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## GEOGRAPHICAL VARIATIONS OF OXYGEN-18/OXYGEN-16 RATIO IN SURFACE SNOW AND ICE FROM QUEEN MAUD LAND, ANTARCTICA

by

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## Geographical Variations of Oxygen-18/ Oxygen-16 Ratio in Surface Snow and Ice from Queen Maud Land, Antarctica

THE work recorded here is a continuation of that reported in *Nature*<sup>1,2</sup> on the isotopic composition of Antarctic snows.

The ratio of oxygen-18 to oxygen-16 has been measured in some hundred samples of surface snow and ice in the region of the King Baudouin Station (70° 26' S., 24° 19' E.), and taken from an area extending from the coast to the southern slopes of the Sør-Rondane Mountains, situated 300 km to the south. Information concerning the geodesy and morphology of this region has been published<sup>3,4</sup>.

These samples were collected during the Belgian Antarctic Expeditions of 1959 (Commandant F. Bastin) and 1960 (Commandant G. Derom).

Detailed results will be published elsewhere. We report here only those results relative to samples of which the thickness represents one or more years of accumulation, in order to minimize the seasonal variations.

The ratio of oxygen-18 to oxygen-16 is expressed, as in previous publications, by  $\delta$ , in parts per thousand of relative variation with respect to the standard mean ocean water (SMOW).

Fig. 1 shows the locations at which samples were taken and the values of  $\delta$ . Each value corresponds, in general, to the average of several neighbouring samples of similar isotopic composition.

Fig. 2 shows the variations of  $\delta$  as a function of the altitude at which the samples were taken. We have added two points taken from other publications: the point from the South Pole according to Epstein and Sharp<sup>5</sup>, and a group of points corresponding to Victoria Land, and measured by Roth, Nief and Botter. The latter points have been estimated from the average content of deuterium reported by Lorius<sup>6</sup>, and the altitudes reported by Stuart and Heine<sup>7</sup>; the deuterium concentrations have been translated into  $\delta$  according to the relation found at the King Baudouin Station in 1958<sup>2</sup>.

Despite the poor statistical value of samples of which most represent only one year, the values of  $\delta$  follow well the general scheme of variations of isotope composition of precipitations<sup>8,9</sup>. It is known that the value of  $\delta$  depends principally on the temperature of precipitation. In the Antarctic, the average annual temperature is essentially a function of the altitude.



TABLE 1. AVERAGE OXYGEN-18/OXYGEN-16 RATIO OF SURFACE SNOW FROM THE FOUR GEOGRAPHIC ZONES—PRINCESS RAGNHILD COAST

Zone	$\delta$ (SMOW) averages
Sea ice* and ice-shelf (68°-70° S.)	-22
Continental slope (70°-71° 30')	-22 to -26
Mountains (71°-72°)	-26 to -37
Polar plateau (73°-90°)	-37 to -50

\* Snow precipitated on the ice-pack. The sea ice itself shows  $\delta$  of + 1.

Table 1 indicates that the four classical geographical zones of the Antarctic are characterized by clearly different values of the  $\delta$  of precipitations.

The most-pronounced difference is between the ice formed on the plateau and that formed on the continental slope. The variation of  $\delta$  in the 300 km separating the coast from the mountains is as great as the variation over the whole of the polar plateau. This corresponds to the increasing spacing of the curves of equal elevation, equal temperature and equal accumulation when proceeding from the coast toward the centre of the continent.

It will be important to make a network of measurements of  $\delta$  of surface snows extending throughout the continent, as well as measurements of  $\delta$  as a function of the depth at diverse points of the Antarctic ice-cap. These data could provide important information on the large-scale displacements of the ice-cap (see, for example, ref. 10 in reference to Greenland).

We take from the present work two examples of information which can be derived from the application of isotope methods on a more local scale:

(1) The sample of ice *LD* comes from a region of the continental slope where the bare ice is exposed over large areas, at more than 60 km from any rocky outcrops. The origin of these fields of bare ice is still controversial. In this particular case, the isotopic composition ( $\delta = -22$ ) indicates that this ice does not come from the polar plateau, but that it must have been formed at the expense of snow precipitated in the same zone (assuming that it has never experienced strong evaporation).

(2) The entire zone of the Sør-Rondane Mountains shows traces of important glacial recessions. Although most of the glaciers of the northern slopes no longer connect with the plateau, it is probable that in the past the ice-cap ran over the mountain range.

