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Volcanic Eruptions as a Threat to Public Security

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ABSTRACT

Public security is nowadays considered to be a key area of national security. Its main objective is to protect the population from the effects of various types of threats that may appear on the territory of Poland, but also beyond its borders. Such threats include undoubtedly volcanic eruptions. In this article, the author makes an attempt to analyse the above phenomenon from the perspective of direct and indirect threats it poses to public security. The author included in it: the definition and basic types of volcanoes, the characteristics of volcanic eruptions and their consequences, as well as the characteristics of volcanic threats in Poland. The article ends with the author's summary and conclusions in which the author refers to the impact of volcanic threats on public security.

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Introduction

Modern human is every day exposed to various types of threats, which, depending on the circumstances and the scale of a particular phenomenon, may take on the size of a natural or catastrophic disaster. The prevalence of the effects of such events and situations makes them the subject of interest in an important area of national security, which is, undoubtedly, public security.

For centuries, volcanoes have both fascinated people and aroused fear in them; they were a place of worship; it was believed, among other things, that there were gods living in their depths. Volcanoes can be classified as ecological threats of natural origin, belonging to the group of geological threats. Their destructive effect is caused by the escape of hot volcanic lava to the ground, as well as the escape of pyroclastic materials and volcanic gases. Products of the eruption constitute a direct threat to the safety of people and the environment in the place of the eruption itself, but may also cause other dangerous phenomena, such as earthquakes, tsunamis, mudslides, fires, etc. They can contaminate the air and the environment, and cause climatic disturbances. Particularly dangerous are the so-called supervolcanoes, whose explosions can practically destroy large areas and cause permanent climate change.

Due to the destructive nature of volcanic eruptions, they are a serious concern to security professionals and should be subject to a continuous monitoring process. Therefore, the author's intention is to try to bring closer the nature of volcanic eruptions and the dangers they carry, mainly in the context of public security.

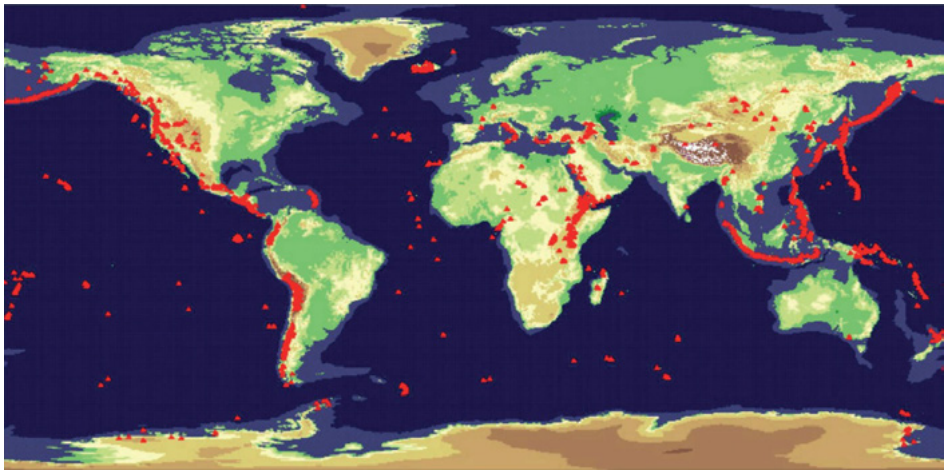
The concept, main elements, and types of volcanoes

The name 'volcano' comes from the name of the Roman god of fire, Vulcanus, who according to myths inhabited the island of Vulcano (located in the Aeolian archipelago).[1] Volcanism plays an important role in shaping the face of the Earth, especially at the meeting point of tectonic plates. As a result of volcanic processes, significant volumes of material originating from the upper mantle and the lithosphere are released to the ground. This material takes part in creating new forms of sculpture, so volcanism can be constructive. Nevertheless, eruptions of the explosive type can lead not only to the creation but also to the destruction of previous forms. For example,

[1] M. Pańczyk, *Erupcje wulkaniczne. Formy i produkty*, "Kosmos. Problemy nauk biologicznych", 2011, vol. 60, no. 3–4, p. 219.

as a result of the eruption of the St Helens volcano in the United States in 1980, the elevation was reduced by almost 400 m. Thus, from the geological point of view, volcanism can also be destructive.[2]

Fig. 1. The distribution of volcanoes on Earth



Source: B. Bagiński, *W jakich miejscach na Ziemi pojawiają się wulkany?*, "Kosmos. Problemy nauk biologicznych", 2011, vol. 60, no. 3–4, p. 211.

The distribution of volcanic phenomena on Earth is not accidental, as it is subordinated to global tectonics. (Fig. 1) The vast majority of volcanoes and their associated forms occur near the boundaries of tectonic plates, i.e. in areas with the greatest dynamics of tectonic processes, including seismic phenomena. In addition, in different geotectonical environments volcanic phenomena take on a specific character, which in turn is reflected in the types of eruptions and appearance of the volcanoes themselves.[3] Outside the edges of the tectonic plates, volcanoes are formed over so-called hot spots (e.g. in Hawaii). These are areas of volcanic activity or areas with an increased value of the Earth's thermal flux, the existence of which is the result of a hot matter stream reaching from the depths of the Earth into the lithosphere, called mantle plume.[4] There are currently around

[2] P. Migoń, *Geomorfologia*, Warszawa 2006, p. 57.

