On the origin of ignimbrites in relation to the study of recent eruptions.

G. S. GORSHKOV
Laboratory of Volcanology of the Academy of Sciences of the USSR

Opinions regarding to the origin of ignimbrites (Italian « piperno », Armenian « tuff-lavas » and other similar formations) were changing along with the accumulation of new data on the types of eruptions of recent volcanoes. This is quite natural, because « the main method in volcanic geology or paleovolcanology is an explanation of volcanic formations on the basis of those data, which are provided by active volcanoes » (ZAVARITSKY, 1947, p. 3).

The first was a lava hypothesis of the origin of these rocks suggested about a hundred years ago (KALKOWSKY, 1878; ABICH, 1882). This hypothesis seemed to be quite natural as at that time the entire development of volcanology was based on a study of active volcanoes in the Mediterranean with their essentially effusive character. However, a whole number of structural features in the piperno could not have been explained by the purely lava hypothesis. That is why somewhat later (DELL'ERBA, 1892) a pyroclastic hypothesis was suggested for the origin of piperno. The mechanism of eruptions was assumed to be similar to the explosion eruptions of Vesuvium. At the present time the insufficiency of such a mechanism for the explanation of the origin of piperno is quite obvious. However, the limited information available at that time regarding the types of eruptions did not permit to refuse the long ago familiar « classical » types of eruptions.

A great investment in volcanology was the study of the Mont Pelée eruption in 1902 (ANDERSON and FLETT, 1903; LACROIX, 1904). Quite a new type of eruption became known accompanied by hot pyroclastic flows (glowing clouds, nuées ardentes). ZAMBONINI (1919) began to regard piperno as deposits of « glowing clouds » of a Pelean type. Now we know that welded tuffs can not be formed during eruptions of Pelean type, but ZAMBONINI's hypothesis stresses that paleovolcanology (the problem of piperno origin in particular) can get new ideas only from a study of recent eruptions.

For the first time within historical times welded tuffs have been formed during the eruption of Mt. Katmai in 1912. C. FENNER (1920, 1923) studied the area of eruption seven years later. He thought that the material of welded tuffs has been ejected as a « sand flow » from numerous hypothetical fissures in the floor of the Valley of Ten Thousand Smokes, where these tuffs have been deposited. P. MARSHALL (1935) revised the « rhyolites » of the northern island of New Zealand in the light of FENNER's hypothesis and came to the conclusions that acid rocks in the vicinity of Lakes Taupo and Rotorua are of a pyroclastic nature and their source is hypothetic fissures. As it is known, MARSHALL suggested to call these rocks « ignimbrites ».

After MARSHALL's paper has been published there has been a revision of the former concepts on the nature of certain acid rocks in the USA (FENNER, 1937; GILBERT, 1938; ROSS, 1953 etc.), in Peru (FENNER, 1948), in Armenia (ZAVARITSKY, 1946, 1947) and in many other places. Many rocks, which previously have been considered to be of a lava origin, began to be regarded as ignimbrites. In full accord with MARSHALL-FENNER hypothesis, in all cases the source of eruptions was assumed to be associated with the alleged fissures, which have not been discovered in any area, where investigations were proceeding.

During the forty years, which elapsed since the publication of FENNER's papers, new material has been accumulated in volcanology permitting, as it seems to the author, to approach the problem of the origin of ignimbrites in a new way.

The eruption of Bezymianny volcano in Kamchatka on March 30, 1956 (GORSHKOV, 1959) similar in its consequences with the eruption of Katmai volcano, permitted to establish some erroneous premises in FENNER's concept. A criticism of FENNER's ideas was given by the author in an article for the 12th General Assembly of the International Association of Volcanology in Helsinki (see also GORSHKOV, 1961). The main conclusion to which the author came after a comparative study of Bezymianny and Katmai eruptions is that the « sand flow » (ignimbrite) in the Valley of Ten Thousand Smokes in Alaska has not been ejected from problematic fissures in the floor of the valley, but from a summit crater of Katmai and that the formation of the « sand flow » is closely associated with the formation of Katmai caldera.

Thus, if the problem of ignimbrite formation is considered from the point of view of analogies with the Katmai eruption, as has been done by MARSHALL but in accordance with the latest available data on this eruption, it should be accepted that the source of eruptions

of the incandescent pyroclastic material, which forms the ignimbrites, is a sufficiently large volcanic edifice of a central type and not a net hypothetical fissures. In all probability the formation of ignimbrites is most closely associated with the processes of caldera formation.

It is hardly an accident that all large ignimbrite deposits (welded tuffs) are always associated with the vicinities of volcanic depressions of a caldera type: New Zealand - Taupo Lake and Rotorua Lake, Sumatra - Toba Lake, California - Crater Lake and Mono Lake calderas etc. As indicated by P. I. PIIP's researches (article presented to this Symposium and B. I. PIIP, 1961), ignimbrites of Kronotzky region in Kamchatka [1] are associated with Uzon caldera. The author of this article provisionally regards Armenian « tuff-lavas » as ignimbrites associated with the formation of the old Aragatz caldera hidden now under a later central cone (GORSHKOV, 1961 [b]). Japanese volcanologists and geologists came to an unanimous conclusion that all deposits of welded tuffs in Japan are associated with the vicinities of calderas and were formed from pyroclastic flows genetically related to the formation of caldera depressions and are synchronous with them (ISHIKAWA a. oth., 1957).

