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MORPHOLOGICAL AND CHEMICAL DATA ON MICROPARTICLES IN ANTARCTIC SNOWS

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Abstract

The morphology and chemical composition of microparticles left after the slow evaporation of samples of Antarctic snow were studied. These samples were collected in a stratigraphic well located in the Antarctic peninsula at 64°17′S, 61°03′W. Electron-microprobe analyses show the presence of Si, Ti, Al, Fe, Mg, Ca, Na, K, P, C, Pb, N, O, S and Cl. Zeolites, clay minerals, olivine, amphibole, calcium sulfate, organic substances and marine salts were identified by scanning-electron microscopy. The presence of these particles is due to an eolian mode of transportation.

Keywords: microparticles, glacial snow, chemical analysis, Antarctica.

Sommaire

On a étudié la morphologie et la composition chimique de microparticules, résidu de l'évaporation lente d'échantillons de neige prélevés dans un puit stratigraphique dans la péninsule Antartique à 64°17′S, 61°03′W. L'analyse à la microsonde électronique indique la présence de Si, Ti, Al, Fe, Mg, Ca, Na, K, P, C, Pb, N, O, S et Cl. Zéolites, argiles, olivine, amphibole, sulfate de calcium, substances organiques et sels marins ont été identifiés au microscope électronique à balayage. La présence de ces particules est due à un transport éolien.

Mots-clés: microparticules, neige des glaciers, analyse chimique, Antartique.

Introduction

Relatively little attention has been paid to the morphology and chemical composition of microparticles contained in the snow of glaciers. Murozumi *et al.* (1969) studied the chemical concentration of pollutant lead aerosols, terrestrial dust and sea salt in Greenland and Antarctic snow strata. They found that Pb concentrations increased from 0.001×10^{-6} to 0.002×10^{-6} g/kg during the 1940s, probably owing to enhanced lead-alkali contamination after 1940. They also found more dust in interior ice in Greenland (35×10^{-6} g/kg) than in Antarctica (2×10^{-6} g/kg), but sea salt was noted to be more abundant in the Antarctic interior ice (110×10^{-6} g/kg) than in Greenland ice (67×10^{-6} g/kg). Boutron *et al.* (1972) studied the concentrations of chlorine, sodium, magnesium, potassium, calcium, manganese and iron in samples collected in an Antarctic profile between Mirny (66°30′S, 93°E), close to the sea, and Vostok (78°27′S, 107°E), 1925 km from the sea and 3420 m above sea level. They found that the Na and Cl concentrations decrease with distance from the coast. On the other hand, Warburton & Linkletter (1978) found a close relationship between atmospheric processes and the concentration of Na, K and Mg in the snow of the Ross ice shelf in Antarctica. Cunningham & Zoller (1981) found that the major mass of Antarctic aerosols consists of sulfate during the summer season, along with minor quantities of crustal dust, sea salt and meteoritic debris. In the winter season, the levels of sulfate crustal dust and meteoritic debris decrease. Scanning-electron microscope (SEM) observation of portions of the samples revealed no particles larger than a few μm except those associated with ice crystals. They concluded that the chemistry of the aerosol is very similar each summer season, as they did not find drastic changes in the composition of aerosols collected at the South Pole between 1971 and 1978. On the contrary, Warburton (1982) determined that the chemical composition of the snow changes significantly from one type of precipitation to the other and that the aerosols also show important changes in their chemistry with the size of the particles. He suggested that both phenomena are related and relevant to the processes involved in the removal of chemical impurities from the atmosphere.

The aim of this paper is to discuss the relationship between the chemistry and morphology of particles of Antarctic snow. Electron-microprobe, scanning-electron-microscope and distribution-analysis techniques were used to accomplish this objective.

Sample Preparation and Experimental Procedure

The samples studied are representative of microparticles contained in the snow accumulated during the periods December - February of the years 1971 - 1972, 1972 - 1973 and 1973 - 1974, in a stratigraphic well on an ice cap located at Hughes Bay, Antarctic peninsula, 64°17′S, 61°03′W, 5 km south of Punta Spring.

After melting, the samples were subject to a process of slow evaporation on a sample holder made of brass and covered with a thin layer of gold to avoid the penetration of the EPMA electron beam. The incrustations left after this process were analyzed by scanning-electron microscopy using a 240 × - 1200 × magnification, in order to study their morphology.

The chemical composition of the particles was obtained with a Cameca N 46 scanning-electron microprobe equipped with optical microscope, absorption microscope and a distribution-analysis device. A 2-μm electron beam was used for spot analyses and an average surface of 40 × 40 μm was scanned in the absorption and distribution analyses.

