THE CONDITIONS OF FORMATION OF ACID CRETACEOUS-PALEOGENE VOLCANIC ROCKS OF PRIMORIE

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Primorie is part of the Sikhote Alin folded region, which includes a volcanic belt and is bordered on the east by the shoreline of the Sea of Japan and Tatar Strait. The section of the volcanic belt is dominated by the Late Cretaceous-Paleogene calc-alkaline silicic volcanics of the dellenite-liparite series. Tholeiitic and alkali basalts occur in minor amounts. Intrusive bodies are usually genetically connected with volcanic rocks and are the hypabyssal analogues of the latter. The rocks investigated were sampled at the axial and back parts of the Sikhote Alin volcanic belt.
We studied inclusions in minerals from the granosyenite porphyry of the Ust-Mikulinskii Stock and quartz porphyries of various facies including dikes, lava flows, and extrusive bodies.

The Ust-Mikulinskii Stock is interesting in many aspects. In particular, it is made up of fayalite-bearing granosyenite porphyry, which is geochemically different from the coeval intrusions of the granodiorite-adamellite-granite series and can be classed as anorogenic granite. In addition, it is an ore-bearing massif hosting a tin-tungsten deposit.
Porphyritic quartz crystals from the Ust-Mikulinskii rocks bear numerous primary inclusions. Fluid and crystalline (muscovite and potassium feldspar) inclusions are the most common and inclusions of silicate melt were also found. The latter are up to 30 mkm in size. They are distributed along linear zones or randomly within crystals. The melt inclusions contain one or several daughter crystals and a fluid phase in the interstices. The heating of these inclusions at atmospheric pressure resulted in their dehermetization at temperatures of 600-700oC. Heating experiments at a pressure of 3 kbar showed that the inclusions were homogenized at 760-800oC. An opaque mineral was observed to coexist with glass in some of inclusions under such conditions.

The compositions of the rocks and quenched glasses of melt inclusions in quartz are shown in Table 1.

Table 1. Representative compositions of Ust-Mikulinskii rocks and of homogenized melt inclusions in quartz phenocrysts

Component	1	2	3	4	5	6	7
SiO2	69.90	67.10	72.88	76.28	73.80	75.01	76.41
TiO2	0.40	0.40	0.09	0.14	0.11	0.05	0.09
Al2O3	15.10	15.30	15.74	12.09	14.08	8.93	11.11
FeOtot	3.00	4.30	0.75	0.96	0.99	0.75	1.08
MnO	0.08	0.12	0.04	0.04	0.08	0.00	0.06
MgO	0.21	0.29	0.03	0.00	0.08	0.02	1.09
CaO	1.80	1.90	0.58	0.77	1.35	0.36	1.19
Na2O	3.50	3.00	2.14	2.11	2.98	2.54	2.73
K2O	5.10	5.00	5.81	4.16	4.35	2.74	4.66
P2O5	0.12	0.13	0.03	0.06	0.05	0.00	0.02
F	n.a.	n.a.	0.00	0.10	0.18	0.00	0.08
Cl	n.a.	n.a.	0.15	0.16	0.35	0.21	0.34
Sum	99.21	97.54	98.24	96.87	98.40	90.61	98.86

Note. Rocks: 1-sample 2034; 2-sample 2025. Quench glasses: 3-sample 2023 (7700C, 3.1 kbar); 4-sample 2024 (7700C, 3.1 kbar); 5-sample 2026 (7700C, 3.1 kbar); 6-sample 2026 (8000C, 3.1 kbar); 7-sample 2034 (8000C, 3.1 kbar). n.a.-not analysed.

Quartz crystallized from plumasitic granitic melt enriched in chlorine. The melt contained more silica and less Al2O3, FeO, MgO, and CaO as compared with the bulk-rock compositions. Such petrochemical features are characteristic of strongly differentiated liquids which form at final stages of magma evolution in a chamber. Late quartz crystallization is supported by the abundance of crystalline inclusions of late minerals, muscovite and potassium feldspar. After an experiment at 800oC and 3.1 kbar, one inclusion contained glass and a three-phase fluid composed of gas, liquid, and an isotropic crystal. The thermometric investigation of the liquid-gas part of this inclusion allowed us to estimate the pressure of inclusion entrapment as about 5 kbar. An attempt to assess the water and chlorine contents of the melt assuming the homogeneous state of the material at the moment of entrapment yielded unrealistically high values. It is reasonable to suppose, therefore, that this inclusion was initially a heterogeneous melt+fluid mixture. This suggestion is reinforced by the presence of three-phase fluid inclusions in the same quartz grains. These fluid inclusions are characterized by salinities similar to that of fluid from the melt inclusion and show a homogenization temperature of 700oC. These observations allow us to infer that the magma heterogenization occurred approximately at 800oC and 5 kbar. Under such conditions, aqueous fluid may extract considerable amounts of silicate and ore matter and promote formation of mineral deposits.

The conditions of formation of quartz porphyries composing dikes, lava flows, and extrusive bodies are summarized in Table 2. The analyses of melts and rocks indicate that the quartz of these rocks crystallized from melts with low water and chlorine concentrations.

Table 2. Results of thermometric investigation of primary melt inclusions in quartz porphyries

Phenomenon in investigation object	T, oC
Quartz porphyries composing dikes	
Melting of devitrificate in melt inclusions	900 - 1070
Homogenization of devitrificated melt inclusions	1115 - 1175
Quartz porphyries of lava flows, and extrusive bodies	
Melting of daughter minerals	920
Melting of devitrificate in melt inclusions	940 - 1050
Homogenization of melt inclusions of different kinds (interval)	1105 - 1195
Homogenization of devitrificated melt inclusions in inner part of porphyritic feldspar crystal	1100
Homogenization of devitrificated melt inclusions in outer part of the same porphyritic feldspar crystal	1025