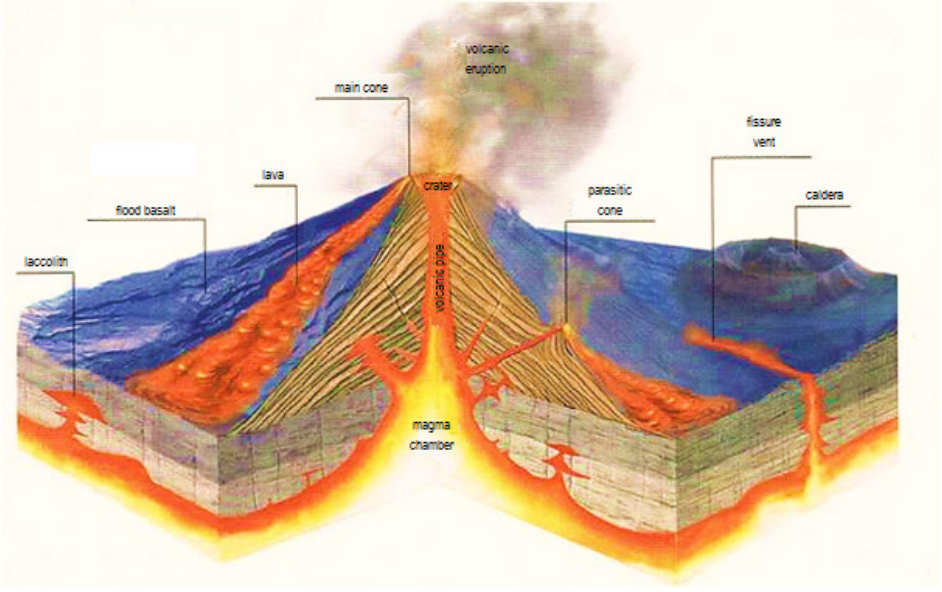
[3] *Ibidem*, p. 58.

[4] *Plama gorąca*, "PWN – Encyklopedia", https://encyklopedia.pwn.pl/haslo/plama-goraca;3957892.html (accessed: 19.05.2014).

450 volcanoes in the world, i.e. those that are known from various sources that they erupted in the historical past or are still erupting today. The distribution of volcanoes on the Earth's surface is shown in Figure 1.

A volcano is a place where the products of the eruption of lava (lava volcano), pyroclastic materials (ash volcano) and volcanic gases (gas volcano) are extracted to the surface of the Earth (including the surface of other planets and their satellites). A volcano is commonly referred to as an elevation created by the accumulation of products of eruption around a crater or a crack with a crater on top; magma flows into an outlet called a crater from a magma chamber (magma tank) underneath through a volcanic chimney; a distinction is made between *active volcanoes* (continuously or sporadically manifesting their activity, e.g. Vesuvius), *extinct volcanoes* (their activity was not observed in historical times, e.g. volcanic cones in Germany and Poland) and *dormant volcanoes* (not active for a long time).[5] The construction of the volcano is shown in Figure 2.

Fig. 2. The volcano and its main elements



Source: *Wulkanizm*, "Procesy litosfery", n.d., https://procesylitosfery.wordpress.com/procesy-endogeniczne/wulkanizm/ (accessed: 20.05.2015).

[5] *Wulkan*, "PWN – Encyklopedia", https://encyklopedia.pwn.pl/haslo/wulkan;3998577.html (accessed: 19.05.2014).

Experts estimate that over the last 10 thousand years there have been about 1,500 volcanoes active on the globe and about 7,900 eruptions have been recorded in this period. Currently, the number of active volcanoes that pose a threat is estimated to be around 800, with more than half of them located in the land area. In addition, there are several thousand inactive volcanoes on land and several tens of thousands underwater.[6]

Another division of volcanoes takes into account the place where the magma flows out. The following volcanoes are then distinguished[7]:

- *cinder cones*, which are characterized by a cone-shaped elevation formed by lava or pyroclastic materials that emerge from the outlet of a volcanic stack during the eruption;
- *shield volcanoes*, which are characterised by a wide and flattened cone with an inclination angle of no more than 8° (it is also characterised by the absence of violent eruptions, with rare and very hot alkaline lava coming out of it);
- *composite volcanoes*, which are characterized by the fact that the magma flows out of their substrate not in one place, but along a long gap.

Volcanoes differ in the dominant type of material that is extracted from them. Volcanoes can then be distinguished into[8]:

- *lava volcanoes* (or: *effusive volcanoes*) – only lava flows out of them and their eruption is mild; they are divided into:
  a) *shield volcanoes* (Hawaiian) – they are low and extensive, and the lava flowing out of them is alkaline, basaltic, of low viscosity;
  b) *lava domes* – very dense, sour, silica lava flows out of them, and the volcanoes themselves look like half a sphere (ball);
- *stratovolcanoes* (or: *mixed volcanoes*) – they throw away dense, viscous andesite lava and pyroclastic materials (volcanic bombs, lapilli, volcanic gases); they are among the most explosive volcanoes and are characterized by high, steep cones;
- *explosive volcanoes* – they throw away the so-called pyroclastic material, as well as the densest and most acidic rhyolite lava;
- *maars* – they are a type of volcanic craters formed during an explosive eruption as a result of the activity of gases released from magma or the

[6] *Wulkany*, "Eduscience", 16 April 2012, http://www.eduscience.pl/artykuły/wulkany (accessed: 20.05.2015).

