Pumices, Ignimbrites and Rhyolites from the Great Kurile Arc. *

V. F. OSTAPENKO, V. I. FEDORCHENKO, V. N. SHILOV

Within the islands of the Great Kurile Arc only Neogene and Quaternary formations were distinguished for sure up till now. The former are represented by folded volcanic-sedimentary deposits, cut by the intrusions of gabbro, diorites and granodiorites; the latter, mainly by products of Quaternary volcanic activity. Some authors suppose the presence of Paleogene rocks here too, but they have no reasonable arguments in favour of this supposition.

The predominantly volcanic character of all deposits, accessible at present for direct investigation, allows the authors to state that, since at least from the Early Miocene, the region under investigation was the arena of intense volcanic activity, occurring in the conditions of island arc. Numerous (about 100) Pleistocene and Recent volcanoes, the majority of which (39) are active at present, are the main peculiarities of the Kurile Island Arc.

The history of volcanic activity in the Great Kurile Islands has so far been studied rather weakly. But even so we have reasons to speak about Miocene, Pliocene and Quaternary periods of volcanic activity. The volcanic products of all these periods are represented predominantly by augite-hypersthene-andesites and near them by andesitic basalts with or without olivine. More basic (olivine-pyroxene-basalts) and more acidic (commonly two-pyroxene-dacites and, rarely, rhyolites) are present in a subordinate amount. The latter are represented by pumice. Ignimbrites and common rhyolites are rather rare. The products of acidic volcanism within the islands of the Small Kurile Arc have not been found up till now.

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Pumices

Among all the pumices of the Kurile Islands we distinguish the following types: 1) « original », unredeposited pumices; and 2) redeposited pumices, being a component of the Neogene and Quarternary coastal-marine deposits, composing the terraces, the foot of the volcanoes and the lower parts of the reliefs.

The first group pumices took part in the formation of the cones only of the Quarternary volcanoes in Simushir (Zavaritzkiy volcano), Iturup (Medvezciy volcano), Urup (Berg volcano), Onekotan (Krenitzin volcano), Paramushir (Ebeko, Tatarinov and Karpinskiy volcanoes) and others.

On the Zavaritzkiy volcano, consisting of two sommas and partly-exposed central cone with a caldera (GORSHKOV, 1960), coarse-fragmental pumice pyroclastics were met in the upper part of the cross section of the inner somma, where they are underlaid with lava flows and pyroclastics of andesitic composition and overlapped with ignimbrites. The thickness of the pumice sequence ranges between 10-20 m in the south-west part and 3-5 m in the east and north parts of the somma. Between separate fragments of pumice sometimes weak sintering is noticed, giving the strata a compact appearance. The occurrence of pumice on the Zavaritzkiy volcanoes is perhaps connected with the formation of the caldera of the inner somma, while the ignimbrites were certainly formed during the process of the formation of the caldera of the central cone (GORSHKOV, 1961). Thin (2-3 m) beds of the pumice pyroclastics, overlapped by alluvial deposits, were also met in the south part of the young caldera.

On the Medvezciy volcano (Iturup Is.), which is a composite volcano having a caldera with central cones, the pumice pyroclastic deposits were met at the north foot of the somma and at the caldera bottom. The thickness of the pumice strata sometimes reaches 8 m. According to the authors the occurrence of these pumices is connected with the caldera formation.

The pumices of the Berg volcano in Iturup Is., composing the peculiar pyroclastic mantle on the outer slopes of the somma, are evidently also genetically connected with the caldera formation. The thickness of the pumice « mantle » ranges from 2-10 m. Even more evidently the pumices, occurring abundantly in the neighbourhood of the Krenitzin peak (Onekotan Is.), appeared here in the process of formation of the caldera surrounding the central cone of the volcano.

In Paramushir Is. a small quantity of pumice pyroclastics was found on composite volcanoes without caldera (Ebeko, Tatarinov and Karpinskiy). Here it is the most acidic product of differentiation of the parental andesit-basaltic magma in feeding channels of the volcanoes and has no relation to the formation of the caldera. On Ebeco volcano its appearing is connected with Recent activity of the central cone, which is confirmed by the presence of pumice fragments at the surface of the youngest lava flows. Thin (2-10 cm) ash-lapilli-pumice strata on the Tatarinov volcano are interbedded with Recent andesite-basaltic scoria of the Chikurachki volcano, which is the most active of all the North Kurile volcanoes. This fact also testifies to their extreme youth. On Karpinskiy volcano single fragments of pumice were found in moraine by G. S. GORSHKOV (Горшков, 1954). They are apparently older. It is interesting to note that in Japan the Holocene pumice is also characterized by small volume and has no genetic relation to calderas (ISHIKAWA *et al.*, 1957).

