ON A CLASSIFICATION OF CENTRAL ERUPTIONS ACCORDING TO GAS PRESSURE OF THE MAGMA AND VISCOSITY OF THE LAVA

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(with plate 6).

In the above title the word magma is used to signify the solution plus the gas disolved in it under pressure and the word lava for the magma that has partially or entirely lost its content of gas.

A clear differentiation of the types of eruptions is not easy, because the character of an eruption depends upon a series of factors.

One of these factors, which belongs to simple physical properties, is temperature. ALBERT BRUN (bibl. 1, p. 11) has introduced the conception „phase'' into vulcanology, which he connects immediately and exclusively with temperature. „The phase is defined by the temperature at the hottest point of the volcano under consideration [1])''. VON WOLFF (bibl. 2, p. 566) in connection with this, says: „The statement of the temperature is sufficient to characterize a volcano quite definitely'' [2]).

This seems to me to be applicable to dormant volcanoes, therefore to volcanoes in the solfatara and fumarole stage, but to classify the types of eruption according to the temperature (of the lava) as v. WOLFF (bibl. 3, p. 3—7) has done, though a useful suggestion, is not in my opinion, an entirely satisfactory solution of the problem of classification of the various types of volcanic eruptions. As a matter of fact the character of the eruption is not determined chiefly by the temperature. Whether an eruption will be of the Volcano-type or the Pelée-type, for instance, does not depend principally upon the temperature.

If we combine with the temperature the chemical composition of the lava, this combination yields a very tangible phenomenon; that of the viscosity or otherwise, the degree of liquidity of the lava.

It is certain ,that the degree of liquidity stands in a closer relation to the character of an eruption, than the temperature, but even this is not sufficient to characterize an eruption. In my opinion the force as well as the viscosity of the lava is a good test of its character.

[1]) La phase est définie par la température du point le plus chaud du volcan considéré.

[2]) Die Temperaturangabe genügt um den Zustand eines Vulkans scharf zu charakterisieren.

To begin with, then, we must define the use of the term force of a volcanic eruption. I have defined this elsewhere (bibl. 4, p. 215 and bibl. 5, p. 585) thus: „The force of a volcanic eruption (therefore) can be physically defined as the product of gaspressure and the amount of gas, and geologically expressed as the function of the depth of the chamber and its volume". Of these two quantities, the gaspressure and the amount of gas, the former is more easy to grasp than the latter. A high gas pressure can be noted in an eruption by a high cauliflower cloud of ash, for instance. But it is only when the amount of escaping gas is very great that it will be observable, either from the long duration of a violent eruption, or from the coring and scouring effect on the vent. The force of an eruption is therefore a complex conception, and for the classification of the character of types of eruption I will only use the gas pressure of the magma. Thus our final selection from the many components which decide the character of an eruption, are the gas pressure of the magma and the viscosity of the lava.

Thinly liquid lava.

An example of this type with a very low gas pressure is presented by the well known Hawai-type [1]), described in all text books.

The familiar Stromboli-type is also characterized by very liquid lava, but in this case the gas escape is not continuous but rhythmic, and although it is not strong it is the consequence of a higher gas pressure than in the Hawai-type.

Viscous lava.

Under this head I reckon the most familiar kind of eruption, hitherto regarded as the normal form. The effusions are flows of lava, which decend along the sides of the volcano as a tough, viscous liquid.

The explosive elements are the usual volcanic clouds of ash. (It should be remarked that the term explosive is misleading as there are by no means always explosions, but very often there is a steadily issuing current of gas). Two types are combined within this class, between which there are naturally all sorts of transitions.

The Vulkano-type is here divided into a weaker and a stronger subtype. In the case of a very high gas pressure, combined with a very large quantity of gas, we have what has been called the Plinian-type but which I have named the Perret-type (bibl. 8, p. 73), because it was Frank Perret wo described the intermediate gas phase, the very peculiar characteristics of this type of eruption, in his masterly work on the eruption of Vesuvius in 1906 (bibl. 9, p. 44—47).

This kind of central eruption, hitherto the most violent known, has a demolishing effect on the volcanic structure contrary to all other types of eruption. The enormous current of gas in this case cores out the vent

[1]) In the geological nomenclator (bibl. 6, pp. 147—150) I have attempted to parallelise the explosive eruption phenomena of the various authors. A. Lacroix has recently characterized several different types of eruptions with extreme clearness (bibl. 7).

into a wide cylinder, whereby large portions of the volcanic mountain, which have been gradually built up during long ages, are hurled miles into the air in a few days, and disseminated by the winds to great distances. The Perret-type is the only one of the eruption types here enumerated, that may lead to the formation of a caldeira (bibl. 4, 5 and 8) [1]).

Highly viscous lava.