[7] *Ibidem*.

[8] *Ibide*m.

activity of steam rising from heated groundwater; they do not have a formed volcanic cone;
- *mud volcanoes* – from these volcanoes a muddy mixture of water, clay, sand, etc. is brought to the surface; this is a phenomenon characteristic of fading volcanoes.

Volcanic eruptions and their consequences

The immediate threat posed by volcanoes is their eruption. Volcanic eruptions are among the most serious and at the same time the most fascinating natural threats. Historical records and contemporary events provide numerous examples of eruptions with catastrophic consequences, which have resulted in the destruction of large areas and hundreds and thousands of human victims. The *eruption* (Latin *eruptio*: 'explosion', 'outburst') is the process of the extraction of products of volcanic activity to the Earth's surface and atmosphere (colloquially – a volcanic explosion).[9]

Considering the manner of eruption, there are usually two basic categories of eruptions: *effusive* and *explosive*. The first of them, relatively calm, consists in the outflow of lava from the uppermost part of the main vent known as a volcanoe's throat. Lava can spread further down the slopes of the volcano, where it gradually solidifies in the form of lava streams. Explosive eruptions are violent; magma is ejected from the volcano as fragments. Fragmentation of magma occurs in the main vent of the volcano and is mainly caused by the pressure of the gases emitted from it. The product of explosive eruptions is *tephra*: volcanic ash, pumice stone, volcanic bombs, crystals, and other so-called pyroclastic fragments.[10]

As regards the form of eruption, the following categories thereof can be distinguished[11]:
- *central eruptions* (or: *point eruptions*) – the most common type of eruption at present; during them, the volcanic material is extracted from the central vent or its nearest vicinity by point;
- *linear eruptions* (or: *linear eruptions*, *crevice eruptions*) – volcanic material, mainly basalt lava, is extracted along the fissures in the earth's crust.

[9] See: *Erupcja*, "PWN – Encyklopedia", http://encyklopedia.pwn.pl/ (accessed: 19.05.2014).

[10] M. Awdankiewicz, *Największe erupcje wulkaniczne na Ziemi*, "Kosmos. Problemy nauk biologicznych", 2011, vol. 60, no. 3–4, p. 227.

[11] http://www.wulkany.ovh.org/erupcje.php (accessed: 19.05.2014).

In the geological past, such eruptions were common and resulted in extensive lava tubes;

- *undersea eruptions* – they take place on the seabed and often produce pillow (shaped) lava. As a result of the accumulation of volcanic materials from such eruptions, volcanic islands are formed;
- *areal eruptions* – known from the geological past, they consisted in the extraction of magma not only through the main vent, but over a wider area, e.g. due to the melting of rocks (the name of an areal eruption is also given to an explosion of many volcanoes in some area, fed from a common volcanic chamber);
- *hydrovolcanic eruptions* – caused by the pressure of water vapour created as a result of contact of surface water or groundwater with hot magma or rocks.

Depending on the type of material escaping during the eruption, one differentiates into[12]:

- *effusions* (efflorescent eruptions, lava eruptions) – characterized by the outpouring of lava without significant explosive eruption through ruptures in the crust of the earth;
- *explosive eruptions* – pyroclastic materials and volatile products are being extracted, this is usually violent;
- *mixed eruptions* – they provide lava, pyroclastic materials and volatile materials simultaneously.

Volcanic eruptions are characterized by different frequencies. For example, the Stromboli volcano, located on one of the Aeolian islands (to the east of Sicily), is almost constantly in a state of eruption. In turn, the Etna volcano erupts regularly every few years, the Oshima volcano (located on a volcanic island off the coast of Honshu, Japan) and Icelandic volcanoes erupt every few hundred years. Fortunately, the strongest volcanic eruptions have a very low frequency.[13]

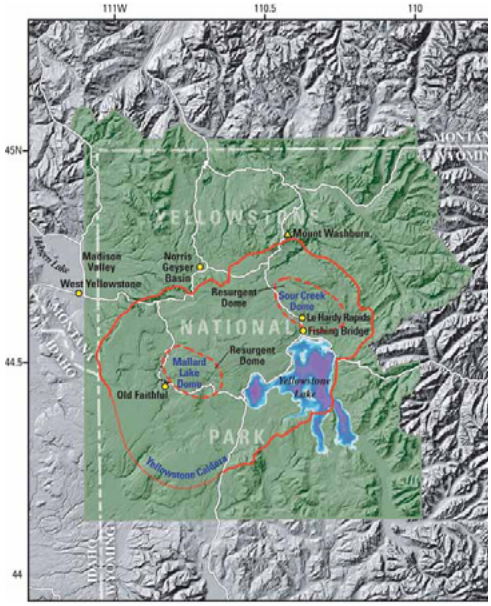
So-called *supervolcanoes* are a specific threat. A supervolcano is a volcano that is created by a powerful explosion of magma lying in a huge tank or several tanks several kilometres below the surface of the earth. Such a magma chamber usually has a volume of several to several hundred thousand cubic kilometres. After the eruption of the supervolcano, there remains a trace of a sunken, vast crater with a diameter of several dozen kilometres.

[12] *Ibidem*.

[13] More: M. Graniczny, W. Mizerski, *Katastrofy przyrodnicze,* Warszawa 2009, p. 59.

