System of Volcanic activity

II PART

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Summary. — A comparison is made among the systems of B. G. Escher (3), of R. W. van Bemmelen (1) and that of the author (4). In this connection, on the basis of Escher's classification, the terms of "constructive" and "destructive" eruptions are introduced into the author's system and at the same time Escher's concept on the possible relation between the depth of magma-chamber and the measure of the gas-pressure is discussed briefly. Three complementary remarks to the first paper (4) on the subject of system of volcanic activity are added.

Riassunto. — Viene fatto un confronto fra i sistemi adottati da B. G. Escher, R. W. van Bemmelen e quello dell'autore stesso. A seguito di ciò, nel sistema dell'autore vengono introdotti i termini di eruzioni « costruttive » e « distruttive », in base alla classificazione di Escher e — nello stesso tempo — viene brevemente discusso il concetto dello stesso Escher su una possibile relazione fra la profondità di camera del magma e la misura della pressione del gas.

Alla prima parte di questo lavoro (4), concernente sempre lo stesso argomento, sono aggiunte altre tre osservazioni complementari.

1. — The classification elaborated by B. G. Escher

In our previous paper (4) we discussed the system of van Bemmelen (1,2), the main principles of which are given in Table I.

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TABLE I

Viscosity	Gas-content		
	Low	Medium	High
Low (basic composition)	Lava sheets (A)	Strombolian (D)	(Ytrian) (G)
Medium (intermediate composition)	Lava tongues (B)	Vulcanian (E)	Plinian (H)
High (acid composition)	Lava plugs and domes (C)	Peléean (nuées ardentes) (F)	Ignimbritic (I)

On the same physical base — that is taking into account the gas-pressure of magma on one hand and the degree of fluidity on the other — Escher (3) has elaborated also a system which is similar to that of van Bemmelen, however not the same. Escher's (3) classification can be found in Table II. In his respective paper (page 45) the term

TABLE II

Viscosity of lava	Gas-pressure of the magma			
	Constructive activity			Destructive activity
	Low	Moderate	High	Very high
Thinly fluid	Hawai type (1)	Stromboli type (3)		
Medium		Vulcano I. type (4)	Vulcano II. type (6)	Perret type (8)
Viscous	Merapi type (2)	St. Vincent type (5)	Pelée type (7)	
Depth of magma chamber	Very shallow	Shallow	Deep	Very deep

magma was defined as "the solution plus the gas dissolved in it under pressure" and the expression *lava* had the following definition: "the magma that has partially or entirely lost its content of gas" (see pag. 45).

Characteristics of these types are as follows:

(1) *Hawai type*: Continuous activity, lava-lake with lava fountains. Remark: according to Tazieff (6), volcano Erta'Ale of Ethiopia "is known for its permanent lava-lake activity since 1967... and most probably since 1906. ... Annual observations since 1967 by the CNRS-CNR research team in the Danakil depression show a quiet lava-

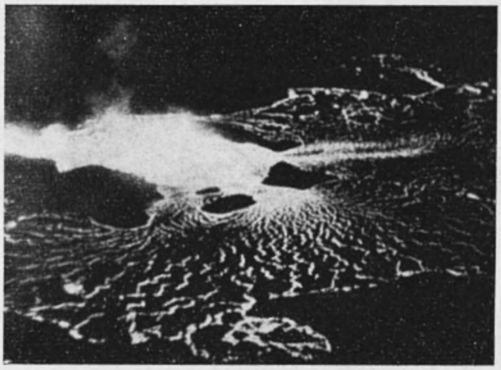

Photo 1. – The Halemaumau lava-lake at Hawai

lake activity". (Erta'Ale volcano is situated at 13°37' N and 40°37' E. It is a basaltic shield volcano, 500 m high, with a base of 50 km across. This volcano is the most active one in Ethiopia). During its activity in 1970-71, many lava-fountains were observed. Accordingly Erta'Ale belongs to lava sheets class (A) of van Bemmelen, or — by other words — to Hawai type (1) of Escher. To mention this fact seems to be important, since very few examples of the true Hawaian activity are known.

(2) *Merapi type*: Glowing avalanches with glowing clouds. Examples: Merapi, 1920, 1930, Mt. Pelée, (1902-1903).

(3) *Stromboli type*: Rhytmic activity, cinders and bombs.

(4) *Vulcano I. (weak) type*: Vertical explosion clouds.

