CLASSIFICATION OF VOLCANO IDS

By G. A. MAXIMOVICH

(Communicated by V. A. Obruchev, Member of the Academy, 20. VI. 1940)

Gases and water passing under a certain pressure through argillaceous rocks cause pseudovolcanic phenomena or volcanoids. Gas and water carrying along on their way clay particles washed off by water appear in fissures. It is natural that the quantity of pelites accumulating as a result of eruption will be the greater, the more gas, the higher its pressure and the more considerable the water supply of the region. A certain rôle is played also by the fineness of deposited materials on the way of the gas-water stream.

In the earth's crust an outstanding rôle ([2]) belongs to chemogenous gases (largely of volcanic origin) and biogenous gases (of oil and gas deposits and those evolved by marine, lacustrian, fluvial and palustrian muds). Of some importance are also gases due to the technical activities of man. Under certain conditions all of them can be responsible for the formation of volcanoids. Volcanoids can attend also seismic phenomena. In literature it is the custom to differentiate after Mercalli ([16]) only mud volcanoes (vulcani di fango) and thermal mud volcanoes (vulcanetti di fango termale).

Below we shall discuss the principal varieties of volcanoids and give their classification. Thermovolcanoids are connected with regions of magmatic volcanism. They contain mud with a temperature amounting to 95° C and practically are a variety of fumaroles. Among the gases evolved the main role usually belongs to CO_2 and N_a. There is also some CH_4, H_2 and H_2S. When there is boiling water, steam is naturally given off. Thermovolcanoids are pyrogenous salses in the shape of low cones, as a rule up to 1 m, rarely to 5 and more in height, or grifons (mud-pots). They occur in Iceland, Central America, the Celebes, New Zealand and Kamchatka (USSR). In Kamchatka ([18]) the gas consists of CO_2 (over 80 %), N_2 (up to 10 %) and CH_4 (1–5 %).

We happened to observe technogenous volcanoids at gas and oil plants of Grozny. Above a steam-pipe buried in clay and steaming, in pits filled with water or wet clay, phenomena similar to mud-pots or grifons of thermovolcanoids could he observed.

It is the volcanoids connected with the underground accumulations of oil or gas that invite particular attention of scientists. From the ample literature bearing on the subject we must note only the studies by Kovalevsky ([9-11]), Gubkin and his school ([6],[7], [19]), Obruchev ([17]), Archangelsky ([1]), Belousov ([3]), Steber ([23]), Blumer ([4]) and Umbirov ([22]). These volcanoids are distributed in a band stretched in almost latitudinal direction and are in most cases confined to oil and gas fields connected with the Alpine folded zone. Such volcanoids are to be found in the Malayan archipelago, Arakan islands (Birma), Northern Iran, eastern Caspian coast, islands of the Baku archipelago, the Apsheron peninsula and adjoining part of the Caucasus; Georgia, the Taman and Kerch peninsulas, Rumania, Italy, the isle of Trinidad, Columbia, the USA (states of Idaho and Texas). In these regions the typical features of volcanoids are the temperature of pelites approaching that of the air, the predominance of hydrocarbons in the composition of gas, and waters similar to those of oil.

As to the nature of action, these volcanoids can be classified into tectogenous and naphthogenous proper. The former are confined to strongly dislocated regions with crumpled rocks in the core of folds. They are largely diapyrous structures. Tectogenous volcanoids display diverse activity. They squeeze out breccia. Fold-forming movements in the crushed rocks of the core periodically block the escape of gases. Pressure is created in the depth. Eruption takes place, autoclastites being thrown up. These fragments of interior rocks are from 1–2 cm to several meters large. Blocks 2–3 m large were observed by us in the volcanoid Akhtarma near the Karadag station on Apsheron peninsula. Movements of folding are accompanied also by the squeezing out of breccia and blocks. These volcanoids not only produce explosions, but also behave quietly, giving off pelites, cone breccia, water and gas. At times gas ignites spontaneously, forming a column of fire, and thus heightens the external resemblance of volcanoids to magmatic volcanoes. The greatest accumulation of materials is naturally observed in tectogenous volcanoids. The most eminent, having cones 400–500 m high, are situated in the region of the oil fields of Baku which are the largest in the world, with its naphtha-gas-water bearing productive layer 1 km thick and diapyr structures. There are some considerable volcanoids on the Taman peninsula. On the island of Timor one of the cones reaches the height of 36 m.

