Relations between the type of eruptions and the composition of lava as exemplified by Kamchatka and Kuriles Volcanoes.

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There have been 31 active volcano in the Kuriles-Kamchatka volcanic zone during this century: 16 volcanoes on Kamchatka and 15 on the Kuriles Islands.

Their activity was manifest in an usual form, i.e. effusive, extrusive (under an extrusive form of activity we understand a squeezing out of viscous lavas as domes, crater plugs and Pelée's spines) and explosive. However, even if one form predominated other forms of activity were also manifest. The same is true regarding the types of eruptions. The enumerated forms of activity usually combined several classification types of eruptions or there might have been a predominance of one of them.

Thus manifestations of effusive activity were recorded during this and past centuries on Kliuchevskoi volcano, Plosky Tolbachik, Maly Semiachik, Karymsky, Avachinsky, Alaid, Chikurachki, Karpinsky caldera. However, the activity of these volcanoes meant not only lava effusions but also other manifestations. Among the volcanoes mentioned lavas of Kliuchevskoi, Plosky Tolbachik, Maly Semiachik and Alaid are of a basaltic composition, lavas of Avachinsky, Chikurachki and Karpinsky caldera — are andesitic and of Karymsky volcano — dacitic.

The first four volcanoes of a basaltic composition form lateral craters. However, Plosky Tolbachik has the greatest number of such craters — about 120; then comes Kliuchevskoi — about 70 and much less on Maly Semiachik (only 6) and even less on Alaid.

Usually, their eruptions begin with relatively weak explosions of Vulcanian and Strombolian types from the main summit crater. Gradually getting stronger and stronger they reach they culmination point and then eruptions from lateral craters begin.

In certain cases, like on Kliuchevskoi volcano, for instance, during the eruption, which began early in December 1944 the intensification of the strength of explosion proceeded rather quickly and

on January, 1st, 1945 an enormous explosion of Vulcanian type took place from the main crater. This explosion was close to the Plinian type and afterwards during 20 days lava was flowing quietly from

