Relationship Between Chemical Composition of Volcanic Rocks and Depth of the Seismofocal Layer As Shown by the Kliuchevskaya Volcanic Grup (Kamchatka) and the Kurile-Kamchatka Island Arc *

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The Kliuchevskaya group of volcanoes is located in the central Kamchatka Depression, and consists of three active volcanoes (Kliuchevskoy, Ploskiy Tolbachick, and Bezimianniy) and eight extinct volcanoes (Ostriy Tolbachick, Blizhniy Ploskiy, Dalniy Ploskiy, Kamen, Bolshaya Udina, Malaya Udina, Bolshaya Zimina, and Malaya Zimina) and of a moltitude of small mainly due to a single outbreak eruptive centres. This volcanic area is shaped as an ellipsis of dimensions of about 90 × 75 km, whose major axis lies at an azimuth of 10°-15°.

The volcanoes of the Kliuchevskaya group have been subdivided by the present authors into two series: the western series consisting of Ploskiy Tolbachick, Ostriy Tolbachick, Blizhniy Ploskiy and Dalniy Ploskiy volcanoes, and the eastern series including the other volcanoes, *i.e.* Kliuchevskoy, Kamen, Bezimianniy, Bolshaya and Malaya Zimina and Bolshaya and Malaya Udina. The strike of the two series is the same as that of the volcanic group as a whole (Fig. 1). Comparison of the two series shows a spatial variation of the main volcanic features as shown in Table 1.

The volume of volcanites as shown by recent cuttings is almost 2.5 times greater in the western than in the eastern series. Moreover, moving towards the West, the height of the volcanoes and the proportion of lava flows increase, the range of composition of vol-

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canites becomes more narrow due to the absence of andesite-dacites, and the average SiO_2 contents decrease. Also, comparing monotypic (as to SiO_2 contents) coeval lavas it is evident that basic volcanites are more alkalic in the western than in the eastern series (Table 2). On the average, all these volcanic features vary from South-West

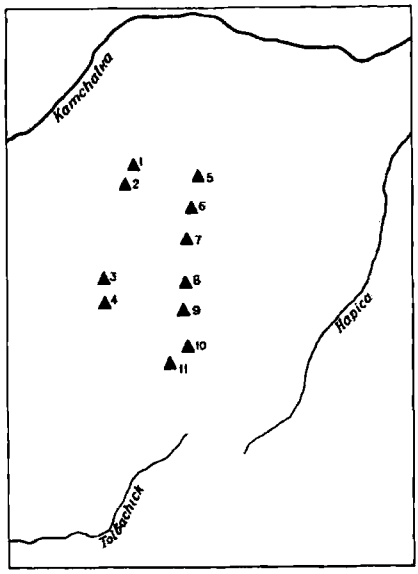

FIG. 1 - Schematic map of the volcanoes of the Kliuchevskaya volcanic group.
Western Series: 1. Blizhniy Ploskiy; 2. Dalniy Ploskiy; 3. Ostriy Tolbachick; 4. Ploskiy Tolbachick.
Eastern Series: 5. Kliuchevskoy; 6. Kamen; 7. Bezimianniy; 8. Malaya Zimina; 9. Bolshaya Zimina; 10. Malaya Udina; 11. Bolshaya Udina.

to North-East within each series such as they do from E to W for both the series.

The variation pattern of such volcanic features for the Kliuchevskaya group is very similar to that observed earlier for many volcanoes of the Kurile island arc (MARHININ and STRATULA, 1969). This can be explained considering the effect of two main factors, namely the duration of volcanic activity and the composition of the original magma.

The effect of the duration of volcanic activity on the main volcanic parameters can clearly be seen in the eastern series. There, the normal sequence of evolution with increasing explosive activity

TABLE 1 - Some Geomorphological and Petrochemical Features of the Volcanoes of the Kliuchevskaya Group, Kamchatka.

Series and Volcanoes		*Height m*	*Volume km³*	*Proportion of lava flows %*	*Explosion index*	*Rock types*	*Average SiO_2 %*
Eastern Series		3,700*	930	30-50	50-70	Basalt-dacite	53-55
Udina Volcanoes	Bolshaya Ud. Malaya Ud.	2,923*	50	30	70	Basalt-andesite-dacite	57-58
Zimina Volcanoes	Bolshaya Zim. Malaya Zim.	3,081*	50	30	70	Basalt-dacite	57-58
Bezimianniy Volcano		3,085**	30	30-50	50-70	Andesite-basalt-dacite	58-60
Kamen Volcano		4,617	400	30-50	50-70	Basalt-andesite-basalt	50-54
Kliuchevskoy Volcano		4,850	400	30-50	50-70	Basalt-andesite-basalt	50-53
Western Series		3,850*	2,170	80	20	Basalt-andesite	52-54
Tolbachick Volcanoes	Ploskiy T. Ostriy T.	3,682*	700	50	50	Andesite-basalt	53-55
Ploskiy Volcanoes	Blizhniy P. Dalniy P.	4,030*	1,470	90	10	Basalt-andesite	50-53

* Average height.
** Before the 1956 eruption.

