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Chemical Compositions of Aerosol Particles and Snowfalls at Alta, Northern Norway

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Abstract

Samplings of aerosol particles in the atmosphere and in fresh snowfalls at Alta River Camping area (69°56'N, 23°16'E), Finnmarksvidda, Northern Norway were performed to determine the relationship between the compositions of aerosol particles and wind direction during the mid-winter season of 1987/1988. As a result of analysis, high concentrations of marine aerosol particles were mainly found in northerly and westerly winds by the effects of the Arctic Ocean and Norwegian Sea. On the other hand, those of natural and anthropogenic aerosol particles were found in southerly and easterly winds blown from the continental areas. Snowfall events with acidity below pH 5.5 values were observed in this area under conditions of southerly and easterly winds.

Key words : Aerosol particles, Chemical compositions, Natural aerosols, Marine aerosols, Anthropogenic aerosols.

1. Introduction

Aerosol particles exist in organic or inorganic compositions, and as liquid or solid states in the atmosphere. They are, therefore, multicomponent particles of very small sizes, in general, ranging roughly from 0.01 to 10 μm in diameter (Pilinis et al., 1987). Vast quantities of aerosol particles formed in the atmosphere have some effects on environment and human health (visibility, respiration, disease etc.) as well as plants and animals. These effects change according to the meteorological and environmental situations (Stoker, 1972).

In recent years, pollution levels in the Arctic atmosphere have increased by the anthropogenic sources in industrialized regions in the lower latitudes. A number of studies regarding the atmospheric transport of Arctic aerosols have been done to date. For

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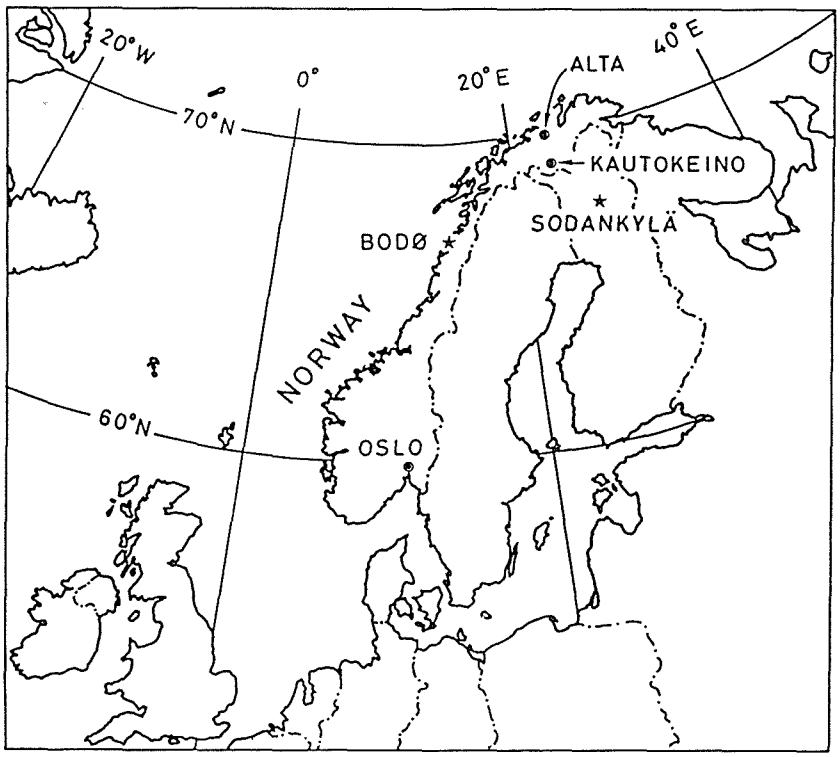

Figure 1. A location of observation site.

instance, the examinations of weather maps and air trajectory analyses by Rasmussen et al. (1983) and Pacyna and Oehme (1988) have shown that pollutants are thought to be originated from anthropogenic sources in the densely populated and industrialized regions and transported into the Arctic. In order to understand the air quality more practically in Northern Norway, samplings of aerosol particles in relation to the wind direction and snowfall events were collected in the Alta region, Finnmarksvidda, Northern Norway as shown in Figure 1. Especially, the aerosol sampling by each wind direction is important to estimate the direction of aerosol transport as well as the variation of the concentration of aerosol substances. This paper summarizes the measured results of the concentration of aerosol substances obtained on filter papers and in fresh snowfalls.

