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Microparticle analysis of the 101-meter South Pole ice core

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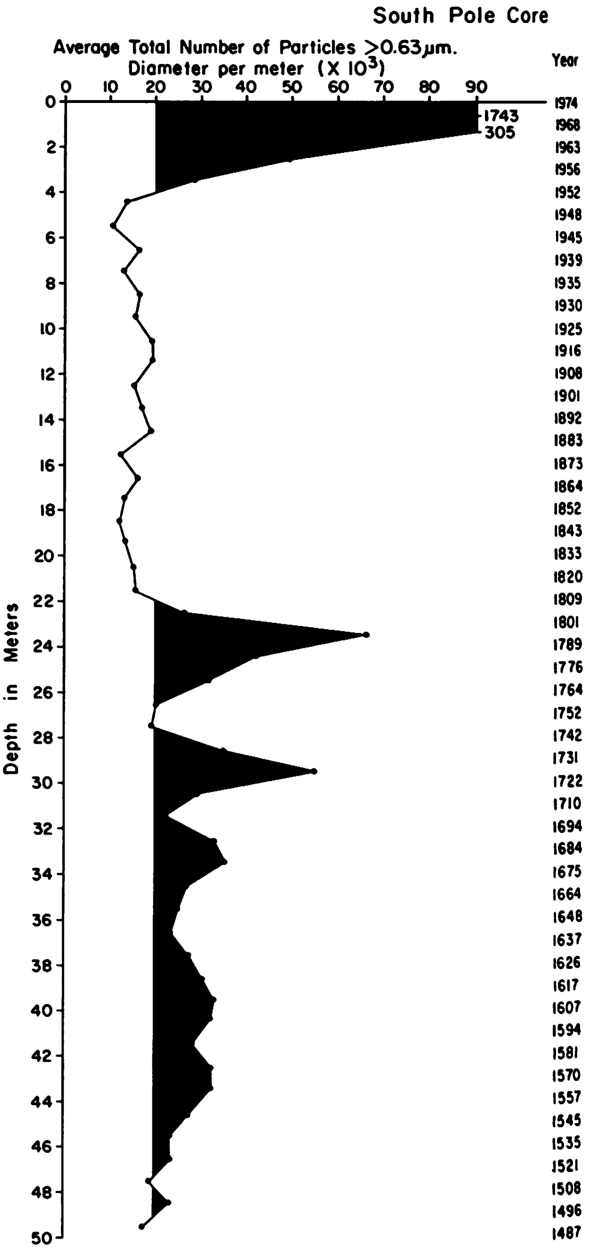
During 3 days in November 1974 a 101-meter core was recovered at the site of the new Amundsen-Scott South Pole Station. We obtained one-quarter sections of this core for a detailed microparticle analysis. The objectives of the research are to test the feasibility of microparticle variations for dating cores from regions of low annual accumulation, to obtain a continuous record of atmospheric turbidity over the last thousand years, to examine the variations in accumulation rates over the last millenium, to ascertain turbidity changes due to increased industrial activities over the last hundred years and investigate possible changes in the elemental content of the aerosols, and to examine variations in particle concentrations, size distributions, and elemental compositions before, during, and since the Little Ice Age.

The microparticle facility described by Thompson (in press) has been upgraded by interfacing the Coulter equipment to automatic send-receive (ASR) teletype equipment and by designing and implementing of a library of computer programs for reduction, storage, retrieval, and representation of the microparticle data. The data from processed samples are selectively examined and plotted, and all data are stored by the end of the following day's processing.

A total of 6,218 samples representing the entire South Pole 101-meter core have been analyzed for microparticle concentrations and size distributions. The final data reduction and comparisons with other core parameters such as variation in oxygen-18, gross beta activity, and ice chemistry should provide an informative chronology of the last millenium. The initial microparticle results are intriguing. The figure illustrates 1-meter averages of the concentration of particles with diameters greater than 0.63 micron for the top 50 meters of the core. The top 3 to 4 meters of the core exhibit anomalously high particle concentrations (figure) as a result of human activities since the establishment in 1956 of 'old' south Pole Station. The dates in the figure are obtained by counting the concentrated particle layers and by assuming the presence of one annual particle peak.

The stratigraphic studies of Giovinetto (1960) which are based on the identification of fall depth hoar layers, yield an annual accumulation rate of 7.4 centimeters water over 69 years (1947 to 1878 A.D.). Using the microparticle chronology and the depth interval between successive microparticle concentration peaks, we obtained a value of 7.8 centimeters water for the same accumulation period. This suggests that the assumption of an annual microparticle concentration peak is probably valid for the South Pole site.



Increase of dust concentration of 2.0 times during the Little Ice Age.