TABLE 2 - Alkali Contents in Coeval Volcanites of the Kliuchevskaya Area, Kamchatka.

Age	*Series and Volcanoes*	*Rock types as SiO_2 %*	*SiO_2 %*	*K_2O %*	*Na_2O %*
Lower-middle Pleistocene	Western Series	50-53	51.7	1.7	3.8
		53-55	54.2	2.0	4.0
		55-57	56.7	1.4	4.4
	Eastern Series	50-53	52.3	1.6	3.5
		55-57	65.0	1.1	3.3
		57-60	58.5	2.2	4.0
Upper Pleistocene	Western Series	50-53	51.8	1.2	3.1
		57-60	59.7	1.6	4.1
	Eastern Series	50-53	50.3	0.9	3.2
		53-55	54.2	1.1	3.6
		55-57	55.4	1.9	3.2
Holocene	Western Series	50-53	50.6	1.4	3.0
		53-55	54.6	1.2	3.7
		55-57	56.3	2.4	4.1
		57-60	57.3	2.1	3.9
	Eastern Series	50-53	52.3	1.1	3.0
		53-55	54.3	1.7	3.3
		55-57	56.1	1.2	3.6
		57-60	58.4	1.6	3.9
Lower-middle Pleistocene	Tolbachick Volcanoes	53-55	54.5	2.1	4.0
	Udina Volcanoes	50-53	51.9	1.7	3.4
		55-57	56.0	1.1	3.3
		57-60	58.5	2.2	4.0
		50-53	52.1	1.3	3.1
Upper Pleistocene	Tolbachick Volcanoes	50-53	51.5	0.9	3.0
	Udina Volcanoes	53-55	54.9	1.2	3.8
		50-53	50.8	1.5	3.0
Holocene	Tolbachick Volcanoes	53-55	54.2	1.6	3.2
	Udina Volcanoes	55-57	56.2	1.3	3.6
		57-60	58.3	1.4	3.8

and the homodromic order of differentiation (ERMAKOV, 1969) are characteristic of the central volcanoes and of the group as a whole. In the long-living volcanoes, the range of acid rock types is wide, the explosion index is high and, hence, the proportion of lava flows in the structures is low. Young volcanic structures are numerous.

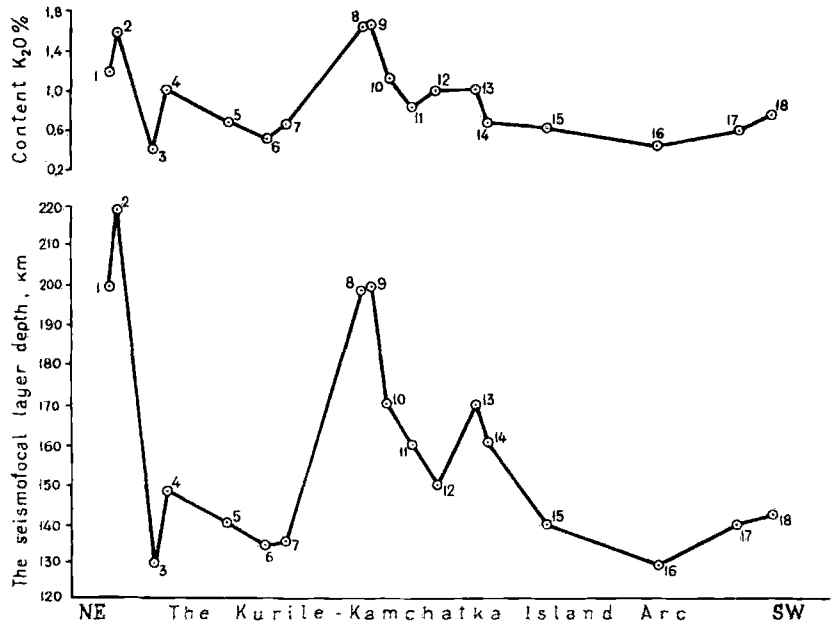

FIG. 2 - Depth variation of intermediate earthquakes and of K_2O contents of holocenic and historic basalts and andesite-basalts along the Kurile-Kamchatka volcanic arc.

