is expected to remain for a longer period to oversee the experimental work of the company until it is well under way.

DR. SAMUEL J. HOLMES, professor of zoology at the University of California, who has been traveling in Europe during the past year, has returned to Berkeley.

DR. ROBERT K. NABOURS, who is spending the year as associate in the department of genetics of the Carnegie Institution at Cold Spring Harbor, will return to the Kansas Agricultural College on September 1.

DR. ALEXANDER SILVERMAN, head of the department of chemistry of the University of Pittsburgh, sailed on August 21 for Europe. He will visit educational and research institutions in France, Holland and Belgium, and will attend the Tenth International Congress of Industrial Chemistry at Liége, Belgium, during the week of September 7, as a delegate from the American Ceramic Society, and the tenth International Union of Pure and Applied Chemistry, also at Liége, during the week of September 14, as one of fifteen delegates from the National Research Council and the National Academy of Sciences.

DISCUSSION

RELATIVE LENGTH OF PLEISTOCENE GLACIAL AND INTERGLACIAL STAGES

IN a report by R. T. Chamberlin[1] dealing with fluctuations of sea-level as controlled by glaciation, an estimate is presented of the percentage of the Pleistocene glacial epoch involved in glacial as compared with interglacial stages, and also an estimate of the percentage of time in a glacial stage in which the ice-sheets were at about their greatest extent. The estimates were given him by ten American glacialists who had had considerable experience in the study of glacial deposits in North America. In this composite estimate the glacial stages were given only one fourth the length of the interglacial stages, or 20 per cent. of the time involved in the Pleistocene glacial epoch. It was estimated by seven of the ten glacialists (three failing to give estimates) that the ice-sheet was at about its greatest extent for only one fifth of a glacial stage, or 4 per cent. of the glacial epoch, being in process of advance and retreat for four fifths of the glacial stage or 16 per cent. of the glacial epoch.

It now appears from a study of the distribution of moraines developed in the Wisconsin stage of glaciation that there was very little difference in the area covered by the ice-sheet throughout the greater part of that glacial stage, or from the time of the outermost Early Wisconsin moraine, the Shelbyville, to the time of the outermost Late Wisconsin moraine, the Port Huron. By extensive westward growth in Middle and Late Wisconsin time beyond the limits reached in Early Wisconsin time, the shrinkage shown by the exposed part of the Early Wisconsin deposits in the south part of the area was counterbalanced by the greater westward extent in higher latitudes. This shifting seems to have been due to a greater nourishment on the western side of the ice-sheet rather than to a change to higher temperature. The southern part became undernourished and showed a corresponding shrinkage. In view of these conditions it is probable that not less than 60 per cent. of the Wisconsin stage should be allotted to the culmination, and 20 per cent. each to the advance and the retreat of the ice-sheet.

From a study of the recession of Niagara Falls by Spencer, Taylor and others[2] it appears that the Port Huron morainic system, which marks the limits of the Late Wisconsin drift, was formed some 25,000 to 30,000 years ago. It also appears from a study of the Falls of St. Anthony on the Mississippi by Winchell, Grant and especially by Sardeson[3] that the outlet of the Glacial Lake Agassiz did not shift to Hudson Bay until some 8,000 to 10,000 years ago. This being the case the Wisconsin ice-sheet persisted in central Canada to within 10,000 years of the present time. It also appears that a period of about 15,000 years is involved in the retreat from the Port Huron moraine to the breaking up of the ice-sheet in central Canada. If then this retreat represents 20 per cent. of the time involved in the Wisconsin stage of glaciation, the length of this glacial stage is some 75,000 years and its beginning about 85,000 years ago. If then the culminating phase involved three fifths of the entire glacial stage, it endured some 45,000 years.

Estimates of the relative ages of the Kansan, Illinoian and Wisconsin drifts are based mainly on the erosion each has suffered. The Kansan drift appears to have been eroded to such a degree that an average of fifty feet of material would be required to restore the original surface as left by the withdrawal of

[1] Rollin T. Chamberlin, "Geological Interpretation of the Coral Reefs of Tutuila, American Samoa," pp. 145–178, Publication 340, Carnegie Institution of Washington, 1924.

[2] See Niagara Folio, U. S. Geological Survey.