This assumption of an annual cycle has been found to be valid for two other sites in Antarctica, namely Byrd Station (Marshall, 1962; Thompson, in press) and at 66°00'W. 67°32'S. in Graham Land (Thompson, 1977). However, final verification of this assumption for the South Pole gion requires the analysis of surface cores and associated t and stake measurements of accumulation. If the depth of ie 1955 layer (pre-IGY) resulting from the 1954 Castle omic bomb test (yield: 36 megatons) could definitely be tablished by gross beta activity analysis of the top portion f the South Pole core, it would help us set a fixed date from hich to count particle concentration layers.

Assuming that our chronology is reasonably accurate, the igure illustrates a marked increase in the 1-meter particle oncentration averages ($\overline{C}$) for the period between 1530 and 810 A.D., which corresponds to the late Holocene Little ce Age. The $\overline{C}$ value for the 22- to 46-meter segment is 2075 and that for the 13- to 22-meters section (1810 to 1900 .D.) is 15209. Thus the Little Ice Age firn is 2.1 times dirier than the firn immediately postdating that period. The reatest increase in $\overline{C}$ is 66800 for the 23- to 24-meter segment, and this represents a greater than three-fold increase ver the $\overline{C}$ value of 22060 for the 3- to 22-meter section. An rror of up to 10 percent or ± 1 year out of each 10 years, ould not change our general conclusion that atmospheric urbidity at the South Pole was greatly increased during this most widely documented Neoglacial stade.

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Dielectric constant and reflection coefficient of the snow surface and near-surface internal layers in the McMurdo Ice Shelf

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Radio and radar echo sounding of the Greenland and antarctic ice sheets has revealed internal dielectric discontinuous horizons called reflective or internal layers (e.g., Harrison, 1973; Elachi and Brown, 1975; Gudmandsen, 1975; Kovacs and Gow, 1975; and Paren and Robin, 1975). However, because of sounding system limitations, reflective layers have not been detectable within the first 5 meters of snow depth. In January 1977 an impulse radar system was used to profile the shape and lateral extent of the brine layer in the McMurdo Ice Shelf (Kovacs and Gow, 1977). A small antenna (13 by 23 by 35 centimeters) was also used to determine if reflective layers could be detected in the upper 5 meters of snow. The radiated impulse center frequency was 625 megahertz with an estimated frequency spectrum of 375 and 875 at the − 3 decibel points.

The antenna was first supported 60 centimeters above a sheet of aluminum foil. A recording of the two-way travel time (t) of the radiated impulse from the antenna to the foil and back was made on an FM magnetic tape recorder. An individual impulse was later played back onto an X-Y plot (figure 1). Since the velocity of a radar impulse in air (c) is 3×10^8 meters per second and the distance between the antenna and aluminum foil was 60 centimeters, the two-way travel time of the impulse from the antenna to the foil and back was 4 nanoseconds. The distance between the peak of the transmit impulse and its reflected peak from the aluminum foil shown on the X-Y plot in figure 1 is therefore 4 nanoseconds.

The antenna was then supported 60 centimeters above the snow surface (surface − 15 °C). An X-Y plot of the impulse travel time from the antenna to the snow surface and back is shown in figure 1. The amplitude of the reflected signal from the snow surface and the amplitude of the reflected signal from the aluminum foil were then compared to determine the snow surface reflection coefficient and dielectric constant. Since aluminum foil is a perfect reflector, the amplitude of the reflected radar impulse from this surface equals a reflection coefficient (p_f) of − 1. The reflected impulse amplitude from the snow surface is 14.8 percent of that from the aluminum foil. The reflection coefficient of the snow surface (p_s) is therefore −0.148. The dielectric constant (ε_r) of snow was then determined to be 1.81, from:

$$\epsilon_r = \left(\frac{1-p_s}{1+p_s}\right)^2$$

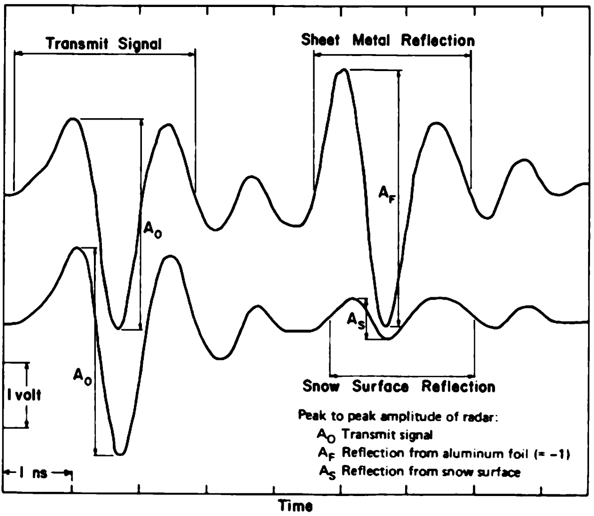

Figure 1. Radar impulse signal reflected from aluminum foil and snow surface.