Ignimbrites of southern Kamchatka.

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There is a group of volcanic rocks, which by its textural features occupies an intermediate position between effusive and volcanoclastic rocks. Their specific feature is a cementation of lava fragments by lava or a complete absence of cement. They are subdivided into three groups: 1) breccia lavas, 2) clastolavas (tufolavas), 3) ignimbrites. The first two are of an effusive (lava) nature, while the latter - pyroclastic.

In breccia lavas lava fragments and cementing lava are of the same composition and texture, but more often cement is completely absent and the cementation of the fragments takes place as result of baking. This produces a peculiar lava agglutinate.

Breccia lavas are found in upper, lower and marginal parts of lava flows, in the marginal and apical parts of the domes.

Clastolavas are characterized by the presence of a lava cement with a structure, texture or composition different from the fragments. Usually this cement possesses a certain fluidity. Clastolavas are developed in circumcrateral parts of volcanoes, in lava flows, domes, necks and volcanic pipes. The overfilling of lava by lava fragments takes place both under abyssal conditions and on the surface of the earth during eruptions.

Ignimbrites are characterized by the presence of cinder structure relics. Cinder particles are welded or baked together, sometimes to a state and appearance of a lava. Quite often there are in a rock only some parts welded to a lava outlook. Such lenses are called fiamme.

To illustrate the pyroclastic nature of such formations we give a characteristic of ignimbrites developed in the south of Kamchatka.

On Kamchatka ignimbrites are very widely developed. One of the areas of their occurrence is the southern part of Kamchatka.

The southern part of Kamchatka peninsula in the area of Ozernaia village consists of volcanic rocks of Pliocene and Quaternary age. They are represented by various effusive and volcanoclastic rocks of basaltic, andesitic, dacitic and liparite-dacitic composition. Eight kilometers south-east of Ozernaia we have studied in 1959 ignimbrites of a liparite-dacitic composition resting on olivine plateau-basalts and their tuffs. Along the strike ignimbrites change into tuffs and are overlain by andesitic and liparite-dacitic volcanoclastic rocks of the Pauzhetsk suite. Younger volcanic rocks are associated with recently extinct or active volcanoes (Diki Greben, Bambalny, Koshelev). On the basis of age determinations for the spores and pollen from the rocks, which underly ignimbrites, the age of the latter is considered to be the very top of Pliocene.

Ignimbrites occur in a horizon about 80 m thick, which can be clearly seen in continuous exposures. They possess a columnar jointing. The columns about 2 m across have mostly four and rarer five faces. The orientation of the columns is vertical, sometimes with a slight inclination south-eastwards under an azimuth of 140°. In a continuous exposure displaying the ignimbrite horizon practically from bottom till the roof its structure can be observed (Fig. 1). The surface of the ignimbrite horizon is nearly horizontal. Throughout the entire thickness of the ignimbrite horizon there is a complete absence of lamination. In an exposure from roof to bottom the structure of the ignimbrites undergoes a regular change. In the upper part of the sequence (5 m from the roof) we find the usual tuff structure; in the central part of the horizon typical ignimbrites with a great amount of fiamme are developed. In the lower part of the sequence the number and size of the fiamme decreases and the rock changes to a mixed tuff cemented in a hydrochemical way. Contrary to the rocks in the central part of the ignimbrite horizon, which sometimes produce a ringing sound when hit by a hammer, the tuff is cemented only slightly. The bottom of the ignimbrite horizon has not been exposed. The apparent thickness of the tuff without fiamme at the bottom comes to about 5 m. Ignimbrite has also channel-like pores of an ellipsoidal cross-section and an average diameter of 5-7 cm. Their length is up to 1.5 m. The pores are vertical in their orientation. Apparently, they have been formed by the rush of gases during the deposition of pyroclastic material on a humid surface.