So, among the « primary » original unredeposited pumices we clearly distinguish the following types: a) pumices restricted to calderas and characterized by great volume; and b) pumices of the volcanoes having no caldera, occurring in rather small volume.

The redeposited pumice in comparison with those considered above, is rather more widely distributed in the islands of Great Kurile Arc. First of all, pumice deposits of the South Kurile Islands (Kunashir and Iturup), the greatest within the region under consideration, must be attributed to these redeposited pumices.

In Kunashir Is. pumices took part in formation of the Golovnin volcano somma, and are contained in lacustrine deposits, outcropping at the bottom of its caldera. Besides, in the south part of the island around this volcano the thick (up to 250-300 m) strata of coastal-marine pumiceous deposits, united into Golovninskaya series, are developed. These deposits are represented by alternated bands and lenses of pumice tuffs, ashes, sands, gravels, siltstones and argillites. Bedding is calm: the beds, in general, dip to the south with an angle of 10°.

Formations, with nearly common lithology, are distributed along isthmuses of Vetrovoy and Rok in Iturup Is. On the former, coastal-marine pumiceous deposits are exposed in the cliffs of the marine terraces. They are represented by alternated pumiceous gravels and sands, which along the strike gradually turn into one another. The impression occurs that they both form a great number of lenses superimposing one another. The thickness of the deposits is about 300 m. The bedding of these rocks is nearly horizontal. At separate places the sandy-pumiceous formations are gently (5-10°) inclined towards depressions of old relief (enveloping the substratum). The occurrence of pumiceous pyroclastics, serving as a parental material for formation of the deposits under consideration, apparently, must be connected with the near Tornaya caldera, within which domes of acidic composition are developed (Mt. Tornaya and others).

Sandy-pumiceous rocks, composing the marine terrace with a height of 250 m above sea level, are exposed along the Rok Bay coast in the south part of Iturup Is. This terrace rims the slopes of the volcanoes Berutarube and L'vinaya Past' in the south and of Urbich caldera in the north. The coarse-fragmental variations predominate in the composition of pumiceous deposits: pumiceous breccias, gritstones, conglomerates. Some bands are entirely composed of pure pumice, although the mixing with foreign material (andesitic pebbles and others) is rather essential. The terrace section is capped with a four-meter thick horizon of pumiceous breccias, which forms something like a cornice. The full thickness of pumiceous formations reaches 150 m. Ju. S. ZCELUBOVSKIY and some other investigators believe that the pumices of the south part of Iturup Is. are the product of activity of L'vinaya Past' caldera. But the result of investigation shows that the amount of pumiceous material and size of fragments notably decrease towards this caldera. This fact makes us suppose there is another source of pumice. As the authors believe the caldera Urbich was most probably such a source.

As to the age of redeposited pumices of the South Kuriles there is no common point of view. Till recently the deposits under consideration were dated as Early Quaternary, but the marine fauna, found by B. N. PISKUNOV (1964), in the rocks of Golovninskaya series, made him suppose a Pliocene age. This conclusion is in accordance with the relationship existing between pumiceous strata and high terraces of Iturup Is.

Pumices in Neogene deposits of Great Kurile Arc are rather poorly studied. The information on them is mainly restricted to data on their stratigraphic position and geographic distribution.

The sporadically occurring pumice fragments are noted in Pliocene deposits on the middle part of the series Parusnaya (Iturup Is.), composed of alternated lava flows and stratified bodies of volcanic andesitic and andesite-basaltic breccias, the full thickness of which reaches 700-1000 m.

The redeposited pumices are rather widely distributed in Late Miocene-Pliocene deposits in Kunashir, Iturup and Paramushir. In the first of these islands they are rarely noted among andesitic volcanic clastics of Alehinskaya series. In Iturup Is. the alternating pumice gritstones, conglamerates and breccias compose the section of the Kamujskaya series. The thickness of this section is 650-700 m. The Kamujskaya series is widely distributed in the north-east part of the island. The pumice fragmentary material plays nearly the same role in deposits of Okrugliy Cape series, developed to the south of Severo-Kuril'sk town (Paramushir Is.) and reaching the thickness of 500 m. The Middle Miocene rocks of Kunashir Is. (Lovtcovskaya series) and Urup (Lopuhovskaya series) are the oldest formations in which single pebbles of pumice were found.

