Distribution of microparticles in a 299-m core through the Devon Island ice cap, Northwest Territories, Canada

R. M. Koerner

Abstract. A general survey of the distribution of microparticles (1.0–2.0 μm) in a 299-m core from the top of the Devon Island ice cap has shown no significant long period variations in particle content between the surface and 295 m depth. Between 295 and 297 m depth there is a dramatic increase in particle content which is attributed to increased atmospheric particulate content, and a decrease in the accumulation rate and size of the snow grain during the last glacial period. Three patterns of the seasonal variation of particulate content of the ice have been found. Two of the patterns allow detection of annual layers within the core but the third breaks the continuity of that record.

Distribution des micro-particules dans une carotte de 299 m à travers la calotte de glace de Devon Island, Territoires du nord-ouest, Canada

Résumé. Une étude générale de la distribution des micro-particules (1–2 μm) dans une carotte de 299 m prélevée au sommet de la calotte de glace de Devon Island ne montre pas de variation de longue période significative sur les 295 premiers mètres. Entre 295 et 297 m de profondeur, on observe un accroissement 'dramatique' de la teneur en particules que l'on attribue à une teneur de l'atmosphère en particules plus importante, à une décroissance du taux d'accumulation et de la taille des grains de neige durant la dernière période glaciaire. On trouve trois sortes de variations saisonnières de la teneur en particules dans la glace. Deux permettent la détection de couches annuelles dans la carotte mais la troisième détruit la continuité de cette séquence.

INTRODUCTION

Three cores have been taken with a CRREL-designed thermal drill from the top of the Devon Island ice cap at 1800 m a.s.l. The first of these cores taken in 1971 penetrated to 223 m depth, the second and third taken in 1972–1973 penetrated to bedrock at 299 m depth. This paper considers firstly, the general distribution of particulate matter throughout the 1973 core, and secondly, the seasonal variations of particulate matter from seven sections of the 1971 core.

METHOD

Sampling

The general distribution of particulate matter was measured on samples taken from the drill melt-tank which is the reservoir of water suctioned up from the heated drill annulus. For the seasonal dust variations, samples were melted from the core with a 2.5-cm stainless steel probe heated by steam passed through the head without contacting the ice itself. The melted sample, measuring about 10 ml and representing about a 1-cm vertical increment, was drawn by vacuum from the head and up through the length of the probe by Teflon tubing. The probe melted down through the middle of the ice core generating a 10-ml sample a minute.

Counting

Either a Model B or Z_b Coulter counter with a 30-μm aperture tube was used to count particles $\geqslant 1$ μm in diameter. The sample and glassware were housed in a clear plastic chamber through which filtered (0.2 μm) air was blown. The housing was opened only to introduce the samples via a 0.2 μm filter-protected pipette; all other operations were made without opening the housing.

RESULTS

Long period variations

The general survey of particulates (Fig. 1) shows no significant changes of dust fallout (both dry and as precipitation nuclei) over the past approximately 10 000 years.

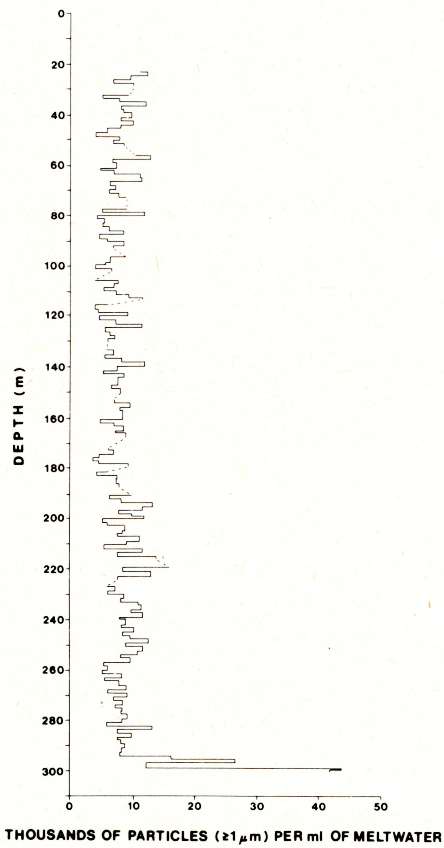

FIGURE 1. Distribution of particles ⩾1.0 μm diameter in a core to bedrock from the Devon Island ice cap.

At a depth of 295 m ice, which shows very negative $\delta(^{18}O)$-values (W. Dansgaard, personal communication), and which as a result is considered to consist entirely of ice deposited during the last glacial period ending 10 000 ago, has a very high dust content. Microscopic examination of this and other samples shows that the 'Wisconsin ice' dirtiness is attributable to a dramatic increase in the small size range of < 1.5 μm; there is no similar increase in the number of particles over 2 or 3 μm diameter. Below this there is a return to cleaner ice for one core before relatively dirty ice appears which continues to bedrock. The ice for 0.5 m above bedrock contains several rounded rock fragments up to 3 mm diameter.

