Soil volatile B and NH_3 distribution prior the 1994 eruption at Rabaul caldera, Papua New Guinea

Distribución de los volátiles B y NH_3 en los suelos de la caldera de Rabaul, Papua Nueva Guinea, antes de la erupción de 1994

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ABSTRACT

Soil volatile B and NH_3 distribution in and around Rabaul caldera were evaluated by statistical graphical methods in order to investigate the distribution pattern of these volatile components prior the 1994 eruption of Tavurvur and Vulcan volcanoes. A very clear relationship was found between anomalous soil volatile B and this 1994 recent eruptive activity, but it was not observed from the analysis of the soil volatile NH_3 distribution pattern.

Key words: *Volatile, Boron, Ammonia, Soil, Rabaul, Papua New Guinea*

RESUMEN

La distribución espacial de los componentes volátiles B y NH_3 en los suelos de la caldera de Rabaul ha sido evaluada mediante el uso de técnicas gráfico-estadísticas con el fin de detectar y correlacionar las anomalías de estos volátiles con la actividad eruptiva de los volcanes Tavurvur y Vulcan en 1994. Se ha observado una clara relación entre las anomalías del B en los suelos y esta actividad volcánica reciente, mientras que no se ha observado este comportamiento en el caso del NH_3.

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Introduction

The early detection of anomalous volatile and gas concentrations in the soil horizon can be very useful in volcanic prediction studies. This observation is specially important in volcanic environments such as calderas and rifts zones where diffusse degassing monitoring would be essential for any volcanic surveillance program.

The Quaternary calderas of Campi Flegrey (Italy), Long Valley (California, USA) and Rabaul (Papua New Guinea) attracted the international volcanological community attention because of their seismic-uplift crisis in the 1980s (Barberi et al., 1985; Newhall and Dzurisin, 1988; McKee et al., 1985). In July of 1985 the term seismic-uplift crisis was interpreted to have concluded for Rabaul caldera, although several short-term seismic crisis post-1985 indicated that Rabaul was still restless and showed some anomalous behavior (Lowestein, 1984; McKee and Lowestein, 1987). Fluid and gas geochemistry data still showed high $^3He/^4He$ ratios from the volcanic-magmatic-hydrothermal discharges of Rabaul caldera in 1989; therefore, geochemical signatures were also clear evidences of a restless stage of the caldera "magmatic reactivation" (Pérez et al., 1990; Pérez, 1992). Gases from Campi Flegrey caldera have never had a clear signature of magmatic reactivation (Tedesco et al., 1988), and Long Valley shows recently a more significant mantle input to the activity (Sorey et al., 1993; Farray C.D., 1995).

The most recent eruption of both Tavurvur and Vulcan volcanoes on September 19, 1994, is the most clear geological evidence of the unrest of Rabaul caldera (Rabaul Petrological Group, 1995; Williams, 1995). Actual eruptive activity is still occurring at Tavurvur volcano while Vulcan does not show any (Ben Talai, personal communication).

We reported data on soil volatile B and NH_3 distributions at Rabaul caldera by analyzing these volatiles in soil samples collected for a soil gas ^{222}Rn and Hg^0 survey carried out in 1989 (Pérez and Williams, 1990).

Population	⟨x⟩ ≡ 50%	⟨x⟩ + σ ≡ 84%	⟨x⟩ - σ ≡ 16%
I	52	64	41
II	220	445	108
III	940	1100	570

Table 1.- Statistical results for soil volatile B distribution at Rabaul caldera.

Tabla. 1.- Resultados estadísticos de la distribución de B en la caldera de Rabaul

Sampling and analytical procedures

Soil samples were collected at 40 cm depth to avoid the soil organic rich top layer. Sampling sites were selected according to geological and structural characteristics of Rabaul caldera as well as accessibility. Soil samples were air dried and sieved (<2mm).

Soil volatile B measurements were performed by leaching 10 g of soil with 100 ml of deionized water at 70°C for one hour with a constant shaking. Soil solutions were filtered through 0.45 mm Millipore filters. Analysis of soil volatile B was carried out by ICP-AES. Soil volatile NH_3 measurements were performed by leaching 10 g of soil with 100 ml of KCl 2 M with a constant shaking (Aredes and Nicholson, 1990), and subsequent analysis were carried out by potentiometric techniques using an ammonia selective electrode.