Pumices of the Kuriles are similar in mineralogical and chemical compositions as well as textural-structural features. As a rule they are white, light-grey and yellow, porous and light rocks, often having fibrous constitution. They are composed of fresh uncrystallized or weakly devitrificated acidic volcanic glass, containing about 35 per cent of porphyric phenocrysts, represented by melted quartz, zonal plagioclase, hypersthene, augite, titanomagnetite and ilmenite. Sometimes the hornblende is noted too.

The plagioclase crystals, having dimensions up to 1-2 mm in cross section, have the characteristic tabular form, distinct direct zoning (very sharply repeated) and twinning structure (as a rule, albite or Carlsbad twinning). In the cores of coarse phenocrysts an abnormally high content of anortite component is found (An_{80-90}), while the marginal parts and small phenocrysts have an andesine composition (An_{40-50}). Plagioclase often contains numerous zonally distributed inclusions of glass, pyroxenes and ore mineral.

Pyroxenes as a rule are enriched with iron components. Predominant hypersthene forms idiomorphic prismatic crystals, reaching 1-2 mm in cross section and possessing distinct pleochroism according to common scheme. 2V(—) ranges between 59° and 65°. Ore mineral and glass are present as inclusions. Augite occurs as small (0.5-0.8 mm) single crystals of green colour, and as thin margins around hypersthene. It sometimes forms glomeroporphiric intergrowths with plagioclase and rhombic pyroxene.

To characterize the peculiarities of the chemical composition of

TABLE 1 - Chemical compositions of the Kuriles pumices.

Components	Unredeposited (« original ») pumices									Redeposited pumices								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	65.51	65.73	66.99	67.08	70.19	63.15	61.01	60.82	70.46	70.44	66.32	65.83	65.99	66.67	67.81	65.52	68.00	68.14
TiO_2	0.48	1.01	0.97	0.99	0.66	0.57	0.55	1.18	0.40	0.82	0.52	0.91	1.17	1.02	0.54	0.92	0.84	0.90
Al_2O_3	14.42	14.52	13.98	14.11	13.84	16.71	18.38	16.98	14.34	14.61	16.73	14.73	14.46	13.91	14.30	15.61	15.29	15.49
Fe_2O_3	2.04	6.01	2.73	1.75	0.79	2.31	3.43	2.91	0.74	1.55	2.52	1.78	0.93	0.70	1.60	3.29	1.75	1.61
FeO	3.25	0.50	2.16	2.98	1.67	1.77	2.93	3.68	1.27	1.35	2.28	2.98	3.09	2.01	2.34	1.35	2.15	2.17
MnO	0.15	0.20	0.15	0.15	0.09	0.16	0.10	0.18	0.09	0.12	0.11	0.10	0.09	0.11	0.12	0.14	0.15	0.15
MgO	1.41	1.24	1.11	0.97	0.67	1.37	2.61	2.50	0.62	0.70	1.24	1.25	1.48	1.54	1.31	1.53	1.38	1.45
CaO	4.23	4.06	3.08	3.46	3.03	3.97	6.78	4.99	2.70	2.90	5.29	4.18	4.16	3.68	4.49	3.92	4.11	4.16
Na_2O	3.69	4.42	4.99	4.44	4.01	3.77	2.55	3.03	4.73	3.91	3.40	3.62	4.05	4.00	3.43	3.60	3.65	3.41
K_2O	0.84	1.10	0.45	0.85	0.78	1.06	0.82	2.16	2.09	0.63	0.97	0.97	1.20	1.23	1.33	1.06	1.23	0.97
P_2O_5	0.02	0.20	0.36	0.46	0.58	0.21	0.20	0.35	—	0.49	0.02	0.50	0.32	0.60	—	0.54	0.40	0.40
Total S	0.12	0.08	0.09	0.12	0.12	0.16	0.05	0.02	0.04	—	—	0.14	0.13	0.11	—	—	0.02	—
H_2O^-	0.39	0.10	0.10	0.12	0.04	1.56	0.07	0.22	0.08	0.13	0.31	0.07	0.08	0.07	0.40	0.24	0.19	0.14
H_2O^+	3.52	0.93	3.62	2.44	3.47	4.07	0.66	1.03	2.83	2.75	0.65	3.57	3.18	2.97	2.58	2.67	1.48	1.36
Total	100.07	100.10	100.78	99.92	99.94	100.84	100.14	100.05	100.39	100.40	100.36	100.63	100.33	99.62	100.25	100.39	100.64	100.35