On the gray background of the matrix in the ignimbrites one can clearly distinguish lenticular bodies of fiamme of a black colour, which make up to 10 % of the rock volume. Their maximum size comes to 10 cm in diameter with a thickness of 2-3 and rarely 4 cm; their minimum is about 1 mm. The predominant size of fiamme is 5 cm across and 2 cm thick. They are located in a subparallel way, sometimes under an angle up to 30° (fig. 2). On the black background of the fiamme there are crystals and more rarely fragments of transparent quartz up to 7 mm in diameter and of milky-white feldspars up to 3 mm in diameter. Their number reaches 30 - 35 %. Crystals of dark-coloured minerals, which are present in small numbers, are difficult to distinguish on the black background of the fiamme.

The main mass of ignimbrites contains about 50 - 60 % of rock and crystal fragments immersed into a vitroclastic mass with a varying degree of remelting and baking.

The pyroclastic nature of the groundmass of ignimbrites can be easily established under a microscope. The total mass of fragments includes about 50 % of plagioclase fragments, from 20 - 30 % of quartz, about 10 % of hypersthene, amphibole and biotite, from 3 - 5 % magnetite and about 10 % fragments of a foreign material. Large crystals are of an isometric and rarer of a fused form, the partially melted and corroded form being most characteristic for quartz crystals with a size of 3-7 mm.

The presence of a great number of minerals with preserved crystallographic forms separated from the groundmass indicates that the material has been ejected in an incandescent (probably, semiplastic) state.

Foreign fragments are represented by basalt, andesite-basalt, andesite, dacite (material of former eruptions), aleurolite and flinty slates (debris of the volcano basement). The shape of the fragments is angular or rounded. In the debris of basic rocks ferruginous minerals are coloured dark brown, probably, as result of a secondary heating.

The vitroclastic cementing mass reveals all the intermediary forms of baking and melting up to an amorphous mass with a refraction index of 1.492.

In the slightly baked parts of ignimbrites fragments of glass are preserved. They have the shape of triangles with concave ribs, crescents etc., often with partially melted edges. At the same time a deformation of glass fragments is observed, their parallel arrangement and sort of streamlining of certain fragments (fig. 3). In those parts, which have been strongly baked the ash particles loose their contours and only hardly noticeable white streaks are remaining. In the parts poor in rock and crystal fragments remelting acquires a maximum importance forming lenticular bodies of amorphous glass with split edges - microfiamme. In the most baked sections microfiamme are grouped in parallel bands in the fiamme and at this stage fluidity appears.

This way fiamme represents sections of a re-fused vitroclastic material.

The process of re-fusion is so far advanced that the glassy ash becomes fused into an amorphous glassy mass, possessing fluidity and a perlitic structure. In certain fiamme it is still possible to distinguish under ordinary light slight traces of vitroclastic texture relics. In the fiamme crystal and crystal fragments have been preserved. Their composition, shape and optical properties are analogous to those of the groundmass, however, their number in the fiamme in somewhat smaller than in the total mass of the tuff. The fiamme glass refraction is 1.492, just as in the baked tuff (fig. 4).

As mentioned above, towards the base of the exposure ignimbrites gradually change into unbaked tuffs. The shape of the fragments and the ratio between glass and crystals, as well as the mineralogical composition of ignimbrites and tuffs are analogous. The composition of the plagioclase, honblende and pyroxene is identical. However, the refraction index of the tuff glass is somewhat higher (1.495), than the glass of ignimbrites and fiamme.

The main specific feature of the tuff is the absence of an amorphous cementing glass. Contrary to the overlying ignimbrites fragments of glass and crystals in a tuff are cemented by an opaline clayey mass and by opal with a refraction index 1.455.

The table gives the chemical composition of ignimbrites without fiamme and of the fiamme separately (analyst V. G. SILNICHENKO).

The below given chemical analyses show that compared with its enclosing mass the fiamme contains a higher amount of silica and potassium oxide and lower amount of alumina, calcium, iron and sodium. This fully corresponds our ideas on the formation of fiamme by a baking of the sections enriched by glass fragments, this glass being more acid, poorer in calcium, aluminium and sodium as compared with the crystalline part (intratelluric inclusions, the main part of which consists of plagioclases (1).