Other volcanoids in the regions of oil deposits, situated in the areas of faulting, are not accompanied by explosions or squeezing out of breccia and blocks. They contain, therefore, no autoclastites. They quietly give off cone-breccia, pelites, water and gas. According to Gubkin ([7]), we shall term such volcanoids salses (mud-volcanoes). They are ordinarily 4–6 m high, reaching at times 10, rarely 15 m.

The form of the eruptive apparatus varies. It consists of a cone (simple or complex) and a shield formation with a mud lake (of a big diameter) or grifon (mud-pot). The height of the latter is usually 0.5–1 m. Besides, there exist all kinds of combinations of these forms; one and the same complex volcanoid can display several forms and change with the time depending on the nature and abundance of eruptives. Shield volcanoids form in the case of abundance of water and lack of pelites.

The gases of tectogenous and naphthogenous volcanoids of biogenic origin contain largely CH_4 with CO_2, N_2 admixed. Sometimes small amounts of H_2 and H_2S are observed. In Azerbaidjan the content of CH_4 is more than 90 %, of CO_2 from 0.1 to 6–7 %, the rest usually consisting of N.

The volcanoids under consideration are characterized by the action of biogenic depth gases that accumulate from extensive areas in elevated portions of structures. Therefore, even when they are not accompanied by explosions or squeezing out of breccia, considerable accumulations of pelites take place here.

The gases of recent and quaternary muds of litoral parts of seas, rivers- and, under particular conditions, lakes and swamps can naturally not yield great accumulations. These formations were therefore scarcely given any attention by those studying the classification of pseudovolcanic phenomena.

Along coast of the gulf in the Mexico in the states of Louisiana and Texas, over an area of some thousands of km^2, salses with a diameter of 5–10 m and height of 1–2 m (gasmounds, antmounds) are developed ([4]). Gases escaping from these salses are, in our opinion, products of decomposition of marine muds. These volcanoids are thalassogenous. Similar phenomena are known of the eastern coast of the Caspian near Chikishlar. Here the group of salses erupts mud containing CH_4 with H_2S admixed. Most of the gas is of deep origin, and H_2S comes from sands resting at a depth of 6–10 m below the sea level and containing algal remains. These volcanoids are, properly speaking, of promiscuous origin.

In the Mississippi delta, near New Orleans, the escape of gas (CH_4 – 86 %, CO_2 – 9.41 %, N_2 – 4.39 %) has caused the development of small salses (mudlump springs), erupting mud with brine and infusoria. These volcanoids are potamogenous. The gases here are biogenic. We consider them to have derived from river muds (partly also marine), deposited in the initial delta and then covered with fluvial alluvia.

A separate group is presented by cryovolcanoids. They had been recorded as early as by Middendorf ([16]). Data on them are given by Sukachev ([21]), Lvov ([14]), Kushev ([12], [13]), Loparev ([25]) and others. Gladtsin's description ([5]) is worth nothing. There are salses up to 1.5 m high, with the cone base 3.0–5.5 m wide and the vent up to 0.75 m wide, in the vicinity of Doroninskoye Sodovoye ozero (Doronin Soda Lake) in East Siberia. They are formed in March-April, when winter freezing of the active layer, in the direction from the surface to the upper limit of frozen ground, causes cohering of horizons. The continued afflux of ground waters from more elevated areas results in a formation of hydrolaccoliths and cryovolcanoids in depressions, in the given case on lake-shores. We believe that these develop wherever there is a greater accumulation of gases from organic lacustrian muds [CH_4, H_2S, HF (?)]. The pressure of gases makes the top of frozen mound burst along the fissures, and thus a cryovolcanoid is formed. It erupts finest liquid mud containing gas. If gas pressure is insufficient, the mound freezes and changes into a hydrolaccolith. It is sufficient to prick the top of the hydrolaccolith with a stick to change it into a cryovolcanoid. According to measurements made in July 1929, the temperature of mud was: on the surface +15°, at the depth of 0.2 m +4°, of 0.5 m +1.5°, of 1 m – 0° G. Deeper a layer of permanent frozen ground or an ice lens is found by means of a pole. In the region of Hada-Bulac (East Siberia) the cracks along which mud pours out, form at the expense of ice. The development of cryovolcanoids seems to be possible under subaqueous conditions. The cryovolcanoids in tundras seem to have an analogous genesis. But here organic muds are largely of soil-swamp origin.