NOTES: 1-4: dacitic pumices of Zavaritzkiy volcano in Simushir Is. (N 96 b, coll. of O. I. BENT; NN 3024 a, 3035, 3024, coll. of V. F. OSTAPENKO); 5: rhyolitic-dacitic pumice of Zavaritzkiy volcano, Simushir Is. (N 1, coll. of O. I. BENT); 6: dacitic pumice of Medvezciy volcano in Iturup Is. (N 4044 a, coll. of V. F. OSTAPENKO); 7: andesitic pumice of Berg volcano in Urup Is. (N 2, coll. of O. A. HVEDCHENJA); 8: andesitic pumice of Ebeko volcano in Paramushir Is. (N 2279, coll. of V. N. SHILOV); 9: rhyolitic-dacitic pumice of Karpinskiy volcano in Paramushir Is. (N 684, coll. of G. S. GORSHKOV); 10: rhyolite-dacitic pumice of Golovnin caldera in Kunashir Is. (N 4, coll. of V. I. FEDORCHENKO); 11: dacitic pumice of Golovnin caldera in Kunashir Is. (N 4, coll. of V. I. FEDORCHENKO); 11: dacitic pumice from Golovninskaya series in Kunashir Is. (N 48, coll. of O. I. BENT); 12-15: dacitic pumices from the Vetrovoj isthmus in Iturup Is. (NN 3087, 3084 b, 3084 v, coll. of V. F. OSTAPENKO; (N 43, coll. of Ju. S. ZCELUBOVSKIY); 16-18: dacitic pumice from the Rock Bay in Iturup Is. (N 3090, 3091 a, 3092 a, coll. of V. F. OSTAPENKO).

pumices of the Kuriles the authors have 18 analyses, given in Table 1. As we see from this Table, within the region under consideration, dacitic pumices, containing 65-69 per cent of silica predominate. Liparitic pumices rarely occur. The same can be said as to andesitic pumice. It is noted that pumices, genetically connected with volcanoes without a caldera, have small total volume and comparatively basic composition (contain up to 60-65 per cent of silica) while they are more abundant in caldera volcanoes. Here their composition is more acidic (65-72 per cent of silica).

As to their chemistry the investigated pumices are similar to corresponding lavas of the Kuriles and Japan. They are all related to common Pacific calc-alcalic rocks. They are characterized by low total alkalinity, stable sharp predominance of soda over potash, high content of CaO and alumina. All these determine the great role of anortite component in the composition of plagioclases and predominant development of rhombic pyroxene.

Ignimbrites

Since the ignimbrites of the Kuriles are studied rather poorly, we have no possibility at present to speak about their distribution within the considered region and about the role they play among the products of acidic volcanism. The authors investigated these ignimbrites on Zavaritckiy volcano (Simushir Is.) and Medvezhiy volcano (Iturup Is.), where their appearence is connected with the processes of caldera formation. It is quite possible that they are present on other volcanoes too, but have not yet been described. Some investigators point out the presence of ignimbrites in Neogene deposits of Kunashir Is. (V. M. Dunichev, E. N. Nichina and N. A. Solov'eva) and of Urup Is. (B. N. Piskunov). But the authors believe that these data need to be re-examined, as it is possible that, here, hyaloclastics and common volcanoclastic rocks are taken for ignimbrites.

Ignimbrites of Zavaritzkiy volcano in Simushir Is. form the peculiar mantle on the slope of the central cone and the inner somma, regularly coating large territory irrespective of the substratum morphology. The thickness of this mantle is 8-10 m. This thickness according to the point of view of G. S. Gorshkov, testifies to the fact, that the rocks under consideration were formed by fire rain in the pure sense of this word and are not the deposits of hot unconsolidated flows. Two layers of ignimbrite are distinctly distinguished: lower, having red-brick colour and containing numerous lenses and bands of black glass (« fiammae ») near the foot, and upper, dark-grey in the mass and red-brick near the roof. This fact shows that the explosive process, having formed ignimbrites, was two-stroke. Unlike those described above, the dark-grey commonly flow-banded ignimbrites of Medvezcja caldera occur in depressions of the volcano somma, which makes them cognate with the deposits of hot unconsolidated flows. The thickness of these formations reaches 60 m.