Results and discussion

The results for B (Fig. 1) were statistically separated into three overlapping populations: background, peak and intermediate "threshold" group (Sinclair, 1974). The background mean for B is 52 ppb and represents 20% of the total data. The peak group had a mean of 940 ppb B (> 18 x background) and represents about 25% of the total data (Table 1). Most of the caldera and its surrounding area had background and intermediate B concentration levels. Four clusters of anomalously high (above threshold, > 15 x background) B concentrations were identified inside the caldera (areas 1, 2, 3 and 4; see Fig. 2). Area 1 occurs over Airport and Matupit Island where a maximum uplift took place during the 1980s seismic-deformation crisis (McKee et al., 1985). High soil B concentrations at Airport were detected in the same zones where we observed very low soil pH values, but no correlationship was found with respect to the relatively high soil gas ^{222}Rn at Airport. In the case of Matupit Island anomalous soil B levels as well as high Hg^0 concentrations may be related to faults (Pérez and Williams, 1990; Pérez, 1992). Area 2 occurs over Vulcan where a new volcanic vent was built-up during the 1994 eruption (Rabaul Petrological Group, 1995; Williams, 1995) and where the highest density of anomalous soil B values (> 21 x background) were detected at Rabaul caldera as well as very low soil gas Rn levels observed during the 1989 soil gas survey (Pérez and Williams, 1990). The distribution of soil B concentrations in this Area 2 does only show a good agreement with soil Hg^0 distribution in the Southeastern part of Vulcan, where is located the volcanic vent responsible for the formation of Vulcan Island, but low Hg^0 levels had been detected in the Northwestern part of Vulcan. On the contrary, a very good agreement has been found between high soil B anomalies and normalized