The relative dirtiness of the Wisconsin ice can be attributed to any one or a combination of three causes:

(1) A decrease in the precipitation rate. [If dry fallout (in this case fallout of particles not associated with a snow-grain) continued at approximately the same rate as before, then, coupled with a decrease in snowfall, the snow accumulation on the ice cap would contain a greater concentration of dust particles.]

(2) A decrease in the size of the snow-grain and hence an increase in the volume ratio of nucleus to snow.

(3) Increased volcanic activity or a nonvolcanic increase in the atmospheric content of dust.

Other work on the Devon Island ice cap cores (in preparation) has shown that while there is an increase in K and Na and more particularly in Mg and Ca in the Wisconsin ice there is a decrease in water soluble matter. The problem is therefore complex. While it is evident that during this period of time the open sea was much more distant from the ice cap (lower electrolytic conductivity of core meltwater) so too was the source of dust (lower size range). The Devon Island ice cap studies have not yet reached the stage where one can be certain of the cause of the increased dirtiness. However, because of the dramatic increase in particle numbers, their changed size distribution and the lower content of water soluble material it seems certain that the source areas were different and more distant.

The increased dirtiness in the bottom 0.5 m of the 299-m core is associated with less negative $\delta(^{18}O)$-values (which, in fact, extend over most of the lowermost 2 m). The less negative $\delta(^{18}O)$-values, together with the presence of mm size material, leads to a preliminary conclusion that during the period of

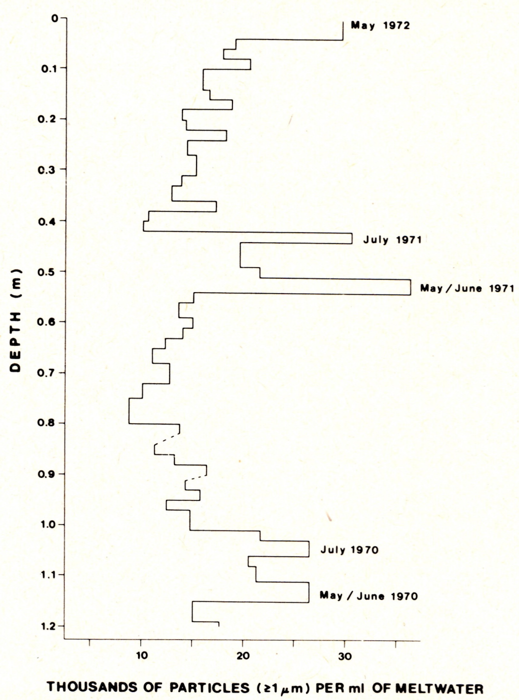

FIGURE 2. Distribution of particles $\geqslant 1.0\ \mu m$ diameter from a snow pit at 1800 m a.s.l. on the Devon Island ice cap.

time (pre-Wisconsin) when the 0.5 m of ice accumulated, the ice cap was considerably smaller than at present, perhaps no more than a few square kilometres in area.