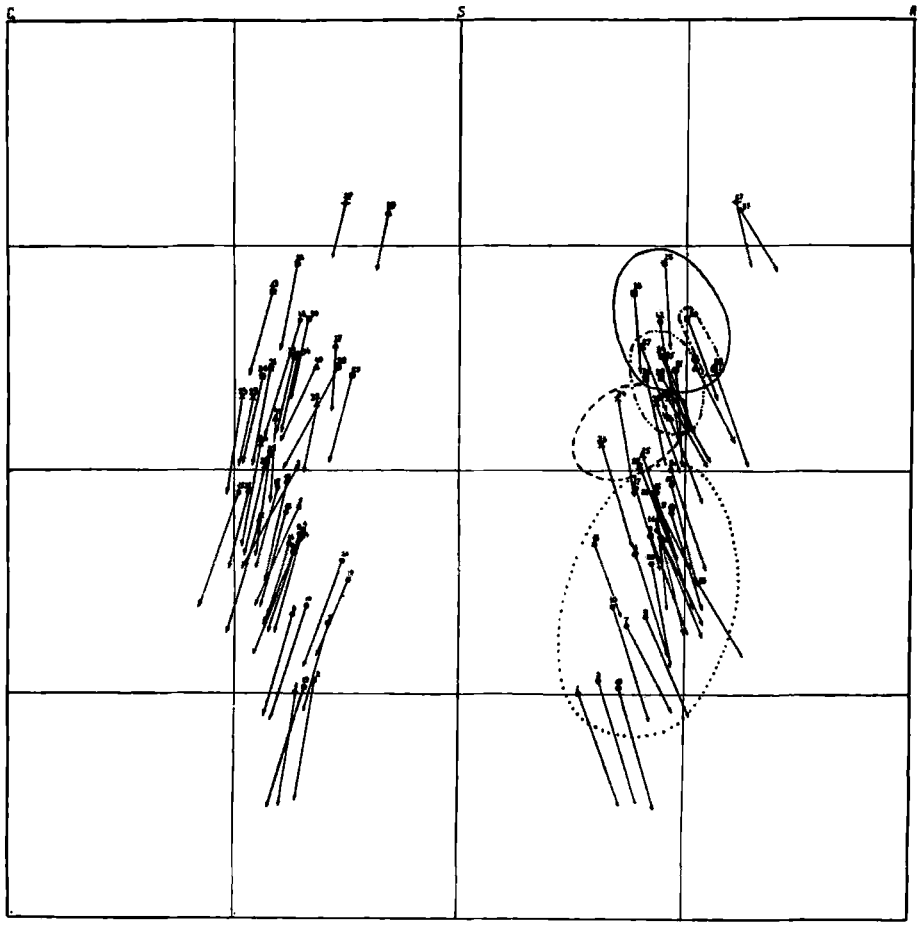

Fig. 1 - Numerical characteristics according to A. N. Zavaritzky. Diagram of lava vectors of Kamchatka and Kuriles volcanoes according to A. N. Zavaritzky.
..... ● Rocks of the effusive (basaltic) field
— — — — × Rocks of the effusive-explosive (andesitic) field
———— ■ Rocks of the extrusive field
—.—.— ■ » » » » » with glowing clouds and sand flows
—..—..— ▲ Rocks of the explosive field
⊘ Exceptions.

the main crater. Five months later a number of adventive craters has been formed, all the upper ones being explosive and the lowest one — a lava crater. A similar picture was observed during the

eruptions of this volcano in 1937-1939 — an intensification of the force of explosions, then an effusion from the main summit crater and, finally, a burst of a number of lateral craters, the two top ones being explosive and the three lower ones — lava craters. The lowest — Biliukai crater — produced the greatest amount of lava (a flow 16 km long).

During these eruptions the compositions of the lavas changed (this has been especially striking during the eruption of 1937-39) from relatively acid basalts to more basic and then again to more acid, which proves a magma differentiation in the channel of the volcano.

The lava from Plosky Tolbachik is more liquid and this volcano yielded not only lava flows up to 40 km long but also lava fields. During the eruption from the main summit crater not only ash was erupted but also Pelée's hair. During the eruption of 1939-1941 the bottom of this crater was flooded by liquid lava. Thus, the eruptions of Plosky Tolbachik are close to the Hawaian type and the formation of numerous adventive craters on its flanks approaches it to the Etnaean type. In the recent past Maly Semiachik effused lavas, but its last eruption was purely explosive.

While in the eruptions of the first two volcanoes there was a considerable predominance of lava effusions, the activity of Alaid basaltic volcano during the past century was mostly of an explosive character. During this (20th) century only the eruption of 1933-1934 was of a Strombolian type accompanied by the formation of an adventive crater Taketomi.

As to the Avachinsky volcano, partly Karpinsky caldera and Chikurachki volcano — mainly andesitic — their eruptions sharply differ from the preceding. They happen only from the main summit crater and are manifest by sufficiently strong explosions of a Vulcanian type accompanied sometimes by effusions of comparatively small quantities of rather viscous lavas.

The dacitic lava Karymsky volcano approaches by the character of its eruptions the Avachinsky volcano but there is a predominance of explosions of Vulcanian type. We find here also effusions of sufficiently long lava flows but of a more acid composition. Thus, the flow effused in 1935 is of a total length of about 6 km.

An extrusive form of activity was recorded on volcanoes of an andesitic composition like Sheveluch, Bezymianny, Kizimen, Krenitzinpeak, Severgin volcano, Zazaritzky caldera and Goriaschaia Sopka, the eruptions of the first two being accompanied by glowing

Table 1 - Chemical composition of lavas of Kamchatka and Kuriles Volcanoes.
ХИМИЧЕСКИЕ СОСТАВЫЛАВ КАМЧАТКИ И КУРИЛЬСКИХ ОСТРОВОВ

