Modelling of the magmatic process of the Ploskie Sopky volcano

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Introduction

This report presents the results of the computer mathematic modelling of the magmatic processes based on the petrochemistry and geochemistry of one of the volcanoes of Kamchatka - volcano Ploskie Sopky. The Ploskie Sopky volcano is the biggest volcanic construction of Kamchatka, disposed inside the Central Kamchatka depression. It is one of the volcanoes of the Kluchevskaja Group.

Previous research

Previous investigations on petrochemistry, geochemistry and isotope systematics of the rocks showed heterogeneity of this volcanic series. The volcanic melts were fed by at least two sources: the mantle one during the development of both shield and strata volcano; the crustal one during the development of certain strata-volcano zones, calderas and the superimposed slag zone. The assimilation of granitic melts, derived from metamorphic rocks of the Early Paleozoic continental crust, by differentiates of the primary basaltic magma occurred within the crustal magmatic chamber [1].

Method

The COMAGMAT batch software which will used in this work was elaborated by the group of scientists from the Vernadsky Institute of Geochemistry and Moscow State University. This model differ from previously applied ones, when considering a number of key aspects: 1. The model is based on run-gained distribution coefficients crystal-melt for rocks of different compositions under various physical-chemical conditions. 2 Using the COMAGMAT software, one can execute calculations for multi-component system, that includes olivine, two pyroxenes, plagioclase of variable composition, magnetite and large number of impurities. 3. The software accounts for crystallization dynamics of melts [2].

Results

Taking into account all foregoing materials, we have modeled the formation of rocks of shield volcano and strata volcano. We have considered the origin of existing cinder cones later. The seven different clusters of the basaltic magma was logically considered as the originated from the primary magma. In the process of the modelling was suggested dry conditions, lithostatic pressure as 1Kbar, and NNO buffer.

The calculated model reproduces the observed mineral paragenesis well enough (Fig.1). The sequence of crystallization depends on the rock composition. Olivine-plagioclase association of minerals, where pyroxene is absent one, exists only in the subalkaline basalts. We see that crystallization field of augite decreases for the subalkaline basalts having the temperature 1125°C. Association of plagioclase-olivine-magnetite minerals crystallizes earlier.

SiO_2, CaO, MgO, being the major components, correspond well to their real concentrations. K_2O, Na_2O, P_2O_5, FeO are reproduced worse, but qualitatively similar. The real concentrations of the trace elements are found to be in good correlation with major elements. These dependencies are traced to the model too. Ba, Rb, Sr, Ni, Co correspond to their real concentrations. Sc, Cr, V are not reproduced by this model. Probably, it is connected with not so good iron reproduction.

The MgO-Al_2O_3 plot (Fig.2) displays the calculated crystallization paths which lie below the real rock compositions. Thus the Ploskie Sopky volcanic rocks lie over saturation line and alumina content higher than calculated one. The plagioclase is the host-mineral for alumina. It is obvious that the high alumina concentrations show that they are enriched by the cumulus plagioclase. The petrography of rocks confirms this supposition. Most of rocks contains a lot of plagioclase phenocrysts. The increase of water pressure in melt increases the aluminium solubility and delays the early plagioclase crystallization even in the high-aluminium melts.

The second stage of modelling included the attempt to estimate the influence of water pressure and general lithostatic pressure on the melts crystallization. High-magnesian and low-aluminium basalt was used as the primary magma. The paths were calculated under different

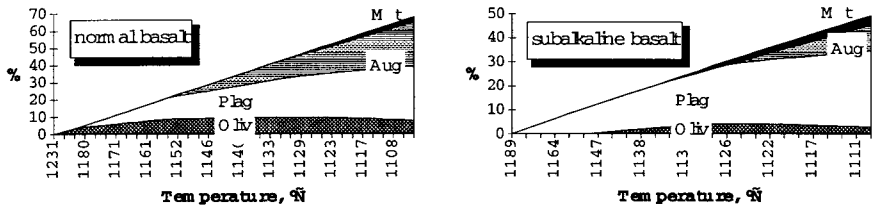

Fig.1. Sequence of the mineral crystallization from basalt melts.

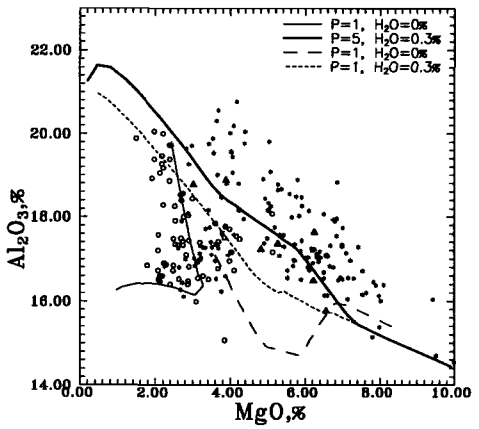

Fig.2. The diagram $MgO-Al_2O_3$ for the rocks of Ploskie Sopky volcano.

Crosses - the rocks of stratavolcano
Triangles - the rocks of shield volcano
Circles - the rocks of the superimposed zone.

conditions: 1. P=1Kbar, H_2O=0.3%; 2. P=5 Kbar, H_2O=0.3% (Fig.2). Variations of general pressure change the path insufficiently, whilst even minor water input increases the aluminium solubility in the melt, resulted in absence of solid plagioclase and liquid enriches herself with alumina. The shield and strata-volcano rocks is well described by the model under 0.3% water content in the melt.

According to aforesaid data, the rocks of superimposed zone originated under subsurface "dry" conditions with low lithostatic pressure. The third stage of modelling included the crystallization path for these rocks by P=1Kbar, H_2O=0%. High-aluminium basaltic andesite was used as primary magma. The crystallization path correlates perfectly with real rock compositions, which are showed by circles on Fig. 2.

Conclusion

1. The NNO buffer is the closest to the real oxygen fugacity during the Ploskie Sopky volcanic rocks. 2. The model used reproduces real mineral parageneses well enough. 3. Real rocks are over saturated with alumina comparatively to calculated compositions of liquids. This is likely related to the presence of surplus cumulus plagioclase. 4. Maximum temperatures for crystallization to start are characteristic for both high-magnesium and high-alumina varieties. 5. The model reproduces real major components and minor elements chemistry of real rocks well enough. 6. Change in general lithostatic pressure has minor influence on crystallization paths. 7. The elevated water pressure affects heavily the alumina solubility in the melt. This is likely to cause generation of magmas, which are over saturated in alumina. 8. The process of fractional crystallization controls the entire observed diversity of rock compositions. The experiment provided allows to suggest, that the shield volcano and strata volcano rocks were crystallized under elevated water pressure, averaging 0.03%; but rocks of superimposed cinder zone and calderas were crystallized under subsurface water-absent conditions.

References

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