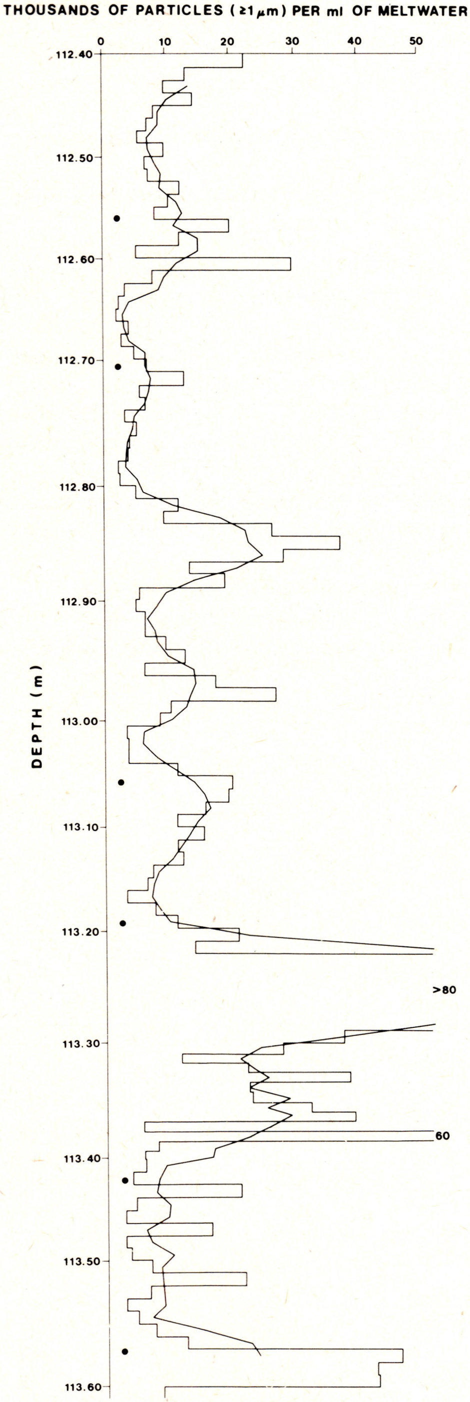

FIGURE 3. Distribution of particles ⩾1.0 μm diameter between 112.4 and 113.6 m in the Devon Island ice cap. The dots represent summer surface layers.

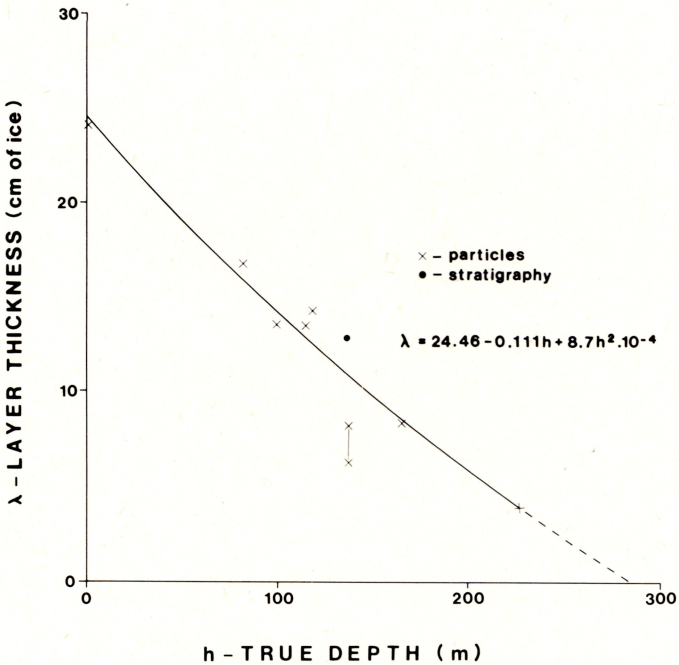

FIGURE 4. Annual layer thickness in a core from the Devon Island ice cap as deduced from particulate distribution and stratigraphic analysis.

Seasonal variations

Previous work (e.g. Hamilton and Langway, 1967) has shown that dust distribution in ice cores shows seasonal peaks. These peaks can be used to trace annual layers back in time in deep cores. Surface samples from the drill site on Devon Island (Fig. 2) show a double-peaked annual dust profile. The dates in Fig. 2 were obtained from a knowledge of snow accumulation for that period in the drill site area. The June–May peak is in essence a spring maximum preserved at the sur face until June or May by a lack of accumulation in late April and early May of each year. The July peak is caused by melt-concentration during the short melt season in July; i.e. percolation leaves particles at the surface. A similar but much reduced melt-peak is also evident in the profile of Hamilton and Langway (1967). However, a similar double-peak has rarely been found at depth in the deep core (Figs. 3 and 4) where, due to the densification process, the two may be too close to separate at the sampling interval used. Instead, a single maximum per year is found, often with a stratigraphically identifiable summer surface at its leading edge. A 5-point running mean is fitted to the results to facilitate layer identification. To date, seven different levels have been studied covering a total of over 70 annual layers. In general, the profiles are as shown in Fig. 3. However, some sections (e.g. the entire section at 137 m depth) show several isolated peaks with separations several times more or several times less than an annual layer thickness for that depth. These sections prevent a continuous series of annual layers being identified between 60 m (the firn-ice transition) and 260 m where layers are too thin for this technique. The results fit reasonably close to a curve, which, if extrapolated, shows zero annual layer thickness at 283 m (16 m above bedrock). A tentative conclusion from this distribution is that the snow accumulation rate at the drill site has not varied significantly over the past approximately 2000 years.

Distinctive dirt horizons

Occasionally, very dirty layers have been found (approximately 10 times the normal count). One such horizon is shown in Fig. 3 and spans almost 2 years of accumulation. A layer of this type cannot result from a single storm blowing dust from ice-free land and is most likely the result of a volcanic eruption. Identification of the volcanic mineral content of such horizons using electron probe analysis could provide dateable levels in the core. Failing this, determination of a specific mineral signature of such a layer might allow correlation with identical layers in cores elsewhere, thereby simplyifing comparisons involving time scales between these cores.

REFERENCE

Hamilton, W. L. and Langway, C. C. Jr (1967) A correlation of microparticle concentrations with oxygen isotope ratios in 700 year-old Greenland ice. *Earth Planet. Sci. Lett.* **3**, 363–366.