Unlike normal volcanoes, supervolcanoes are flat. On the surface of the earth above them there are hydrothermal phenomena: geysers, fumaroles, solfataras, among others.[14]

Fig. 3. Volcanic caldera in Yellowstone Park



Yellowstone National Park

• Location: Idaho, Montana, Wyoming, USA
• Established: 1 March 1872
• Area: 8,980 km²

The park is situated on a vast volcanic plateau, under which magma chambers are located at a depth of 7–17 km (measured by seismic methods).

In 1978 Yellowstone Park was inscribed on the UNESCO World Cultural and Natural Heritage List.

Yellowstone Park has now become an object of interest for volcanologists, due to the location of two huge magma reservoirs underneath it. The eruption, as volcanologists call it, of the Yellowstone supervolcano could have disastrous, direct consequences for the entire United States. It can also cause climate change throughout the Earth.

Source: "USGS Publications Warehouse", http://pubs.usgs.gov (accessed: 20.05.2015).

The Yellowstone supervolcano is of great interest to scientists today. The area of the park is in fact a crater of the currently dormant supervolcano (powered by magma from a stationary *hot spot*), whose powerful eruptions took place about 2.1 million, 1.3 million, and 640 thousand years ago. Currently, the system is in a transitional phase until the next eruption.[15] It is therefore a volcanic caldera[16] located under the surface of the earth in the Yellowstone National Park. The Yellowstone Caldera, which is about

[14] *Superwulkan*, "Wikipedia", https://pl.wikipedia.org/wiki/Superwulkan (accessed: 15.05.2015).

[15] B. Sudnik-Wójcikowska, *Park narodowy w kraterze wulkanu – rośliny Yellowstone tolerujące wysokie temperatury*, "Kosmos. Problemy nauk biologicznych", 2011, vol. 60, no. 3–4, p. 227.

[16] Volcanic caldera – a large depression at the top of the volcano, created by a violent explosion. See M. Klimaszewski, *Geomorfologia*, Warszawa, 1994, p. 32.

55 x 80 km in size, is located above the so-called *hot spot* and is a remnant of the gigantic supervolcanic explosions that took place about 2.1 million, 1.3 million and 640 thousand years ago. As the research shows, these were the highest degree eruptions on an 8-stage VEI scale.[17] During the last eruption, which took place about 640 thousand years ago, over 1,000 km^3 of pyroclastic material was thrown into the atmosphere. At the end of this eruption, the empty chamber collapsed and a caldera formed.[18] (Fig. 3)

Recent research has shown that under the surface there are two, not one, huge magma reservoirs. A group of seismologists from the University of Utah discovered that there is a second, much larger reservoir under the first one. It turned out to be 4.4 times bigger than the shallow, previously known volcanic chamber (the reservoir supplying the eruption site). The reservoir occupies about 10,000 cubic kilometres and the magma in it would fill the Grand Canyon 11 times.[19]

According to scientists from the US Geological Survey, an explosion of the Yellowstone supervolcano would have disastrous consequences for the entire US territory. (Fig. 4) From a simulation by USGS geophysicist, it is known that if the supervolcano in Yellowstone National Park explodes again, most of the United States will be covered in ash. It is predicted that cities within a radius of about 480 km from the volcano site in Wyoming will be covered with a layer of ash up to 90 cm. It is also estimated that more than 390 cubic kilometres of volcanic material will be released into the atmosphere. These emissions will reach cities such as New York and Los Angeles, on both sides of the United States.[20]

A volcanic eruption causes the release of gases, dusts and aerosols (mainly: water vapour, sulphur dioxide, hydrogen sulphide, carbon dioxide, hydrogen chloride, hydrogen fluoride) into the atmosphere. Lava, larger particles of solids ejected from the volcano, and the high temperature and high kinetic energy of the emitted substances also pose a risk. Volcanic gases are a threat to human and animal health and life. Volcanic eruptions can be accompanied by secondary phenomena such as earthquakes and tsunamis.

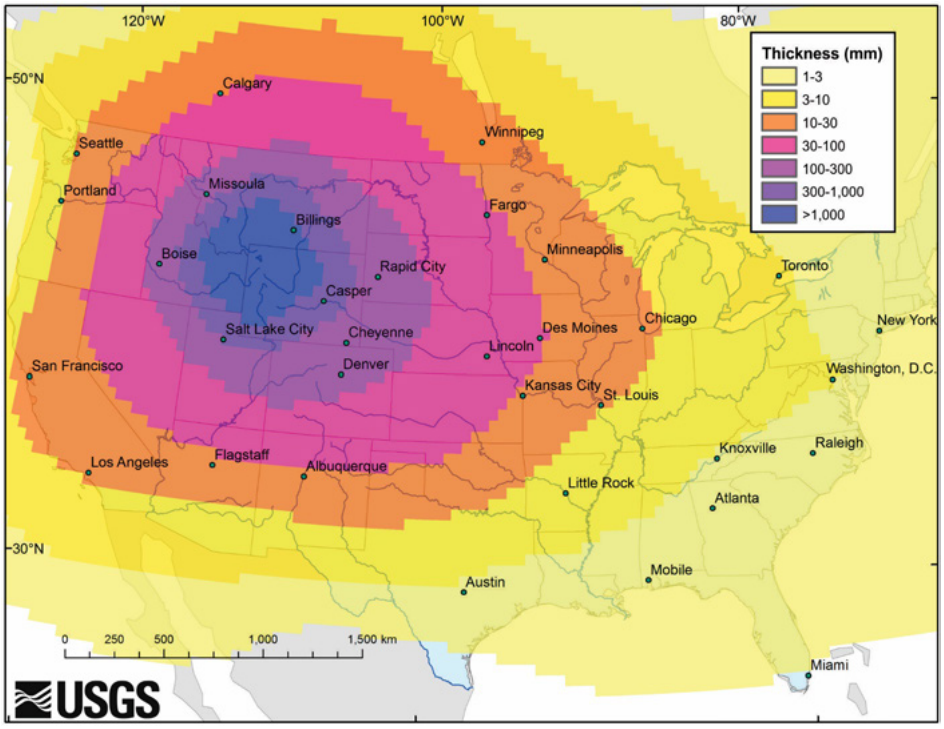
[17] VEI – Volcanic Explosivity Index.