Two types of ignimbrites can be distinguished: of greatest development are ignimbrites deposited from incandescent pyroclastic flows. These ignimbrites cover extensive areas and occur in relief depressions levelling out all its unevennesses. As a rule, the thickness of these ignimbrites is quite considerable exceeding sometimes a hundred meters. More rarely ignimbrites are formed by an aerial transport of incandescent material as a result of powerful directed explosions. Ignimbrite deposits of this kind occupy always smaller areas, they are not thick (several meters) and occur as an even layer both in relief depressions and on elevations or hill slopes (MANSFELD and ROSS, 1935; MARWICK, 1946; GORSHKOV, 1961 [c]). Both varieties of ignimbrites represent all degrees of welding from nearly loose rocks up to very compact, which by external appearance and under the microscope resemble lavas (rheoignimbrites).

This way all ignimbrites (or at least their overwhelming majority) are of a pyroclastic origin and are genetically associated and synchronous to the formation of calderas. The primary lava origin of ignimbrites seems very doubtful in the light of studies of the processes of active volcanicity.

---

[1] Including former « tuff-lavas » of Semiachik (VLODAVETZ, 1953).

REFERENCES

ABICH, H., 1882 - *Geologie des armenischen Hochlandes* - II Theil. Wien.

ANDERSON, T., and FLETT, J. S., 1903: *Report on the eruption of the Soufrière in St. Vincent, in 1902 and on a visit to Montagne Pelée in Martinique* - Pt. I. Philos. Trans. Roy Soc. Lond., A, v. 200.

DELL'ERBA, L., 1892 - *Considerazioni sulla genesi del piperno* - Atti della R. Accad. delle Scienze fis. e mat. di Napoli. Ser. 2, n. 3.

FENNER, C. N., 1920 - *The Katmai region, Alaska, and the great eruption of 1912* - Journ. Geol., v. 28, No. 7.

———— 1923 - *The origin and mode of emplacement of the great tuff deposit of the Valley of Ten Thousand Smokes* - Nat. Geogr. Soc., Techn. Papers, Katmai Series, No. 1.

———— 1937 - *Tuffs and other volcanic deposits of Katmai and Yellowstone Park* - Trans. Amer. Geophys. Union, 18th Ann. Meeting.

———— 1948 - *Incandescent tuff-flows in southern Peru* - Bull. Geol. Soc. Amer., v. 59, No. 9.

GILBERT, Ch. M., 1938 - *Welded tuff in eastern California* - Ibid. v. 49, No. 12 pt. I

GORSHKOV, G. S., 1959 - *Gigantic eruption of the Volcano Bezymianny* - Bull. Volc ser. 2, t. 20. Napoli.

———— 1960 - *On the classification and terminology of Pelée and Katmai type eruptions.* - A paper read at the Helsinki Assambly of IAV.

———— 1961 a - *On the question of terminology of some types of blast eruptions* Coll. « Problems of Volcanism ». Moscow (in Russian).

———— 1961 b - *On the structure of the Aragatz volcano and its ignimbrites* - Trans. Lab. Volc. v. 20. Moscow (in Russian).

———— 1961 c - *Welded tuffs of Zavaritsky caldera* - Ibid.

ISHIKAWA, T., MINATO, M., KUNO, H., MATSUMOTO, T., and YAGI, K., 1957 - *Welded tuffs and deposits of pumice flow and nuée ardente in Japan* - Int. Geol. Congr., XX Sesión, Secciún I. Mexico.

KALKOVSKY, E., 1878 - *Über den Piperno* - Zt. deutsch. Geol. Geselsch. Bd. 30.

LACROIX, A., 1904 - *La Montagne Pelée et ses eruptions* - Paris.

MANSFIELD, G. R., and ROSS, C. S., 1935 - *Welded rhyolitic tuffs in southeastern Idaho* - Trans. Amer. Geophys. Un., 16th Ann. Meeting.

MARSHALL, P., 1935 - *Acid rocks of the Taupo-Rotorua volcanic district* - Trans. and Proc. Roy. Soc. of New Zealand. v. 64,, pt. 3.

MARWICK, J., 1946 - *The geology of the Kuite subdivision* - Bull. New Zealand Geol. Survey. No. 41.

PIIP, B. I., 1961 - *Ignimbrites of Kronotsky region in Kamchatka* - Trans. Lab. Volc., v. 20. Moscow (in Russian).

ROSS, C. S., 1953 - *Characteristics of rhyolite welded tuffs in western North America* Proc. 7th Pacific Sci. Congr., v. 2.

VLODAVETZ, V. I., 1953 - *On some Semyachik tufflava and its origin* - Bull. Acad. Sci. USSR, ser. geol., No. 3 (in Russian).

ZAMBONINI, F., 1919 - *Il tufo pipernoide della Campania e i suoi minerali* - Mem. per serv. alla descrizione della Carta geologica d'Italia. v. 7, pt. 2.

ZAVARITSKY, A. N., 1946 - *On the Quaternary volcanic tuffs of Armenia* - C. R. Acad. Sci. USSR, v. 53, No. 8.

———— 1947 - *Ignimbrites of Armenia* - Bull. Acad. Sci. USSR, ser. geol., No. 3 (in Russian).