(5) *St. Vincent type*: Vertical eruption with glowing clouds. Examples: Soufriere de St. Vincent, 1902, Koloet, 1919.

(6) *Vulcano II. (strong) type*: Vertical explosion clouds.

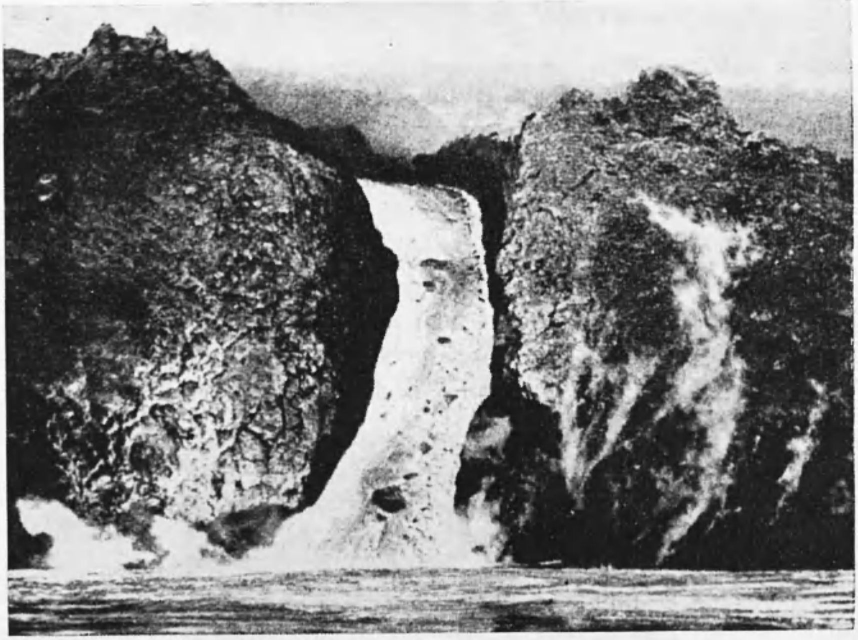

Photo 2. – A thinly fluid basaltic lava-flow reaches the water of the Pacific Ocean at Hawai

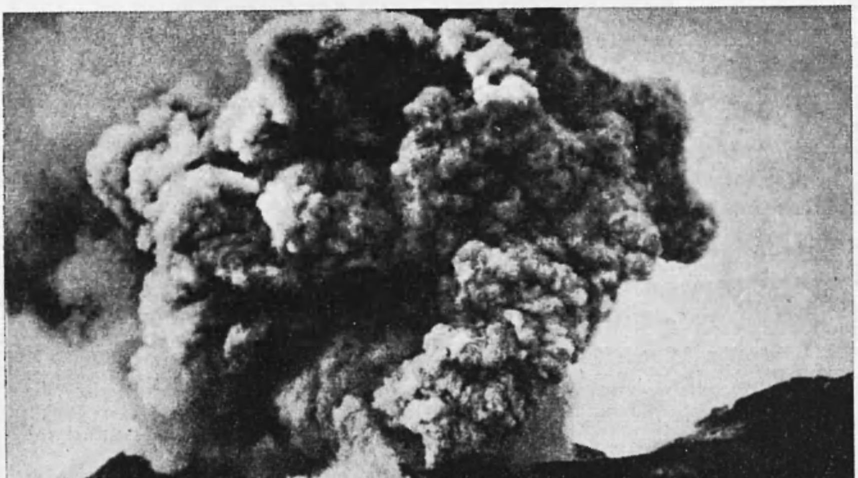

Photo 3. – Eruption-cloud of Nea Kameni (Santorin) during the 1925-26 cycle of eruptions