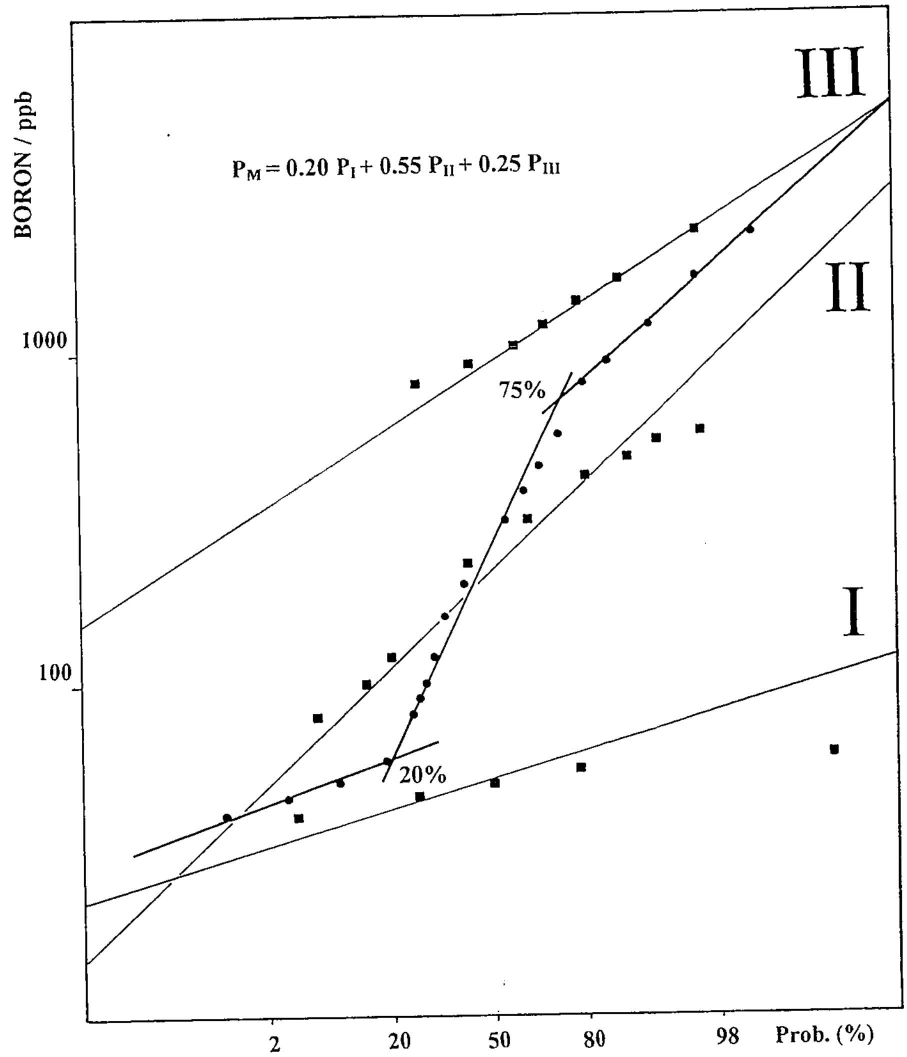

Fig. 1.- Accumulated frecuency diagram for soil volatile B concentrations at Rabaul caldera.

Fig. 1.- Diagrama de frecuencias acumuladas de las concentraciones de B en la caldera de Rabaul

Hg^0 in Vulcan area (Pérez and Williams, 1990). Area 3 is related to Rabanalakaia and Tavurvur volcanic edifices and their surrounding volcanic-geothermal activity areas. High heat flow values, greater than 200 mWm^{-2} (Graham et al., 1993) were observed along this area as well as high soil gas ^{222}Rn and Hg^0 concentrations and low soil pH values (Pérez, 1992). Area 4 is less well defined and is largely related to coastal areas in the south part of Tavurvur and Karavia bay. Heat flow measurements along these coastal areas show values higher than 125 mWm^{-2} (Graham et al., 1993).

The results for soil volatile NH_3 were also separated in three overlapping populations (Fig. 3). The background mean is 2.00 ppm and represents 18% of the samples. The peak group shows a mean of 20.00 ppm and represents 2.2% of the total data (Table 2). Most of the caldera and its surrounding areas showed background NH_3 concentrations, and the highest NH_3 levels do not show a clear pattern in relation to recent geophysical and geological characteristics of Rabaul caldera (Fig. 4). Relatively high NH_3 concentrations (> 3 x background) were observed in several areas of Rabaul caldera, but a high density of these NH_3 levels are located in the Airport and along Tavurvur and Rabanalakaia volcanoes.

Population	⟨x⟩ ≡ 50%	⟨x⟩ + σ ≡ 84%	⟨x⟩ - σ ≡ 16%
I	2.00	3.40	1.15
II	4.90	8.60	2.90
III	20.0	33.0	12.0

Table 2.- Statistical results for soil volatile NH_3 distribution at Rabaul caldera.

Tabla 2.-Resultados estadísticos de la distribución de NH_3 en la caldera de Rabaul.

Conclusions

The detection of three geochemical populations clearly differentiated for B and NH_3 at Rabaul caldera's surface environment indicate that

