Proposal for a genetic classification of hyaloclastites. (*)

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Introduction

During recent geological surveys in Sicily a number of new outcrops of mostly submarine volcanic formations have been found (1).

These formations consist of olivine basaltic to tephritic lava-flows and fragmentary materials of various aspects.

In this paper the writer proposes a classification of these materials which is based on the structures and geological relations, taking into consideration the most probable mechanism of the formation. Most of the observations have been made in the Iblean Region, where such volcanites are widely distributed and have not suffered any kind of metamorphism. The youngest members of these formations are of the Pleistocene period.

Previous authors

SARTORIUS V. WALTERSHAUSEN (1846, 1853) mentioned that there were in the Iblean Region volcanic « tuffs » and « breccias » formed essentially of angular fragments of basic, more or less altered, volcanic glass, named by him « palagonite ». For the breccias he used the term « peperino », which in Latium, however, has a different meaning. Also C. GEMMELLARO (1829, 1833, 1865) believed these « palagonitic formations » to be pyroclastica produced by explosive eruptions of several volcanoes.

Among the various authors who wrote on this subject in the second half of the XIXth and at the beginning of the XXth century, only G. PLATANIA (1891, 1902-3, 1922) emphasized the submarine nature of the « palagonitic tuff », but without discussing its origin. He stated

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(1) A. CAMPIONE (1961), S. CUCUZZA SILVESTRI (1954, 1961), P. FAZZINO (1948), V. GOTTINI (1961), A. RITTMANN (1958), etc.

furthermore that the cementing material is formed of zeolites and carbonates and that the so called « vitreous lapilli » often show a fresh glassy core (« sideromelane ») and an altered outer shell of « palagonite », which is due to the action of hydrothermal solutions.

G. PONTE (1908, 1910, 1916) showed that the glass of the fragments is identical with that of the glassy crusts of the pillows.

Since 1930 the name « palagonite tuff » has been extended in Iceland to cover all kinds of clastic formations: fragmented subglacial basalt lavas, glacial moraines, solifluxion products, banks of scoriae, genuine tuffs and alluvial deposits (RITTMANN, 1960, pag. 82).

This confusion and the fact that the original « palagonitic tuffs » of Sicily are not due to explosive eruption but to the fragmentation of submarine lava chilled by the sea water, induced RITTMANN (1960) to abolish the name « palagonite tuff » and to introduce the new term « hyaloclastite » (from the Greek ὕαλος = glass and κλάζω = to brake).

Some remarks on the mechanism of submarine eruptions of basic magmas

By far the most submarine eruptions of basaltic and related magmas are fissure eruptions comparable to the subaereal linear effusions of the kind of those of Iceland or Hawaii. The fact that they occur at the sea bottom does not change their fundamental mechanism, but the surface phenomena will be completely different.

First of all the weight of the water column hinders or completely prevents the formation of vescicles. Hence, the already small explosivity of such magmas is still more reduced and, in the deep sea, the eruptions take the character of sill intrusions between the Earth's crust and the sea, without any explosive phenomenon.

This extreme case was hardly ever realized in the regions where the hyaloclastites have been studied up to now and therefore it will be neglected in the following.

The normal sequence of phenomena during an effusive linear eruption on the bottom of a relatively shallow sea can be summarized as follows:

Immediately after the opening of the fissure, the sea water penetrates into it, comes into contact with the rising magma and chills it. Thus a solid crust is formed but rapidly broken to pieces by the upward pushing magma which is repeatedly chilled and shattered. In this way a great quantity of brecciated material, with which many

xenolithic blocks are sometimes admixed, is formed and consecutively expelled to the sea bottom and accumulated along the fissure.

The erupting magma may partially intrude between the sea bottom and this initial breccia like a sill, but, more often, it will perforate the covering breccia pushing it aside and flowing out quietly.