[18] See: *Summary of Eruption History. Hot spot volcanism is responsible for Yellowstone eruptions*, "USGS Publications Warehouse", https://volcanoes.usgs.gov/volcanoes/yellowstone/geo_hist_eruptions.html, n.d., (accessed: 15.01.2016).

[19] See "Unews – The University of Utah", http:// unews.utah.edu (accessed 15.05.2015).

[20] "USGS Publications Warehouse", http://pubs.usgs.gov (accessed: 20.05.2015).

Fig. 4. Simulation of the effects of the Yellowstone super-volcano explosion



Source: "USGS Publications Warehouse", http://pubs.usgs.gov (accessed: 20.05.2015).

This is confirmed by the results of analyses of the eruptions of the largest volcanoes, which are listed in Table 1.

The most deadly volcano in modern times is Tambora, which in 1815 took the lives of nearly 92 thousand people. A mountain on the island of Sumbawa (Indonesia) erupted with the greatest force ever observed, and the sounds of the eruption were heard even 1.5 thousand kilometres from the volcanic crater. The volcano emitted so many ashes into the atmosphere that for months they fell within a radius of hundreds of kilometres. Around the volcano a layer of poisonous ashes was 3 meters high and the eruption itself received the highest intensity on the VEI scale.[21]

[21] "TwojaPogoda.pl", n.d., http://www.twojapogoda.pl/wiadomosci/114097,erupcje-wulkanow-spowodowaly-smierc-200-tysiecy-ludzi (accessed 20.05.2015).

Table 1. Examples of major volcanic eruptions

Volcano	Country and date of eruption	Description of eruption and its strength (VEIb)	Effects of eruption, comments
Santorini (Thira) 556 m	Greece (Cyclades) approx. 1628 B.C.	A violent volcanic eruption ruptured the island, on the site of the volcano a caldera with a diameter of 8 km was created, filled with sea water; ashes covered the nearby islands up to Crete; a tsunami caused by the earthquake ravaged the coast of the Aegean Sea; **VEI = 6**.	The inhabitants of Thira probably managed to evacuate; damage throughout the Aegean region, contributing to the decline of the Minoan civilisation (destruction of Thira and Knossos in Crete among others).
Vesuvius 1,277 m	Italy 24 August 79	The announcement of the eruption: a cloud of gases shaped like a pine tree, intense rain of ashes, hydrogen sulphide fumes and an earthquake in the area; no lava flow; volcanic mud streams flowed towards Herculaneum and pyroclastic materials covered Pompeii with a layer of about 7 m thick; it is likely that the eruption broke the top of the volcano, reducing its height; **VEI = 5**.	Herculaneum flooded with a dozen or so meters of volcanic mud (ash and water), hardening into rock; Pompeii and Stabiae buried in ash; 1,500–2,000 people died; archaeological works allowed to reconstruct the living conditions of the time; the first accurate account of the volcano explosion (Pliny the Younger).
Laki about 500 m	Iceland 8 June 1783	From the 24 km long crack adjacent to the volcano, huge masses of lava flowed out, along the crack about 100 new cones formed (up to 150 m high); one of the lava streams reached a length of 45 km; there was an earthquake and ashfall; in June and July there was an increase in activity, up to 8,000 m^3/s of lava; sudden melting of snow and ice and damming by the lava of river valleys caused floods; the eruption lasted for 2 years, the ashes covered the whole of Iceland and reached Scotland, and the ashes reached as far as the Netherlands; 90 million tons of sulphuric acid was released into the atmosphere; **VEI = 4**.	National disaster of Iceland – due to the eruption and subsequent emaciation, disease and famine, nearly 24% of Icelanders died, as well as 79% of sheep, 76% of horses and 50% of cattle on the island; lava covered 565 km^2 with an average layer of 20 m thick; losses in Scotland's agriculture (plant damage, lack of fodder, famine among the population); exceptionally harsh winter of 1783/84 and cool, foggy and stormy summer of 1784 in the British Isles (average annual temperature reduced by about 1°C).
Tambora 2,850 m	Indonesia (Sumbawa) April 1815	A pillar of smoke rose from the crater, glowing rock fragments were flying out; the explosion was so strong that the walls of houses burst on the island (the sounds could be heard from Java, New Guinea, Australia); at the same time the earthquake caused a tsunami and the island was ravaged by a cyclone of unprecedented strength; coastal waters were covered with a 50 cm layer of pumice stone; the ash cloud reached the mesosphere (60–70 km high), the ashes reached Java and Celebes; it is estimated that the volcano threw 150 km^3 of volcanic material away; **VEI = 7**.	Huge destruction – the green island turned into a grey wasteland, 12 thousand people died on the Sumbawa Island and 44 thousand (from hunger, among others) on the 30 km distant island of Lombok; after the explosion a clear cooling was observed in North America and part of Europe (1815 – "the year without summer"); the volcano decreased by about 1,300 m; its cone was replaced by a 7 km diameter caldera, 130 m deep.