It can be seen (Figs. 1 and 2) that all the samples taken from the northern slope of the range have about the same isotopic composition ( $\delta = -30$ ), whether it is bare ice from the ablation zones, or surface snow representing recent precipitation. These ices, then, were formed from local precipitations, and do not represent possible remainders of the ice-cap, dating from before the recession.

Only the sample *GU* has a clearly more negative  $\delta$  (-39). This value is in good agreement with the geographical



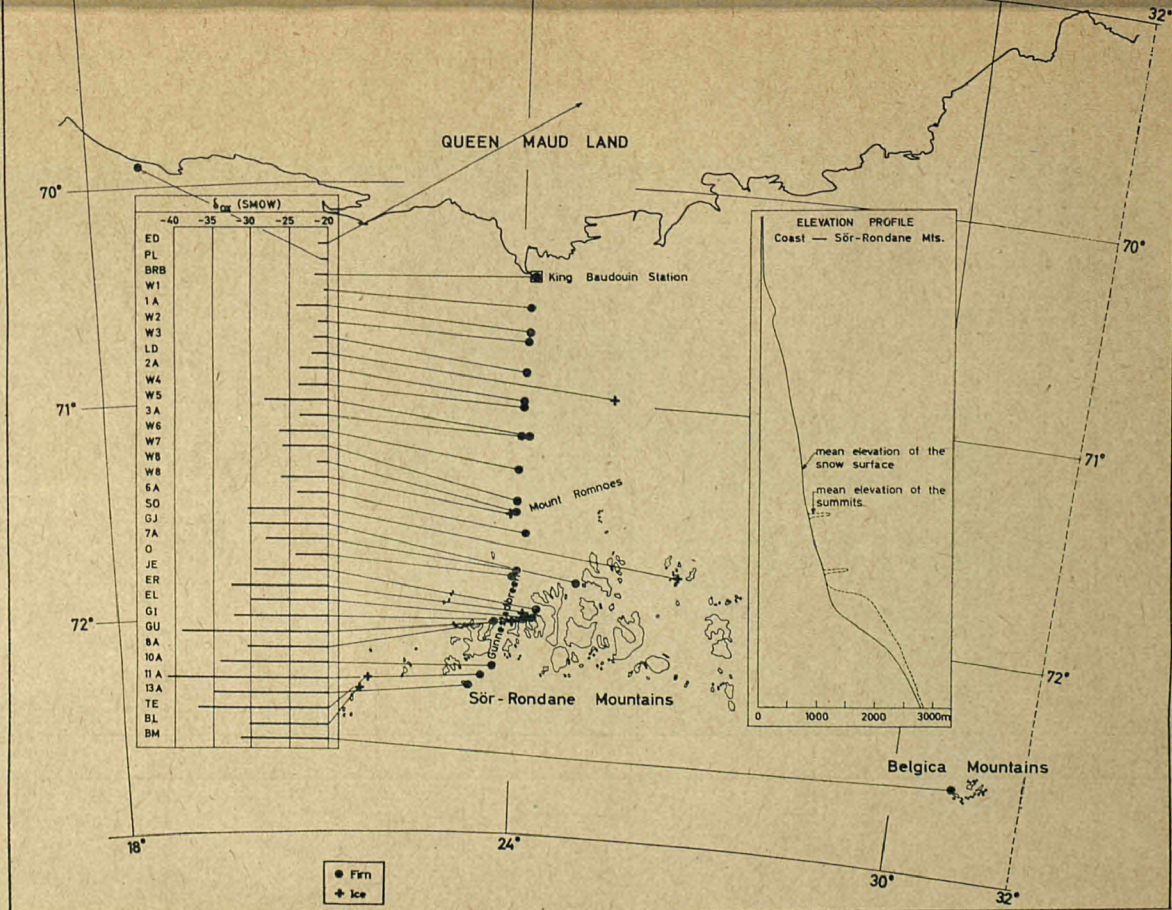


Fig. 1. Geographical distribution of surface samples and annual average  $^{18}\text{O}/^{16}\text{O}$  ratio