The outflow of the lava under these conditions is comparable to that of the subaereal pahoehoe with the difference, however, that the glassy skin forms much more quickly and it is continuously crumbled to small fragments in consequence of chilling by the sea water.

At the surface of the lava the glassy fragments accumulate to build up *hyaloclastites*, which may derive also from the surface of the lava flow itself as well as from the glassy crusts of the growing pillows.

The formation of these latter can be compared with that of the toes of the pahoehoe with the difference that, under submarine conditions, these protuberances grow the glassy fragments of the crusts.

The lava flowing under a relatively thick cover of hyaloclastite is protected against direct chilling action of the sea water. It carries with it the whole cover, causing in this latter tensions and stresses, according to the irregularity of the movement.

In this way the materials of the cover suffer an intimate brecciation or fissuring. There are many evidences that the lava penetrates in such opening fissures, forming « dikes » within hyaloclastites.

It has to be mentioned that the hyaloclastites are soaked with sea water which, in the deeper parts, is heated up and mixed with the gasses released by the lava forming thus hydrothermal solutions, which, in their turn, act chemically upon the glassy fragments.

The product of this hydrothermal alteration is what many authors call « palagonite ».

That such a « palagonitization » is only a secondary process can be proved by the fact that some hyaloclastites are known in the Iblean Region in which the glassy fragments are completely fresh.

It is evident that a submarine effusion is sometimes accompanied by rather violent convection currents in the sea by local heating. Especially at the margins of the lava flows these currents are strong enough to rework the finer hyaloclastitic material and to deposit it again after sorting.

Genetic classification of the hyaloclastites

The various products of a submarine eruption of the kind described above, can easily be distinguished in the field. Their characteristic properties are the following:

1) *Initial hyaloclastitic breccias* are those which are formed immediately after the opening of the fissure.

The angular fragments of these breccias are very different in size, ranging from a few millimeters up to some tenths of centimeters (Pl. I, Fig. 1). They are mostly pieces of aphanitic lava, sometimes with a few small vescicles and often covered by a glassy crust. It must be stressed that this glassy skin envelops the whole of the angular pieces, while in the case of fragments of pillows only one side may show signs of a glassy crust.

In some of these initial breccias the xenolithic blocks can be seen to predominate.

The cement of these breccias is often of sedimentary origin deriving from calcareous or argillaceous oozes. Admixed with it are hyaloclastitic materials and sometimes zeolites. According to the nature of the blocks and cementing materials several varieties of « initial breccias » may be distinguished. They all are entirely chaotic, and the size of the blocks varies in wide ranges.

Analogous breccias may be formed at the places where « lava-dikes » perforate the hyaloclastitic cover of the flow and reach the submarine surface. In this case the cementing material of the breccia is constituted essentially of altered glassy fragments; zeolites are frequent (Pl. II, Fig. 1).

2) *Hyaloclastite breccias* are widely distributed especially above the submarine lava-flows.

They derived from hyaloclastites with embedded pillows which have been removed by underlying flowing lava. The differential movement causes the fragmentation of the pillows into angular pieces which are dispersed in the hyaloclastitic matrix. Frequently the fragments of the external parts of the pillows show on one side relics of the glassy crust.

Also among these « hyaloclastite breccias » several varieties may be distinguished:

Just above the lava-flow the fragments of pillows predominate to such a degree that the term *pillow breccia* is suitable (Pl. III).

At higher levels the hyaloclastitic material becomes prevailing and all transitions can be observed between hyaloclastites with a few embedded pillow and « hyaloclastite breccias » with irregularly distributed angular fragments of pillows (Pl. IV).

3) *Common hyaloclastites* are constituted exclusively of glassy fragments of various sizes up to a few centimetres. They are generally of yellow-brown colour due to the « palagonitic alteration » of the glass, but sometimes hyaloclastites are found in which the black glass is completely fresh.

In both varieties secondary zeolites, often in beautiful crystals are found (DI FRANCO, 1901 and C. STURIALE, personal communication). Impregnations and veins of calcite are frequent.