2. Materials and Methods

2.1 Sampling method

To obtain the difference of the concentrations of aerosol substances for each wind direction, samplings of aerosol particles using filter papers were performed from December 24, 1987 to January 20, 1988 at the Alta River Camping site (69°56'N, 23°16'E) on a riverbank of the Alta River, Finnmarksvidda, Norway as shown in Figure 2. This sampling site is

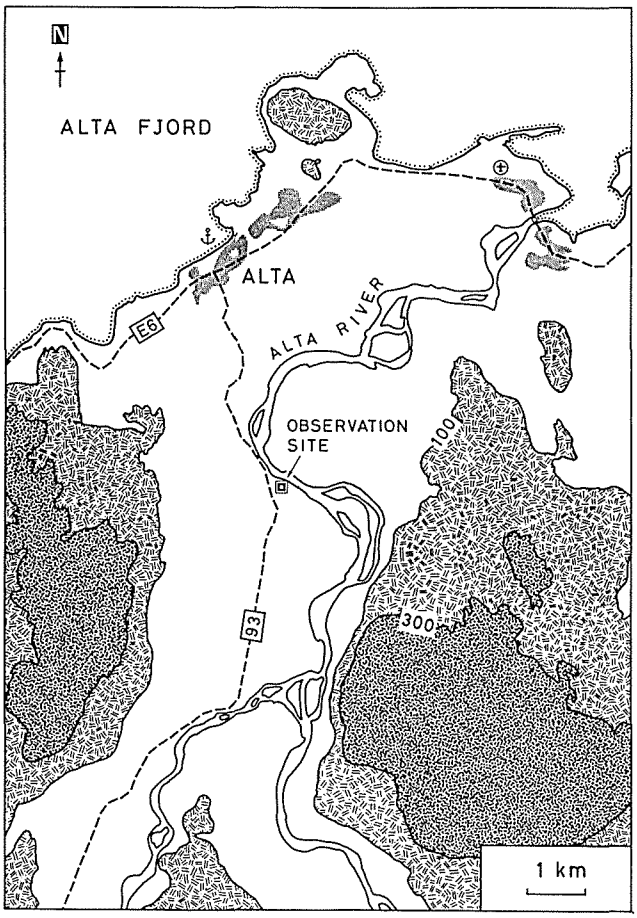

Figure 2. Map of observation site.

located 5km south from the Alta Fjord and downtown Alta. This town has almost no industrial activities especially in the winter season. Therefore, we could discount pollution from the downtown area. In general, weak southerly winds blow northward from a plateau along the valley of the Alta River.

The apparatuses used in this study are an aerovane and a selection circuit unit assembly of four quadrants of wind directions and calm condition as shown in Figure 3. These are used in conjunction with an filter air sampler with an electric solenoid valve to sample air when the wind is coming from a specific wind direction. Solenoid valve C (calm) is opened automatically, when the wind speed is less than 1m/sec. Two types of filter papers of 47 mm in diameter were used in low volume (35 1/min) air sampling for each wind direction. One is an AF07P teflon filter for measuring the ionic components and metal contained among the atmospheric aerosols and the other is a Pallflex 2500 QAST quartz fiber filter for carbon measurements. This filter paper is heated in a electric furnace at 850° C in air for one hour to remove carbonaceous contaminants before aerosol sampling. These

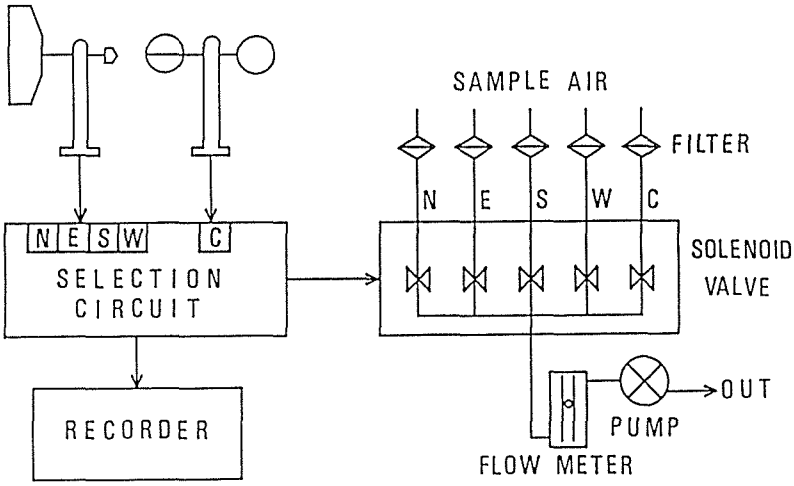

Figure 3. The wind direction controlled air sampling apparatus.

