

Two Types of Acid Volcanism *

E. F. MALEYEV

Institute of Volcanology, Academy of Sciences of the USSR

Acid volcanism has been widely developed all over the globe during all the geological ages but, especially, during the Meso-Cenozoic — during the period of an orogenic development of geosynclines. By the intensity of this phenomenon, the relative role of acid volcanic rocks as compared with basic, by the ratio of plutonic and volcanic facies, their character, their association with different stages in the development of geosynclines, their association with various geostructural zones and areas with a different thickness of the crust, as well as by their petrochemical properties and the ore indications, we can distinguish two types of acid volcanism.

Because of a wide areal development of eruption products of the first type of acid volcanism, we call it a *regional type of acid volcanism* contrary to the second type with thick deposits of tuffs and lavas of basic composition, which is termed by us as a *local type of acid volcanism*.

Below, proofs are given of the existence of these two genetic types of acid volcanism.

Absolute Amount of Acid Volcanites (¹)

The regional type of acid volcanism is characterized by the development of acid volcanites over enormous territories. Their masses occupy very large areas and, consequently, the volume of acid volcanites amounts to very high values. During the Meso-Cenozoic acid volcanism was especially active in the framework of the Pacific Ocean basin. Within the Okhotsk-Chukotka (Chaunsk) volcanic belt acid

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(¹) The term « volcanites » has been adopted by us according to A. RITTMANN (1964).

volcanites are mostly of a liparite-dacitic composition and of Mesozoic age; they extend in a stretch from the city of Okhotsk almost to the eastern extremity of Chukotka Peninsula. This stretch is several hundred kilometers wide and from a hundred meters to 2-3 km thick (E. K. USTIEV, 1963).

In their mass development Mesocenozoic volcanites extend to the south-west from the city of Okhotsk into Sikhote-Alin, Korea, Eastern China and further south up to Indonesia, New Zealand, as well as the western part of South and North America. Within the Alpine belt of south-western Eurasia acid volcanic products also play an important role. On the territory of the Pannonian Median massif (Hungary) acid volcanic rocks of Miocene age form three horizons from 50-100 to 60 m thick, each of which occupies areas of 6, 30 and 40 thousand sq. km (PANTO, 1962). According to E. E. MILANOVSKY and N. V. KORONOVSKY (1963) their volume comes to about 10000 km³. Intense manifestations of acid volcanism took place in Eastern Carpathians during the Miocene, where thick horizons of acid tuffs in the Transcarpathian depression, according to our computations have a volume of about 5000 km³ (MALEYEV, 1964). A just as intense acid volcanism is recorded within the Prešov - Tokai massif. Intense manifestations of acid volcanism have been also established in South-Western Bulgaria (Rhodope median massif). During the Eocene-Lower Miocene there was an accumulation of volcanic deposits of a latite-andesitic and dacitic composition in two depressions, their thickness coming to 3-4 km³. During the Oligocene-Miocene the formation took place of thick masses of volcanic rocks of a liparitic composition and the injection of minor intrusions (R. IVANOV, 1963, 1964). In the median massifs of Anatolia (Turkey) the tuff-ignimbritic rock masses of liparitic and dacitic composition of Miocene-Pliocene age form vast plateaus of an area over 15000 sq. km with thicknesses up to 400 m (WESTERVELD, 1957). Less intense acid volcanism occurred on all continents and during different geological periods.

As an example of a local type of acid volcanism mention could be made of the areas of the Pacific volcanic belt, which include also Pliocene-Quaternary volcanites. Here the volume of products of medium acidity and fully acid products comes to units, tens and, rarely, the first few hundreds of cubic kilometers, these acid rocks occurring among thick masses of basic volcanic rocks. Small acid massifs are known in many points of the Mediterranean folded belt of Pliocene-Quaternary age. They are also known in older volcanic

formations on all continents. The above mentioned data quite obviously indicate the incomparably different amounts of acid volcanic products produced by the regional and local types of acid volcanism.

Relative Amount of Acid products as Compared with Basic Rocks

Acid volcanic products of a regional type are accompanied by an insignificant amount of basic products. Thus, for instance, in the Transcarpathian depression 5000 km³ products of an acid composition correspond to 20-25 basic products (MALEYEV, 1964). In some areas products of a basic composition are absent and the formation of the acid volcanic series begins with products of a medium-acid composition. In this way, in the Rhodope median massif, at first, products of a latite-andesitic composition were ejected, and then of a liparitic composition (R. IVANOV, 1964). An analogous regularity is recorded also in other regions, where there is a distinct predominance of acid products over basic rocks. Different relations are characteristic for the local type of acid volcanism. Basic products of a mainly andesite-basaltic composition make up the main mass, whereas medium-acid and acid volcanic products form only fractions or the first few percent of the total volume of ejected material. In this way, in Kamchatka, acid and medium-acid rocks form only about 0.43 % of the total mass of ejected matter (VLOVADETZ, 1946) and for the Transcarpathian depression, 2-4 % (MALEYEV, 1964). On all volcanic arcs in the Pacific Ocean volcanic rocks have similar ratios of acid and basic compositions. Similar relations are also recorded in older volcanic geological formations (²).

