DEGASSING PROCESSES WITHIN THE KARYMSKY VOLCANO-AKADEMY NAUK CALDERA SYSTEM, KAMCHATKA VOLCANIC BELT, RUSSIA

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Introduction

The Karymsky Volcano-Akademy Nauk Caldera System is located on the Kamchatka Peninsula in the Kamchatka Volcanic Belt, approximately 100 km north of Petropavlovsk. Karymsky Volcano has had > 25 eruptions (VEI 2-3) since 1900. The most recent cycle of activity began in 1996 when mafic ash erupted from a new vent within Karymsky Lake. Concurrently, Karymsky volcano erupted andesite ash and later produced an andesite lava flow. In September1999 small, discrete ash blasts were occurring at Karymsky volcano every 10-20 minutes. Typically, a volcanic plume was only visible for short periods (0.5 to several minutes) following each blast. Incandescent bombs, visible at night, indicate that the eruptions were magmatic. Hot springs and fumaroles characterize the hydrothermal features in the caldera and degassing occurs along a N-trending fracture which extends northward from Karymsky Lake to Karymsky Volcano.

COSPEC Measurements

A stationary COSPEC was installed on the southern flank of the volcano approximately 0.6 km from the vent in order to continuously measure SO_2 emissions before, during and after ash blasts. The data were collected by vertically scanning through the volcanic plume at a rate of approximately 5sec/scan. Measurements taken on September 11 and 12, 1999 show the most complete degassing records. During the 3 to 4 hour sessions the level of SO_2 flux varies from <2 t/day to 50 t/day. The highest flux levels and the majority of SO_2 release occurs between blasts when no ash plume is visible.

Two distinct degassing patterns were observed: (1) short events with large gas pulses which slowly decay to background and (2) long degassing events characterized by waxing and waning, yet overall high SO_2 flux levels (up to 600 g/sec) (Figure 1). An audible 'chugging' was sometimes heard during the initial onset of the long degassing events. We define the initiation of an 'event' by the visible and audible explosive ash blast. The termination of the event is defined by decay of the measured SO_2 flux to background. The background (passive) degassing level is clearly distinguishable on the COSPEC record: the SO_2 flux gradually decreases (80 to <50 g/sec) and remains at that level until the initiation of the next event. The duration of the Type-1 events is on the order of 3-4 minutes. The Type-2 events, in contrast, can last up to 15 minutes. During these long events the SO_2 flux waxes and wanes in 4-5 minute cycles.

The total SO_2 output per event is calculated for Type-1 and Type-2 events. In order to distinguish between passive degassing and degassing associated with an eruptive blast, we calculate the total amount of SO_2 released during the blast and during passive degassing for each event. The 'threshold' for passive degassing is when the SO_2 flux decays to < 80 g/sec, which is clearly distinguishable from the peaks during the eruptive periods. As shown in Figure 2, the relative amount of SO_2 degassed per event is inversely correlated to the amount of SO_2 degassed passively prior to the event. Events with low SO_2 output are generally preceded by episodes of significant passive degassing. Type-2 events with large SO_2 output, are generally preceded by events with a relatively low amount of SO_2 degassing passively.

Noble gases

Gases discharge from bubbling hot springs on the caldera floor and on the shore of Karymsky Lake. Gas samples collected from thermal springs and low-T fumaroles have

$^{3}He/^{4}He$ ratios of 4.9–0.1 to 6.3–0.1 Ra (Ra is the ratio of air). The highest ratios occur at the south end of Karymsky Lake, the lowest at the northern edge of the lake. Other noble gas isotopes (Kr and Xe) can be modeled by mixing of volatiles from MORB-type source and air-saturated water at shallow levels (Figure 3). Noble gas data from Mutnovsky Volcano (Kamchatka) are included for comparison.