[3] See St. Paul-Minneapolis Folio, U. S. Geological Survey.

the Kansan ice-sheet. The Illinoian drift is sufficiently eroded to require about fifteen feet for its restoration. The Early Wisconsin drift seems to need only five feet and the Middle and Late Wisconsin still less. The Iowan drift is too thin and patchy to furnish a basis for measurement of its erosion. The Nebraskan drift is so completely covered by the Kansan that its degree of erosion can not well be determined. That it is much older than the Kansan drift is known, however, from the development of gumbotil on its surface prior to the burial beneath the Kansan drift, and also by deep leaching and oxidation. On the basis of relative erosion the Illinoian drift appears to be about three times as old as the Early Wisconsin drift. Taking the estimates given above, the outer part of the Early Wisconsin drift is about 70,000 years old, in which case the age of the outer part of the Illinoian can be put at about 200,000 years. The close of the Illinoian glacial stage, however, may be between 150,000 and 175,000 years ago. The age of the Kansan drift appears to be more than a half million years and may reach three fourths of a million. The Nebraskan is probably a million years old.

There is no question of the occurrence of long interglacial intervals of relatively warm climate between the Nebraskan and Kansan glacial stages and between the Kansan and Illinoian stages. The latter appears to be more than four times the length of the Wisconsin glacial stage and thus to bear out the estimate made by glacialists and reported by Chamberlin. But there seems need for a recalculation of interglacial intervals between the Illinoian and Wisconsin glacial stages. The place and rank of the Iowan glaciation are also of importance in this connection.

An early interpretation that the Iowan is a distinct glacial stage falling between the Illinoian and Wisconsin glacial stages is still stoutly adhered to by several glacialists, but the present writer and also T. C. Chamberlin have expressed the view that the Iowan may stand as the western or Keewatin phase of the same glacial stage as the Illinoian and have a similar relation to it that the Late Wisconsin drift has to the Early Wisconsin.

If the Iowan is a distinct glacial stage, falling between the Sangamon and Peorian interglacial stages, it should fill a considerable part of the interval separating the Illinoian and Wisconsin stages and thus leave a very brief interglacial stage between it and the Illinoian stage, as well as between it and the Wisconsin stage. As a separate glacial stage the Iowan would probably embrace at least 30,000 years, the time estimated for the advance and disappearance of the Wisconsin ice-sheet. Taking the above estimate that the Illinoian glaciation ended 150,000 to 175,000 years ago and that the Wisconsin glaciation began about 85,000 years ago, there would be an interval of between 65,000 and 90,000 years between these two glacial stages. If the Iowan glaciation occupied 30,000 years in the midst of this interval, there would remain 35,000 to 60,000 years to be divided between the Sangamon and Peorian interglacial stages. In case of so brief interglacial intervals it may be more consistent to regard the Illinoian, Iowan and Wisconsin as a triple glaciation occupying the 200,000 years since the culmination of the Illinoian glaciation, and consider the Sangamon and Peorian times of slightly increased warmth between times of low temperature, causing a marked retreat of the ice border but not having the duration or degree of warmth of a true interglacial stage. This raises the question whether the ice had disappeared in the Sangamon or the Peorian interval to as great degree as at the present time in the northern part of the North American continent. The data at hand do not seem to be decisive on this matter.

It is of interest in this connection to note that Dr. Paul Woldstedt, a member of the Prussian Geological Survey, after spending a summer in the study of the North American drifts, in order to clear up correlations with the drifts of Europe, on which he had made extensive studies, has placed the Iowan drift in the midst of the European third interglacial stage in his recent book "Das Eiseitalter."[4]

The present writer, as already indicated, favors the reference of the Iowan drift to the same glacial stage as the Illinoian and places it near the close of the third glacial stage, about as the Late Wisconsin came in the last glacial stage. The combined Illinoian-Iowan, it is thought, may have covered a period similar to that of the Wisconsin, about 75,000 years, from say 210,000 down to 135,000 years ago, leaving an interval of 50,000 years between its close and the beginning of the Wisconsin stage. On this interpretation, as on that of a separate Iowan glaciation, it is an unsettled question whether the northern part of the North American continent was deglaciated to the present degree in this interval. The well-known Toronto interglacial beds suggest a warmer climate than the present, but it is not certain that they fall in this interglacial stage. They may prove to belong in the second, or Yarmouth, interglacial stage.