Seismovolcanoids are caused by earthquakes: they are most short-lived volcanoids. They were observed in Quito 4.II.1797 ([8]), on the coast of the gulf of Corinth 26. XII. 1861 ([20]), in the valley of the r. Sava 9. XII. 1880, on the shore of lake Issyk-kul 28. V. 1887, during the Californian earthquake of 1906 ([24]). The volcanoids have arisen in the cracks formed during the earthquake, for the most part at the points of their intersection or where they reach the greatest size. The greatest cones have been formed in Achaia ([2]°Y, where their height reached 5 m, the diameter of the base being 20 m and the angle of dip 20°. The diameter of crater-like holes (one or several) was up to 1 m.

Seismovolcanoids take place for the most part in alluvial, more rarely in lake deposits. In the course of the above-said earthquakes, sand and silt erupted formed accumulated structures in the shape of cones. Sometimes, as in Assams 12. VI. 1897 ([24]), funnel-like holes are formed after sand and water have been erupted. Seismovolcanoids are largely due to the mechanical effect of the seismic wave. There occur ruptures on the surface, the crumpling of underlying waterbearing rocks and squeezing out of liquid bodies–water and sand or clay. Some part is also played by the gas evolved from alluvial and lacustrian muds manifest themselves. 'Development of thalassogenous volcanoids is possible.
Escape of H_2S was recorded at the eruptions in Achaia, in the Sava river valley, on the shore of Issyk-kul. CH_4 is probably given off, too, but under the conditions of earthquake this remained unrecorded. H_2S was noticed by its keen odour. Thus, seismovolcanoids differ from other types in their acting mainly under the influence of hydraulic shocks and in their erupting sand. The role of gas has not been elucidated yet, but it seems to be of minor importance. Their further investigation is necessary. Cryovolcanoids are formed under the forcing pressure of water and the increase in its volume when freezing. Gas seems only to break through the mantle.

Such are the fundamental data on volcanoids. Their classification is given in Table 1. Among purely gaseous volcanoids should be classed pyrogenous, technogenous, thalassogenous, potamogenous and naphthogenous ones. Tecto-, cryo- and seismogenous volcanoids are to be referred to complex volcanoids, the formation of which is due, besides the movement of gas and water, to some other force (tectonic, seismic, ice) (Table 2).

It is necessary to study not only pyrogenous and naphthogenous volcanoids, but other varieties, in particular, their morphology, genesis, as well as the mechanical composition of pelites and the composition of gases. The insignificant depth of cryovolcanoid foci and of potamogenous and thalassogenous varieties permits of a better study of the mechanism of their activity. This may be of some aid when studying volcanoids associated with oil, which are the most interesting with regard to their practical importance.

