It is only when astronomical data are combined with Babylonian dates that we can hope to determine the corresponding Julian date.

Another similar question which chronology has to answer is, whether the change of date was reckoned according to a point of time, or according to the civil day. According to the evidence brought forward by Ideler, the ancients were convinced generally that the Babylonians reckoned the day from one sunrise till the next, and therefore made the change of date take place in the morning. Ideler finds a difficulty here, in that such a supposition would hardly be compatible with a chronology depending on the changes of the moon. We must allow that he is right, and we think we have sufficiently proved that the first day of each month coincided with the first visibility of the crescent moon. Whether the Babylonians were first prompted by the Macedonians, at the outset of the Seleucidæan era, to put off the date till evening, cannot be learnt from the documents, but it is not probable, if we disregard Pliny, Censorinus, &c., for they reckoned in lunar months earlier. If we honour these historical statements as we are bound to do, there is yet a kind of explanation to be offered.

We have seen that the Babylonians referred their calculations for the new moon to midnight, so that astronomically speaking the change of date was accomplished at this hour, so it is not impossible that they did not forestall the civil day, but let it succeed the astronomical. This is nothing but a conjecture, in order not to reject the authority of the ancients.

The last chronological element upon which we have to speak is the division of the day. It is generally accepted that the Babylonians cut up the day into twenty-four hours—twelve day and twelve night hours. There is so much evidence here that we cannot doubt the fact. Our tables show another division which was in use among astronomers. It is completely demonstrated in the calculation tables, where the whole day is split up into six divisions, and each division into sixty subdivisions, so that the whole day falls, like the circle, into 360 parts, of which one equals four of our minutes. For the sake of calculation, the subdivision is carried on to sixty, and yet another sixty. The application of this method of calculation shows itself also in the ephemerides, first of all to express the duration of visibility with regard to the moon, and also to declare the time when, according to calculation, an eclipse should happen. It is remarkable that we have here two starting-points, sunrise and sunset; while in each case it is announced how many degrees of time before or after these terms the eclipse will happen. The extreme points, therefore, for both then touched at midday or midnight.

TEMPERATURE IN THE GLACIAL EPOCH.

THE late long frost has naturally suggested the question, What permanent fall of temperature would produce a recurrence of the Glacial epoch? It is a question not easily answered, for it is like a problem complicated by too many independent variables. It is not enough for us to ascertain the actual temperature of a district in order to determine whether it will be permanently occupied by snow and ice. There are regions where the ground, a short distance below the surface, is always frozen to a depth of several yards at least; and yet glaciers do not occur, even among the hills, because the amount of precipitation is so small that the summer rapidly dissipates what the winter has collected. There are other regions partly covered by ice though their mean annual temperature is distinctly above the freezing-point; as where glaciers descend to the sea from hilly districts, of which a considerable area lies above the snow-line, and on which there is much precipitation. In the case of Great Britain, at least, a further difficulty enters into the problem—namely, that much controversy still prevails as to the interpretation of the symbols upon which our inferences in regard to the temperature of these islands during the Glacial epoch must depend. Some authorities would concede no more than that the highland districts of Scotland, Wales, and England were enveloped in snow and ice, and the glaciers, whether confluent or not, extended from their feet for a few leagues over the lowlands—say, to some part of the coast of Lancashire and of Northumberland; while others desire to envelop a large part of the British Isles in one vast winding-sheet of ice, a corner of which even rested on the brow of Muswell Hill, above the valley of the Thames. The one school regards the Boulder Clay of England as a deposit mainly submarine, the product of coast-ice and floating ice in various forms; the other attributes it exclusively or almost exclusively to the action of land-ice. Into this thorny question we do not propose to enter. The approximation which we shall attempt—and it can only be a rough one—can be easily modified to suit the requirements of either party.

We will assume throughout that the annual isothermal of 32° coincides with the line of permanent snow. This, obviously, is an assumption; often, owing to small precipitation, it will be found to be erroneous, but we take it as the only simple approximation, for, under favourable circumstances, masses of ice may protrude beyond it.

The question, then, may be put in this form. Assuming a sufficient amount of precipitation, what changes of temperature are required in order to bring within the isothermal of 32° regions which are generally admitted to have been occupied by land-ice during some part of the Glacial epoch?