techniques are described in detail in Lee et al.(1987, 1988 a,b). In addition, to collect the atmospheric aerosol particles contained in fresh snowfalls, a vinyl sheet (0.8 m^2) was used, and the collection was made manually.

2.2 Analytical methods

The sample preparation and analytical methods are described in Table 1. In quartz filters, one half of the discs used for the determination of elemental carbon was heated in an electric furnace at 300°C in air for 30 min. to remove organic carbon. The carbon determination was made in combination with a NC-analyzer (Sumitomo Chemical Industry Inc., Model NC-80) and a gas chromatography apparatus (Hitachi Inc., Model 163 FID) equipped with a nickel catalyst methanizer and flame ionization detector (Ohta and Okita, 1984). The difference in the amount of total and elemental carbons gives the amount of organic carbon. In teflon filters for determination of ionic components, one half portion of the filter was placed in a teflon beaker, and a specified quantity of warm pure water was added to it to extract the ionic components. The ultra-sonic wave extraction by a ultrasonic cleaner (Branson Model B-301) was done for more than 10 minutes in the front and the back of a 1/2 filter facing each other. After these procedures, a sample solution was pipetted from a teflon beaker in adequate proper amounts (10ml for NH_4^+, 20 ml for NO_3^-, 20 ml for Cl^- and 10ml for SO_4^{2-}) for the analyses of each ionic component. And these solutions prepared by individual methods (ammonium-indophenol method, nitrate-hydrazine reduction method, chloride-mercury thiocyanate method and sulfate-barium perchlorate thorin method) were determined by an UV Spectrophotometer (Shimadzu Inc., Model 120-02 SFU) at 640 nm, 530 nm, 460nm and 520nm (APHA, 1977; APNC, 1975; Persson, 1966). The other half portion of the teflon filter was used for analyses of metal elements. Each element was extracted and prepared by strong acids such as nitric acid and hydrochloric acid etc. over several times according to the conventional atomic absorption

Table 1. Analytical methods of individual items and instruments.

Item	Analytical method		Instrument
T.C.	850°C combustion system		Carbon analyzer
E.C.	300°C, 30min. (burn)		(SUMIGRAPH, NC-80)
NH_4^+	Indophenol method		
NO_3^-	Hydrazine reduction		UV
Cl^-	Mercury thiocyanate		Spectrophotometer
SO_4^{2-}	Barium perchlorate-thorin		(SHIMADZU, 120-02 SFU)
Al	HNO_3		
Ca	+		Flameless
Cu	$HClO_4$	Atomic	Zeeman effect
K	+	absorption	Atomic absorption
Mg	HF	analysis	Spectrophotometer
Mn	Dry		(HITACHI, 170-70)
Na	+		
Zn	HCl		
pH			pH meter (HORIBA, C-1)

methods (APHA, 1977). After these preparations, each metal element was measured by a Flameless Zeeman Effect Atomic Absorption Spectrophotometer (Hitachi Inc., Model 170 -70) at specific wave lengths corresponding to individual metals. PH values in each snowfall events were measured as soon as possible by a portable compacted pH meter (Horiba, Model C-1).

2.3 Meteorological conditions

Table 2 indicates the cumulative time (hrs) in each wind direction at the Alta River Camping area during 4 sampling periods (one weak interval). As shown in this table, southerly winds and calm conditions were predominant in the winter season as compared with other wind directions. This phenomenon coincided with weather maps of 850mb level provided from Norsk Meteorologisk Institutt, Norway. During one month in the midwinter season in 1987/1988, the precipitation amount in this area is less than that was expected, except for a snowfall event (about 10 mm in winter) of December 27, 1987.