TABLE 2 - Chemical compositions of ignimbrites of the Kuriles.

Components	1	2	3	4
SiO_2	64.60	64.40	61.13	62.67
TiO_2	1.67	0.96	1.10	0.43
Al_2O_3	13.96	14.62	16.94	15.04
Fe_2O_3	6.91	2.59	4.11	2.21
FeO	0.68	4.56	3.07	1.56
MnO	0.49	0.49	0.17	0.05
MgO	1.74	1.88	2.12	0.96
CaO	5.26	5.21	5.52	4.01
Na_2O	4.16	4.20	3.23	2.97
K_2O	0.63	0.75	0.82	0.46
P_2O_5	0.10	0.10	0.13	—
Total S	—	—	0.09	0.02
H_2O^-	0.14	0.05	0.77	5.85
H_2O^+	0.15	0.14	1.20	3.98
Total	100.49	99.95	100.40	100.21

NOTES: 1: red ignimbrite from Zavaritzkiy caldera in Simushir Is. (N 900 a, coll. of G. S. GORSHKOV); 2: black glass from « fiamma » of ignimbrites from Zavaritzkiy caldera in Simushir Is. (N 900, coll. of G. S. GORSHKOV); 3: ignimbrite from Medvezcja caldera in Iturup Is. (N 4031, coll. of V. F. OSTAPENKO); 4: ignimbrite from Miocene deposits in Kunashir Is. (N 2038/1, coll. of N. A. SOLOV'EVA).

The microscopic investigation of ignimbrites showed that they are composed of dominant vitroclastic groundmass, in which can be found irregular glass inclusions (« fiammae ») flattened along the bedding plane, fragments of crystals of plagioclase (andesine), pyroxenes (rhombic and monoclinic) and foreign rocks. The fragments of glass possess concave-convex, fibrous and thread-like forms. « Fiammae » vary in size between 2 and 4 cm. While the amount of « fiammae » and their oblateness increase, the ignimbrites possess the characteristic flow-banded structure.

According to their chemical composition all the considered ignimbrites are dacitic (Table 2).

Rhyolites

As was noted above, rhyolites in the Kuriles are present in subordinate amount in comparison with the more basic variations of the rocks.

Up till now, Quaternary rhyolites were met in Medvezcja caldera and described by one of the authors; these rhyolites composed about 20 coarse and fine extrusive domes. The considered rocks have porphiric structure. Their phenocrysts (about 15 per cent of total volume) are represented by coarse crystals of predominant plagioclase (andesine), quartz and hypersthene. The last two are present in nearly equal amounts. Groundmass is formed of volcanic glass with numerous crystallites. The fluidal appearance of the groundmass is caused by flow-like distribution of these crystallites. In lower parts of Miocene deposits of some islands of the Kurile Arc, rhyolites have a very wide distribution. For example, effusive and volcano-sedimentary formations of Kunashirskaya series (Early Miocene), the thickness of which reaches 1000 m, are nearly completely composed of rhyolites and, in lesser degree, dacites. The other lava types are present in subordinate amounts (andesites and basalts). Most of the rocks under consideration show the traces of intense propilitization, which makes them resemble the « Green Tuffs » of Japan. Rhyolites possess a weak porphyric structure. Their rare phenocrysts, formed by albite, sanidine and quartz, are enclosed in a dominant felsitic groundmass (AVER'JANOV, 1961). Zircon is noted among the accessory minerals. Unlike rhyolites, phenocrysts of porphyric dacites are represented by oligoclase-andesine, rarely by quartz and more rarely by monoclinic and rhombic pyroxenes, enclosed in felsic and microfelsic groundmass.

In Urup and Paramushir Is., in the lower part of a cross section of the Miocene deposits, rhyolite-dacites were met. As the same kind of rocks of Kunashir Is., these rocks are intensively propilitized and,

TABLE 3 - Chemical compositions of the Kuriles rhyolites.