Melt Inclusions

Melt inclusions in olivines from the 1996 eruption of Karymsky Lake have a basaltic-andesite composition. Initial results of FTIR analyses show water contents of 3.9 wt.% and CO_2 below detection (<50 ppm) indicating minimum volatile saturation pressures of ~1.6kb.

Discussion

Recent activity within the Akademy-Nauk Caldera defines degassing at several levels. The noble gas isotope ratios from fumaroles and springs are consistent with recent influx of mantle-derived magmatic fluids. The1996 Karymsky lake eruption is evidence of a basaltic andesite magma at depths of ~5 km based on volatile saturation pressures. The low SO_2 output of andesite magma at Karymsky volcano indicates shallow level degassing.

The time-series measurements of SO_2 flux by the COPSEC method provide insights into the mechanism of eruptions at Karymsky. The comparatively low output of SO_2 per event suggest that the degassing of the magma occurs at shallow levels. Exsolution of volatiles from the magma does not cease between eruptions but significantly continues at low levels for long periods of time. The low-level passive degassing accounts for approximately 10-15% of the total SO_2 released. The patterns of degassing are most easily explained by a vent that is opened during ash blasts and the re-seals itself during a period after the blast. Individual blasts may be due to secondary boiling. The COSPEC record of SO_2 release shows that the blasts have a sudden large onset and continued low level degassing. The cycles of the Type-2 events indicate that the effectiveness of the re-sealing varies from one event to the next. It is plausible that after an explosive eruption, the conduit becomes sealed and the exsolving volatiles accumulate at depth resulting in over-pressurization of the magma. Once the pressure exceeds the tensile strength of the seal, a new eruption is initiated.

During the eruption the accumulated gases are released and account for part of the SO_2 flux. Due to the sudden pressure release, additional volatiles exsolve from the magma body as indicated by the increase in SO_2 flux after the volatiles associated with the initial blast are released. As indicated in Figure 2, Type-1 events are preceded by large amounts of passive SO_2 degassing. In contrast, Type-2 events are preceded by very little passive degassing. This suggests that the effectiveness of vent sealing and gas accumulation is variable. When the vent is poorly sealed (i.e. leaky) SO_2 passively leaks and small Type-1 ash eruptions occur. In contrast, when the vent seals more effectively, there is little or no SO_2 output. This condition culminates in the larger Type-2 ash eruptions.

Conclusions

The results show that by combining time-series COSPEC measurements of an erupting volcano with melt inclusion studies and gas sampling, the degassing processes of active caldera systems can be evaluated. The Akademy-Nauk Caldera system shows evidence of mantle volatile input and recharge of the hydrothermal system by mantle derived fluids. The current activity at Karymsky is characterized by eruptions which are the direct result of gas over-pressure accumulation in the magma conduit. Our COSPEC data suggest that variations in the effectiveness of a sealing mechanism in the magma conduit result in two different eruptive events. Type-1 events are preceded by comparatively less gas accumulation than the larger Type-2 events. Type-2 events are characterized by longer durations, higher SO_2 output and less passive degassing prior to the event. The effectiveness of the sealing mechanism may be related to the depth at which the seal occurs in the magma column. Type-1 eruptions may be the result of shallower sealing than the Type-2 eruptions. Johnson et al. (1998) and Ozerov et al. (1999) have distinguished between three types of explosive events at Karymsky based on seismic and acoustic data: single impulse, hybrid, and chugging events. Our results suggest that there are two types of events at Karymsky and that the difference in the events is strongly related to the degassing processes and efficiency of gas accumulation in the volcanic conduit.

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References

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Ozerov, AY, Lees, JM, Ispolatov, J (1999) Long and short term periodic activity at Karymsky Volcano. EOS Trans. Am. Geophys. Uinion. 80 (46) p. 1084.

