OXYGEN-ISOTOPE MEASUREMENTS ON 1 700 ± 300 YEAR OLD ANTARCTIC ICE*

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Abstract. Values of $\delta^{18}O_{SMOW}$ measured on ice from 250 m depth at old "Byrd station", Antarctica, averaged about −33‰. A monotonic trend in values through the 16 cm long core piece suggested that part of an annual layer was represented. Snow accumulation in excess of 14.4 g cm⁻² year⁻¹ ca 1 700 years b.p. is indicated.

Résumé. *Mesures des isotopes de l'oxygène sur de la glace de l'Antarctique vieille de 1 700 ± 300 ans.* Les valeurs de la teneur en $\delta^{18}O_{SMOW}$ mesurées sur de la glace venant d'une profondeur de 250 m à la vieille "Byrd station" en Antarctique sont en moyenne de −33‰. Une tendance à trouver des valeurs semblables sur un même élément de carotte de 16 cm de long suggère que l'on avait à faire à une même couche d'accumulation annuelle. On indique un excès d'accumulation de neige de 14,4 g/cm² et par an il y a environ 1 700 ans.

Zusammenfassung. *Messungen der Sauerstoffisotope in 1 700 ± 300 Jahre altem antarktischem Eis.* Die Werte von $\delta^{18}O_{SMOW}$, die in Eis aus 250 m Tiefe an der alten "Byrd-Station", Antarktika, gemessen wurden, betrugen im Mittel etwa −33‰. Ein gleichförmiger Verlauf der Werte durch das 16 cm lange Kernstück weist darauf hin, dass es sich um den Teil einer Jahresschicht handelte. Für die Schneeakkumulation 1 700 Jahre vor der Gegenwart ergibt sich ein Wert von mehr als 14,4 g pro cm² und Jahr.

Introduction

Values of $\delta^{18}O$ have been measured on seven samples of a 16 cm long quarter-piece of ice core from 250 m depth (relative to the 1957–58 summer surface) at old "Byrd station" (10 km west of the new station), Antarctica. The core was drilled in 1957–58 and was shipped to the United States where it was stored at approximately −20°C until the time of the analyses (June 1970). The age of the ice is based on two estimates of snow-accumulation rate. One obtains 1 400 years by using the data of Gow (1968) and 2 000 years from the estimates of Epstein and others (1970).

Sample preparation and analysis

The core was sawn into seven approximately equal-sized samples that were put into plastic bags and then sealed to keep out room air and water vapor. The samples were allowed to melt slowly and, as they did so, the melt water was periodically decanted (five times) and discarded. In this way surface contamination was flushed away, leaving only about 15 g of pure glacier ice. The uncontaminated melt water was transferred by pipette into 200 cm³ flasks. After degassing, the samples were allowed to equilibrate at 25.3°C with tank CO_2 for more than 4 d. Then, a small sample of the equilibrated CO_2 was removed from each flask (in random order) and analysed with the McKinney-Nier mass spectrometer. A second analytical run was made 2 d later. This method has been described by Epstein and Mayeda (1953).

Results

The corrected values of $\delta^{18}O$ (relative to standard mean ocean water, smow) are given in Table I together with the sample data. The $\delta^{18}O$ values have been calculated as follows:

$$\delta^{18}O = \left\{ \frac{R_I}{R_{SMOW}} - 1 \right\} \times 1\,000$$

where R, the mass ratio, is equal to [^{18}O]/[^{16}O], and the subscript I refers to the ice melt water. Taking into account the corrections indicated by Craig (1957), the equilibration correction (Epstein and Mayeda, 1953) and the machine corrections (personal communication from Mrs T. K. Mayeda), $\delta^{18}O$ values were calculated from the measured mass ratios of the samples and the Chicago calcite working standard.

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TABLE I

Sample number	Thickness (depth interval) cm	Sample weight g	δ¹⁸O Run 1	Run 2
1	2.0	15.0	−33.41	−33.42
2	2.3	16.5	−33.10	−33.32
3	2.4	13.6	−32.97	−33.04
4	2.3	13.5	−32.69	−32.86
5	1.9	13.7	−32.69	−32.78
6	1.5	11.8	−32.65	−32.69
7	2.4	16.0	−32.71	−32.72

DISCUSSION

The differences in individual values of $\delta^{18}O$ between runs (Table I and Fig. 1) range from 0.22 to 0.01‰, while the trend of values between samples 1 and 6 in both runs changes monotonically by about 0.74‰. Because the samples were analyzed in random order, the experimental error, while undesirably large in samples 2 and 4, was distributed randomly with respect to length along the core and did not contribute to the trend. The experimental error was probably the result of insufficient equilibration before the first run, because the values for all samples rose in absolute value (became lighter) in run 2, and the tank CO_2 was considerably heavier (-4.59 relative to SMOW) than any of the ice samples.
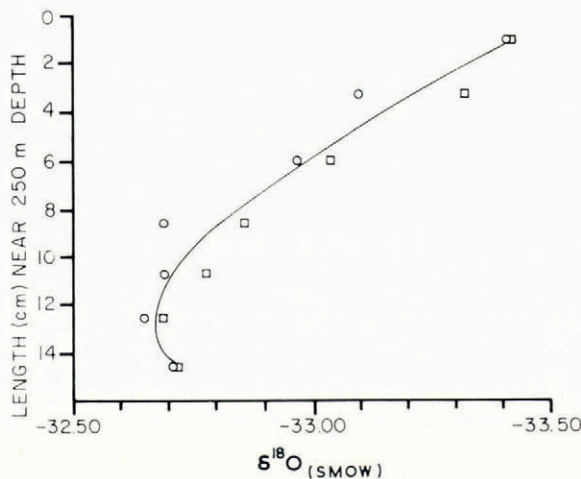

Fig. 1. Oxygen-isotope ratio ($\delta^{18}O$) versus depth in a piece of ice core from old "Byrd station", Antarctica. The circles and squares indicate values obtained in analytical runs 1 and 2 respectively on seven contiguous samples.

The result reported here compares very favorably with the measurements of Epstein and others (1970) on an ice core from new "Byrd station". They obtained average values of $\delta^{18}O$ of between -34 and -32‰ at depths of between 200 and 300 m.

The orientation of the core piece (which end was up) could not be determined, therefore the ordinate axis in the figure is labeled length rather than depth. Nevertheless, the $\delta^{18}O$ values give additional information. If the trend in values is the result of seasonal temperature variation at the deposition site, only about half an annual layer is present, and the amount of annual accumulation for the time and place represented was in excess of 16 cm ice (14.4 cm H_2O). Of course, this probably does not represent average conditions 1 700 years B.P. Moreover, the approximate mean annual temperature represented by this ice is about $-30.3°C$ ($\delta^{18}O_{SMOW} = -0.9T - 6.4$; Picciotto and others, 1960). Finally, it appears that the full seasonal $\delta^{18}O$ variation has been greatly damped, presumably by diffusion, because the apparent seasonal temperature variation is only 0.8°C.

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