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ATMOSPHERIC CO_2 VARIATIONS OVER THE LAST CLIMATIC CYCLE (160 000 YEARS), DEDUCED FROM THE VOSTOK ICE CORE, ANTARCTICA

(Abstract)

by

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ABSTRACT

This is a summary of the main CO_2 results obtained from the Vostok core which have been presented in two papers recently published (Barnola and others 1987; Genthon and others 1987).

Previous results of ice-core analysis have already provided valuable information on atmospheric CO_2 variations associated with anthropogenic activities (Neftel and others 1985, Raynaud and Barnola 1985[a], Pearman and others 1986) and with climatic variations back to about 40 ka ago (Delmas and others 1980, Neftel and others 1982, Raynaud and Barnola 1985[b]). The Antarctic Vostok ice core provides a unique opportunity for extending the ice record of atmospheric CO_2 variations over the last glacial–interglacial cycle back to the end of the penultimate ice age, about 160 ka ago.

CO_2 measurements were made at 66 different depth levels on the air enclosed in the 2083 m long core taken at Vostok Station. The air was extracted by crushing the ice, under vacuum, in a cold-room, and analysed by gas chromatography (Barnola and others 1983). The selected sampling corresponds to a time resolution between two neighbouring levels which range approximately from 2000 to 4500 years. The ages quoted in this abstract are based on the Vostok ice chronology given by Lorius and others (1985) and take into account the fact that the air is trapped in the firn well after snow deposition (between about 2500 and 4300 years after precipitation in the case of Vostok). The CO_2 variations observed are compared directly with the changes in Antarctic temperature as depicted by the stable-isotope record of the Vostok ice (Jouzel and others 1988, this volume).

The most obvious feature of the Vostok CO_2 record lies in its high correlation (r^2 = 0.79) with the climatic record. The results obtained show high CO_2 concentrations during warm periods (mean CO_2 values of 263 ppm volume for the Holocene and 272 ppm volume for the last interglacial period) and low concentrations (between about 240 and 190 ppm volume) over glacial periods. Within the last glaciation, the CO_2 concentrations are higher during the first part (mean CO_2 value of 230 ppm volume between about 110–65 ka B.P.) than during the second part (203 ppm volume between 65–15 ka B.P.); the second part also indicates that climatic conditions were colder.

Furthermore, a CO_2-orbital forcing-climate interaction is suggested by spectral analysis of the CO_2 and temperature profiles, which both show a concentration of variance around orbital frequencies. The temperature profile is clearly dominated by a 40 ka period (which can be related to the obliquity frequency) (Jouzel and others 1988, this volume), whereas the CO_2 record exhibits a well-defined 21 ka peak (which can be related to the precession frequencies) and only a weak and doubtful 40 ka peak. To check the relative influence of CO_2 and orbital forcings on the temperature at Vostok, we modelled the temperature signal deduced from the stable-isotope record of the ice as a response to CO_2, Northern Hemisphere ice volume and local insolation forcings. The results indicate that more than 90% of the temperature variance can be explained by these three kinds of forcing and that the contribution of the CO_2 radiative effect associated with an amplification factor (which should reflect the long-term feed-back mechanisms) lies between 27 and 85% of the explained variance. This approach stresses the important role that CO_2 may generally have played in determining the Earth's climate during the late Pleistocene.

Our results point to some limitation on the possible mechanisms driving the atmospheric CO_2 variations and, in particular, the influence of some oceanic areas or of changes in sea-level (see, for example, Broecker and Peng 1986). The weak 41 ka cycle (this cycle seems to be a characteristic of the spectra of the proxy data for high latitudes) in our CO_2 record suggests that high latitudes may not have a major influence on CO_2 variations. Furthermore, the phase relationship between CO_2 and the temperature variations indicates that at the beginning of the two deglaciations around 145 ka B.P. and 15 ka B.P., taking into account the time resolution of our profile, the CO_2 increases roughly in phase with the Vostok temperature. As surface-temperature changes around Antarctica are expected to lead to changes in sea-level (see, for instance, CLIMAP Project Members 1984), our results suggest that the CO_2 increase cannot lag the increase in sea-level and thus that this parameter cannot initiate the CO_2 variation recorded at the beginning of those two deglaciations. Nevertheless, this does not rule out influence of variations in sea-level on atmospheric CO_2 for other periods of interest, in particular during the last interglacial–glacial transition, where the CO_2 lags the Vostok temperature.

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^{10}BE CONCENTRATIONS IN ANTARCTIC ICE

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ABSTRACT

Measurements of the cosmogenic isotope ^{10}Be ($T_{\frac{1}{2}}$ = 1.5 Ma) on Greenland ice cores produced interesting results. Variations in the ^{10}Be concentrations can be interpreted in terms of changes in the production rate and in atmospheric circulation and deposition. During the Holocene, good agreement between short-term variations in ^{10}Be and ^{14}C indicates that the production rate of both isotopes was changing, probably due to solar modulation. During the last ice age, periods with significantly higher ^{10}Be concentrations are observed. The good anti-correlation between ^{10}Be and δ^{18}O suggests that these intervals correspond to periods of low precipitation rates.

Work on Antarctic ice cores is in progress, but only relatively few ^{10}Be data have been published yet. ^{10}Be results from Antarctic ice cores are presented and compared with data from Greenland.

STUDIES ON THE BASAL-ICE ZONE OF FINDELEN GLACIER, SWITZERLAND

by

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ABSTRACT

Basal and englacial debris layers have been observed to coincide distinctly with the location of glacier thrust planes or shear zones, e.g. at Shoestring Glacier (Brugman and Meier 1980) and Variegated Glacier (Kamb and others 1985). They are also evident at Findelen Glacier. Field observations strongly suggest that the mechanics of debris-laden ice can be important for understanding the flow response of certain glaciers. In this paper the material properties of basal ice at Findelen Glacier are examined, as studied with the aid of ice-core drilling techniques.

Ice cores were taken from near the center line of Findelen Glacier during the summer of 1985, for the express purpose of characterizing the basal ice in terms of observed structures, composition and rheology. Related studies were simultaneously performed on bore-hole and surface strain-rate deformation (Iken and others, unpublished) and bore-hole resistivity (Schütz and Röthlisberger 1985). The ice core, retrieved from the deepest level possible (approximately 4 m above the bed), contained only a minor amount of fine rock debris. The presence of a debris-containing basal-ice zone is strongly suggested by the evidence that further hot-water drilling in the bore holes resulted in abraded drill stems and in the irregular progress of the drill for the few remaining meters to the glacier bed. Therefore, during 1986 samples of debris-laden basal ice were taken from several locations where the basal material was clearly exposed along lateral ice cliffs in the ablation area of the glacier.

Three distinct types of ice at Findelen Glacier were compared: clean bubbly coarse-grained ice taken from above the glacier bed, clean clear coarse-grained ice taken from