Judging by the chemical analysis and the refraction of glass, which comes to 1.495, by its composition ignimbrite belongs to liparite-dacites.

(1) The established regularity, probably, does not extend to ignimbrites, in which vitroclastic material is predominant.

The above mentioned shows that ignimbrites are of a pyroclastic nature, especially if one considers their gradual transition in the lower and upper parts of the horizon into hydrochemically cemented tuffs. Special features in the texture, structure and composition of ignimbrites permit to form an opinion on the source of material for the ignimbrites and the character of volcanic activity.

Table 1.

	28-a (fiamme)	28-b (ignimbrite without fiamme)
SiO_2	69.98	66.56
TiO_2	0.44	0.36
Al_2O_3	14.14	16.25
Fe_2O_3	1.16	1.68
FeO	1.98	2.06
MnO	0.08	0.09
MgO	1.48	1.30
CaO	2.99	4.13
Na_2O	3.81	4.29
K_2O	2.45	1.66
S	0.08	0.09
P_2O_5	traces	traces
H_2O-	0.11	0.10
H_2O+	0.81	1.10
Total	99.51	99.67

Inasmuch as the majority of the minerals is separated from the glass and preserves its crystallographic forms, it means that at the moment of disintegration the material has been hot, this resulting in its disintegration along the boundaries of the glass and of the minerals. As a rule, when cold material is shattered lava fragments and crystal fragments are being formed. The formation of vitroclastic material in the shape of crescents and other characteristic forms associated with the swelling of the glass and its subsequent shattering also indicates an original overheating of the erupted material. The eruption was taking place as a result of a strong explosion, which is indicated by the presence of a great quantity of fragments from the basement of the volcano and of its edifice. The pyroclastic material was deposited as a thick horizon with a nearly even surface over an area of about a hundred square kilometers during one act and has not been re-deposited, which is shown by an absence of lamination or sorting of the material. These features are characteristic of an eruption of Katmai type. The substance composition of the erupted material is also similar to the eruption products of Katmai in 1912.

The formation of ignimbrites by the baking of the groundmass of the glass with a fusion of individual parts up to the state of fiamme, was taking place after the deposition of the incandescent material, which is proved by a gradual transition from tuffs to ignimbrites and by the presence in the ignimbrites of gradual transitions from baked fragments to fused debris in certain sections of amorphous glass.

The heat for this process has been partly primary, determined by the character of the Katmai eruption, with a dispersion of an acid, overheated and gas saturated magma. There has been a superposition on this heat of a heat from a secondary heating up during exothermal reactions (oxidation). The fusion together takes place under conditions of a formational pressure and it happens in deposits of a great thickness in the central part of the rock mass.

Ignimbrites can be regarded as a special volcanic formation associated with a definite stage in the development of a geosyncline. The first period in the life of a geosyncline is characterize by the development of spilitic and keratophyric formations in submarine conditions. Ignimbrites are not formed during this period. They are also not associated with a volcanicity of platform type, which is characterized by fissure effusions, the formation of cinder cones, lava extrusions of a higher alkalinity.

The formation of ignimbrites is usually associated with the last stage of geosynclinal development — a semi-platform stage, which is characterized by various differentiated movements and a development of volcanicity in subaerial conditions.

Such a character of volcanism is typified by a frequent replacement of basic rocks by acid rocks with a sharp predominance of pyroclastic products over lavas and by the development of strato-volcanoes. Ignimbrites are formed during the final phases of volcanicity characterized by acid differentiates and are associated with violent explosions and outbursts of glowing avalanches very often accompanied by the formation of calderas. Usually ignimbrites cover considerable areas levelling out the relief.

Fig. 1 - Columnar jointing in ignimbrites (in 8 km to S-E from the village Osernaja).

