Zimbabwe, South Africa), the Niagara waterfall of the Niagara River (on the frontier between the USA and Canada); one of the largest waterfalls in Europe is the Dettifoss on the Jökulsá River (Iceland), and many others. In order to preserve these natural monuments most of them with the surrounding area were given the status of national parks and reservations. Volcanism causes considerable changes in the landscape. Repeated eruptions of one and the same volcano build up large volcanic uplifts, the stratovolcano, the slopes of which are often covered with supplementary parasitic craters. There are volcanoes in the Antarctic and Hekla and Snaeffelsjokull volcanoes in Iceland, Fujiyama in Japan, and Etna and Vesuvius in Italy, and so on. The eruption of large volumes of magma results in the devastation of the deep magmatic chambers, i.e., magmatic foci, and the collapse of the surface layers tectonic collapse. This kind of ring depressions in the relief can be also formed as a result of an explosive eruption (explosion funnels), when the finely dispersed magma, i.e., volcanic ash, with small porous pieces of lava (scoria) covers large areas and forms beds of loose volcanic deposits (tephra). Large tectono-volcanic depressions in the relief, calderas, are observed on active and extinct volcanoes. The largest of them are tens of kilometers in diameter (La Garita and Vallis in the USA, Bulder on the Aleutian Islands, Aso in

Japan, Uzon on Kamchatka, etc.). Such well-known volcanoes as Vesuvius, Krakatau, Santorin, Katmai, Kilauea, Bezymyanny, and others, likewise have calderas.

Volcanism is responsible for the formation of most of the oceanic islands. One of the largest is Iceland, which is actually formed by extremely intensive eruptions in the course of almost 20 million years. The chain of the Hawaiian Islands, the Canary archipelago, the Azores Islands, the numerous chains of island arcs, all of them are created by volcanism. Many of them are just the above-water parts of volcanoes formed on the ocean floor. Some of them appear and disappear before the observer's eyes. In the second half of the 20-th century, at the southern coast of Iceland, the Surtsey I. was born (1963-1965), whereas five years earlier, near the Fayal I, (the Azores Islands), the Ilha-Nova I. appeared. There are many cases of "disappearing" islands. Being born by eruption of not only lava but also ash and slag, they soon are destroyed either by repeated explosive eruptions (for example, the islands that were formed near the Medzin reef and the MacCalloch on the Bogoslof I., Alaska) and wave erosion (the small volcanic islands south and west of Iceland, the Graham I. in the Mediterranean). Only dense lava beds protect an island like armour and preserve it from the quick destruction and annihilation. Only owing to this protection that nowadays the Surtsey I. still exists.

2. Volcanism and biosphere

Volcanism is an important factor in the distribution and existence of the biosphere on the Earth. One of the hypotheses states that actually volcanism of tremendous power caused the extinction of whole species and groups of fauna at the Cretaceous-Paleogene boundary, including the dinosaurs, its largest representatives. This extinction was a result of the major cooling on the Earth owing to a long-term contamination of the atmosphere with ash particles and to a reduced amount of solar heat reaching the Earth's surface. When passing from such a hypothetic global effect to concrete local influences of volcanism on geological environment, we should note such phenomena as the burial under lava and tephra beds of vast areas, the damming of rivers and overlapping of water basins, the contamination of the atmosphere and hydrosphere (particularly, the lakes) with poisonous gases and acids, the high dust contamination of the atmosphere. A striking example of the cardinal changes in the landscape as a result of volcanism is the eruption of the Katmai volcano in Alaska in 1912. The ash deposits (ignimbrites) of gigantic explosions of the volcano covered a valley 8 km wide and 25 km long, the flat surface of which was many years covered with numerous steam discharges. A group of researchers, headed by Griggs, an American botanist, visited this almost inaccessible site and called it the Valley of Ten Thousand Smokes. As a result of the Great Tolbachik Fissure Eruption (GTFE) on Kamchatka in 1975-1976, the vast valley that was covered with woods and brush was completely buried under the tephra beds many meters thick. The acid rains poured during the entire eruption period. The eruption of only the Tolbachik Northern Craters during 72 days caused complete extinction of vegetation covering about 400 km^2, and all this territory was turned into lifeless scoria-ash desert. During the eruption, in the radius of 300-500 km, a higher content of sulphurous gas and dust was recorded in the atmosphere. Irrespective of the active Kamchatka volcanoes, the Cl/Br ratio in atmospheric precipitation in this volcanic region of the Earth reached 785, whereas normally this ratio is 300. We may, therefore, state the local permanent influence of volcanic gases on the composition of the atmosphere. Consequently, by E.K. Markhinin's definition, for mankind the areas of active volcanism constitute specific medico-geographical provinces.

A catastrophic landslide and explosive eruption of St.Helens volcano in southwest Washington, USA, on May 18,1980, transformed one of the most scenic alpine landscape of the Cascades Range into a gray, barren wasteland in only a few minutes. This eruption devastated 550 square kilometers of forest, sent damaging mudflows down rivers draining the volcano, and produced ash fallout hundreds of kilometers to the east. It removed 2.3 cubic kilometers of material from the top of the volcano and within minutes an ash laden eruptive column rose more than 20 kilometers above the volcano. After this and next explosions during 1980 lava extruded from the vent and formed lava domes. It was the most impressive eruption in the end of twentieth century.