Компоненты	№ анализов									
	1	2	3	4	5	6	7	8	9	10
SiO_2	51,51	52,34	54,48	53,50	53,93	53,48	53,17	51,03	53,08	53,46
TiO_2	0,57	0,95	1,10	0,78	1,14	0,93	0,88	1,00	1,08	1,01
Al_2O_3	14,91	14,57	17,42	16,67	16,91	16,53	14,27	17,03	16,62	15,37
Fe_2O_3	3,02	2,69	2,45	3,41	3,45	4,52	5,92	3,58	2,50	2,59
FeO	6,26	6,09	5,94	5,63	5,51	5,64	5,92	5,23	6,52	6,13
MnO	0,20	0,11	0,29	0,20	0,20	0,16	0,16	0,35	0,25	0,19
MgO	9,37	9,89	5,12	5,66	5,74	6,56	6,35	6,75	6,11	8,12
CaO	10,80	9,76	8,31	9,33	8,57	8,80	9,40	10,45	8,80	9,42
BaO	—	—	0,01	—	0,04	—	—	—	—	—
Na_2O	2,15	2,54	3,43	3,20	3,23	2,56	2,58	2,93	3,08	2,40
K_2O	0,63	0,67	1,19	1,06	1,07	1,46	1,23	1,34	1,08	1,10
H_2O+	0,32	0,48	0,12	0,55	—	—	0,04	0,20	0,59	0,04
$H_2O—$	—	0,03	—	0,08	—	—	—	0,10	0,14	0,14
P_2O_5	—	0,11	0,32	0,23	0,27	—	—	0,11	0,25	0,27
SO_3	—	—	—	—	0,07	—	—	—	—	—
CO_2	—	—	—	—	—	—	—	—	—	—
Cl	—	—	—	—	—	—	—	—	—	—
F	—	—	—	—	—	—	—	—	—	—
S	—	—	—	—	—	—	—	—	—	—
	99,74	100,23	100,18	100,30	100,13	100,64	99,92	100,10	100,10	100,24
Numerical characteristics according to A. N. Zavaritzky Числовые характеристики по А. Н. Заварицкому										
a	5,3	6,2	9,4	8,8	8,8	7,8	7,4	8,3	8,5	6,8
c	7,1	6,3	7,1	6,8	7,0	7,2	5,7	7,3	7,0	6,7
b	29,8	29,3	19,9	22,6	21,6	23,6	26,8	26,4	22,8	26,0
s	57,8	59,2	63,6	61,8	62,6	61,4	60,1	58,0	61,7	60,5
f′	28	27	40	37	39	38	40	34	38	31
m′	52	55	44	43	45	47	40	46	45	52
c′	20	18	16	20	16	15	20	20	17	17
n	85	85	81	81	81	72	76	77	81	76

Table 1 - *Continued.*

Компоненты	№ анализов									
	11	12	13	14	15	16	17	18	19	20
SiO_2	52,90	53,22	53,22	51,52	50,10	53,97	53,89	51,30	49,84	53,86
TiO_2	1,06	1,12	0,80	1,11	1,03	0,72	0,92	1,65	0,95	1,14
Al_2O_3	17,70	18,19	17,28	17,02	19,99	15,43	17,30	15,22	15,73	13,99
Fe_2O_3	3,36	3,18	3,64	4,20	4,19	7,48	4,21	3,74	3,28	4,88
FeO	5,36	6,68	6,22	5,81	5,02	6,16	7,20	7,98	6,16	6,35
MnO	0,16	0,10	0,20	—	0,25	0,14	0,09	0,20	0,12	0,35
MgO	6,40	5,23	5,42	5,97	5,98	4,46	4,41	5,12	9,83	6,70
CaO	9,21	7,91	8,60	9,02	8,58	8,27	8,33	8,36	9,61	5,96
BaO	0,08	0,04	0,10	—	—	—	—	0,10	0,04	—
Na_2O	2,30	3,52	2,90	2,71	2,84	2,07	2,75	3,40	2,51	2,78
K_2O	1,00	1,11	1,20	1,07	1,52	0,94	1,11	2,15	1,17	1,62
H_2O+	0,20	0,10	0,11	0,98	0,12	0,03	0,07	нет	0,08	1,15
$H_2O—$	0,08	0,08	0,08	0,29	0,08	0,04	0,02	нет	нет	0,25
P_2O_5	0,17	0,09	0,20	0,11	—	0,24	0,08	0,80	0,25	—
SO_3	0,10	0,10	0,06	0,16	—	0,23	0,06	—	—	—
CO_2	0,06	нет	нет	—	—	0,28	0,03	нет	0,35	—
Cl	0,12	нет	0,10	—	—	0,03	0,03	0,06	нет	—
F	0,01	0,01	0,02	—	—	0,03	0,04	0,05	0,02	—
S	—	—	—	—	—	—	—	0,20	0,10	—
	100,27	100,68	100,15	100,21	99,70	100,52	100,54	100,33	100,04	99,03