Volcano	Country and date of eruption	Description of eruption and its strength (VEIb)	Effects of eruption, comments
Mont Pelée 1,397 m	Martinique (Little Antilles) 8 May 1902	Initially it took a stream coming down from the volcano, there was a rain of ashes and a new small cone formed in the crater; on 5 May, through the torn edge of the crater the lake flowed, forming a muddy stream; a violent explosion broke the slope of the volcano and then a fiery cloud of hot gases (800°C) "flowed" down the slope to the town of Saint Pierre at a speed of 160 kmph, tearing and burning trees; the poisonous cloud was accompanied by a wave of fire, an avalanche of rock blocks and ashes; eruptions took place in May and August, when an andesitic spire with vertical walls, 300 m high, grew out of the crater (it soon fell apart as a result of rapid erosion); **VEI = 4**.	Total destruction of the city of Saint Pierre; 26–29 thousand people suffocated, burned alive or died from respiratory burns (only one man survived, a prisoner locked in the underground). The port of Saint Pierre was destroyed, along with anchored ships that burned and sank. The August eruption destroyed the village of Morne-Rouge, where 1,000 people died.
Paricutin 2,774 m	Mexico 20 February 1943	The volcano was formed directly in the field of one of the farmers, without any particular announcement of the explosion; initially there were emissions of steam; around 5 p.m. from east to west a crack was opened, from which smoke, sparks, stones and shreds of lava began to flow out, starting fires within a radius of several hundred meters; after one day a cone 6–7 m high and about 20 m in diameter appeared, the volcanic cloud reached 5000 m high; the eruption lasted 9 years.	In total, the volcano threw out about 1.3 km^3 of ash and 0.7 km^3 of lava; the volcanic cone grew to a height of 440 m above the previous ground level.
Saint Helens 2,549 m	USA (Cascade Mountains) 18 May 1980	Eruption announcement: gases and steam appeared over the volcano in March; main explosion with a force equivalent to 500 atomic bombs (100 million tons of TNT) and the resulting blast (several hundred kmph) destroyed 200–300 m of the summit and knocked down 60 m high forests, and the cloud of ejected gases reached 19 km in height; **VEI = 4–5**.	Flooding in the valley (sudden melting of snow and ice lying on the slopes), destroyed forests, 80,000 hectares of burnt land; 66 people were killed; dust fall within a 15 km radius was 2–2.5 tonnes/ha; the location of the volcano on US territory ensured media interest and publicity far greater than the extent of the damage caused by the eruption.

Pinatubo 1,759 m	Philippines 15 June 1991	A certain increase in activity occurred in April; in June the volcano erupted rapidly, throwing huge masses of dust and ashes into the atmosphere – the smoke pillars reached 16 km and completely overshadowed the sun; the main eruption, 3 days after the first one, was accompanied by tremors; the volcano erupted 26 times and at the same time a cyclone raged in its area; on 21 August, clouds of gases surrounded the whole Earth in the intertropical belt, they also reached the north, e.g. as far as Kamchatka; **VEI = 5**.	The evacuation resulted in the deaths of 80,000 people; 24 cities were buried under ash or mud, flowing downhill at 120 kmph; the ash covered hundreds of square kilometers; sulphur dioxide emissions to the atmosphere were estimated at 19 million tons; there was a cooling down in the Philippines and globally in 1992; there was a very strong decrease in ozone over Antarctica.
Volcanic Explosivity Index (VEI) – eruption force (class) according to Smithsonian Institution (USA); eruptions with VEI = 3 occur several times a year, VEI 4 means a clear impact on the stratosphere, eruptions with VEI = 7 occur exceptionally.			

Source: *Tablice geograficzne*, collective work edited by W. Mizerski and J. Żukowski, Warszawa 2004.

The second most deadly eruption in modern times was the Krakatoa volcano (Indonesia). During the night 26–27 August 1883, the volcano exploded with unbelievable force, and from inside the volcano, unprecedented amounts of ashes rose into the sky, overwhelming with time almost the entire planet, especially in the far north; details can be seen in Box 1.

The eruption of the Krakatoa volcano had global consequences. The world not only felt and heard the explosion itself, but also had to deal with its long-term consequences. The average Earth's temperature the following year fell by more than one degree Celsius, because the wind-borne volcanic dusts simply let less sunshine through. Temperature anomalies on the scale of the entire planet lasted for the next five years. The sky around the world has become darker as millions of tons of sulphur dioxide have been released into the atmosphere and a layer of aerosol has spread, reflecting the sun's rays. The effect of these destructive actions of natural forces were unexpected optical phenomena. Even in the USA or Great Britain, sunsets were accompanied by glows so intensely red that people – convinced that there had to be a fire nearby – called the fire department.[22]

[22] M. Zimmermann, *Krakatau – kataklizm nieprzewidziany*, "Onet Wiadomości", 28 August 2013, https://wiadomosci.onet.pl/kiosk/krakatau-kataklizm-nieprzewidziany/x9g93 (accessed: 20.05.2015).

