Chapter 23

Zhupanovsky Volcano

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Synonym. Zhupanovskaya sopka, Vakhul'skaya sopka.

Location. Coordinates of the highest point: 53°35'N, 159°17'E.

Geographic position. The volcano is located within the southeastern volcanic belt of Kamchatka. It is associated structurally with a northwestern fault aligned with a chain of Quaternary volcanoes of Dzenzursky-Zhupanovsky volcanic ridge.

Geology of the basement. Dislocated and metamorphosed, volcano-sedimentary strata of the Cretaceous-Paleogene basement outcrop in the east and southeast 20-30 km from the volcano where they are 600-700 m above sea level. The Cretaceous-Paleogene basement underlies Miocene volcanic units belonging to the first stage of the volcanic formations. The volcanics vary in terms of their facies and composition, showing intrusions of gabbros and diorites. The strata are dislocated due to dome-building deformations.

The second stage corresponded to Pliocene-Middle Pleistocene formation of volcanic and volcano-sedimentary deposits. They are also deformed due to the continuous dome-building and cauldron sinking. There is such a Pliocene-Early Pleistocene caldera immediately below the volcano. The reconstructed outlines suggest it was 25 by 30 km in size. The height of the cauldron scarp east of the volcano is 350 m.

Morphology and structure. Zhupanovsky volcano is the eastern part of the Dzenzur-Zhupanovsky volcanic range composed of four merged cones of stratovolcanoes of similar ages and structures. The absolute height of the lowest, western, cone is 2505.6 m, that of the highest, eastern, is 2958.0 m. The relative height of the volcano is 2300-2400 m. The western part of Dzenzur-Zhupanovsky ridge is 6 km long and up to 2300 m high, represented by ruins of Dzenzursky volcano; the middle part are units of multiple-vent volcanism with relatively big volcanoes of Yurievsky, Tetyaev and Sirenevy, and a large number of smaller apparatuses in the form of extrusions and lava cones with long lava flows. The overall length of the volcanic range is 20 km, that of the middle part is 7 km, and that of the chain of Zhupanovsky cones 6 km.

Zhupanovsky has relatively well preserved primary forms and shows only shallow barrancos pronounced on northern slopes. The cones of the constituent stratovolcanoes are morphologically distinguishable only at the summit of the massif while below 2300 m they merge in a single structure. The summits of the cones have craters from 0.3 to 1 km in diameter. The crater of the fourth from the east cone is an oval depression 0.35X0.55 km in size and extended from SE to NW. It **is** — 150 m deep. The third cone has a round summit crater about 300 m in diameter and is up to 100 m deep, with steep walls. In 1966, three fumaroles were observed at the bottom of the crater and in its eastern wall but by 1970 only one remained. On the southwestern slope of the cone 200 m from the edge of the crater there is a blast crater 80 m in diameter and 40 m deep. Two fumarole fields are situated at a height of 2650 m (30 by 20 m) and 2750 m (a steep wall 50-60 m high and 40-50 m wide) on the northwestern slope of the third cone. The crater of the second cone is preserved only in a crest facing north. There are two fumarolic craters and one fumarole field at its western tip which release the bulk of the gases and heat of the volcano. The first, eastern cone does not have a pronounced crater, with only fragments of it preserved. Thus, the third cone, as the best preserved and with the freshest primary forms, is the youngest: it has gone through all the historic eruptions. However, in terms of heat losses, the first place belongs to the second cone which has the strongest fumarolic activity.

Lava flows of the volcano are morphologically distinct on the southern slope since the northern one is buried under pyroclastics. There are numerous tuya-type domes on the southern slope. Pyroclastic flows are associated with the activity of the volcano their deposits at the southern and eastern foot of the volcano are developed up to 20 km from the summit of the volcano. The caldera is morphologically pronounced only in the eastern sector of the piedmont as an arcuate scarp 12 km long and up to 350 m high.

