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TEMPORAL VARIATIONS IN THE ^{10}Be CONCENTRATION LEVELS FOUND IN THE DYE 3 ICE CORE, GREENLAND

by

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ABSTRACT

In order to study in some detail the variability of the ^{10}Be concentration and its correlation with climatic parameters such as $\delta^{18}O$ we have investigated 28 samples of the deep ice core from Dye 3, Greenland, covering the depth interval from 1 860 to 1 890 m which corresponds to the period 30 to 40 ka BP. The results show that the mean ^{10}Be concentration during this period is higher by a factor of 1.7 than during the twentieth century and that there is a correlation between ^{10}Be results and $\delta^{18}O$ values. A possible explanation is that during cold periods (low $\delta^{18}O$ values) precipitation rates are lower and therefore the number of ^{10}Be atoms per gram of ice is higher. However, processes strongly related to $\delta^{18}O$ values alone cannot explain the entire variability of the ^{10}Be results.

^{10}Be is a radioisotope with a half-life of 1.5×10^6 a. It is produced continuously in the atmosphere by cosmic-ray induced spallation reactions on nitrogen and oxygen. Within a short time it becomes attached to aerosols and after a residence time of 1 to 2 a it is removed from the atmosphere by precipitation and stored in different archives on the Earth's surface. Polar glaciers and ice sheets contain the precipitation of the last 10^5 to 10^6 a in an undisturbed stratigraphy and are therefore best suited to study variations of ^{10}Be production and deposition processes during this time period.

Raisbeck and others (1981) first reported an increased ^{10}Be concentration during the last glaciation and an apparent correlation with $\delta^{18}O$ in Antarctic ice samples. These results were confirmed by more detailed measurements on ice cores from Dye 3, Greenland, recovered in 1981 in the frame of the Greenland Ice Sheet Programme (GISP) which reveal the following results (Beer and others 1983): (i) the ^{10}Be concentration in biannual ice samples of the period 1900 to 1977 shows variations which are correlated with the 11-a solar cycle, (ii) at the end of the last glaciation the ^{10}Be concentration was higher by a factor of 2 or 3 than during the Holocene, and (iii) the ^{10}Be variations during this period and the transition from glacial to postglacial time are correlated with $\delta^{18}O$ values and the CO_2 content of air bubbles in ice.

To study in more detail the variability of the ^{10}Be concentration and its correlation with other parameters we investigated the ice core from Dye 3, Greenland, at a depth from 1 860 to 1 890 m, which corresponds approximately to the time interval 30 to 40 ka BP (Dansgaard and others 1982). This interval shows several strong variations of the $\delta^{18}O$ values. The 30 m-long section of the ice core was cut into pieces of length 1 m, each thus corresponding to about 350 a. The first 3 cm of each piece were used to determine the CO_2 content (Stauffer and others 1984). The rest (1 to 2 kg) was melted and a few ml of water were separated to measure the $\delta^{18}O$. ^{10}Be

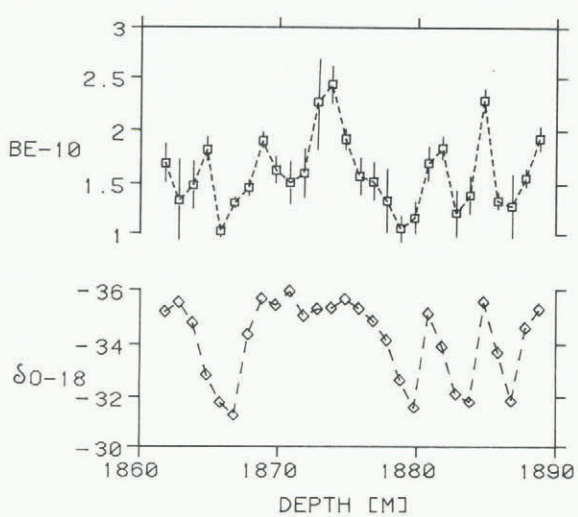

Fig.1. ^{10}Be concentration in units of 10^4 atoms per gram of ice in the Dye 3 deep ice core (upper part) and $\delta^{18}O$ values in parts per thousand (lower part).