Table 1

Classification of volcanoids

Type»	Class	Gas: Origin	Gas: Main constituents	Temperature of mud	Main cause of volcanoid action	Nature of action: Explosion	Nature of action: Quiet flow	Morphology of eruptive apparatus: Cone: Complex	Cone: Simple	Shield: Mud lake	Shield: Grifon(mud-pot)	Maximum height of cone in m	Solid eruptives: Autoclastites	Crater breccia	Pelites	Sand
Thermovol-canoids	Pyrogenous	Chemical (volcanic)	CO_2, N_2, CH_4, H_2, H_2S	to 95°	Gases ascending along cracks		+		+	+	+	6			+	
	Technogenous	Technoge nous	Steam	to 95°	Steam ascending through liquefied clay		+				+	0.2			+	
Volcanoids (proper)	Tectogenous	Biogenic, of depth	CH_4, CO_2, N_2	Near to the temperature of air	Tectonic movements and action of oil	+	+	+	+	+	+	500	+	+		
	Naphthogenous				Oil gases ascending along cracks		+		+		+	15		+	+	
	Thalassoge nous	Biogenic, near surface	CH_4, H_2S		Action of biogenic (mud) gases		+		+			2			+	
	Potamogenous		CH_4, CO_2, N_2		Action of biogenic (mud) gases		+		+			2			+	
Crvovolca-noids	Helogenous		CH_4, H_2S	Near to 0°C	Crumpling at the conversion of water into ice, water streaming and gas playing some part		+		+		+	0.7			+	
	Limnogenous		CH_4, H_2S, HF(?)	At the depth of 1 m 0°C			+		+			1.5			+	
Seismovol-canoids	Seismogenous		CH_4(?), H_2S	Near to the *t*° of air	Seismic waves, gases playing some part		+		+		+	5			+	+

Note. Under subaqueous conditions tectogenous, naphthogenous (?), potamogenous and limnogenous volcanoids

Table 2

	Type	Class
Simple (gaseous)	Thermovolcanoids	Pyrogenous
		Technogenous
	Euvolcanoids	Thalassogenous
		Potamogenous
		Naphthogenous
Complex		Tectogenous
	Cryovolca noids	Helogenous
		Limnogenous
	Seismovolca noids	Seismogenous

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Below we shall discuss the principal varieties of volcanoids and give their classification. Thermovolcanoids are connected with regions of magmatic volcanism. They contain mud with a temperature amounting to 95° C and practically are a variety of fumaroles. Among the gases evolved the main rôle usually belongs to CO_2 and N_2. There is also some CH_4, H_2 and H_2S. When there is boiling water, steam is naturally given off. Thermovolcanoids are pyrogenous salses in the shape of low cones, as a rule up to 1 m, rarely to 5 and more in height, or grifons (mud-pots). They occur in Iceland, Central America, the Celebes, New Zealand and Kamchatka (USSR). In Kamchatka ([18]) the gas consists of CO_2 (over 80%), N_2 (up to 10%) and CH_4 (1—5%).

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As to the nature of action, these volcanoids can be classified into tectogenous and naphthogenous proper. The former are confined to strongly dislocated regions with crumpled rocks in the core of folds. They are largely diapyrous structures. Tectogenous volcanoids display diverse activity. They squeeze out breccia. Fold-forming movements in the crushed rocks of the core periodically block the escape of gases. Pressure is created in the depth. Eruption takes place, autoclastites being thrown up. These fragments of interior rocks are from 1—2 cm to several meters large. Blocks 2—3 m large were observed by us in the volcanoid Akhtarma near the Karadag station on Apsheron peninsula. Movements of folding are accompanied also by the squeezing out of breccia and blocks. These volcanoids not only produce explosions, but also behave quietly, giving off pelites, cone breccia, water and gas. At times gas ignites spontaneously, forming a column of fire, and thus heightens the external resemblance of volcanoids to magmatic volcanoes. The greatest accumulation of materials is naturally observed in tectogenous volcanoids. The most eminent, having cones 400—500 m high, are situated in the region of the oil fields of Baku which are the largest in the world, with its naphtha-gas-water bearing productive layer 1 km thick and diapyr structures. There are some considerable volcanoids on the Taman peninsula. On the island of Timor one of the cones reaches the height of 36 m.

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Seismovolcanoids take place for the most part in alluvial, more rarely in lake deposits. In the course of the above-said earthquakes, sand and silt erupted formed accumulated structures in the shape of cones. Sometimes, as in Assams 12. VI. 1897 [24], funnel-like holes are formed after sand and water have been erupted.

