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DATING GREENLAND FIRN-ICE CORES WITH Pb-210

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The ^{210}Pb dating method is applied to deep thermally recovered firn-ice cores from the North Greenland ice sheet. The ^{210}Pb activity is found to decay exponentially with depth (expressed in water equivalent). The corresponding rate of snow accumulation, averaged over the past 150 years, is (32 ± 3) g/cm^2-yr, in good agreement with present day surface snow accumulation obtained by different methods.

1. INTRODUCTION

^{210}Pb, a beta emitter with a 21.4 year half-life, is one of the natural radioactive nuclides contained in atmospheric precipitation. It is a member of the ^{238}U series and has a tropospheric residence time of about 20 days [1].

The possibility of dating firn or ice layers by radiochemical techniques using the ^{210}Pb isotope was first demonstrated by Goldberg [2] on firn samples from the South Greenland ice sheet representing a time interval of about 20 years.

Similar studies were later carried out in Antarctica on firn and ice profiles spanning a time interval of more than 200 years at both the King Baudouin Base and the South Pole Station [3]. Both of the Antarctic studies support, as a basic assumption of the method, the hypothesis that the initial ^{210}Pb concentrations in polar snows and the rate of snow accumulation have remained approximately constant at these locations during the last 100 years [3, 4].

The study presented here was made to appraise the value of the ^{210}Pb dating method over an appreciable depth profile of the North Greenland ice sheet.

2. CORE SAMPLES AND EXPERIMENTAL PROCEDURE

The core samples used in this investigation were obtained at Camp Century, Greenland (77°10'N, 61°08'W). This site is located on the ice sheet 210 km east of Thule at an elevation of 1885 m and has a positive net annual snow accumulation. The mean annual surface temperature is -24.6°C, but it is not uncommon for air temperatures to rise slightly above the melting point during some summer periods.

Table 1 lists the samples measured for ^{210}Pb activity. Sample No. 1 is a 7.6 cm diameter hand-augered core which extends from the July 1964 snow surface down 12 m to the 1947 firn layer. This sample is the composite vertical core profile upon which detailed stratigraphic and fission product analyses had already been performed [5]. All other samples (2 through 7) are from the upper 76 m of a 12.7 cm diameter 1002 m deep thermal-electro-mechanically drilled ice core (Hansen and Ueda, personal communications).

The upper 76 m of this core was thermally bored in 1961 and stored in a frozen state since that time. During drilling the heat from the thermal boring device physically altered the original firn structure above about 70 m and precluded investigating the core by any of the classical stratigraphic techniques [6]. For this study the deep thermal cores were split in half vertically and the sample increments (2 through 7) ranged in height from 4 m to 13 m. At the moment of melting, July 1965, approximately 5 mg of a lead nitrate inactive carrier in nitric solution was added to each of the 10 to 30 kg samples.

Table 1
^{210}Pb concentration as a function of firn depth, Camp Century, Greenland.

Sample	Depth of core sample (m) *		Depth of core sample (m) (in water equivalent) **		Sample weight (kg)	Chemical yield (%)	^{210}Pb concentration (dph/kg)
	Top	Bottom	Top	Bottom			
1	0	12	0	5.7	19.76	59	170 ± 15
2	14.9	19.7	6.9	9.7	12.70	80	55 ± 6
3	23.1	27.1	11.8	14.3	10.68	98	58 ± 6
4	32.9	42.2	18.1	24.5	31.45	95	21 ± 3
5	43.6	54.0	25.5	33.3	27.59	100	10 ± 2
6	54.0	62.8	33.3	40.2	30.00	100	5 ± 2
7	62.8	75.8	40.2	51.0	30.65	100	3 ± 1

* Depths are measured from the July 1964 reference surface.
** From measured density values.

The ^{210}Pb radiochemical techniques performed in this study are identical to those previously described in detail by Crozaz et al. [3].

3. RESULTS AND DISCUSSION

The concentrations of ^{210}Pb in the core samples as a function of depth are shown in table 1. The depths indicated in water equivalents were obtained by integrating the continuous depth-density data over the profile. The activities measured have been taken to represent the middle of the depth interval covered by each sample. Since the time span represented by each core sample is always less than 30 years, this approximation introduces an error of less than 4% (which has not been taken into account).

To evaluate the contamination introduced by the core drilling operation and the experimental procedures, we have assessed the measured activity of the deepest sample which should be 150 years old (using the accumulation rate obtained in ref. [5]). By taking into account the ^{210}Pb radioactive decay, we calculate a ^{210}Pb contamination of 4 disintegrations per hour per kilogram (dph/kg) for this sample. This value has been subtracted from all the ^{210}Pb activity measurements.

