Magmatic evolution of Avachinsky volcano (Kamchatka) during the Holocene revealed from composition of tephra, their matrix glasses and melt inclusions in minerals

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Avachinsky volcano is one of the most active volcanoes in the frontal volcanic zone of Kamchatka. Previous studies have recognized two distinct phases in the Holocene eruptive history of Avachinsky: 1) early phase of rare and voluminous andesitic eruptions (7.3-3.5 ^{14}C ka BP) and 2) later phase of frequent eruptions of basaltic andesites associated with the construction of the Young Cone (3.5 ^{14}C ka BP to the present) [1]. The change in the eruptive style was marked by the initial eruption of the Young Cone ~3.5 ^{14}C ka BP, which produced ≥3.6 km^3 of basaltic andesite tephra [2, 3]. In order to assess the chemical changes of Avachinsky magma, we have studied a representative collection of 61 samples representing 40 main Holocene eruptions from the ^{14}C-dated composite section covering the entire history of the volcano. Here we report the results of this study, obtained by chemical analysis of bulk tephra samples, microprobe investigation of matrix glasses (~600 an.) and more than 500 melt inclusions in minerals.

Both matrix glasses and melt inclusions in minerals have systematically more evolved compositions compared to their host rocks and span a large range of compositions within the fields of the low- and middle-K island-arc series. Low- and marginally middle-K rhyolitic compositions of glasses and inclusions predominate during the early Holocene. Relatively high-K melt inclusions were found in minerals from six tephra samples. The compositions of matrix glasses and inclusions change to predominantly middle-K dacitic and andesitic in the late Holocene (fig. 1). Primitive basaltic melt inclusions occur in olivine in the 600 ^{14}C yrs old tephra. Chemically contrasting glass shards and melt inclusions were found in the samples of different ages and often found in the same tephra sample. The data on matrix glasses and melt inclusions thus testify an important role of magma mixing in the origin of Avachinsky rocks that occurred along with fractional crystallization. Compositions of bulk tephra span a much narrower range of compositions compared to matrix glasses and melt inclusions and represent magmas formed by effective mixing of compositionally contrasting melts, crystallization and accumulation of phenocrysts.

The most pronounced chemical changes in the composition of bulk rocks from andesites to basaltic andesites correlate with the beginning of the later phase of activity at 3.5 ^{14}C ka BP. The data on melt inclusions and matrix glasses indicate, however, arrival of relatively K-rich mafic melts in the magma feeding system starting already at ca. 4.1 ^{14}C ka BP (fig. 1). The catastrophic eruption AV 3500 and the volcano changes at 3.5 ^{14}C ka BP were thus preceded by frequent injections of mafic K-rich magmas in the magma chamber beneath Avachinsky volcano during the previous 500-600 ^{14}C years.

On the basis of our new data, we propose that the Holocene evolution of Avachinsky volcano was driven by fractional crystallization associated with periodic injections of mafic middle-K magmas into initially low-K silicic magma reservoir, perhaps, left over after deceasing of Kozelsky volcano, whose early Holocene products are compositionally quite similar with Avacha's early phase. The injections of mafic magmas and subsequent volcanic eruptions led to exhausting of the low-K rhyolite magmas and resulted in the systematic change of magma compositions to more mafic and K-rich over time. The most pronounced changes in the magma composition had occurred during period from 4.1 to 3.5 ^{14}C ka BP.

References:

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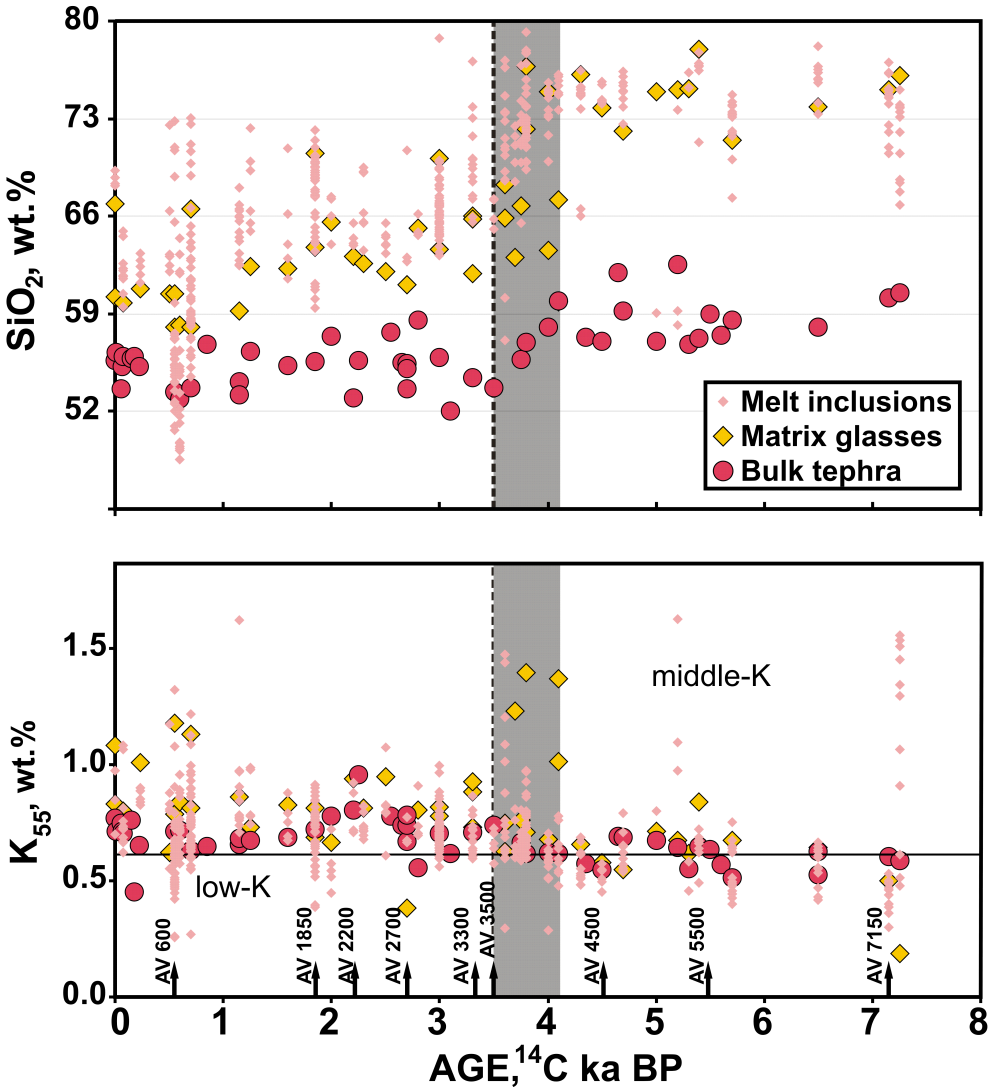

Figure 1. Variations of SiO_2 and K_{55} contents in matrix glasses, melt inclusions and bulk tephras of Avachinsky volcano during the last 8 ^{14}C ka. K_{55} is K_2O content normalized to 55 wt. % of SiO_2. Dashed line - the border dividing andesitic and basaltic andesites phases of volcanic activity; grey field – time period of frequent injections of mafic K-rich magmas in the magma chamber; black arrows – the largest Holocene eruptions of Avachinsky volcano.