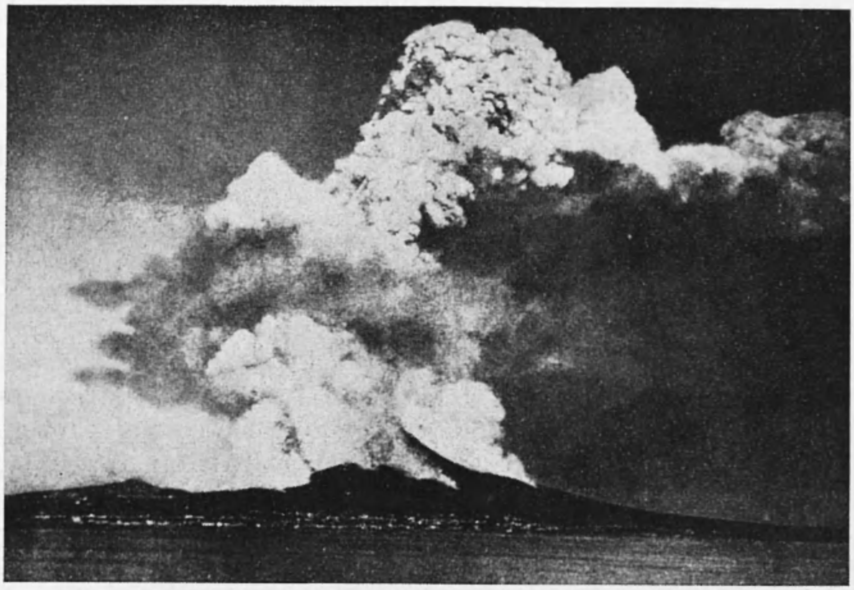

Photo 4. – An old picture about the eruption-cloud of Vesuv

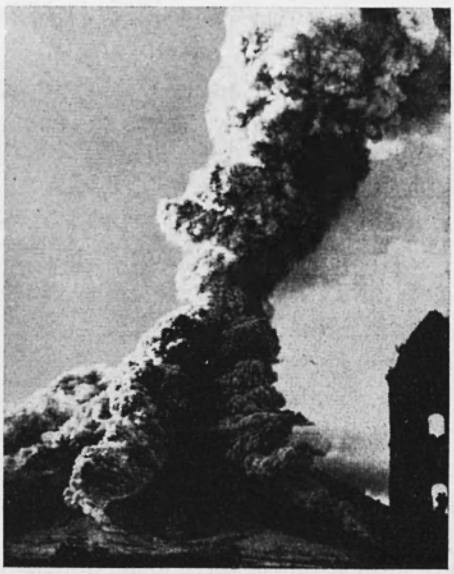

Photo 5. – Eruption-cloud and nuée ardente during a recent eruption of volcano Mayon

(7) *Pelée type*: Discharged glowing clouds. Examples: Mt. Pelée, 1902-03, Merapi, 1930 (?).

(8) *Perret type*: gigantic eruption cloud, with intermediate gas-phase. Examples: Vesuv, 79, 1906, Krakatau, 1883.

2. — A COMPARISON BETWEEN THE TWO SYSTEMS DISCUSSED

First of all we shall quote again the original text of Escher's paper (3) (page 48):

"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 Strombolian-type would have to be placed more to the left". And later on concerning a classification made by Tanakadata in 1930, Escher wrote: "His *ultravolcanian* eruptions, to which the Bandai-San type belongs in particular, fall outside our scheme".

Concerning this last sentence, we should like to mention that the ultravolcanian (that is phreatic) type was included (as *type 22*) into our own classification (1971) which is, as a matter of fact, an enlarged version of van Bemmelen's one.

Combining our present Table I and II, respectively, we find some agreements and disagreements between the systems of Escher and of van Bemmelen (see Table III). Type-names, due to Escher (3) are written with capital letters.

According to Table III, types (1) and (A), furthermore (3) and (D) as well as (4) and (E) are identical. The place of Plinian (H) and Ignimbritic (1) activity is between the columns of *high* and *very high* gas-pressure. In reality both belong to the *very high* cathegory. There is a disagreement between the Pelée type (7) of Escher and Peléean class (F) of van Bemmelen. Taking into account, however, the words of Escher (3) quoted above — "the Mount Pelée-type would probably have to be placed at a lower gas pressure than the Vulcano-type (strong)" —, this contradiction will be subsided. On the other hand, taking Plinian class (H) into the *very high* cathegory, we can experience an excellent agreement in this respect between the two systems, since *the Perret-phase (gas-phase) is the paroxysm of the Plinian eruption.*

