

a depth of 15 m. in 1931 had already hinted at the surprising absence of a temperature increase with depth<sup>1</sup> which has been clearly shown in the much deeper bores of the French Expedition to the same region in 1949-51<sup>2</sup>. Sorge had suggested (p. 269) that the horizontal removal of heat by the moving ice was the most likely reason for the nearly isothermal state of the firn layers; but this anticipation by no means diminishes the merit of Robin's work which for the first time puts the explanation of this surprising feature on a firm footing and opens the way to a more detailed study of the phenomenon, once more extended observations of the physical state of the upper layers of the ice cap become available.

Robin assumes in his derivation of equation (7) for the vertical temperature distribution in an ice cap that the horizontal temperature gradient is negligible. As according to Table I the vertical temperature lapse rate in a thick ice cap is also very small, one does not at first sight easily see what becomes of the heat which continuously emanates from the ground, and it might have been useful to show that even with the very small horizontal temperature differences allowed ( $< 10-8^{\circ}\text{C./cm.}$ ) the necessary heat transport can be accomplished.

It has previously been discussed among glaciologists that the vertical temperature distribution must be influenced by the fact that the ice below the surface has been deposited at a greater height and consequently under a lower temperature; but it is important to find in Robin's paper this vague impression replaced by a numerical expression. Further observations of the temperature distributions in deeper layers which are planned during the International Geophysical Year will enable us, following the line indicated by Robin, to separate this effect from that of climatic changes.

It is likely that the strong temperature lapse at Borg and West Station are not so much due, as suggested by Robin, to shear or thinning of the ice as to the heating of the lower layers by the infiltration and refreezing of melt water in crevasses.

It might finally be mentioned that simultaneously with Robin P. Jaspersen (*Über Schmelzvorgang und Wärmehaushalt im Zentralgebiet des Inlandeises, Eiszeitalter und Gegenwart*, Bd. 6, 1955) in a very elementary discussion also arrives at the conclusion that the greatest fraction of the heat gained in the central parts of a stationary ice formation is lost to that region and that it is doubtful whether any melting occurs at the bottom of the ice.

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#### REFERENCES

1. Brockamp, B., and others. *Glaziologie*. Leipzig, F. A. Brockhaus, 1935. (Wissenschaftliche Ergebnisse der deutschen Grönland-Expedition Alfred Wegener 1929 und 1930/1931, Bd. 3.)
2. Holtzscherer, J.-J., and Bauer, A. *Contribution à la connaissance de l'inlandsis du Groenland . . . 2e partie (no. N.II.3), synthèse glaciologique*. Paris, Expéditions Polaires Françaises, 1954.

#### COMMENTS ON DR. LOEWE'S LETTER

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I WOULD like to thank Dr. Loewe for his kind remarks and for drawing attention to the earlier comments of Sorge on this subject.

Dr. Loewe's suggestion about the effects of melt water at Borg and West Station may well be correct and further field observations are needed to solve this point. The essence of the point concerning heat transport outwards from the centre of the ice sheet, is that this is coupled with the mass transport of ice and is similar to advective heat transfer in meteorology. The various equations are included to show that this effect, due to downward and outward spreading of the ice, may be sufficiently great with large ice sheets to make the normal process of thermal conduction negligible near the surface. In such a case the horizontal temperature gradient could be zero or even negative (decreasing outwards) with the necessary outward transport of heat still taking place.

#### CONCLUSION OF VOLUME 2

This issue closes Volume 2 of this Journal. Full particulars will shortly be available in regard to an index, title page and binding cases. Back numbers may be had on application to the Secretary in Cambridge.