The hyaloclastites *in situ* are characterized by the complete absence of stratification.

4) *Stratified hyaloclastites* are found *in situ* at the top of the formations, and at its margins graded bedding is sometimes seen; rarely also cross bedding is observed. The stratifications may be due to the removal of the finer glassy fragments by convective currents of the hot sea water or also by submarine gliding of the loose materials on the marginal slopes of the formation (Pl. V).

5) *Reworked hyaloclastites* are well bedded and often mingled with sedimentary materials. They occur sometimes far away from the locality where the eruption took place.

Their grain size decreases with the distance from the eruptive centre. The resedimented hyaloclastites differ from the normal tuffites by the fact that they are formed of small, mostly angular, glassy fragments which may or may not have suffered a « palagonitization ».

According to the grain size and to the quantity and quality of the admixed sedimentary material and the presence or absence of fossils, many varieties of reworked hyaloclastites can be distinguished (Pl. VI, Fig. 1).

One of these varieties is worth special mention: this is a pelitic reworked hyaloclastite formed exclusively of smallest unaltered fragments of black glass which gives to the rock an obsidian-like aspect (Pl. VI, Fig. 2).

Scheme of classification

The normal sequence of the products of a submarine eruption of basic magmas is as follows:

5. Reworked hyaloclastites (with or without sedimentary materials);
4. Stratified hyaloclastites (in situ);
3. Common hyaloclastites;
2. Hyaloclastite breccias
   a) with complete pillows,
   b) with fragments of pillows;

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   lava-flow

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1. Initial hyaloclastitic breccias.

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Fig. 1 - *Initial hyaloclastitic breccia* with marly cement. Sigona Grande, Iblean Region (Sicily).

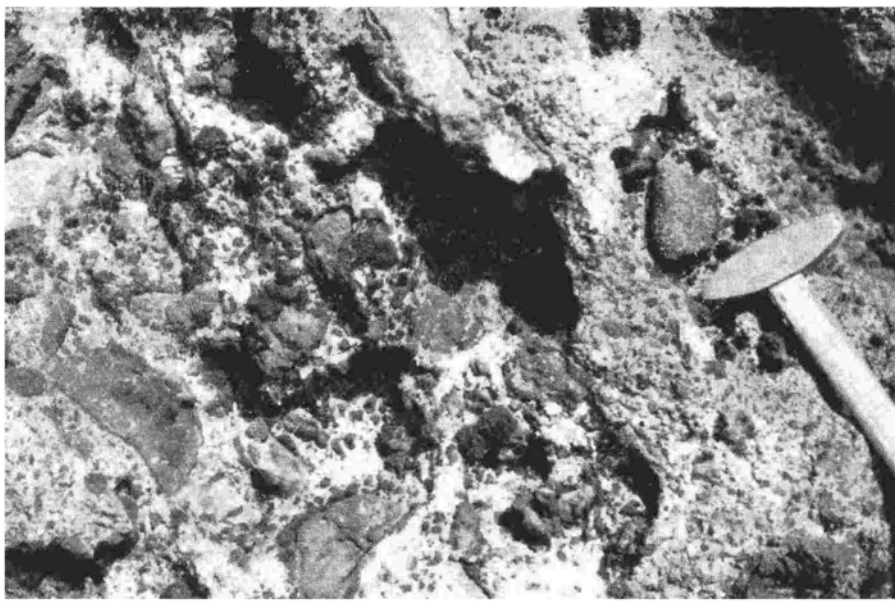

Fig. 1 - *Initial hyaloclastitic breccia* of a lava-dike. Note the glassy crust all around the irregular blocks, which are embedded in hyaloclastite rich in zeolites (Phillipsite). Acicastello, Mt. Etna.

Fig. 1 - *Pillow breccia* at the roof of a lava-flow. The fragments of pillows predominate over the blocks. Contrada Nicchiara (Stazione Mineo), Iblean Region.