Zhupanovsky is a centre of intense modern glaciation. The biggest glaciers descend from summit firn fields along the northern slopes of the massif (Figs **139—142).**

Age and evolution. Rocks composing the caldera scarp suggest a Pliocene-Early Pleistocene age of the volcano's caldera. Formation of the caldera is associated with the eruption of ignimbrite pyroclastics. Consequently, already at the second stage of the evolution of the Nalachevo volcanic centre there was an independent volcano, or a group of volcanoes, at the base of Zhupanovsky that could be regarded as an initial phase of its activity. There are no data on the Middle Pleistocene behaviour of the volcano though it is known that at least 40-50 thousand years ago, in the Upper Pleistocene, there was a major centre of Upper Pleistocene glaciation. By the start of the Holocene, there had been three big cones of a stratovolcano (I, II, IV, Figs **140,** 143). Their thick long lava flows spread southward as far as Nalachevaya river and northward to Zhupanovskaya river. Late in the Upper Pleistocene, there were also lava domes on the southern slope of the volcano. Lavas erupted under ice producing a specific, tuya-type morphology.

The third cone formed during the Holocene in effusive-explosive eruptions. Traces of explosions are registered by scores of ash horizons in the soil-pyroclastic sheets at the foot of the volcano. Early in the Holocene, .the activity of the volcano was characterized by frequent alternation of moderate and weak eruptions that deposited members of poorly stratified coarse ashes (5-7 thousand years ago). The mode of explosive activity changed in the later half of the Holocene: then, single strong eruptions were separated by long periods of rest. A strong eruption took place about 2 thousand years ago: its tephra lies immediately under 1850-1900-year old ashes of Khodutka volcano. The later half of the Holocene is marked also by eruptions of pyroclastic flows; one of those has been dated from the enclosed coals as 2170 ±5 (ИВ-546) years old. The last big eruption must have occurred about 800-900 years ago judging by its tephra relation with the dated ashes of Karymsky volcano (about 400-500 years ago) and Opala volcano (1400-1500 years ago). The then formed lava flows on the southern slope were up to 5-6 km long.

In other parts of the structure effusive activity was limited, concentrated only at the summits of the cones. Lava flows rarely exceeded 1-2 km in length. They were erupted largely from bocche close to the summit or rarely from the central-vent craters.

Description of eruptions. Historic eruptions are associated with the third cone. Their dates are 1776, 1882, 1925, 1929, 1940, 1956-1957. They all were relatively small explosions. The overall volume of the rocks erupted by the volcano since the Upper Pleistocene is as large as 350 km^3. Average productivity is $7 \cdot 10^6$ mVyear, or(15-20)$\cdot 10^6$ tons/year, which is 20-25-10^7 cal/sec. Such output of energy gives reasons to regard the volcano as productive (Fig. **144).**

Products of eruptions. Zhupanovsky rocks are represented by basalts, andesite-basalts, andesites and dacites. The most widespread are andesites. They account for 50%, or 68% together with dacites, of the sample of analyzed specimens. Basalts and andesite-basalts make up 16% each. These data agree with the calculated areas of rock types distribution: basalts and andesite-basalts — 34%, andesites and dacites — 66% of the area [Yermakov et al., 1973]. Such distribution of rock types can therefore be assumed as close to their proportions by volume in the volcano. Then, the average and the weighted average silica content in rocks of Zhupanovsky must be 59.66%, which makes the volcano andesitic. Actually, the silica content histogram suggests three groups of rocks: basalts, andesite-basalts and andesites, and dacites separated by profound minima.

In the chemical composition, the bulk of the rocks belong to the calc-alkaline series (Table 23). This is true in the first place of

Table 23

Average Chemical Composition of Rocks of Zhupanovsky Volcano, per cent of Mass

Oxides	Volcanics				Xenoliths				
	1	2	3	4	5	6	7	8	9
SiO_2	50.52	55.60	60.47	68.80	46.60	52.00	50.20	55.11	59.0
TiO_2	1.26	0.92	0.79	0.52	0.95	1.20	1.12	0.95	0.82
Al_2O_3	18.31	16.91	16.38	15.20	22.59	16.12	18.36	17.64	18.20
Fe_2O_3	5.56	2.94	2.51	1.20	7.38	3.42	4.76	8.99	7.60
FeO	4.55	4.62	3.72	1.40	2.64	6.85	5.45		
MnO	0.19	0.18	0.15	0.12	0.14	0.21	0.19	H.o.	H.o.
MgO	4.68	5.05	2.93	0.84	4.36	4.72	4.60	"	"
CaO	9.50	7.76	6.24	3.14	12.17	8.76	9.89	"	"
Na_2O	3.49	4.06	4.07	4.87	2.84	4.22	3.76	"	"
K_2O	0.85	1.32	1.60	2.71	0.18	0.67	0.51	"	"
H_2O	0.15	0.18	0.15	0.14	0.18	0.10	0.13	"	"
H_2O'	0.64	0.53	0.56	0.91	0.17	0.68	0.51	"	"
P_2O_5	0.30	0.29	0.20	0.14	0.10	0.11	0.11	"	"
Total:	100.00	100.36	99.77	99.99	100.30	99.05	99.59		