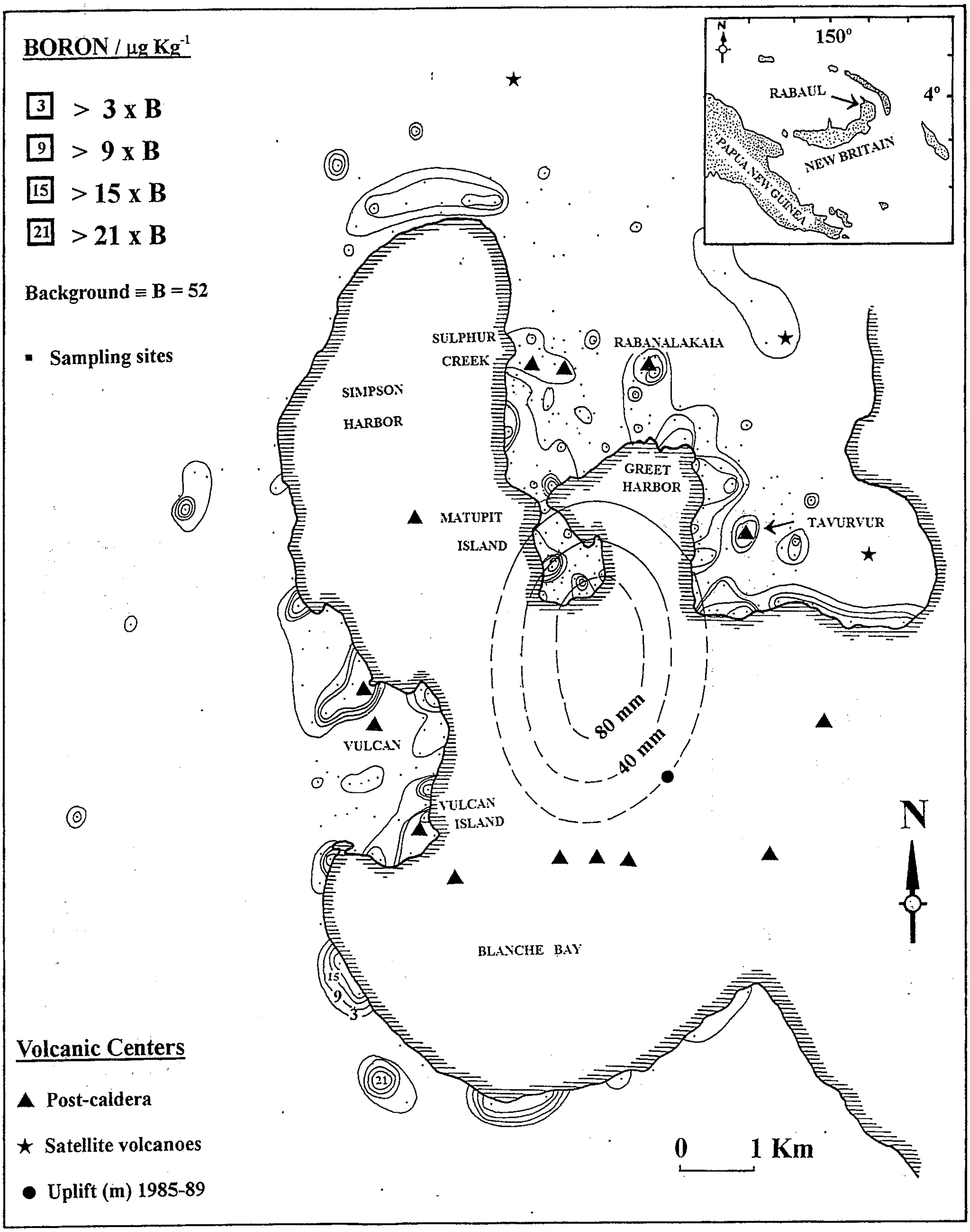

Fig. 2.- Soil volatile B distribution prior the 1994 eruption at Rabaul caldera, Papua New Guinea.

Fig. 2.- Distribución de B en los suelos de la caldera de Rabaul antes de la erupción de 1994, Papua Nueva Guinea

the emission of volatile components before the 1994 eruption ofTavurvur and Vulcan volcanoes reveal deep pertubations in the Rabaul's volcanic-hydrothermal system. Soil volatile B distribution shows a better relationship with geological and geophysical characteristics than soil volatile NH_3 distribution pattern. Our results suggest also that the early detection of anomalous volatile concentrations of multiple components in the soil horizon is a very useful tool for volcanic prediction studies.

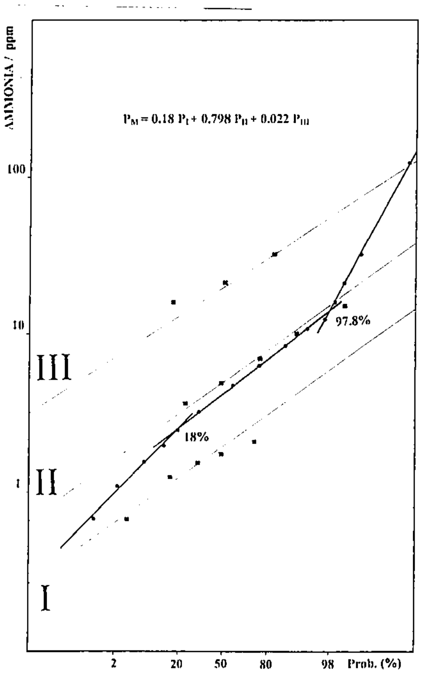

Fig. 3.- Accumulated frecuency diagram for soil volatile NH_3 concentrations at Rabaul caldera.