As regards the biosphere, the role of volcanism was not only destructive. There are hypotheses suggesting the germination of life on the Earth by volcanic products in the atmosphere and the hydrosphere. Mention was made that volcanic gases contain the necessary components for the germination of pre-biological organic components, such as hydrogen, ammonia, hydrocarbons, carbon oxide, water vapour. E.K. Markhinin and other Russian scientists, who studied volcanic gases and thermal springs on Kamchatka and the Kuril Islands, arrived at the conclusion about the generation in them of organic compounds such as aldehydes and aminoacids. These biological "bricks" could have formed more highly organized molecules of organic life. Figure 1 shows a scheme, composed after E.K. Markhinin's data, of the evolution of volcanic products and their contribution to the formation of the Earth's crust, the atmosphere and hydrosphere, and the living organisms.

Volcanic fields and structures, particularly the calderas, are hydrochemically extremely active; they have higher humidity and a more temperate climate. Owing to the combined enrichment of loose volcanic deposits and products of weathering of volcanic rocks with natural "mineral fertilizers", these areas are highly fertile and the flora and fauna flourish in them. For example, on the basalt covers of the Rio Grande do Sul in Brazil, thick subtropical woods have grown. The warm climate and the fertile soil contributed to the growth of wood on the lava that was ejected in 1840 from Kilauea. A real oasis in the rigorous mountain conditions of Eastern Kamchatka is the Uzon caldera that left an indelible impression on the members of the expedition that was first to reach this place. Surrounded by snow, the area of the hot springs was covered with riotous greenery and life was in full swing. The influence of hot springs in the caldera prevents the formation of sharp elevation of zonality of vegetation typical of mountain conditions. At this locality, four vegetation zones are combined: the rock-birch woods and tall grass prairies, the swamps with scarce rock-birch and dwarf cedars, and islets of mountain meadows and tundra. The permanently green thermal lawns and thermophilic algae in the numerous springs attract to the caldera masses of different birds, including white swans. The animal life of Uzon is very diverse; the mammalian fauna includes bears, foxes, wolves, wolverines, wild sheep and deer. The uninhabited volcanic island Surtsey in Iceland became a reserve of reviving life and a natural laboratory for researchers in different fields of science.

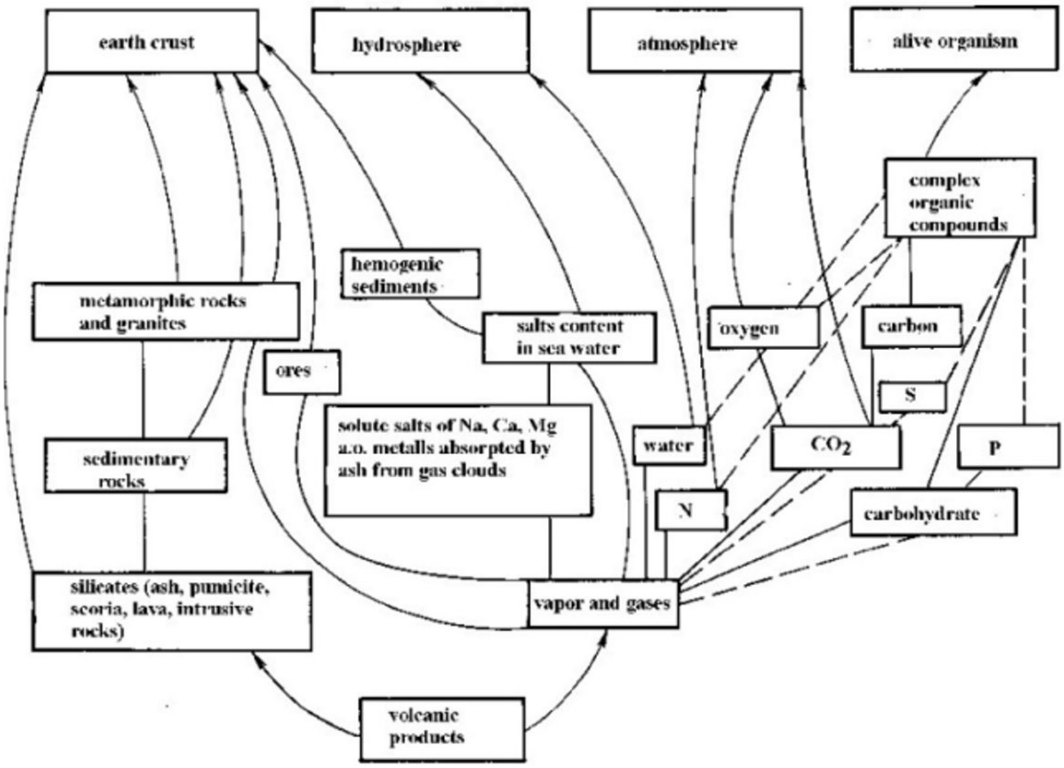

Figure 1. Scheme of volcanic products evolution, after E.K.Markhinin.

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Biographical Sketch

Yu.S.Genshaft, was born 1935, is one of the leading Russian scientist who works extensively on various areas in geology and geophysics. He is head of laboratory of physical-chemical dynamic of tectonosphere and conducts investigations in the field of experimental mineralogy and petrology, the construction of regional substance models of the Earth's crust and upper mantle, the study of volcanism, magmatism and geodynamics of different structures of the Earth. For a long time he conducted the field works in Kamchatka, Mongolia, Central Europe, Caucasus, Iceland. He had published over 300 works in Russian and International journals and several monographs.