Box 1. Krakatoa volcano eruption

Source: *The eruption of Krakatoa, and subsequent phenomena. Report of the Krakatoa Committee of the Royal Society, 1888*, G.J. Symons (ed.), London 1888.

Krakatau, also known as *Krakatoa* or *Krakatao*, is an island located in the Sunda Strait, between the islands of Sumatra and Java in Indonesia.

The Sunda Strait, from the waters of which Krakatau Island emerged, is located in one of the most seismically active areas on Earth. From the northern ends of Sumatra, the volcanic archipelago stretches for almost 5,000 km across Indonesia today.

Two tectonic plates clash in this area: the Indo-Australian and Burmese (the latter is part of the larger Eurasian plate). One plate literally "goes underneath the other" – this process is called subduction. This process is accompanied by earthquakes and/or volcanic eruptions when the molten rocks come to the surface.

On 27 August 1883, one of the largest volcanic eruptions recorded in the history of humankind, and also one of the largest natural disasters known in the history of humankind happened. The bang could be heard from 320 km away. The eruption started on 26 August at 12:53 p.m. local time. At night the explosions were heard from a distance of 4,325 km, and the pillar of smoke, ash and gases reached 27 km in height.

Decks of ships in the Sunda Strait were covered with ash, dust and pieces of pumice stone with a diameter of about 10 cm. Between 6 p.m. and 7 p.m. small tsunami waves spread out concentrically and hit the coastline which is up to 40 km away.

On 27 August on 5:30 a.m., 6:42 a.m., and 8:20 a.m. local time more eruptions followed. Each of them caused catastrophic tsunami waves. The last explosion took place at 10:02 a.m. The volcano threw 19 km^3 (some sources say even 25 km^3) of ashes into the air at a height of 55 km, that is to the stratosphere.

The shockwave created by the explosion moved at a speed of over 1100 kmph. It is estimated that the sound level at 160 km from the epicenter was over 180 decibels.

Two thirds of the island disappeared from the surface of the earth, and on the rest of the island (Rakata) life was completely destroyed. A tsunami wave of up to 40 metres high and speed of over 700 kmph washed away local villages on nearby land and circulated half the Earth before it disappeared completely. Ships off the coast of South Africa wobbled as a result of a tsunami caused by the eruption. The seismic wave has circulated the Earth seven times. About 40,000 people probably died.

Source: *Tablice geograficzne*, collective work edited by W. Mizerski and J. Żukowski, Warszawa 2004; M. Zimmermann, *Krakatau – kataklizm nieprzewidziany*, "Onet Wiadomości", 28 August 2013, https://wiadomosci.onet.pl/kiosk/krakatau-kataklizm-nieprzewidziany/x9g93 (accessed: 20.05.2015); W. Mizerski, *Geologia dynamiczna*, Warszawa 2010; *Największe katastrofy naturalne w historii*, "Liceum Ogólnokształcące im. Kazimierza Wielkiego w Kole", n.d., http://lowkole.pl/geografia/najwieksze-katastrofy-naturalne-w-historii/ (accessed: 28.03.2014); J.H. Latter, *Summary of causes, with particular reference to Krakatoa, 1883*, "Bulletin Volcanologique", September 1981, vol. 44, issue 3, pp. 467–490.

There are currently several active volcanoes in Europe. Some of them are located in Iceland, where volcanic eruptions are not unusual. However, after the eruption of the Eyjafjallajökull volcano, the effects of which were felt by people all over Europe, more attention is being paid. The volcanic ash cloud, which instead of heading to the North Pole, has come over Europe due to an unusual pattern of atmospheric currents, has caused considerable disruption to air traffic. The eruption of the Eyjafjallajökull volcano in Iceland has triggered a number of speculations about the further escalation of such threats, i.e. expected eruptions of other European volcanoes.[23]

Table 2. Characteristics of selected European volcanoes

Volcano name	Location	First eruption	Number of eruptions	The last eruption
Etna	Italy	6190 B.C.	209	2001
Grimsvatn	Iceland	1332	45	1996
Hetla	Iceland	4650 B.C.	23	2000
Katla	Iceland	930	19	1955
Vesuvius	Italy	1150 B.C.	84	1944
Santorini	Greece	1470 B.C.	13	1956

Source: "Rządowe Centrum Bezpieczeństwa", http://rcb.gov.pl/ (accessed: 20.05.2014).

Volcanic eruptions have different effects, many of which are a threat to human and animal health. However, most of the threats occur locally – near the volcano. The risk to human health mainly results from harmful effects of dusts and volcanic aerosols on the respiratory system. The vulnerable groups are children, the elderly, and the sick (especially those suffering from respiratory diseases). Volcanic dust is only harmful to people if it starts to fall to such an altitude that people start to breathe in air contaminated by the dust. Volcanic gases are also harmful to health, especially: sulphur oxide, carbon dioxide, hydrogen sulphide, hydrogen chloride or hydrogen fluoride.[24]

[23] "Rządowe Centrum Bezpieczeństwa", http://rcb.gov.pl/ (accessed: 20.05.2014).
[24] *Ibidem*.