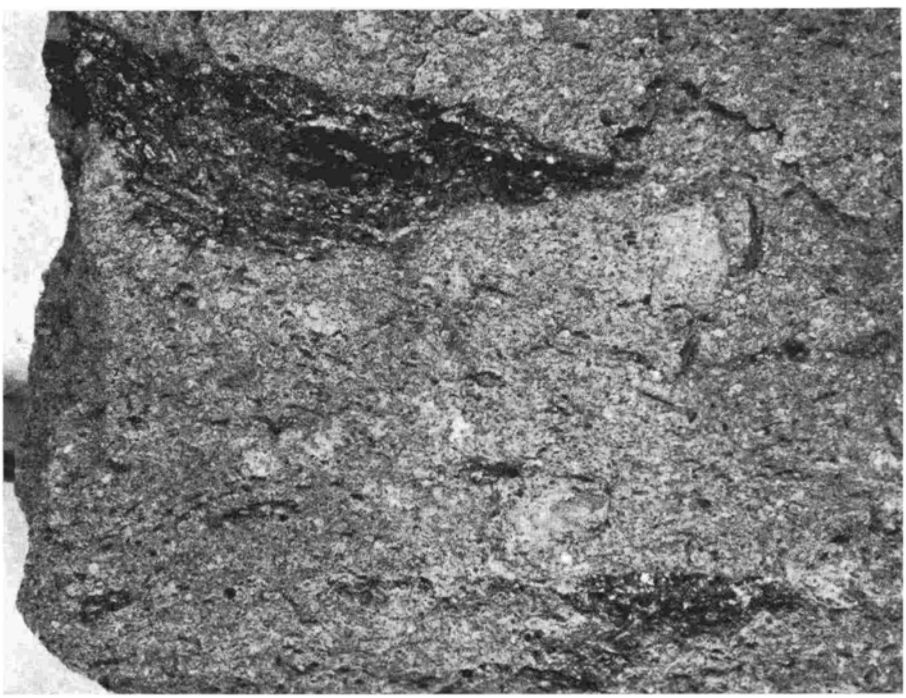

Fig. 2 - Ignimbrites from the middle part of the level (x 1).

Fig. 3 - Relics of the ash-structure in the groundmass of ignimbrites. Without the analyser (x 30).

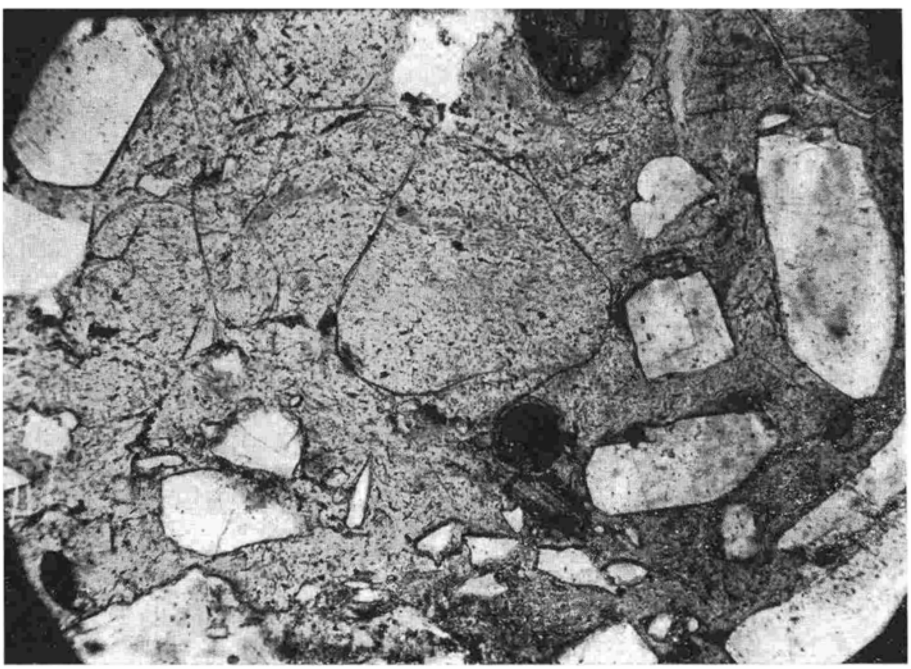

Fig. 4 - Character of the flamme. Without the analyser (x 30).