Fig. 1 - *Hyaloclastite breccia* with some disarticolated pillows and angular fragments of others. Buccheri, Iblean Region.

Fig. 1 - *Hyaloclastite breccia* passing at its roof into *stratified hyaloclastite in situ*. Contrada Annunziata (Stazione Minco), Iblean Region.

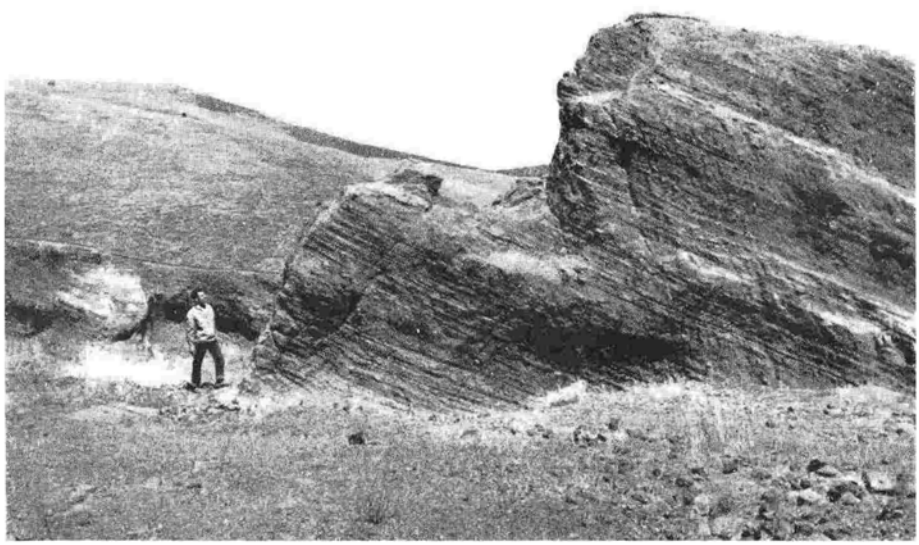

Fig. 2 - *Stratified hyaloclastite in situ* at the marginal slope of a submarine lava-flow. Casa Solonia (Stazione Vizzini), Iblean Region.

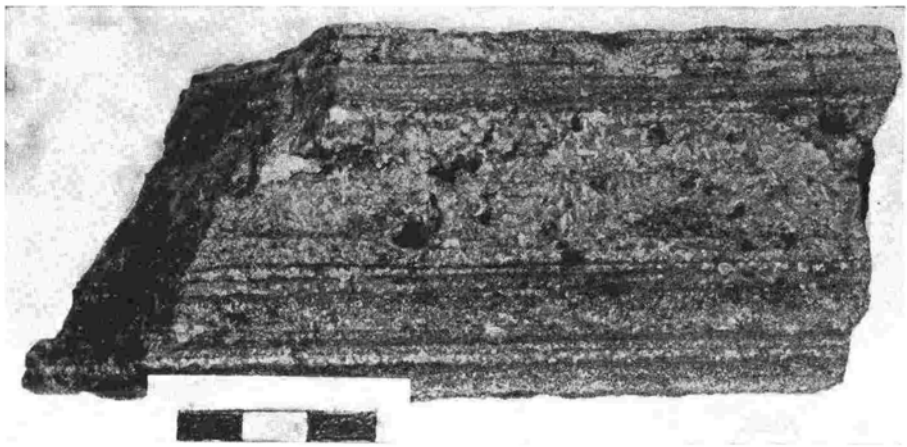

Fig. 1 - *Reworked hyaloclastite,* well stratified and sorted with fossils. Contrada Scirumi (Scordia), Iblean Region.

Fig. 2 - *Reworked fine grained hyaloclastite* intercalated between Quaternary calcarenites. The hammer indicates a layer of obsidian-like aspect. Scordia, Iblean Region.