As A. LACROIX showed some time ago there is not one kind only of glowing cloud. In 1904, in his great work he pointed out the difference between the hot blasts which were typical of the eruptions of Mt. Pelée (bibl. 11, p. 362) and of the eruption of St. Vincent, both of which took place in 1902. In 1908 he distinguished these two types according to the primary direction of the shot. In the St. Vincent-type the direction of shot is vertical and also feeble, in the Pelée-type the direction of shot is oblique. Finally in 1930 he designated the glowing cloud in the Pelée-type as: *„nuées péléennes d'explosion dirigée"* (bibl. 7, p. 459) and those of the St. Vincent-type as *„nuées ardentes d'explosions vulcaniennes"*. A third type of glowing cloud was distinguished by LACROIX in 1904 under the name of *„avalanches de pierres des volcans andésitiques du Japon et de Java"* (bibl. 11, p. 366). In his latest summary of 1930 (bibl. 7, p. 460) LACROIX calls the third type, that occured in Mt. Pelée also, *„nuée ardente d'avalanche"*, caused by crumbling of the lava plug due to the bulging up of the lava by a gradual forcing out of very tough lava. The last type of eruption and of descending glowing cloud is typical of the activity of Merapi (e. g. in 1920 and now again in 1930). According to J. B. GRANDJEAN the Merapi eruption of 1930 has also formed some glowing clouds of the Pelée-type.

The *Merapi-type* consists of avalanches of blocks of lava, that are already solidified but still hot, which break up during their descent into innumerable pieces and ash and form a glowing cloud. Clearly this type only occurs when the lava plug is at the top of the volcano and a very slow extrusion takes place of new magma, causing the plug to crumble down, that is to say, only when the gas pressure is low. If, however, the lava plug closes the vent completely, so that the magmatic gasses cannot escape, the gas pressure will increase untill it is violently released. If the weakest point in the plug is somewhere at the side, a diagonal shot will take place, which is directed obliquely, or more or less horizontally, giving rise to a *Pelée-type* of glowing cloud. In other cases there is no lava plug at the top of the volcano, but the vent is closed at the

[1]) In the Bulletin of the Netherland East Indian Volcanological Survey of July and Aug. 1930 (bibl. 10, p. 25—26) STEHN discusses short and relatively feeble gas currents, which rise from the new crator of Anak-Krakatau and compares them to the (intermediary) gas phase of Perret. We must not forget, however, that in order of magnitude these currents cannot be compared to the gas phase which occured in the Vesuvius on April 8th and 9th 1906. The Perret-type, as I use the expression here and earlier signifies the most terrific demonstration of volcanic activity that is known. In my opinion it can only lead to confusion when a short and comparatively weak stage of an eruption, in which principally magmatic gasses escape, is compared to Perret's gas phase.

bottom of the crater by a cork of tough lava. When the gas pressure accumulates, the cork may burst and break into pieces. If the gas pressure is not very great the pieces of the cork may be thrown just over the rim of the crater after which glowing clouds will descend in radial directions. This is the *St. Vincent-type,* to which the Kloet eruption in 1919 also belongs. Both in the eruption of the Soufrière of St. Vincent on May 7th 1902 and the Kloet on May 19th 1919, the water of the crater lake was first thrown out and after that came the glowing clouds.

It will be seen that all these three types are connected with very viscous lava.

Finally LACROIX (bibl. 7, p. 465—66) describes the very remarkable volcanic tuffs in the Valley of Ten Thousand Smokes in the neighbourhood of Katmai (Alaska) for which FENNER claims a peculiar kind of glowing cloud, which is supposed to be due to the bubbling up of gaseous lava through innumerable cracks in the bottom of the valley (bibl. 13, p. 72). LACROIX considers that glowing clouds of this sort should first be observed, before a theory can be formed as to how they arose. This still mysterious genesis would seem nearest to the St. Vincent-type, but the presence of Novarupta volcano in the Valley of Ten Thousand Smokes which has a lava plug warns us to be cautious.

On plate 6 the eruption types are given, arranged according to both principles: viscosity of the lava and gas pressure of the magma. I am fully aware, that this classification is open to criticism. We are not yet able to express the gas pressure in kg. per cm^2.; if we were able to do so, the Mt. Pelée-type would probably have to be placed at a lower gas pressure than the Vulcano-type (strong). The St. Vincent type might stand in the place of the Mt. Pelée-type, or vice versa. Probably the Stromboli-type would have to be placed more to the left. The graphic representation, however, would not gain in lucidity by such alterations.

On the plate, further, the depth of the magma chamber, which usually will be in direct proportion to the gas pressure, is given in a horizontal line. For this see bibl. 4, p. 215 or bibl. 5, p. 584.

TANAKADATA has recently arranged the eruptions in Japan of the last years in types. It might be possible, after a precise study of the literature to determine whether and in which way the types that he counts as „*Lava Eruption*'' would fit into our scheme. But I think it would be better to leave this to experts on Japanese volcanoes.

His „*ultravolcanian*'' eruptions, to which the Bandai-San type belongs in particular, fall outside our scheme. I have pointed out in the Geological Nomenclator (bibl. 6, p. 149) that ultravolcanic eruptions, semi-volcanic explosions and phreatic eruptions, are different terms for the same phenomenon.

LACROIX also (bibl. 7, p. 467—468) calls the Bandai-San eruption semi-volcanic. This eruption is ascribed to the formation of steam. The Papandajan eruption on March 1923 (bibl. 15) also belongs to the semi-volcanic type.

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