The global system of counteracting threats is mainly based on limiting settlements in the areas directly threatened, educating the society, developing evacuation procedures, and constant monitoring of threats. The main elements of monitoring are[25]:

- volcanic cone monitoring system based on satellite positioning – GPS;
- monitoring the possibility of a volcanic eruption using seismic stations;
- Volcanic Ash Advisory Centres (VAACs), collecting information on volcanic ash clouds and their potential threat to aviation worldwide;
- the European Space Agency (ESA), which provides data on the concentration of sulphur dioxide through a special SACS (Support to Aviation Control Service);
- data from Envisat, Metop, EOS-Aura, Aqua.

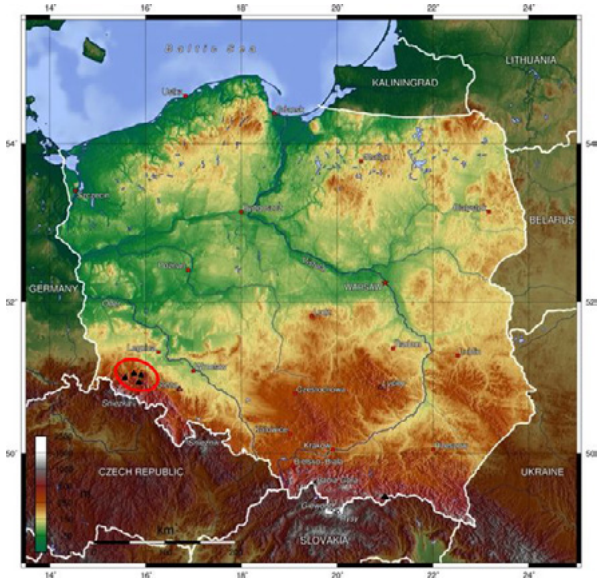
Threat of volcanic eruptions in Poland

The last active volcanoes disappeared from the Polish landscape several million years ago. Traces of volcanoes in Poland can be found in Upper Silesia, in the Pieniny Mountains, as well as in Lower Silesia, near Złotoryja. Much as the risk of a volcanic eruption in Poland is small, it cannot be entirely ruled out that in the distant future their activity will be re-activated. However, it is possible that eruptions of large volcanoes, whose eruptions may have a global range, such as Tambora or Krakatoa, may have a destructive impact. Negative effects, mainly of an indirect nature, may also be caused by European volcanic eruptions, the extent of which can be described as regional or local.

In order to limit the possible consequences of a volcanic eruption, it is important to determine in advance, on the basis of the expected or existing situation, the strength and type of the volcanic eruption and the expected direction of the volcanic cloud movement. This allows for the early publication of appropriate warning messages and preparation for the implementation of emergency procedures.

[25] *Wulkany w Europie*, "Rządowe Centrum Bezpieczeństwa", http://rcb.gov.pl/wulkany-w-europie/ (accessed: 20.05.2014).

Fig. 5. Volcanoes in Poland



In Poland one can find traces of old volcanism in Silesia (from Lusatian Neisse [Nysa Łużycka] to St. Anne Mountain [Góra Świętej Anny]); in the Pieniny Mountains; Wdżar Mountain; Beskid Sądecki; and in the southern part of the Olkuska Upland, in Miękinia near Krzeszowice.

The probability of volcanoes getting active in Poland is currently low.

The most picturesque extinct volcano in Poland is Ostrzyca Proboszczowicka, 501 meters high, near Złotoryja.

Source: *Wulkany w Polsce. Czy mogą się przebudzić?*, "Odkrywcy.pl", http://odkrywcy.pl/ (accessed: 20.04.2015).

In Poland, the Polish Geological Institute is responsible for monitoring natural hazards and catastrophes and other natural phenomena having the characteristics of natural disasters and assessing and preventing their effects.

Summary and conclusions

Volcanic eruptions are among the most serious and at the same time the most fascinating natural threats. Not only historical records, but also contemporary events provide numerous examples of eruptions with catastrophic consequences, which have resulted in the destruction of large areas and hundreds and thousands of human victims. Such a threat cannot therefore be ignored in the context of public security. The content of the article gives rise to several important comments and conclusions.

1) Volcanic eruptions are among the most dangerous environmental threats of natural origin. They pose a direct threat to the health and life of people in the area of the explosion, as well as a threat to the environment and entire local ecosystems. The effects of eruptions of large volcanoes, including supervolcanoes, can have a global impact,

and therefore countries not directly affected by volcanism must also take an interest.

2) An important issue from the perspective of common security is to constantly monitor threats from active volcanoes. A threat detected in advance can save hundreds or even thousands of lives once the civil protection services have taken appropriate action. An important issue in this respect is the flow of information between the services responsible for monitoring and civil protection on a local, regional and global scale.
3) People are not able to counteract volcanic eruptions, but they can limit the effects of the destructive influence of these eruptions by, among other things, limiting settlements in endangered areas, and developing procedures for evacuation and dealing with such threats. An important issue is also general public education on environmental safety, which could teach the population appropriate behaviour in the event of various threats, including those caused by volcanic eruptions.
4) Despite the fact that there are currently no active volcanoes in Poland, this problem should be analysed and monitored by the authorities responsible for public security, due to the fact that Polish citizens may be staying in places of direct danger, e.g. for tourist purposes, as well as due to the fact that aircraft of Polish airlines or ships flying the Polish flag may be staying in places where the level of danger is high in case of volcanic eruptions.

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