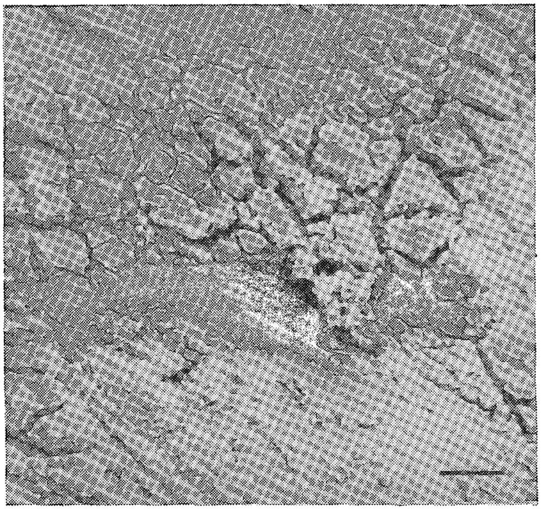

FIG. 1. Planar particles are sulfate, carbonate and silicates (SEM). Scale bar 40 μm.

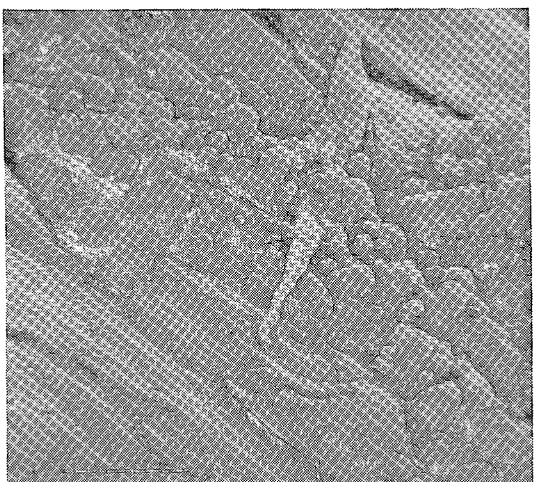

FIG. 2. Oval and planar particles consist of Si, Ca, Al and Pb. Si, Ca, and Al belong to zeolite minerals; Pb is a contaminant element (SEM). Scale bar 20 μm.

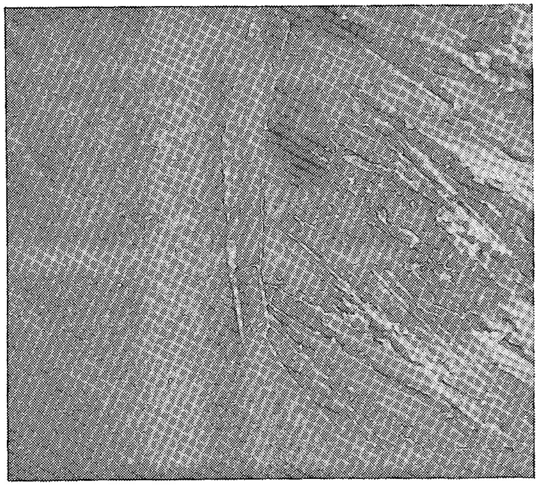

FIG. 3. Organic substance having an elongate shape (SEM). Scale bar 20 μm.

The incrustation left after the slow evaporation needed no further treatment to be analyzed. The incrusted particles do not need to be covered with a layer of gold or graphite in order to enhance their conductivity. The combination of optical microscope, absorption microscope and distribution analysis allows one to obtain either the absorption image or the distribution-analysis image of a particle seen under the optical microscope. In other words, there is assurance that the image observed on the screen corresponds to the particle seen under the microscope.

Experimental Results and Discussion

Incrustations obtained from snow samples belonging to the December - February periods of the years 1971–72, 1972–73 and 1973–74 were analyzed. Since the observed particles and their chemistry are similar in all samples from the three periods, the average results will be discussed. Cunningham & Zoller (1981) also noted that the chemistry of Antarctic aerosols was similar, summer after summer, between 1971 and 1978. According to their morphology, the particles analyzed can be grouped into planar (Fig. 1), oval (Fig. 2) and elongate types (Fig. 3). Their size ranges between 2 and 40 μm and, under the microscope, the planar particles always underlie the other two groups.