1. Kliuchevskoy; 2. Ploskiy Tolbachick; 3. Kronotskiy; 4. Krasheninnikov; 5. Avachinskiy; 6. Mutnovskiy; 7. Hodutka; 8. Ebeko; 9. Bogdanovich; 10. Karpinskiy; 11. Nemo Peak; 12. Sinarka; 13. Raikoke; 14. Sarycheva Peak; 15. Zavaritskogo Caldera; 16. Medvezhia Caldera; 17. Atsonupuri; 18. Tiatia.

Since in each series volcanism rejuvenates northeastwards, the variation of volcanic parameters occurs in the same direction.

The effect of the original magma compostion on some of the volcanic parameters can be seen by comparing volcanoes of the two different series. Thus, the almost coeval Tolbachick and Udina volcanoes differ from each other in all the observed parameters and mostly for the average silica contents in the rocks and for their explosion index (Table 1). This leads to the conclusion that the

differences in composition of the rocks of the volcanoes of the Kliuchevskaya group result in part from a decrease in silica and an increase in alkalies in the mantle magma along the East-West

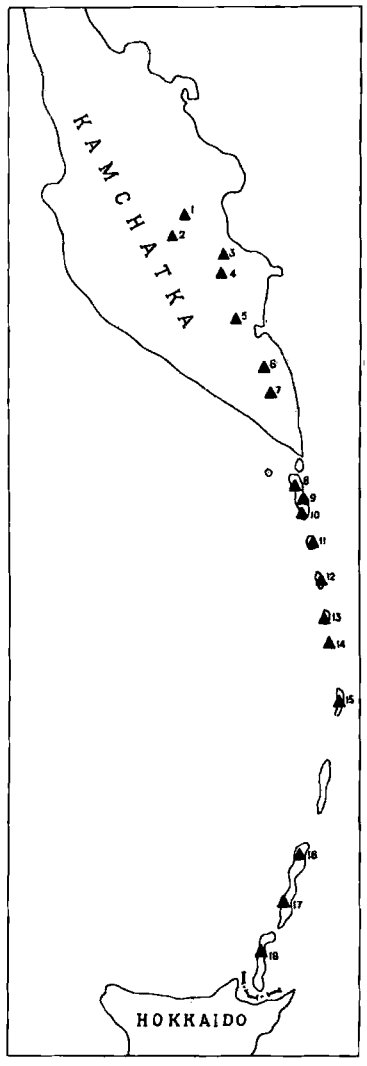

FIG. 3 - Sketch map of the Kurile-Kamchatka volcanic arc. Triangles 1 to 18 represent the volcanoes quoted in Fig. 2.

direction, and in part from an increase in silica with time probably because of magma differentiation processes in intermediate chambers.

The depth of the seismofocal layer between the eastern and the western zone differs by about 20 km.

Lateral variation of rock chemical composition in island arcs is explained by three different hypotheses (KUNO, 1966).

The first hypothesis, supported by the present authors, suggests that magma generates within the seismo-focal layer and that its composition is a function of the focal depth (H) of intermediate earthquakes: the increase of H from the front to the rear of island arcs is accompanied by an increase in basicity and alkalinity in the mantle melt.

The second hypothesis suggests that magma generates at a depth of 100 to 150 km and has an olivine tholeiitic composition. The variation in the igneous rock chemical composition is explained by the island arc front-to-rear increase of depth at which primary fractionation of the original melt takes place. The fact that it is not explained why there is a similar variation in the depth of intermediate magma chambers makes this hypothesis rather ungrounded.

The third hypothesis suggests that the upper mantle temperature gradient is smaller under the oceans than under the continents. Hence, the surface along which initial melting is possible is parallel to the seismofocal layer and is inclined from the outer to the inner side of the arcs. This hypothesis cannot be accepted in the case of the Kamchatka-Kurile Quaternary volcanoes because the chemical composition of the rocks of these volcanoes varies both along and across the arc. In fact, SiO_2 and K_2O contents in such rocks change not only from E to W across the ridge but also from S to N along the structure.

It is quite interesting to note that the variation in the chemistry of the volcanic rocks from holocenic and historic eruptions — particularly, variation in potash contents — does not occur gradually and linearly along the Kurile-Kamchatka arc, but it repeats the « zigzags » of the seismofocal layer depth (Fig. 2, 3).

In conclusion, one can say that there is a definite relationship between seismofocal zone processes and volcanic activity regarding not only the structural and the dynamic character of volcanism, but also the chemical composition of the volcanic products.

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