In fig. 1, the logarithm of ^{210}Pb activity is plotted against depth expressed in water equiva-

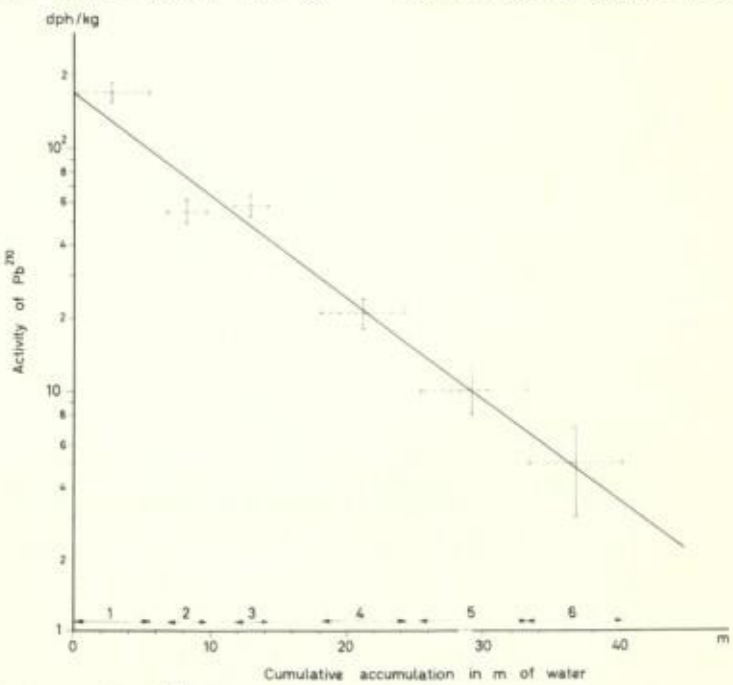

Fig. 1. Variation of the ^{210}Pb activity in the firn as a function of equivalent water depth.

Table 2
Estimates of net annual accumulation at Camp Century, Greenland.

Time interval	Method of measurement	Snow accumulation (g/cm^2-yr)	Reference
1964-1947	Classical firn stratigraphy	31.2	[5]
1964-1947	Fission products	31.2	[5]
1962-1955	Classical firn stratigraphy	31.8 ± 5.7	[7]
1963-1961	Stake measurements	34	[7]
1964-1800	^{210}Pb	32 ± 3	This study

lent. The vertical lines represent experimental errors in the ^{210}Pb measurements. They include the standard deviation of the radioactive measurements and an uncertainty of ±3% in the chemical yield. The horizontal dotted lines specify the depth interval of the core samples. We see that the data approximate a straight line. Using the method of least squares, a best fit line was calculated for the data. From the slope of the line we can infer a mean annual rate of snow accumulation of 32 ± 3 g/cm^2. This value is in good agreement with present day surface snow accumulation measurements obtained by different methods from the same general inland region (see table 2).

The ^{210}Pb concentration extrapolated to zero depth is 170 ± 30 dph/kg (2.9 ± 0.5 dpm/kg). This value is more than twice the 1.3 dpm/kg obtained by Goldberg [2] for South Greenland (71°07'N, 37°19'W) samples. At this stage in the ^{210}Pb investigations, it is not possible to determine whether the difference between the two Greenland stations is due to a geographical effect or to a loss of ^{210}Pb (which is quite likely to occur if the samples are not kept frozen until the addition of the lead carrier).

As expected by considering the geographical distribution of radon sources, the present day ^{210}Pb results from North Greenland are nearly a factor 3 higher than those found in Antarctica [3], and, for the same reason, lower than the mean ^{210}Pb content of 5 dpm/kg in precipitation from the temperate latitudes of the Northern Hemisphere [1].

4. CONCLUSIONS

Seven increments of a 76 m deep firn-ice core from Camp Century, Greenland, were measured for snow accumulation by using ^{210}Pb radioactive decay. The results show activities of 170 ± 15 dph/kg from the surface sample with a linear decay on a semi-log plot, to 3 ± 1 dph/kg for the bottom sample. The obvious interpretation is that both the rate of snow accumulation and the initial ^{210}Pb concentration, averaged over several years, have been nearly constant over the last 150 years at Camp Century. The method is particularly useful to determine snow accumulation rates wherever firn structure is absent as it is the case for thermally obtained deep cores.

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