Seismovolcanoids are largely due to the mechanical effect of the seismic wave. There occur ruptures on the surface, the crumpling of underlying water-bearing rocks and squeezing out of liquid bodies—water and sand or clay. Some part is also played by the gas evolved from alluvial and lacustrian muds

Table 1

Classification of volcanoids

Type	Class	Gas		Temperature of mud	Main cause of volcanoid action	Nature of action		Morphology of eruptive apparatus				Maximum height of cone in m	Solid eruptives			
		Origin	Main constituents			Explosion	Quiet flow	Cone: Complex	Cone: Simple	Shield: Mud lake	Shield: Grifon (mud-pot)		Autoclastites	Crater breccia	Pelites	Sand
Thermovolcanoids	Pyrogenous	Chemical (volcanic)	CO_2, N_2, CH_4, H_2, H_2S	to 95°	Gases ascending along cracks		+		+	+	+	6			+	
	Technogenous	Technogenous	Steam	to 95°	Steam ascending through liquefied clay		+				+	0.2			+	
Volcanoids (proper)	Tectogenous	Biogenic, of depth	CH_4, CO_2, N_2	Near to the temperature of air	Tectonic movements and action of oil	+	+	+	+	+	+	500	+	+	+	
	Naphthogenous	Biogenic, of depth	CH_4, CO_2, N_2	Near to the temperature of air	Oil gases ascending along cracks		+		+		+	15		+	+	
	Thalassogenous	Biogenic, near surface	CH_4, H_2S	Near to the temperature of air	Action of biogenic (mud) gases		+		+			2			+	
	Potamogenous	Biogenic, near surface	CH_4, CO_2, N_2	Near to the temperature of air	Action of biogenic (mud) gases		+		+			2			+	
Cryovolcanoids	Helogenous	Biogenic, near surface	CH_4, H_2S	Near to 0°C	Crumpling at the conversion of water into ice, water streaming and gas playing some part		+		+		+	0.7			+	
	Limnogenous	Biogenic, near surface	CH_4, H_2S, HF(?)	At the depth of 1 m 0°C	Crumpling at the conversion of water into ice, water streaming and gas playing some part		+		+			1.5			+	
Seismovolcanoids	Seismogenous		CH_4(?), H_2S	Near to the $t°$ of air	Seismic waves, gases playing some part		+		+		+	5			+	+

Note. Under subaqueous conditions tectogenous, naphthogenous (?), potamogenous and limnogenous volcanoids manifest themselves. Development of thalassogenous volcanoids is possible.

Escape of H_2S was recorded at the eruptions in Achaia, in the Sava river valley, on the shore of Issyk-kul. CH_4 is probably given off, too, but under the conditions of earthquake this remained unrecorded. H_2S was noticed by its keen odour. Thus, seismovolcanoids differ from other types in their acting mainly under the influence of hydraulic shocks and in their erupting sand. The rôle of gas has not been elucidated yet, but it seems to be of minor importance. Their further investigation is necessary. Cryovolcanoids are formed under the forcing pressure of water and the increase in its volume when freezing. Gas seems only to break through the mantle.

Table 2

	Type	Class
Simple (gaseous)	Thermovolcanoids	Pyrogenous
		Technogenous
	Euvolcanoids	Thalassogenous
		Potamogenous
		Naphthogenous
Complex		Tectogenous
	Cryovolcanoids	Helogenous
		Limnogenous
	Seismovolcanoids	Seismogenous

Such are the fundamental data on volcanoids. Their classification is given in Table 1. Among purely gaseous volcanoids should be classed pyrogenous, technogenous, thalassogenous, potamogenous and naphthogenous ones. Tecto-, cryo- and seismogenous volcanoids are to be referred to complex volcanoids, the formation of which is due, besides the movement of gas and water, to some other force (tectonic, seismic, ice) (Table 2).

It is necessary to study not only pyrogenous and naphthogenous volcanoids, but other varieties, in particular, their morphology, genesis, as well as the mechanical composition of pelites and the composition of gases. The insignificant depth of cryovolcanoid foci and of potamogenous and thalassogenous varieties permits of a better study of the mechanism of their activity. This may be of some aid when studying volcanoids associated with oil, which are the most interesting with regard to their practical importance.

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