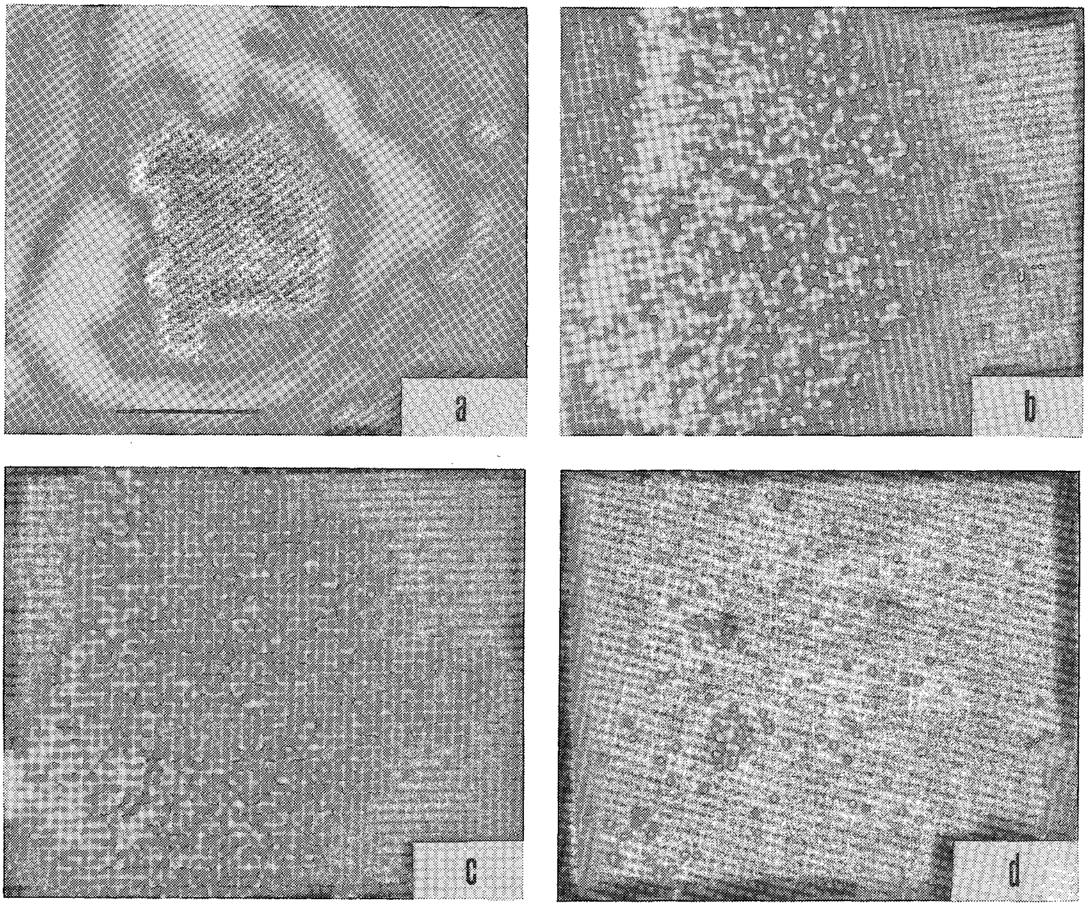

FIG. 4. a) Olivine absorption (EPMA). Scale bar 10 μm. b) Distribution of Si in the same area as in 4a (EPMA). c) Distribution of Mg in the same area as 4b (EPMA). d) Distribution of Fe in the same area as 4c (EPMA).

Electron-microprobe analysis of these particles shows the presence of Si, Ti, Al, Fe, Mg, Ca, Na, K, P, C, Pb, N, O, S and Cl. The combination of electron absorption and semiquantitative analysis leads to correlations between different elements of a given particle. For example, Figure 4a shows the electron-absorption image of a particle, and Figures 4b, 4c and 4d show selected X-ray images. Since a good Si - Mg - Fe stoichiometric correlation is observed, the particles are identified as olivine. Similarly, Figure 5a shows the absorption micrography of another particle, and Figures 5b and 5c exhibit its X-ray images. Since a Si - Al correlation is observed, the analyzed particle is probably a clay mineral. Finally, a Si - Al - Fe - Ca correlation indicates the presence of pyroxene and amphibole. In addition to the Fe - Mg - Si and Al - Si correlations, the following other stoichiometric correlations were observed: the Ti - Al - Fe - Ca - Na - Cl - C correlation indicates, on one hand, the presence of seawater microparticles containing calcium carbonate; the Si - Ca - S, Na - K and Mg - Cl correlations indicate, on the other hand, the presence of sulfate-bearing microparticles of seawater origin.

The morphology combined with EPMA analysis suggest that the cracked surface shown in Figure 1 consists of Ca sulfate, Ca carbonates, and silicates. Likewise, the morphology and EPMA chemistry (presence of Si, Al and Ca) of the particles shown in Figure 2 suggest that they belong to the zeolite family. Pb was also detected in these particles. The presence of this element is probably due to contamination from combustion engines operating in the area. Figure 6 is a combination of Figures 1 and 2. The presence of Si, Al, Mg and Ca in conjunction with the morphology observed in the upper right hand corner also suggests the presence of amphibole.