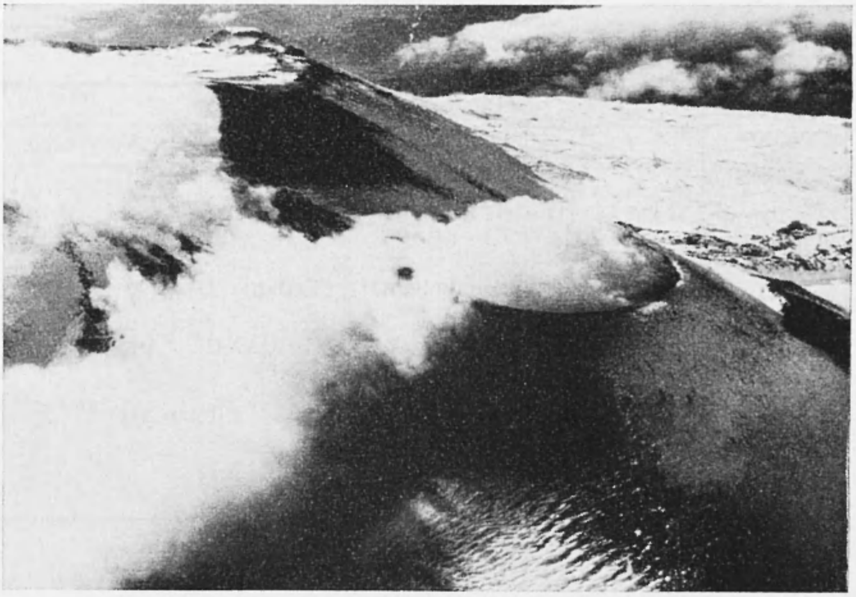

Photo 6 – The eruption of Etna in 1971, (made by WHO).

Photo 7. – The lava of Etna reaches the volcanological observatory (1971)

TABLE III

Viscosity of lava	Gas-pressure of the magma			
	Low	Moderate	High	Very high
Thinly fluid	HAWAI (1)	STROMBOLI (3)		
	Lava sheets (A)	Strombolian (D)	(Ytrian) (G)	
Medium		VULCANO I. (4)	VULCANO II. (6)	PERRET (8)
	Lava tongues (B)	Vulcanian (E)	Plinian (H)	
Viscous	MERAPI (2)	ST. VINCENT (5)	PELÉE (7)	
	Lava plugs and domes (C)	Peléean (F)	Ignimbritic (I)	

Generally speaking the agreement between the two systems is very good, especially if we took into consideration the quoted part of the text of Escher paper [3].

3. — MODIFICATION OF ESCHER'S SYSTEM

It seems that the Merapi type (2) of Escher is not in a correct place. Namely it is in a very close relationship with the Peléean eruptions. Eruptions of Merapi type are often accompanied with the formation of glowing avalanches and thus we can put these kinds into eruptions closer to the Peléean one. A slight modification of Escher's system in accordance with this standpoint, as well as in accordance with his own opinion, cited above, can be as follows (Table IV).

TABLE IV

Viscosity of lava	Gas-pressure of the magma					
	Low	Transitional between low and moderate	Moderate	Transitional between moderate and high	High	Very high
Thinly fluid	Hawai (1)	Stromboli (3)				
Medium			Vulcano I. (4)		Vulcano II. (6)	Perret (8)
Viscous		Merapi (2)	St. Vincent (5)	Pelée (7)		
			(Pelée?)	(St. Vincent?)		

This modificated system of Escher is extremely similar to the system of the present author, discussed in more detail in the previous first part of the paper ([4]). The types, mentioned in Table IV, in our own system [see Fig. 1 ([4])] belonged and are belonging to the following cathegories (Table V).

TABLE V

Type	Viscosity of lava	Gas-pressure of the magma
Hawai	low	low
Stromboli	low	medium; the respective type can be found on the left side of the column, which was signed as "medium", corresponding to the newly introduced cathegory: "transitional between low and moderate"
Merapi	high	medium; the respective type can be found on the left part of the column "medium", and thus it corresponds to the new cathegory: "transitional between low and moderate"
Vulcano I.	medium	medium; the type Vulcano I. of Escher was denominated as Vulcanian one in our system
Pelée	high	medium; the respective type can be found on the right part of the column denoted as "medium", therefore it corresponds either to the new cathegory "moderate" or to the "transitional between moderate and high"

Table V (cont.)