3. Results

3.1 The composition and concentration of aerosol particles by each wind direction

Total mean values ($\mu g/m^3$) of the concentrations of aerosol particles measured at each wind direction nearly once a week are shown in Figure 4. The concentrations of the element Al for easterly and southerly winds were higher than those for westerly, northerly and calm conditions. In the case of the element Cu, the tendency of concentration values for each wind direction was similar to that of Al. This means that aerosols released in Europe and Soviet Union are transported to the Alta area in Northern Norway. However, the concentrations of the elements Na, K and Cl were high in northerly and westerly winds as compared with others. On the other hand, the concentration of anthropogenic aerosol

Table 2. Cumulative time (hrs) for each wind direction. (Dec. 24, 1987 – Jan. 20, 1988)

Date	N	E	S	W	C
12/24–12/31	11.4	2.9	62.3	8.6	67.8
12/31 – 1/7	0.3	7.8	54.5	1.6	99.9
1/7 – 1/14	6.0	5.1	59.0	2.8	71.7
1/14 – 1/20	0.3	5.3	47.4	4.4	85.3

particles in this region was less than those of larger urban areas, since there were almost no industrial activities in the Arctic.

3.2 The concentration of aerosol particles originated by each source

Figure 5 indicates concentration amounts ($\mu g/m^3$) of the element NH_4^+ which is dissolved mainly from botanical and animal bacteria and of the element Al which is formed mainly by crustal and soil dusts (natural origin sources), respectively (Hidy et al., 1980) at Alta River Camping site. During the midwinter season in 1987/1988, the concentrations of the elements NH_4^+ and Al in southerly and easterly winds were higher than those in northerly and westerly winds. Reversely, in Figure 6, the concentration amounts of the elements Na and Cl^-, usually originated from marine aerosol sources were high in westerly and northerly winds. Especially, the concentration of the element Na showed the highest

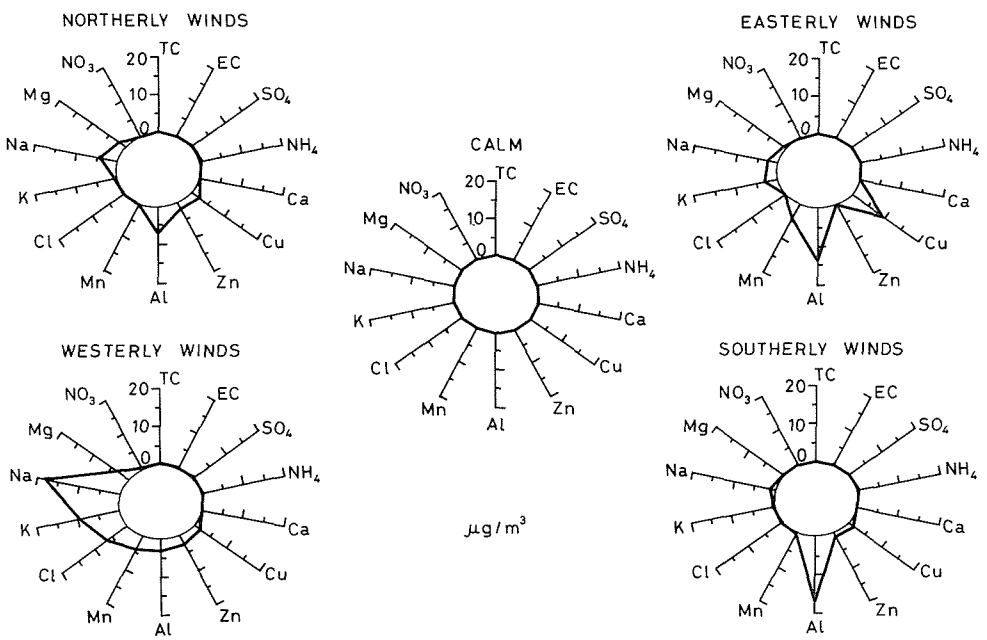

Figure 4. Total mean values of chemical compositions by each wind direction during the sampling period at the Alta River Camping site.

value for westerly winds. It is suspected that sea salt particles may have been transported from the Norwegian Sea which is situated west from the site. The concentration amounts of elemental carbon and SO_4^{2-}, mainly originated from anthropogenic aerosol sources were recognized for each wind direction in Figure 7. As shown in this figure, there were high concentrations in southerly winds and calm condition in elemental carbon and in southerly and in easterly winds in SO_4^{2-}, comparatively.