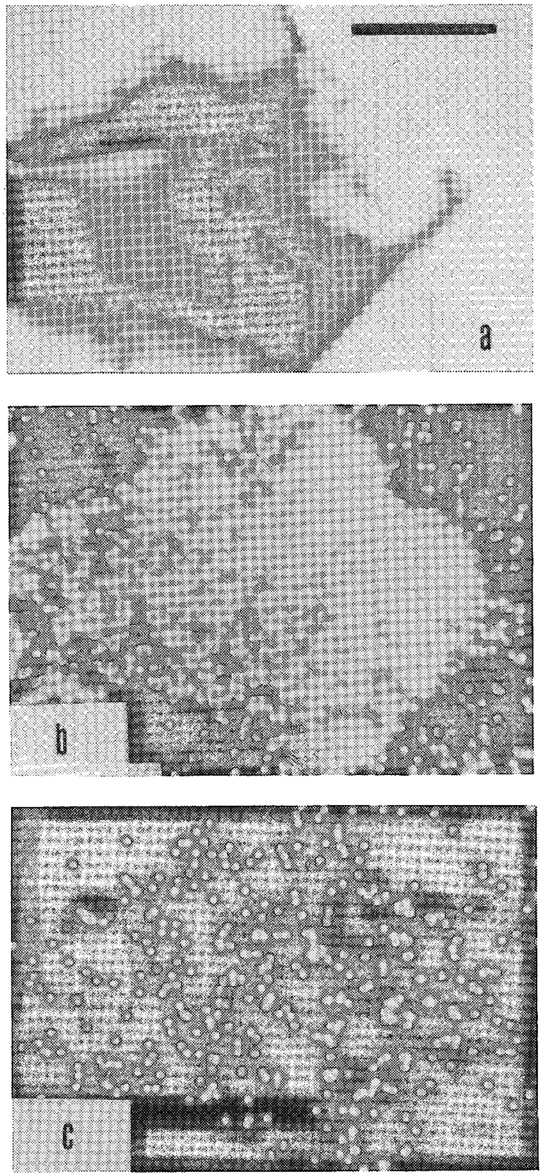

FIG. 5. a) Clay absorption (EPMA). Scale bar 10 μm. b) Distribution of Si in the same area as 5a (EPMA). c) Distribution of Al in the same area as 5b (EPMA).

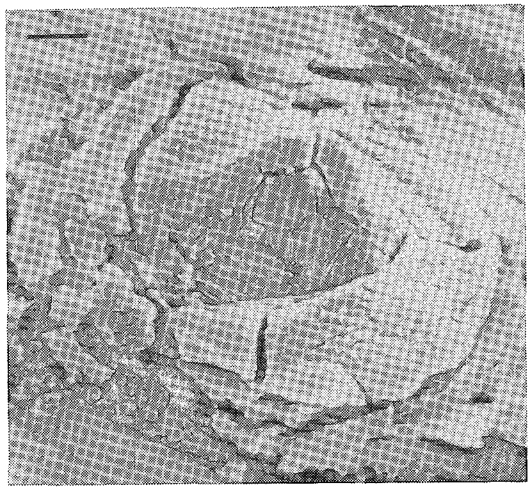

FIG. 6. The combined contents of the sample exhibited in Figures 1 and 2 (SEM). Scale bar 20 μm.

A probable source for the mineral microparticles present in the snow are the Deception Island (62°57′S, 60°38′W) basaltic volcanic eruptions that occurred in 1967, 1969 and 1970. The island is situated northeast of Gerlache Strait, tens of kilometres from the ice cap. The organic (Figs. 2, 3) and marine substances would come from the marine environment. These particles would have reached the well under study through localized turbulent atmospheric phenomena. The increment of dark particles on the snow may have a climatic control. It is well known that microparticles of opaque minerals have a significant power to absorb the solar short-wave radiation. This phenomenon increases the evaporation of the snow, incorporating water vapor into the circulating atmosphere. Studies should be made of the distribution of microparticles in order to evaluate the extension of the air masses of marine origin to the ice cap and their climatic influence.

The combination of EPMA analysis and SEM analysis microscope is recommended as an excellent approach to identify the nature of microparticles contained in snow. Crystallization through slow evaporation, utilized in the preparation of samples for analysis, has the advantage of preserving the typical morphology of the particle (substances in a marine environment). The microparticle analysis carried out in this study demonstrates the presence of the same elements that are commonly reported using other techniques applied to the study of Antarctic aerosols.

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