Type	Viscosity of lava	Gas-pressure of the magma
Vesuv I. It is the more violent version of Vulcanian activity, that is the types Vesuv I. and Vulcano II. (strong) essentially are the same	medium	high; but somewhat smaller than that of the Plinian type (Vesuv II.): the Vesuv I. type can be found in the left side of the column denoted as "high"
Plinian (at the paroxysm of which occurs the Perret phase)	medium	high; the respective type is to be found in the right part of the column "high", corresponding to the newly introduced cathegory "very high"

Escher (3) had introduced the notions of "*constructive*" and "*destructive*" eruptions. Accepting these terms we can state that among our 28 types (4), the following ones *1, 2, 3, 4, ..., 17, 18, 19, 20* belong to *the constructive eruptions*; while *the destructive eruptions* are as follows: *21 (Vesuv I.), 22 (Phreatic and phreatomagmatic), 23 (Bezymianny), 24 (Ytrian), 25 (Vesuv II. - Plinian), 26 (Santorin), 27 (Katmaian), 28 (Phreistoric ignimbritic eruptions).*

4. — Note on the suggested relationship between the measure of the gas-pressure and the depth of the magma-chamber

Escher (3) supposed that the depth of the magma-chamber, as well as its volume may be in direct proportion to the gas-pressure. According to our present knowledge this supposition may be true only partly, namely in the relation between the volume of the magmatic pocket and the gas-pressure inside it. As regards the depth, however, there are no such a close connectionship.

In reality, we have no exact data about the depth of the magma-chambers, however there are some estimations concerning it, due

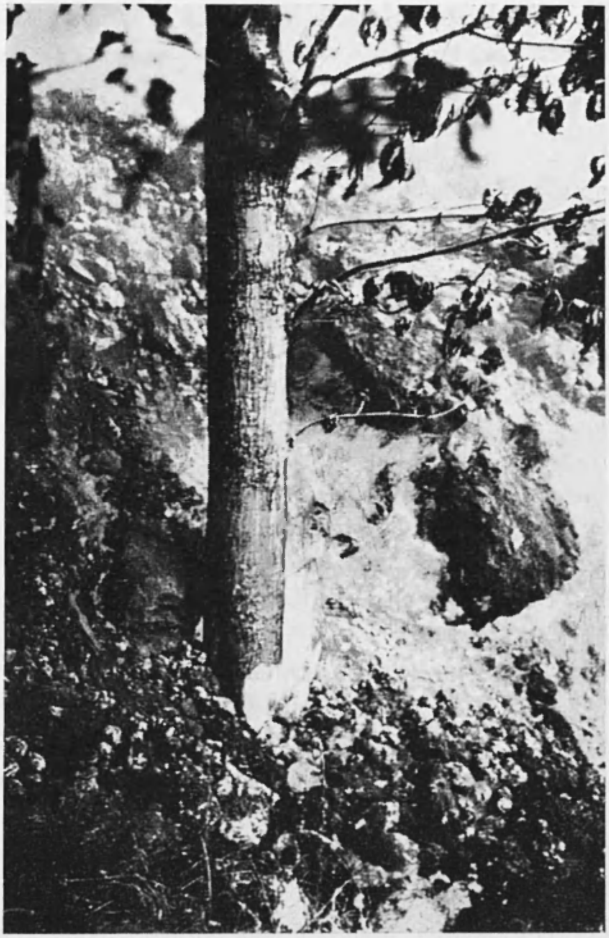

Photo 8. – The lava of Etna destroyes the trees (1971)

to geophysical investigations, geological researches as well as theoretical considerations.

According to Escher's opinion (3), the depth in the case of Hawaii and Merapi types would be *very shallow;* in the case of Stromboli, Vulcano I. and St. Vincent type would be *shallow;* in the case of Vulcano II. and Pelée type would be *deep* and lastly in the case of Perret type would be *very deep.* Let us see now some data regarding the probable real depth of the roof of the magma-chambers, measured from the surface of the Earth (Table VI).

According to the data, presented in Table VI, one can state that *there are none relationships between the depth of magma-chamber and the type of eruption or, by other words, between the depth of chamber and the measure of gas-pressure.*

5. — Complementary remarks to the paper (4) - I part

On page 419 (4), as type 8, we mentioned a volcano, which can be found in Kamchatka. Here a misprint occurred. The name of the respective volcano is not *Polsky* Tolbachik but *Plosky* Tolbachik.

On page 416 there is a drawing, without text. It was made by the present author after Fig. 41 of G. Mercalli's famous textbook (5). The drawing shows the strange electrical phenomena occurred on the 26th May, 1902 at Mount Pelée.