Ratio of Plutonic and Volcanic Facies

Manifestations of acid volcanism during the orogenic stage of the development of geosynclines is accompanied by plutonic facies, which is caused, probably, by the presence of near-surface magmatic foci — intrusions associated with this type of volcanism (IVANOV, 1965). The relations between volcanic and plutonic facies for the

(²) In determining the amount of acid products mistakes can sometimes be made, owing to the extensive range of dispersion and rapid rate of decomposition of the pyroclastic material. However, even big errors cannot change the order of figures in the determination of the relative amount of basic and acid products.

regional and local types of acid volcanism are different. In the regional type the volcanic and plutonic facies are of a similar volume. In this way, within the Okhotsk-Chukotka belt in the Lower Cretaceous volcano-plutonic formation, the volcanic and plutonic facies occupy nearly identical area. The Upper Cretaceous plutonic facies occupies one sixth of the formation area, which can be partly explained by a lesser degree of erosion. In a local type of acid volcanism the plutonic facies forms only fractions and units of a percent of the total volcano-plutonic formation. So, for instance, in the Transcarpathian depression in the volcano-plutonic formation associated with the basic magma, the plutonic facies comes to only fractions of a percent of the total volcano-plutonic formation in the series of acid differentiates. The explanation is that the plutonic facies is associated only with acid differentiates of a basic magma, which rises to the surface from the subcrustal magmatic foci virtually not being subjected to a differentiation. During recent years many authors have made volume computations of volcanic rock lavas and of accompanying hypabyssal intrusions for various volcanic areas of the Soviet Union. The data obtained confirm our computation results that plutonic facies of volcano-plutonic formations associated with the differentiation of a basic magma come to fractions and units of percent of the total volume of ejected material. In the manifestations of a regional volcanism the plutonic facies amounts to tens of percent of the total volume of products of the volcano-plutonic formation. In this way, depending upon the type of acid volcanism, the ratios of plutonic and volcanic facies are different.

Types of Eruptions That Create Acid Rocks

During the Recent period there have been mostly manifestations of the local type of acid volcanism on the globe, *i.e.* a type associated with a basic magma, the acid volcanic products being its differentiates. The regional type of acid volcanism is not known for the Recent period.

For this reason it proves possible to characterize reliably only the eruptions of the local type of acid volcanicity. Many modern volcanoes that eject products of an acid and medium-acid composition like Katmai during the eruption of 1912, Bezymianny (Kamchatka), 1956-1965, Sheveluch, 1948-1950 and 1964, Mont Pelée, 1902, Vesuvius,

79, etc. are characterized by an intense explosive activity with incandescent pyroclastic (agglomerate) flows, direct explosions, with the formation of explosion calderas and, sometimes, viscous extrusions (Katmai, Peléan, Plinian types of eruption).

The regional type of acid volcanism is characterized by more impetuous eruptions, which is indicated by incomparably thicker tuff-ignimbritic rock masses than we find in the local type of acid volcanism. Judging by their sequences, one can assume that during one eruption or a series of them separated by insignificant time intervals hundreds and thousands of cubic kilometers of acid eruption products had accumulated. Consequently, one cannot regard as fully identical the character of the eruptions of a regional volcanism and present-day eruptions. By their character they were similar to the Katmai type of eruptions, but were incomparably stronger and were accompanied not by explosion calderas, but by collapse calderas, which is determined by a supply to the surface of enormous masses of magmatic material from the magmatic chamber.