Components	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	71.11	71.75	74.82	74.87	68.77	70.88	71.11	73.38	76.51	75.31	68.49	73.94
TiO_2	0.27	1.10	0.55	0.63	0.52	0.44	0.55	0.34	0.22	0.30	0.28	0.32
Al_2O_3	14.50	15.15	12.89	12.78	14.33	14.98	13.71	12.38	11.44	13.23	12.62	12.82
Fe_2O_3	2.96	1.78	0.80	1.40	0.92	0.54	2.50	1.82	1.82	1.39	1.43	1.78
FeO	0.58	0.11	1.31	0.76	2.98	2.06	2.00	1.84	0.31	1.27	1.14	0.91
MnO	0.13	0.06	0.10	0.10	0.09	0.13	0.18	0.10	0.02	0.02	0.06	0.03
MgO	0.60	0.13	0.67	0.59	3.29	1.22	1.20	1.72	2.78	1.81	1.10	0.75
CaO	3.14	2.01	2.37	2.25	1.17	1.34	3.57	3.31	0.35	0.42	2.61	2.08
Na_2O	4.45	4.31	4.31	4.52	2.50	3.92	4.18	2.98	1.95	3.33	3.67	3.83
K_2O	1.33	1.05	1.57	1.57	1.41	1.12	0.41	0.44	1.24	1.82	1.62	2.73
P_2O_5	0.08	0.09	0.04	0.08	0.17	—	0.17	0.10	—	0.03	0.13	0.10
Total S	—	0.07	0.01	0.11	0.40	—	0.25	0.52	—	0.88	0.40	0.61
H_2O^-	0.38	0.95	0.16	0.20	0.43	0.72	0.40	0.22	1.04	0.91	3.42	0.36
H_2O^+	1.09	1.97	0.61	0.47	2.99	2.90	0.50	1.48	1.70	0.22	3.41	—
Total	100.62	100.53	100.21	100.33	99.97	100.25	100.73	100.63	100.38	100.94	100.38	100.26

NOTES: 1-4: rhyolites of the extrusive domes in Medvezcja caldera in Iturup Is. (N 4004, 4040, 4033 a, 4038 a, coll. of V. F. OSTAPENKO); 5: rhyolite-dacite from pebbles in Miocene deposits of Kunashir Is. (N 1073, coll. of V. N. SHILOV); 6, 9: rhyolites from the flows in Miocene deposits of Kunashir Is. (N 524, 426, coll. of I. P. AVER'JANOV); 7, 8: rhyolites from pebbles in Miocene deposits of Kunashir Is. (N 3147, coll. of A. F. PR'JALUHINA; N. 2016 i, coll. of G. P. VERVUNOV); 10: rhyolite from pebbles in Miocene deposits of Urup Is. (N 5074 d, coll. of JU. L. NEVEROV); 11: rhyolite-dacite from flow in Miocene deposits of Paramushir Is. (N 8075 b, coll. of K. F. SERGEEV); 12: rhyolite from a flow in Miocene deposits of Paramushir Is. (N 8075 v, coll. of K. F. SERGEEV).

in many respects, are anological to the same formation — « Green Tuffs » of Japan. Microscopically, rhyolite-dacites are porphiritic rocks, having felsic or microfelsic groundmass. Their phenocrysts are formed of albite-oligoclase and quartz. The latter is normally present in subordinate amount in the form of melted rounded crystals.

Chemical analyses of the considered rhyolites are given in Table 3.

Conclusion

All abundant concentrations of acidic products of Pleistocene volcanism in the Kuriles are characterized by distinct restriction to calderas, analogically to what was already noted in Japan (ISHIKAWA *et al.*, 1957). According to this fact we may suppose that a considerable amount of these products in the cross section of some Neogene suites is also connected with the formation of caldera. The authors support the point of view of R. V. VAN BEMMELEN (1961), who believes that great volumes of acidic products, appearing at the daily surface during the caldera formation, cannot be the result of differentiation of original basaltic magma. The authors believe that the role of processes of reomorphism, assimilation and anatexis of the sialic crust in caldera formation (MARKININ, 1964) as well as in the origin of great amounts of acidic volcanic material, is extremely great; which is confirmed by exclusive restriction of calderas due to collapse to the regions of development of andesitic suite, in formation of which a great role was played by assimilation of high-alumina sialic material.

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