Numerical characteristics according to A. N. Zavaritzky

Числовые характеристики по А. Н. Заварицкому

a	6,6	9,4	8,3	9	8,7	6,0	7,8	10,5	7,1	8,5
c	8,8	7,6	7,6	7	9,7	7,5	8,0	4,9	6,8	5,1
b	22,2	20,5	21,8	23	20,9	23,2	20,7	24,8	29,6	24,0
s	62,4	62,5	62,3	61	60,7	63,3	63,5	59,8	56,5	62,4
f′	38	45	43	39	43	55	52	44	29	44
m′	50	44	43	43	52	33	37	35	55	47
c′	12	11	14	18	5	12	11	21	16	9
n	77	82	78	71	74	77	78	71	76	72

Table 1 - *Continued.*

Компоненты	№ анализов										
	21	22	23	24	25	26	27	28	29	30	31
SiO_2	50,29	53,52	53,86	55,61	54,74	55,98	64,60	59,57	61,15	59,82	55,69
TiO_2	1,28	0,86	0,84	0,94	0,72	0.73	0,90	0,51	0,72	0,57	0,95
Al_2O_3	18,96	18,45	19,50	18,88	18,13	17,40	16,38	16,44	16,65	17,19	18,96
Fe_2O_3	3,44	4,41	4,15	2,98	2,74	3,30	1,57	4,11	2,70	3,69	2,93
FeO	6,75	5,16	4,67	4,96	5,21	4,91	3,76	2,49	3,81	3,35	5,45
MnO	0,33	0,16	0,16	0,13	0,10	0,15	0,25	0,29	0,14	0,13	0,11
MgO	4,14	4,50	3,01	4,18	5,15	5,01	1,46	4,04	3,58	2,80	3,82
CaO	10,25	9,24	9,50	8,76	9,18	9,02	4,58	6,43	6,20	6,86	7,24
BaO	—	—	—	—	—	—	нет	—	—	—	0,03
Na_2O	2,85	2,78	3,21	2,66	3,14	2,43	4,39	3,27	2,88	3,60	3,39
K_2O	1,25	1,06	1,08	0,56	0,70	0,65	1,66	2,72	1,60	1,30	1,06
H_2O+	0,20	0,14	0,19	0,22	0,27	0,49	нет	0,40	—	0,08	0,04
$H_2O—$	0,09	0,15	0,14	0,20	0,04	0,31	нет	—	—	—	0,04
P_2O_5	0,40	—	—	—	—	—	0,37	—	0,32	0,18	0,19
SO_3	—	—	—	—	—	—	—	—	—	—	—
CO_2	—	—	—	—	—	—	—	—	—	—	0,25
Cl	—	—	—	—	—	—	—	—	—	—	нет
F	—	—	—	—	—	—	—	—	—	—	0,02
S	0,02	—	—	—	—	—	—	—	—	—	0,11
	100,25	100,43	100,31	100,08	100,12	100,38	99,92	100,27	99,75	99,57	100,28

Numerical characteristics according to A. N. Zavaritzky

Числовые характеристики по А. Н. Заварицкому

a	8,5	8,0	9,2	7,0	8,1	6,3	12,1	11,2	8,9	10,0	9,5
c	9,3	8,6	9,1	9,6	8,4	8,8	5,0	5,4	4,8	6,7	8,4
b	21,0	19,9	16,8	16,8	19,4	18,9	8,1	15,4	15,8	13,2	15,5
s	61,2	63,5	64,9	66,6	64,1	65,0	74,8	68,0	71,1	70,1	66,6
f′	47	46	51	47	38	41	63	40	39	49	52
m′	35	39	31	44	46	46	30	45	39	37	44
c′	18	15	18	9	16	13	7	15	22	14	4
n	75	79	81	88	88	86	80	65	73	81	82