Note. 1 basalts (6 an.); 2 andesite-basalts (6 an.); 3 andesites (18 an.); 4 dacites (7 an.); 5 gabbro-anorthosite (1 an.); 6 gabbro (1-6 an.); 7 average of 1 part of the 5th, and 2 parts of the 6th; 8 gabbro-diorite (7 an.); 9 diorite (3 an.).

andesite-basalts and andesites. All the properties here point to the persistent features of this series. Basalts though show Fe content, which brings them closer to rocks of the tholeiitic series. There is a similar relation between Fe and Mg in dacites as well, in that they resemble products of differentiation of tholeiitic basalts. Mineralogically, all rocks are rather uniform showing predominance of plagioclases in phenocrysts and synchronous presence of rhombic and monoclinal pyroxenes. Olivines are common in basalts. Andesites and dacites often show ampohiboles, quartz is very rare in singular grains. The overall number of phenocrysts ranges from 5 to 35%, the biggest number is in andesites. Disequilibrium associations of minerals and their highest diversity are also typical of andesites.

Xenoliths and homogenous inclusions are widely spread. Xenoliths are crystalline schists with basic composition, gabbro-anorthosites, gabbros and diorites. Homogenous inclusions at the centre of the nucleus often contain relics of unaltered xenoliths. Note the chemical affinity of basic xenoliths and basalts, and that of gabbro-diorite xenoliths and andesite-basalts, and that of diorite xenoliths and andesites. Along with distinct features of melting of xenoliths, their reaction alteration and assimilation this indicates a possible source of magmas: melting of a crystalline substratum similar to xenoliths.

Fumaroles and sublimates. Location of fumarolic fields and craters on the second and third cones is described above. According to A.P. Gorshkov and Yu.B. Slezin [1972], the temperature of the fumaroles ranges from 94 to 430° C, the issue rates of the gas-steam mixture are from 0.2 to 29.0 m/sec, the discharge is from 0.05 to 15.5 kg/sec, and the overall heat output is $7 \cdot 10^7$ cal/sec, which is equal to a discharge of lavas of approximately $5.5 \cdot 10^6$ tons/year. Rocks surrounding fumaroles are heavily altered, and impregnated with sulfur; native sulfur forms a veneer scores of metres wide around one of the craters on the second cone.

Geophysical characteristic. The thickness of the crust below Zhupanovsky is estimated at 25-30 km. The volcano is located at the intersection of the longitudinal and transverse gradient zones in the gravity field. Seismic screening of the roots of the volcano revealed a region of a 65-85% attenuation of the signal immediately below Moho discontinuity. The size of the discontinuity under Zhupanovsky is about 5X15 m. It is extended WSW-ward of the volcano [Farberov, 1974]. The presence of the aseismic zone that coincides with the identified discontinuity and occupies a bigger area south of the volcano and its focal layer can be distinguished on maps of earthquake epicentres [Gorel'chik, **1974].**

Distribution and prognosis of eruptions. Comparison of the average productivity of the volcano with its present thermal output ($20\text{-}25 \cdot 10^7$ and $7 \cdot 10^7$ cal/sec, respectively) indicates uncompensated losses of heat by fumaroles and probable accumulation of energy in the interiors of the volcano. If the 1956-1957 eruption brought the volcano to a state of equilibrium, its deeper parts might since then have accumulated an energy excess equivalent to $3\text{-}4 \cdot 10^8$ tons or 0.1-0.2 km^3 of volcanics. An eruption of such a magnitude is not exceptional and will be of no serious danger. It shall be remembered however that the estimates are tentative, assuming that in the last eruption the volcano has let out all the excess energy of its entrails. The accumulated energy may exceed the indicated level while the process of accumulation will continue. The future eruption of Zhupanovsky may be of some danger for Petropavlovsk-Kamchatsky and some other settlements only if its magnitude seriously exceeds the etrimates, and it is explosive.