From the point of view of the history of sciences, it is important to note that probably one of the first scientific classification of volcanic eruptions — on petrological basis — was made by Mercalli (5) as early as 1907. He distinguished altogether six types which are the followings:

1) *Basaltic-effusive type.* Examples: Kilauea, Mauna Loa, the volcano on Reunion, Masaya, Varmardalr.

2) *Basaltoid-effusive and explosive type.* Examples: Vesuv, Etna, Lemongan, Colima, San Miguel, Fuego, Kluchewskaja, Mayon, Oshima.

3) *Trachy-andesitic, prevailingly effusive type.* Examples: Santorin, Bogosloff, Ischia.

4) *Trachy-andesitic, explosive and effusive type.* Examples: Mt. Pelée, St. Vincent, Semeru, Papandajan, Sangir.

5) *Trachy-andesitic, prevailingly explosive type.* Examples: Vulcano, Krakatau, Tambora, Coseguina, Guntur, Calbuco, Purace, Pacaya, Te Mari, Tarawera, Azuma-san.

6) *Basaltic-explosive type.* Examples: Stromboli, Izalco, Bromo, Sangai, Antuco, Aso-san (5).

Table VI

Volcano or volcanic area	Probable depth of the roof of the magma-chamber	Type	Author	Remarks
Asama-yama, Minami-dake, Sakura-zima, generally: Japanese volcanoes of the Vulcano type	Very shallow, probably 1—4 km	Vulcano	Minakami	Estimated by the distribution of hypocentres of volcanic earthquakes
Paricutin	8—15 km, 40 »	Vulcano	Panto	Two chambers are supposed, an upper and a lower one, on the basis of geological data
Nea Kameni	between 2 and 15 km	Often Vulcano	Hédervári	On the basis of energetic consideration
Vesuv	5 km	Vulcano, Plinian	Rittmann	From geological data
Etna	5 km	Usually Vulcano	Machado	From seismic data
Volcanoes of Hawai	5—10 km, 40—60 km	Hawai	MacDonald	Two systems of chambers are suggested: upper and lower ones. From seismic data
Volcanoes in the Kljuchewskaja group	50—70 km	Vulcano	Gorshkov	From seismic data
Plosky Tolbachik	40—60 km	Transitional between Hawai and Vulcano types	Tokarev and Zobin	From seismic data
Mihara-yama	5—6 km 50 km	Strombolian	Rikitake	From geophysical data. Two chambers are considered, an upper and a lower one
Volcanic area around Katmai	10—70 km	Ignimbritic (Katmai)	Berg and Kubota	Ten chambers are supposed, they are totally independent from each-other. From geophysical data

Photo 9. – The lava and scoria reaches a small village (Etna, 1971)

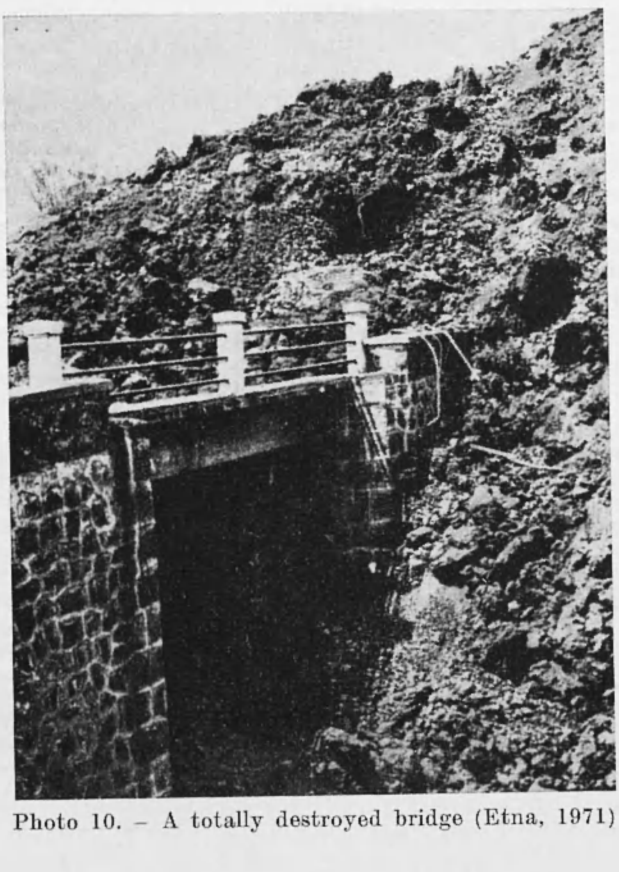

Photo 10. – A totally destroyed bridge (Etna, 1971)