Fig. 3.- Diagrama de frecuencias acumuladas de las concentraciones de NH_3 en la caldera de Rabaul.

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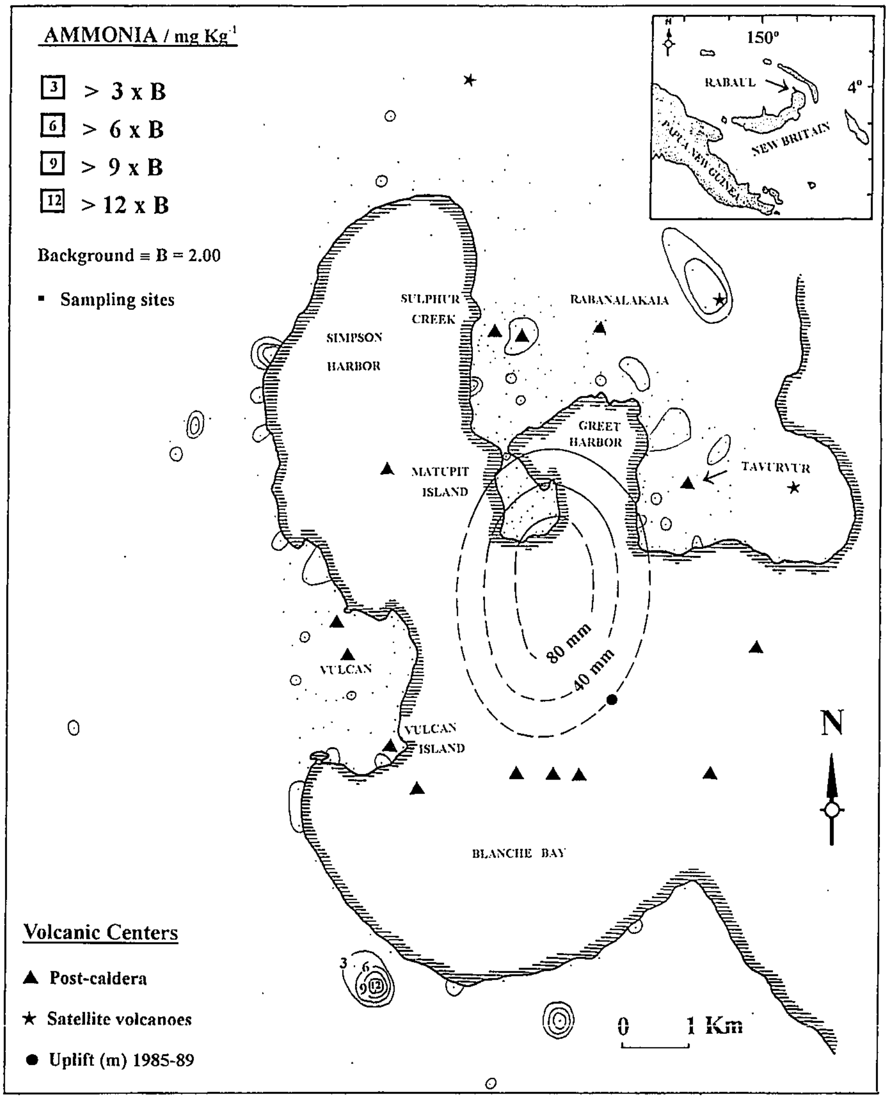

Fig. 4.- Soil volatile NH_3 distribution prior the 1994 eruption at Rabaul caldera, Papua New Guinea.

Fig. 4.- Distribución de NH_3 en los suelos de la caldera de Rabaul antes de la erupción de 1994, Papua Nueva Ginea.