First, in regard to the British Isles. All will admit that in many places the Cumbrian and Cambrian glaciers descended to the present sea-level. The mean temperature of the Thames Valley near London is 50° F. This isotherm cuts the Welsh coast a little east of Bangor. Obviously, the whole region north of this line has a lower mean temperature, no part of the British Isles, however, being below 45°. Hence a general fall of 18° would give a temperature of 32° at most in the Thames Valley and on the shores of North Wales (except on the extreme west), while on the coasts further north the temperatures would range down to 27°. What would be the effect of this? Switzerland may enable us to return an answer. The snow-line in the Bernese Oberland may be placed roughly at 8000 feet above the sea, but it is obvious that the chief feeding-ground of the Alpine glaciers lies rather higher up in the mountains. In the case of such glaciers as the Great Aletsch, or the Aar, the lowest gaps in their upper basins are rather above 10,000 feet, while the surrounding peaks range, roughly, from 12,000 to 14,000 feet, though but few exceed 13,000 feet. Thus the feeding-ground of the Oberland glaciers may be regarded as equivalent to a mountain district the sky-line of which ranges from rather above 2000 to 5000 feet. In reality, however, not very much of it exceeds 4000 feet above the snow-line. This, indeed, rather overstates the case. We find practically that the effective feeding-ground, that which gives birth to glaciers, which protrude for some distance below their supply basins, may be placed about 1000 feet above the ordinary snow-line; so that the glacier-generating region of Switzerland may be regarded as equivalent to a mountain district with passes about 1500 feet, and peaks not often exceeding 3000 feet. It follows, then, that if the temperature at the sea-coast in North Wales were 32°, the whole of the Scotch Highlands, and a large part of the Cumbrian and Cambrian Hills would become effective feeding-grounds, and the glaciers would be able to descend into the plains. In the Alps, the larger glaciers terminate at present at altitudes of from 4000 to 5500 feet (approximately); that is, they descend on an average about 4000 feet below the effective feeding-ground, or 3000 feet below the snow-line. If the temperature of Bangor were not higher than 32°, then the Snowdonian district would be comparable with one of the Alpine regions where the mountains rise generally from about 1000 to 3000 feet above the snow-line; that is, with such a one as the head of the Maderanerthal, where none of the peaks reach 12,000 feet above the sea. Here the Hüfi Glacier leads to passes rather below 10,000, among peaks of about 11,000 feet in altitude, and it terminates a little above 5000 feet. That is to say, a region, rising roughly from 2000 to 3000 feet above the snow-line, generates a glacier which descends more than 2000 feet below it.

But what change is required to give a Glacial epoch to Switzerland? It is generally agreed that an ice-sheet has enveloped the whole of the lowland region between the Alps and the Jura. Let us assume that, other conditions remaining the same, this could occur if the mean annual temperature of this lowland were reduced to 32°. Its present mean temperature varies somewhat; for instance, it is 45°·86 at St. Gall, 49°·64 at Lausanne. Let us take 47°·5 as an average, which is very nearly the mean temperature of Lucerne.[1] So this lowland requires a fall of 15°·5. We may take the average height of the region as 1500 feet above the sea. If, then, we begin the effective gathering ground at 1000 feet higher, the valley of the Reuss from well below Wasen, and the valley of the Rhone from a little above Brieg, would be buried beneath *névé*. So that probably a fall of 16° would suffice to cover the lowland with an ice-sheet, and possibly bring its margin once more up to the Pierre-à-bot above Neuchâtel; at any rate, a fall of 18° would fully suffice, for then the mean temperature of Geneva would be slightly below 32°.

The line of 41° passes through Scandinavia a little north of Bergen; if, then, the climate of Norway were lowered by the same amount, which also is that suggested for Britain, the temperature at this part of the coast would be 23°, corresponding with the present temperature of Greenland rather south of Godhavn; and probably no part of Norway would then have a higher mean temperature than 26°.