Table 1 - *Continued.*

Компоненты	№ анализов										
	32	33	34	35	36	37	38	39	40	41	42
SiO_2	61,91	59,92	58,78	58,50	56,51	57,27	57,90	67,50	58,07	54,36	60,60
TiO_2	0,75	0,80	1,20	0,90	0,80	0,96	1,25	0,45	0,68	0,96	0,74
Al_2O_3	16,89	17,32	16,93	17.08	18,48	13,06	15,68	13,97	17,21	18,55	16,73
Fe_2O_3	3,14	2,86	3,36	2,88	3,01	6,67	3,30	1,63	3,61	4,65	2,02
FeO	3,89	4,42	5,06	5,31	5,41	2,31	7,26	3,50	4,23	3.89	3,76
MnO	0,21	0,16	0,21	0,18	0,17	0,08	0,24	0,14	0,16	0,27	0,12
MgO	2,20	2,54	2,95	2,99	3,50	2,40	3,00	1,36	3,04	3,92	4,05
CaO	5,96	6,93	7,12	7,46	8,02	5,32	6,44	3,76	7,41	8,49	6,52
BaO	—	—	—	—	—	—	—	—	—	—	—
Na_2O	3,21	2,60	3,32	3,28	2,90	3,19	3,30	4,63	3,26	3,84	3,04
K_2O	1,01	1,15	0,97	0,99	0,97	0,12	0,90	1,47	2,35	0,32	1,32
H_2O+	0,32	0,94	0,20	0,10	0,24	3,04	0,44	1,24	0,12	0,19	0,40
$H_2O—$	0,26	0,32	0,03	0,10	0,07	1,07	0,09	0,17	0,20	0,06	0,20
P_2O_5	—	—	—	—	—	0,15	0,08	0,09	—	0,08	0,26
SO_3	—	—	—	—	—	1,87	—	—	—	—	—
CO_2	—	0,03	—	—	—	—	—	—	—	—	—
Cl	—	0,04	—	—	—	0,07	—	—	—	0,27	—
F	—	—	—	—	—	0,19	—	—	—	0,01	—
S	—	0,07	—	—	—	1,97	—	—	—	0,05	0,16
	99,75	100,10	100,13	99,77	100,18	99,74	99,88	99,91	100,36	99,91	99,92

Numerical characteristics according to A. N. Zavaritzky

Числовые характеристики по А. Н. Заварицкому

a	9,0	7,7	8,9	9,0	8,2	8,0	8,7	12,3	10,6	9,2	8,8
c	7,2	8,3	7,1	7,3	8,7	5,5	6,3	3,1	6,4	8,3	7,0
b	10,8	12,1	14,9	15,0	15,8	14,5	17,0	8,5	15,4	17,6	13,4
s	73,0	71,9	69,1	68,7	67,3	72,0	68,0	76,1	67,6	64,9	70,8
f′	61	58	54	53	52	61	59	56	48	47	40
m′	39	37	34	34	39	28	31	27	34	39	52
c′	3	5	12	13	9	11	10	17	18	14	8
n	81	77	83	83	81	98	83	82	68	95	78

Kliuchevskoi volcano

1. Kirgurich,	January,	1932	Analist	N. N. Shavrova
2. Tuila,	June,	1932	»	N. V. Levenfish
3. Summit crater,	May,	1937	»	
4. Summit crater,	July,	1937	»	N. Kh. Aidinian
5. Kozei,	February, 6,	1938	»	K. P. Sokova
6. Trety	February, 7,	1938	»	K. P. Sokova
7. Tiranus	February, 7,	1938	»	P. N. Nissenbaum
8. Biliukai,	February, 7,	1938	»	K. P. Sokova
9. Biliukai,	July,	1938	»	K. P. Sokova
10. Biliukai,	September,	1938	»	K. P. Sokova
11. Summit crater,	January,	1945	»	M. E. Kazakova
12. Obruchev,	June,	1945	»	A. N. Razzhivina
13. Zavaritzky,	June,	1945	»	M. E. Kazakova
14. Zavaritzky,	June,	1945	»	N. I. Vlodavetz
15. Apakhonchich		1946	»	N. N. Shavrova
16. Bylinkina		1951	»	E. F. Prokofiev
17. Beliankin		1953	»	S. S. Krapivina

Plosky Tolbachik

18. Summit crater,	1941	»	O. A. Alekseeva
19. Lateral crater	1941	»	A. N. Razzhivina

Maly Semiachik

20. One of the last lava flows		»	N. N. Shavrova

Alaid

21. Taketomi	1934	»	Laboratory of the Geological Survey of Japan

Karpinsky caldera

22. Last lava flow		»	I. I. Tovarova

Chikurachki

23. Lava flow	1854-1859	»	I. I. Tovarova

Avachinsky volcano

24. Lava flow,	middle of the 19th century.	»	N. F. Levenfish
25. Lava flow,	1909	»	M. M. Stukalova
26. Lava flow,	1926	»	N. F. Levenfish