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was extracted in the form of BeO as described elsewhere (Beer and others 1983). The ^{10}Be measurements were performed using accelerator mass spectrometry (Wölfli and others 1983). Figure 1 shows the results of the measurements in units of 10^4 ^{10}Be atoms per gram of ice together with the $\delta^{18}O$ data as a function of depth. Large ^{10}Be variations are observed. The lowest values coincide with the mean value of the period from 1900 to 1977 (0.9 ± 0.2), but the mean value (1.6 ± 0.4) is higher by a factor of 1.7 than during that period. There are several possible causes which could explain the ^{10}Be variations: (i) changes of the production rate in the atmosphere due to modulation of the cosmic-ray flux by magnetic properties of the solar wind plasma, (ii) changes of the production rate due to variations in the intensity of the geomagnetic field, and (iii) changes of the precipitation rate or the atmospheric circulation and mixing processes which are responsible for the transport of ^{10}Be from the atmosphere to the Earth's surface.

$\delta^{18}O$ also exhibits strong variations between about -31 and -36 ‰ (Fig.1) indicating significant climatic fluctuations. The variations of ^{10}Be and $\delta^{18}O$ are, in general, parallel. In Figure 2 the $\delta^{18}O$ values are plotted together with the ^{10}Be results. The scale is chosen such that the extreme values of the two parameters fit. The correlation coefficient between ^{10}Be and $\delta^{18}O$ is -0.61 (calculated using equal weights for all data points) and is different from zero with a significance level of 0.975. This strongly suggests that there is a mechanism which causes similar variations of both parameters. From the possible causes of ^{10}Be variations mentioned above, atmospheric processes also influence $\delta^{18}O$. One mechanism which would affect ^{10}Be concentration at the same time as $\delta^{18}O$ is suggested as follows. Low $\delta^{18}O$ values correspond to periods with lower mean temperatures. During colder periods the amount of precipitable water in the atmosphere is smaller than during relatively warm periods. This leads to lower precipitation rates. If the precipitation rate is reduced over large areas and if the atmospheric production rate is assumed to be constant, then the ^{10}Be concentration per unit mass of precipitation is increased (Junge 1977). Further insight into the mechanisms determining the ^{10}Be concentration in precipitation can be expected from measurements of additional parameters such as concentrations of NO_3, SO_4, etc.

The correlation in the depth range from 1 880 to 1 890 m is very good. However, the number of ^{10}Be values is relatively small. For the interval from 1 867 to 1 880 m, which is dominated by low $\delta^{18}O$ values, the correlation is less pronounced. This means that the observed ^{10}Be variations can be only partly explained by changes of a single parameter, such as the precipitation rate. Variations of the atmospheric production rate due to changing solar properties cannot be excluded. ^{14}C measurements on tree rings show that cold periods, for instance the Little Ice Age during the seventeenth century, were accompanied by high atmospheric radiocarbon levels, suggesting that both the isotopic production rate and the climate might be influenced by the state of the sun (Suess 1970).

From the results shown in Figures 1 and 2 we conclude that during the period 40 to 30 ka BP there were strong ^{10}Be variations with amplitudes similar to those at the end of the last glaciation (10 ka BP). The ^{10}Be variations are correlated with $\delta^{18}O$ values, probably due to changes of the precipitation rate. However, to explain the entire variability, changes in other processes such as ^{10}Be production and atmospheric circulation and mixing have to be considered. A more detailed discussion is given elsewhere (Oeschger and others in preparation).

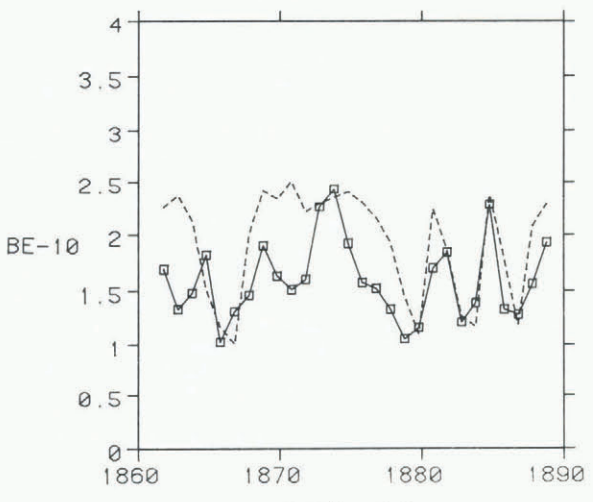

Fig.2. Comparison of the $\delta^{18}O$ curve (dotted line) and the ^{10}Be concentrations (solid line).

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