The Iowan drift displays a conspicuous pebbly concentrate on its surface, developed before the surface coating of loess was laid down. The development of this concentrate the present writer is disposed to refer to the Sangamon interval and consider a somewhat full equivalent. But it is thought by those geologists who are putting the Iowan in a separate and

[4] See table on page 292.

later glacial stage than the Illinoian that this concentrate was formed in a very short time, largely by wind action. As matters now stand, there seems need to determine whether or not this concentrate was formed in a short time. The mere declaration that it was formed rapidly is not to be taken as decisive, even if several geologists unite in the declaration.

The present writer is also skeptical of an interpretation which restricts the glaciation of one stage to the eastern part of the continent and of a succeeding stage to the central part of the continent, for in the Nebraskan, Kansan and Wisconsin stages there was glaciation over both the eastern and the central part. It thus seems more natural for the Illinoian of the eastern part to have its equivalent in the Iowan of the central part.

In the above estimates it was calculated that if the third or Illinoian glaciation covered only the eastern part of the continent it may have lasted only about 50,000 years, or from 210,000 down to 160,000 years ago. But if it covered the central as well as eastern part of the continent and embraced the Iowan it is likely to have lasted 75,000 years, or down to 135,000 years ago.

Summing up the matter of the relative proportion of time involved in the Pleistocene glacial and interglacial stages, it appears that fully 75 per cent. of the last 200,000 years has been under glacial conditions, but that prior to this the interglacial conditions were prevalent for at least 75 per cent. of the time. If then the entire Pleistocene period embraces a million years, the glacial conditions were prevalent for about 300,000 years, and the interglacial conditions for about 700,000 years, of which some 50,000 years, falling in the Sangamon and Peorian intervals, may not have been as warm as the present.

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THE OXYGEN CONSUMPTION OF NERVE DURING ACTIVITY

THE recent article in this journal by Professor Winterstein[1] dealing with the above question has just come to my attention. The increase in oxygen consumption, over its resting value, of a nerve, stimulated by induction shocks, has been regularly interpreted as measuring the active metabolism of conduction. Winterstein presents reasons for considering this excess oxygen as the result largely or entirely of a local response to an artificial stimulus, and therefore unrelated to the normal events of conduction. Some of the points he makes are as follows. (1) When the region of the nerve actually stimulated is in the respiration chamber, the resting oxygen consumption is increased up to 400 per cent.; but when the excited region is excluded and the conducting trunk studied only a 14 per cent. increase or, in his own experiments, no increase is observed. (2) The extra oxygen consumption of the frog's spinal cord is much greater on direct electrical stimulation than when excited *via* a nerve—even when strychnized. (3) After stimulation of a dog-fish spinal cord no longer evoked muscular responses an excess oxygen consumption was still to be obtained. (4) The oxygen consumption of a snake's vagus nerve was not changed when the central and peripheral connections were severed, although normal spontaneously passing impulses were abolished.

It may not be amiss to point out here some possible answers to these points other than that suggested by Winterstein, as well as to indicate some of the important evidence that can not, apparently, be reconciled with his view. (1) It seems unwise to express the oxygen consumption of activity as a percentage of the resting, since much evidence indicates that the variables are independent. The resting metabolism is largely a carbohydrate oxidation or glycolysis, the active surely not. The former depends on nerve fibers, sheath, connective tissue, etc., while the latter is presumably limited to the axones themselves; and these structural elements vary widely from species to species. As a matter of fact, for dog-fish lateral line nerve the percentage increase in respiration on activity as determined by Parker, stimulating outside the experimental chamber, and Fenn, stimulating within, was almost identical. For the American green frog, Parker found a 14 per cent. increase; Fenn a 26 per cent. increase, and I (1930),[2] also stimulating within the chamber, a 35 per cent. increase. For the European frog I found for continuous stimulation a 100 per cent., for intermittent stimulation a 300–400 per cent. increase. The absolute increase in all cases, allowing for temperature, etc., was roughly the same —the values obtained when the stimulus occurred inside the chamber were *not* higher than when it was excluded.

(2) It is doubtful if even on direct electrical stimulation of the spinal cord all nerve cells are activated, and also glia and other cells may be stimulated or injured. The increased oxygen consumption is determined by the sum of all. Stimulation of an afferent nerve not only will fail to affect non-nervous tissues, but also there is ample evidence that, even after strychnine, such afferent impulses will not reach all cells and of those reached not all will be excited—some are actually inhibited. The reflexly evoked

[1] H. Winterstein, SCIENCE, 71: 641, 1930.

[2] R. W. Gerard, *Proc. Soc. Exp. Biol. and Med.*, 27: 1052, 1930.