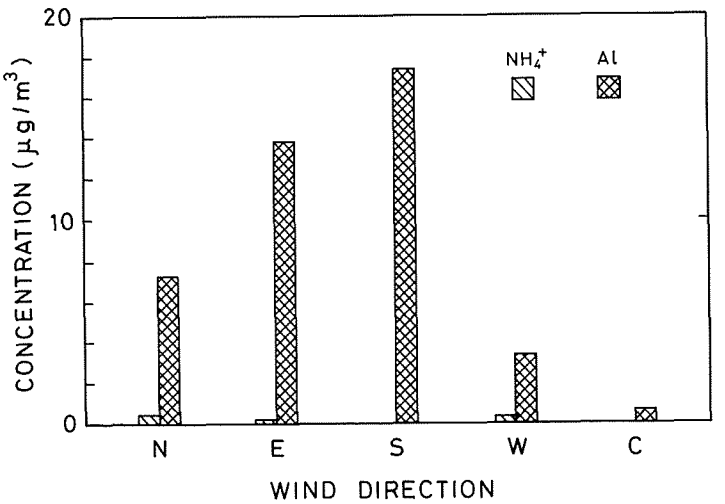

Figure 5. Concentration amounts of NH_4^+ and Al by each wind direction at the sampling site.

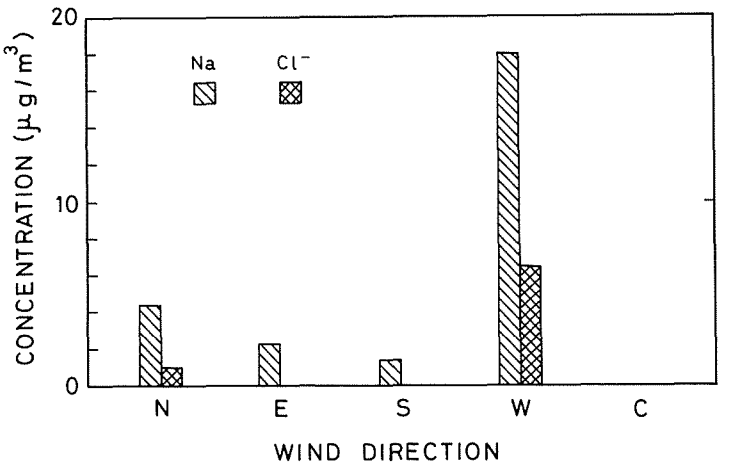

Figure 6. Same as in Figure 5, but for Na and Cl^-

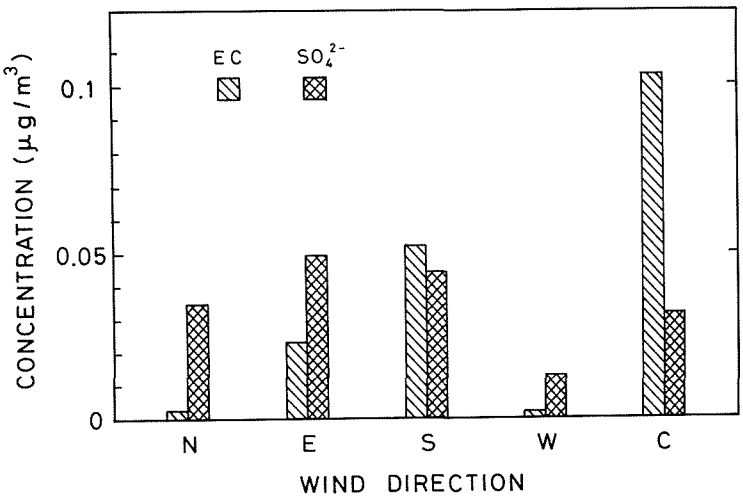

Figure 7. Same as in Figure 5, but for elemental carbon and SO_4^{2-}.