Karymsky

27. Lava flow	1935	Analist	V. M. Nekrasova

Sheveluch

28. Suelich	1948	»	N. N. Shavrova

Bezymianny

29. Dome lava	1956	»	M. P. Baranova
30. New dome	1956	»	V. P. Enman

Kizimen

31. Dome lava		»	A. N. Razzhivina

Krenitzin peak

32. Ashes of the eruption	1952	»	I. I. Tovarova

Severgin

33. Bomb	1933 (?)	»	N. N. Postnikova

Zavaritzky caldera

34. Dome lava, initial portion,	1957	»	I. I. Tovarova
35. Dome lava, middle portion,	1957	»	I. I. Tovarova
36. Dome lava, end portion	1957	»	I. I. Tovarova

Koriaksky

37. Ash	1957	»	V. P. Enman

Ksudach

38. Lava from the wall of the volcano		»	V. E. Kuteinikov
39. Pumice	1907	»	V. E. Kuteinikov

Ebeko

40. Bomb	1935	»	I. I. Tovarova

Sarycheva peak

41. Bomb	1946	»	N. S. Klassova

Dzendursky

42. Last lava flow		»	N. N. Postnikova

clouds of Pelée type. The eruptions of Bezymianny were also followed by sand flows of Katmai-Bezymianny type. On Krenitzin peak and Severgin volcano as well as in Zavaritzky caldera eruptions had a form of vertical explosions accompanied by extrusions.

During the last few decades the most widely developed form of activity has been explosions of Vulcanian type. On some volcanoes like Ksudach, Iliinsky, Ebeko, Sarychev peak and sometimes Avachinsky and Karymsky it has been very strong, while for volcanoes like Kizimen, Maly Semiachik, Zhupanovsky, Koriatzky, Mutnovsky, Gorely Khrebet, Zheltovsky, Chikurachki, Karpinsky caldera, Nemo Peak, Raikoke, Berg, Kudriavy and Atsonopuri — it has been relatively weak.

The dependence of eruption types upon lava composition and certain general laws are distinctly seen on a petrochemical diagram compiled by A. N. Zavaritzky method.

As shown by the diagram, and especially by its right half, lavas of Kliuchevskoi volcano erupted in 1932 (1 and 2), of Plosky Tolbachik erupted in 1941 (19) are similar by composition and the most basic. They occupy the lowest position in the basaltic field of the diagram. Subsequent eruptions of these volcanoes produced relatively more acid differentiates of basalt. During the interval between the eruptions and in the process of ascent, magma was differentiated and during eruptions of different periods or even during different stages of the same eruption there have been lava effusions of several different compositions (3-17 for Kliuchevskoi volcano and 21 for Plosky Tolbachik). In passing from the lower basaltic field with a predominant effusive form of activity to the middle andesitic field there is a change in the character of volcanic activity.

While in the mentioned basaltic field the eruptions have been mostly of a Strombolian or Vulcanian type, and on Plosky Tolbachik — close to a Hawaian type, eruptions recorded on the andesitic field were purely Vulcanian with effusions of small lava flows or tongues or even without lava effusions.

With a higher content of silica and alkalies in the lavas, eruptions of such lavas form either only extrusions or extrusions with glowing clouds (Pelean type) and sand flows (Katmai type). On diagrams this is expressed by the placing of composition vectors in the upper right part of the andesitic field.

In the very top of the diagram a dacitic lava of Karymsk (27) volcano and pumices of Ksudach (39) are recorded. The activity of

the latter is characterized by strong explosions, and the first — by explosions of a Vulcanian type with rare effusions of a dacitic i.e. sufficiently acid lava.

While the form of volcanic activity of Ksudachi fits into the general scheme of dependence between lava composition and the type of eruption for the listed recently erupting volcanoes of Kamchatka and Kuriles Islands, the effusions of lavas from Karymsk volcano violates this regularity, which it is difficult to explain for the time being.

Let us point out one more violation of this regularity. The vector of lava composition from Dzenzursk volcano (42) is placed on the andesitic, i.e. explosive-extrusive field. However, the form of activity of this volcano is effusive. Its last lava flow was 10 km long.

It would seem that by its nature this lava should occupy a place in a more basic — effusive field of the diagram. And true enough, the lava vector of Dzenzursk volcano is in the andesitic field « illegally ». Such a position is explained by the presence in the lava of minute quartz xenoliths. This way, in its ascent a basic lava had entrapped foreign acid material. It is only natural that a chemical analysis has indicated a higher content of silica and the composition vector of this lava got into a more acid field not pertaining to the lava.