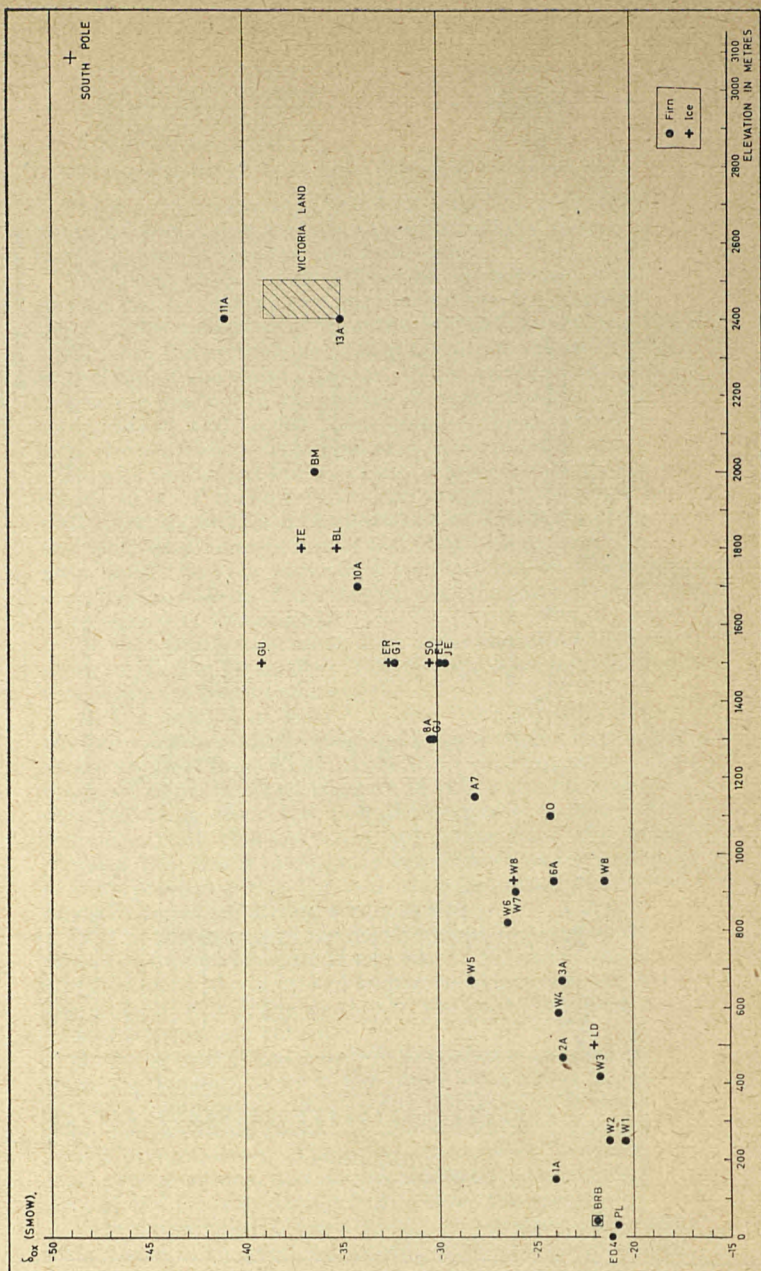


Fig. 9. Annual average 150/150 ratio of surface samples as a function of altitude, Victoria Land and South Pole from Lorius (ref. 6) and



facts. In fact, this sample is the only one which comes from an outlet glacier (the Gunnestadbreen), still in connexion with the plateau and presenting a measurable surface flow (maximum displacement of the order of 10 m/year, according to K. Blaiklock and T. Van Autenboer).

We thank the members of the Belgian Antarctic Expeditions of 1959 and 1960 and of the summer journeys which participated in the collection of samples, notably F. Bastin, T. Van Autenboer, J. Giot and J. Loodts.

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<sup>1</sup> Gonfiantini, R., and Picciotto, E., *Nature*, **184**, 1557 (1959).

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<sup>3</sup> Loodts, J., *Résultats scientifiques, Expédition Antarctique Belge 1957-1958, Géodésie* (M. Weissenbruch, S.A., Bruxelles).

<sup>4</sup> Picciotto, E., *Ciel et Terre*, **77**, 126 (1961).

<sup>5</sup> Epstein, S., and Sharp, R. P., *IGY Bull.*, No. 21 (1959).

<sup>6</sup> Lorius, C., *Ann. de Géophys.*, **17**, No. 4, 378 (1961).

<sup>7</sup> Stuart, A. W., and Heine, A. J., *J. Glaciol.*, **3**, No. 30, 997 (1961).

<sup>8</sup> Epstein, S., and Mayeda, T., *Geochim. et Cosmochim. Acta*, **4**, 213 (1953).

<sup>9</sup> Dansgaard, W., *Geochim. et Cosmochim. Acta*, **6**, 241 (1954).

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