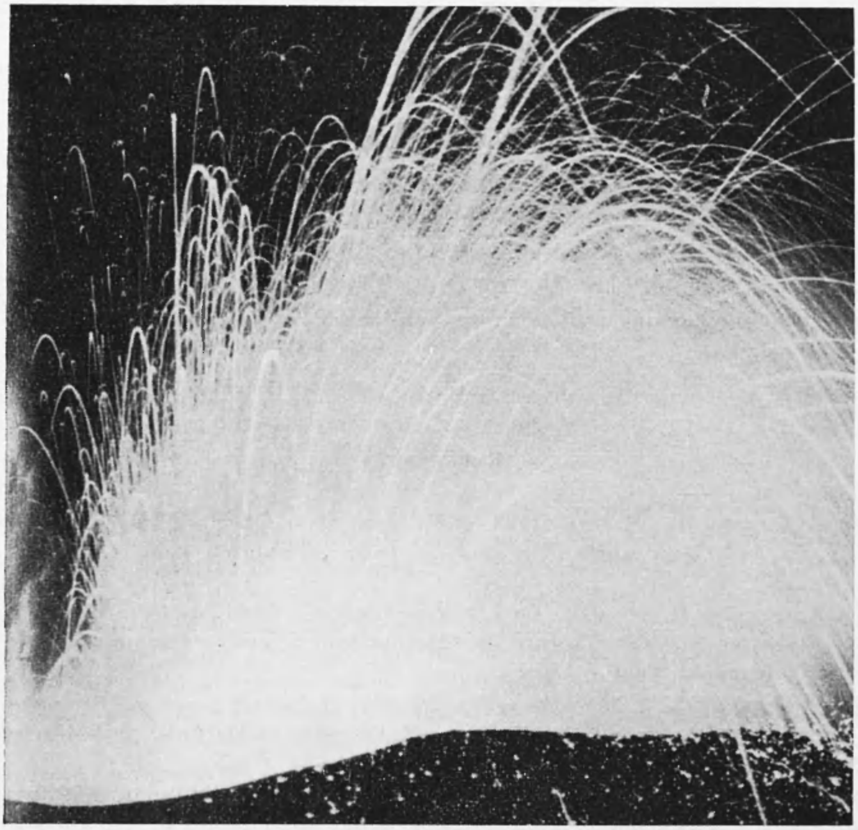

Photo 11. – Glowing volcanic bombs (Etna, 1971)

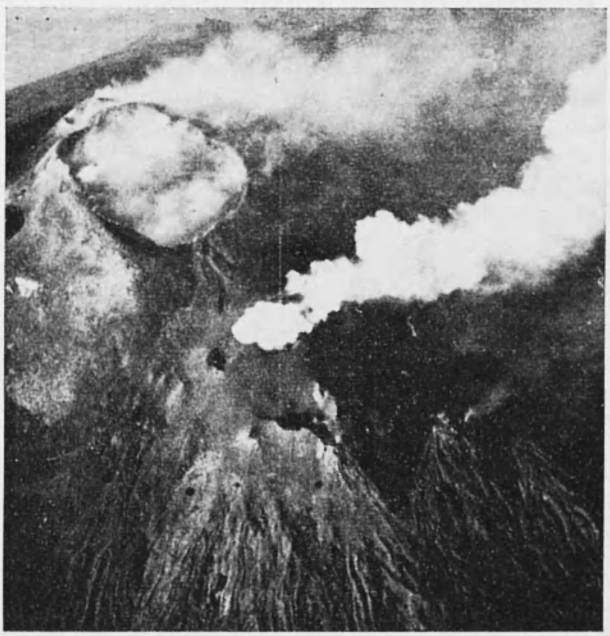

Photo 12. – An other air-photo about the active craters (Etna, 1971)

Acknowledgement

The author is very indebted to Dr. Dragoslav Ninkovich of the Lamont-Doherty Geological Observatory, Palisades, who had the kindness to call our attention to the quoted paper of Prof. B. G. Escher. Also many thanks are due to Dr. Ninkovich for his very valuable advices, suggestions and friendly help when we discussed volcanological problems.

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