Figures

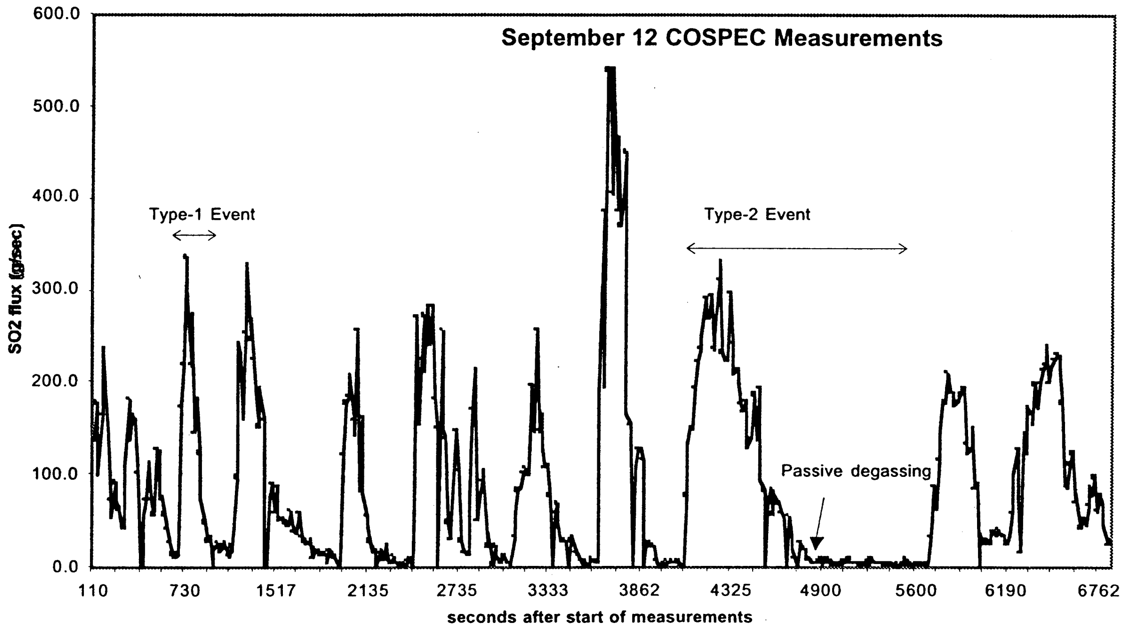

Figure 1: COSPEC measurements performed at Karymsky Volcano on September 12, 1999. Measurements started at 11:24 am and ended at 1:49 pm. Large peaks represent the SO_2output during ash blasts. Passive degassing is characterized by decline to background levels (80 to <50 g/sec). An individual event is defined by a large peak (blast) and the passive degassing level. Two examples of Type-1 and Type-2 events are indicated by horizontal arrows in the figure.