The wants of North America are less rather than greater; though, as geologists affirm, an ice-sheet formerly buried all the region of the Great Lakes and descended at one place some fifty leagues south of the fortieth parallel of latitude. Its boundary was irregular; but if we strike a rough average, it may be taken as approximately corresponding with the present isotherm of 50°. The temperatures, however, in North America fall rather rapidly as we proceed northwards. Montreal is very nearly on the isotherm of 45°, and this passes through the upper part of Lakes Huron and Michigan; that of 39° runs nearly through Quebec and across the middle of Superior, while at Port Arthur, on the same lake, the temperature is only 36°·2. If, then, we assume sufficient precipitation, the maximum fall of temperature required for this North American ice-sheet will be 18°; but less would probably suffice, for the district north of the St. Lawrence would be a favourable gathering ground. This would be brought within the isotherm of 32° by a fall of 12° or at most of 13°.

It seems, then, that if we assume the distribution of temperature in the northern hemisphere to have been nearly the same as at present, we require it to have been lowered, at any rate in the regions named, by about 18° in order to bring back a Glacial epoch. For North Wales a reduction of about 20° might be needed, but if the isotherms ran more nearly east and west, 18° for the Thames Valley might suffice. If we assume the great extension of glaciers in Central and North-Western Europe to be contemporaneous with that in America, we must suppose that these parts of the northern hemisphere had a climate more nearly resembling, but even colder than, that which now prevails in the southern hemisphere. The isotherm of 40° runs a little to the south of Cape Horn; that of 45° passes north of the Straits of Magellan. The latter lie on parallels of latitude corresponding with those of North Wales, but their mean temperature is about 8° lower. If we could restrict ourselves to the British Isles, it would be enough to assume a different distribution of temperature from that which now prevails on the globe, for at the present time, and in the northern hemisphere, the isotherm of 32° twice comes down very nearly to the latitude of London; but it may be doubted whether this alone would account for the great extension of the Alpine glaciers, and the difficulties seem yet greater in the case of North America. Here, where even at present the temperature is rather abnormally low, we have to make a very considerable reduction. But this is too wide a question to discuss at the end of an article in these pages. We seem, however, fairly warranted in concluding that, whatever may have been the cause, a lowering of temperature amounting to 18°, if only the other conditions either remained constant or became more favourable to the accumulation of snow and ice, would suffice to give us back the Glacial epoch. T. G. BONNEY.

[1] St. Gall, 45°·86 F.; Berne, 46°·58; Lucerne, 47°·48; Zurich, 48°·20; Neuchâtel, 48°·74; Geneva, 49°·46; Lausanne, 49°·64. St. Gall and Berne are rather high stations, the one being 2165 feet, the other 1760 feet. The lake of Lucerne is 1437 feet above the sea.

SURVEYING AND LEVELLING INSTRUMENTS.[1]

THIS volume fills a gap that has been long felt in consequence of the great dearth of good books treating of instruments used for surveying and levelling. Various books and pamphlets contain descriptions and methods of using instruments of this class, but there is no work in which each instrument is so completely treated as in the present volume.

The author's former work, which has been found to be a most useful help and guide, and is now in its sixth edition, was limited to drawing instruments, among which were those for plan drawing and calculation of areas. The present work is intended to complete the subject by describing theoretically and practically the different instruments that are required and used at the present day. Not only does the author give an excellent and complete description of each typical instrument, but in many cases he shows the methods of use adopted in the field; thus placing before us a good and trustworthy text-book.

Of the instruments treated therein, one is surprised at the many and various kinds that are in use. Among some of the less common instruments we may mention a tacheometer, our illustration (Fig. 1) showing the author's latest pattern of this instrument. As regards its general appearance, it differs very slightly from a theodolite, but, when closely examined, it will be found that the graduation of the arcs and circles is made upon the centesimal system, the circle reading 400 grades, and reading to 0·01 grade by a micrometer or vernier. The compass is of the cylindrical form, and is inside the small telescope placed below the horizontal circle, and is read by a very ingenious method. The telescope is made of a much larger size and of higher power than those generally employed in theodolites. To facilitate calculation, a logarithmic slide-rule forms part of the equipment of this instrument. A very neat and ingenious mining survey transit, the result of various improvements suggested by the author, is illustrated in Fig. 2. It should be found of

[1] "Surveying and Levelling Instruments." By William Ford Stanley. (London: E. and F. N. Spon, 1890.)