Character of Volcanic Facies

The regional type of acid volcanism is characterized by thick masses of pyroclastics (former pyroclastic flows) represented by pumices or ignimbrites. They are known in numerous volcanic areas and are described in special papers and summaries (« *Tuffolavas and ignimbrites* », Acad. Sci. USSR, fasc. 20, 1961; « *Problems of paleovolcanism* », For. Liter., 1963 — a book of collected articles by foreign authors, etc.). For the local type of acid volcanism, masses of pumices and ignimbrites are recorded more rarely and they are of relatively smaller sizes. However, for this type of volcanism as well, there are examples of thick masses of acid pyroclastic material, which occupy territories of several hundred square kilometers and have a thickness of several tens of meters, such as the modern agglomerate flow on Sheveluch (1964 eruption) which occupies an area of 140 sq. km. The material of pyroclastic flows of the local type of acid volcanism is slightly porous and mainly not baked. However, cases are known when baked pyroclastic material is formed. On Caucasus Minor, in the area of Aragatz volcano there are tuff-ignimbritic masses of a medium-acid composition and Pliocene-Quaternary age that are 50-100 m thick and occupy a territory of about 5000 sq.

km (SHIRINIAN, 1961). On Kamchatka there is also a wide development of ignimbrites and pumice pyroclastic and mud flows, which by appearance and sometimes by composition occupy an intermediate position between the two types of volcanism described above. (At the present time Kamchatka ignimbrites are being studied in detail and there is a chance that features will be established that will permit us to distinguish an intermediate type of volcanism).

Therefore the regional type of acid volcanism is characterized by the formation of ignimbrites and thick pumice horizons, and the local type by the formation of pyroclastic flows, agglomerate flows consisting of coarse fragmental slightly porous material.

The Association of the Types of Acid Volcanism to the Development Stages of Geosynclines

Manifestations of acid and intermediate volcanism are observed not only during the orogenic stage in the development of geosynclines, but also during the truly geosynclinal stage and very rarely during the postorogenic stage. However, the types of acid volcanism that we described took place only during the orogenic stage in the development of geosynclines.

In the Transcarpathian depression the entire orogenic volcanism passed through four stages (phases of volcanism); the first two were represented mostly by acid products and the two last stages by basic material with an insignificant amount (2-4 %) of acid products (MALEYEV, 1964). Each stage of volcanism developed homodromously (from basic to acid). An analogous regularity has been recorded in nearly all volcanic areas during the orogenic stage in the development of geosynclines: in Central and Western Carpathians, in the Caucasus, in Middle Asia, Kazakhstan, in the Okhotsk-Chukotka belt, in Kamchatka, in Sikhote-Alin, in Japan and many other areas. In all cases there is regional acid volcanism during the first stages and local volcanism during the final stages.

Association of Acid Volcanism with Geostructural Zones

Acid volcanism of the regional type is most intensely manifest at a distance from geosynclinal troughs — within median massifs and in their framework. Acid volcanism of a local type, on the con-

trary, is associated with the framework of geosynclinal troughs. In Eastern Carpathians acid volcanism of a regional type is developed both within the Pannonian median massif and along its periphery in the territory of Hungary, the Soviet Union and Czechoslovakia. Local acid volcanism is associated with the Vygortat-Gutta ridge and the Harghita-Calamen range at the junction of the rising Carpathians with the area of molasses, in other words in the flank part of the geosynclinal trough in the territory of Czechoslovakia, USSR and Rumania. An analysis of data indicated that a similar regularity has been observed also in other geosynclines and median massifs. Manifestations of a local acid volcanism are associated with the flank zones of geosynclinal troughs, and events of the regional volcanism with the more distant parts, up to the median massifs.

Petrochemical Features of the Rocks by the Types of Acid Volcanism

The petrochemical properties of volcanites depend upon the types of acid volcanism. It has been established on the example of the Eastern Carpathians that the rocks of the local type of acid volcanism contain a higher amount of alkalies, calcium and magnesium, whereas the rocks of the regional type have a higher content of aluminium and iron. A higher content of potassium takes place in volcanites most distant from geosynclinal troughs and located farther away in the median massifs.

The Association of Minerals with the Different Types of Acid Volcanism

The character of minerals is strictly determined by the types of acid volcanism. This is especially obvious in two volcanic zones fringing the Pacific Ocean: outer zone of a wide development of the regional type of acid volcanism (Okhotsk-Chukotka belt, Sikhote-Alin, Korea, Eastern China, etc.) and the inner zone in which the local type is developed (island arcs of the Pacific Ocean). In the outer belt the largest tin deposits are concentrated, as well as deposits of tungsten, lead, zinc, gold, silver and other metals, which are absent in the inner belt. Within the inner belt there are many shows of ore

minerals, but large deposits are not recorded. At the same time the inner belt is rich in sulphur and other non-ore minerals⁽³⁾.

A comparison of the two distinguished types of volcanism enables us to draw a conclusion that their difference is determined by two types of magma. The regional type of acid volcanism is determined by an acid magma in the crust. The local type of acid volcanism is determined by a basic subcrustal magma of the upper mantle and acid volcanites are differentiation products of a basic magma.

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⁽³⁾ During other geological periods the ore presence in the rocks of a local type of volcanism was different.