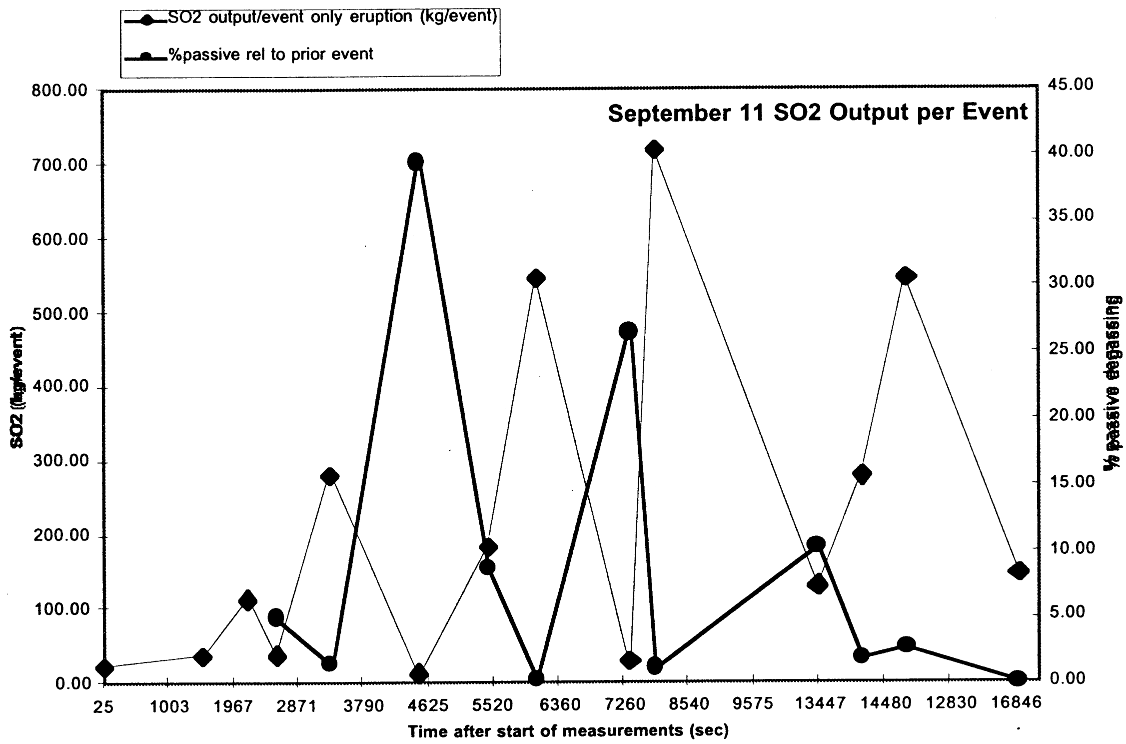

Figure 2: September 11, 1999 data. Shown is: the SO_2 output during the eruptive degassing period of events and the percentage of passive degassing prior to the event relative to eruptive degassing during the event. Note that small events (Type-1) are preceded by periods of significant passive degassing. Large events (Type-2) are preceded by significantly less passive degassing prior to the event.

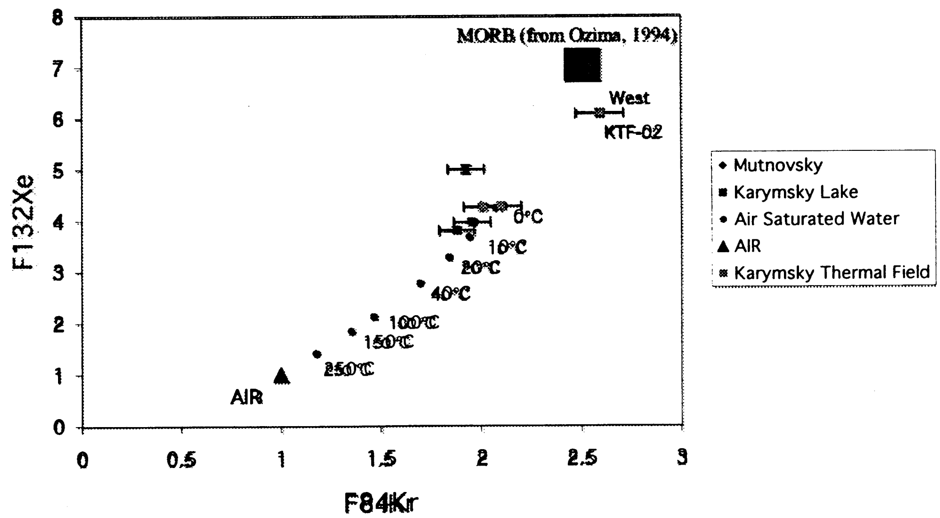

Figure 3: Noble gas data of Mutnovsky and Karymsky Volcano. F-values: $F(i)=(i/^{36}Ar)_{sample}/(i/^{36}Ar)_{air}$ The MORB value is from Ozima (1994) Noble gases in the mantle. Reviews of Geophysiscs 32, 405-426. The noble gas data is consistent with the idea of mixing of mantle derived volatiles with atmospheric gases dissolved in the shallow level hydrothermal systems at Karymsky and Mutnovsky.