3.3 pH and elemental concentration in snowfall events

Figure 8 indicates the pH values in snowfall events during December 26, 1987 to January 10, 1988. Each snowfall sampling was performed at the same place of aerosol collection. Mean pH value in all snowfall events was 5.71 . This means that Arctic snowfalls generally indicate a little acidity as compared with the strong ones in urban cities. However, as shown in this figure, pH 5.42 was measured in the case of January 8, 1988. It reveals that the acid snow (below the pH 5.5) has existed in this region, likewise. During this sampling period, the typical shapes of snow particles were densely rimed and graupel pellet types. However, low pH value was found in the precipitations consisting of larger snowflake particles, although it was difficult to explain the relation between acidity and snowfall patterns in the atmosphere with only a few snowfall events. Figure 9 indicates the mean values of elements contained in the fresh snowfall events. The concentrations of elements Al, Zn, K and Cu showed in high values. As a result, it was considered that aerosol particles which originated in the continental area were transported to the Arctic region. These concentration amounts were greatly changed according to the meteorological situations.

4. Conclusions

Aerosol particle samplings in the atmosphere and in fresh snowfalls at Alta River Camping area, Finnmarksvidda, Northern Norway were performed during the midwinter season, 1987/1988. According to the measurements in relation to wind directions, high concentrations of marine aerosol particles were mainly found in northerly and westerly winds by the effects of Arctic Ocean and Norwegian Sea. On the other hand, high concentrations of natural and anthropogenic aerosol particles were found in southerly and easterly winds blown from the continental areas. Some cases with acidity below pH 5.5

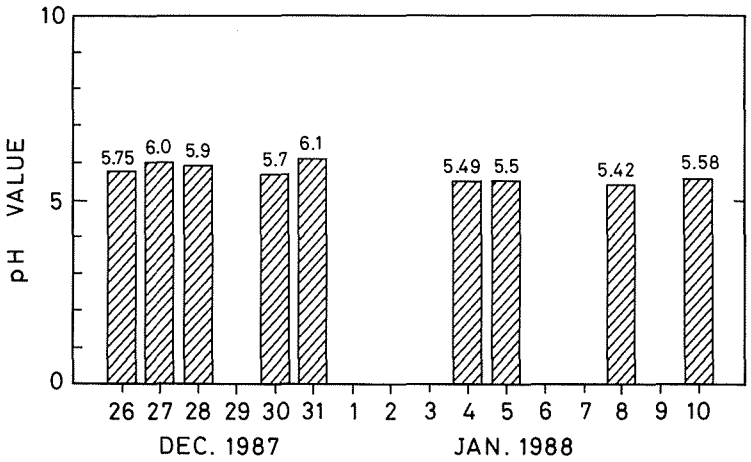

Figure 8. Temporal mean pH values in snowfalls at the Alta River Camping site from Dec. 26, 1987 to Jan. 10, 1988.

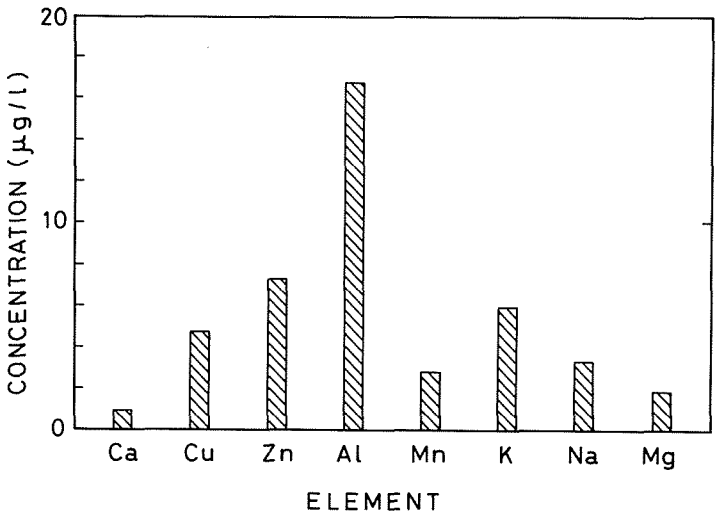

Figure 9. Total mean concentration amounts (μg/l) of each chemical composition in the snowfall events.

values and high concentrations of soil elements were found in snowfall events.

These results indicate that aerosol particles transported by southerly and easterly winds are related to the formation of acid precipitation and air pollution in the Arctic.

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