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1929

719TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL,
WESTMINSTER, S.W.1, ON MONDAY, FEBRUARY 18TH, 1929,

AT 4.30 P.M.

LIEUT.-COL. F. A. MOLONY, O.B.E., IN THE CHAIR.

The Minutes of the previous Meeting were read, confirmed, and signed, and the HON. SECRETARY announced the following elections:—As Associates: T. H. H. Foster, Esq., and Mrs. E. Wieland.

The CHAIRMAN then introduced Lieut.-Col. T. C. Skinner, R.E. (ret.), to read his paper on "The Ice Age: its Astronomical Cause, and the bearing of Drayson's Discovery on the Biblical Account of the Deluge."

*THE ICE AGE: ITS ASTRONOMICAL CAUSE, AND
THE BEARING OF DRAYSON'S DISCOVERY ON
THE BIBLICAL ACCOUNT OF THE DELUGE.*

By LIEUT.-COL. T. C. SKINNER, R.E. (ret.), F.R.Met.Soc.

(Illustrated by Gyroscope and Lantern Slides.)

FOR the geologist the Ice Age has presented a problem at once most fascinating and most baffling. There is no doubt about the fact: evidences lie all around us of enormous tracts of country in Europe, in America, and in the Southern Hemisphere having at one time, or more than once, been covered with ice-sheets to which there is nothing comparable

to-day save in polar regions. The ice seems to have crept down from the Poles toward the Equator till something set a limit; after which it seems to have withdrawn as mysteriously, till naught has remained save polar caps and mountain glaciers.

When all this occurred has been the subject of many guesses, ranging from 7,000 to 1,000,000 years ago. Perhaps it is not quite fair to call them guesses; geologists have time-scales in certain local phenomena, which help toward determining dates, and the tendency is steadily toward increasing accuracy. But the most baffling problem of all has been to assign a satisfactory cause. At least seven causes have been offered, of which I will name, for the moment, only five:—

- (1) The gradual cooling of the earth;
- (2) Variation of the sun's heat;
- (3) The earth passing through a colder zone of space;
- (4) Different distribution of land and water in connection with the flow of ocean currents;
- (5) Alteration of the earth's axis of rotation.

The other two, which have to do with the eccentricity of the earth's orbit and the obliquity of the ecliptic, will be more readily understood later on.

Baffled in their quest of a terrestrial explanation, time and again geologists have appealed for an astronomical cause, but without avail; astronomers have hitherto declared that there is no really satisfying astronomical explanation, and they are, generally speaking, of the same opinion to-day. The purpose of this paper is to show that, local influences apart, the underlying general cause of the Ice Age is astronomical; that it has been shown to be so for more than half a century; and that it can be proven to be so to-day by any astronomer willing to break with the great traditions of the past, and give the question a full hearing and a reasonable test.

I yield to no one in whole-hearted admiration for the magnificent work of astronomers, past and present. I love the men, reverence their work, and sympathize with their difficulties, yet one cannot fail to see that the sheer weight of an immensely valuable built-up system is against acceptance of a new and revolutionary idea from the start, and has prevailed. Without presumption may I suggest that in this case, as so often in the past, the *good* has proved to be the enemy of the *best*?

Before going farther I will ask you to refer to the chart of the

polar hemispheres. Take a little time to study the present and former glaciated areas in America, Europe and the Antarctic ; the dark shades indicating the present, and the lighter shades the former, glaciations. It is an old chart (1888 or earlier) and in need of some revision, but will serve the purpose.

Now, taking Major Marriott's comprehensive definition of a glaciation as " a pronounced lowering of the winter temperature in the Polar and Temperate Zones, enabling glaciers to form at elevated centres of ice-dispersion, and to spread therefrom over certain areas of low elevation, conditioned by the configuration of the land, and by the amount of precipitation in the centres of ice-dispersion," our next step will be to look for these centres of ice-dispersion, which, for short, I will term *ice factories*.

Any important mountain-range with a snow-line is potentially an *ice factory*, but not all are suitably placed for other than purely local glaciation. The Himalayas, for example, though the highest mountains in the world, being in the sub-tropics, have only local effect, and even the Alps, nearly 20 degrees farther north, are but local in effect at the present time. To find an *ice factory* capable of causing glaciation over wide land areas now, we must go north or south to the Frigid Zones, and, to-day, they are only to be found in Greenland and Antarctica.

Again, though a factory can make ice, and go on making ice till its bins are full—so to say—not every factory, even in polar regions, can cause a glaciation. It may lack facility for " delivering the goods." If it has a sea-front it can deliver by sea in the form of icebergs ; but to deliver overland it needs a low-level land-front (or the equivalent), on which the ice can be pushed out in the form of a moving sheet.

Consider the process. Warm winds deposit their moisture on the mountains in the form of snow, and the snow keeps on piling up till its lower layers, aided by soakage from the top, are condensed and compressed into glacier ice. Gravity then operates to force this ice down the valleys, somewhat like a stream of lava, till it finds outlet at the valley mouth, and reaches a point where rate of flow is equalized by rate of melting, when it thaws and runs away as a river.

On the way down, the ice-river bends this way and that in going over or round obstacles, causing crevasses above or below, or on either side. Incidentally also many boulders and much mountain detritus, falling on the surface, are borne along till they either melt their way through to the bottom or are deposited

as lateral or terminal moraines. If the glacier be situate in a Temperate Zone it generally terminates near the valley mouth, but if in a Frigid Zone its radius of influence is extended over land or sea till a more distant melting limit is reached.

Then as the ice-sheet pushes its way down across country from the factory, the boulders, etc., on the surface, melting through to the bottom, are forced along underneath, scratching rock faces, or smoothing and rounding surfaces, till some resting place is found, either at the limit of glaciation, or short of it. In one locality in Ontario, I noticed a substantial house, built of rubble from boulders lying all around, that obviously did not belong to that area at all, but had been "delivered to site" by ice-sheet from some mountain, perhaps, many hundreds of miles away—an economic proposition for the man that built the house.

Now we will run quickly through a few slides that illustrate ice-movement:—

- (a) The Mer de Glace ;
- (b) Sketch of an iceberg illustrating submergence ;
- (c) Sketch showing how a berg is formed, like launching a ship ;
- (d) A berg just formed ;
- (e) Another on a cruise ;
- (f) An ice-mountain, weather-worn and probably ancient ;
- (g) Ice-worn rocks and erratics ;
- (h) Sunken forest (there is evidence of Wales having sunk upwards of 1,400 feet).

Other evidences of glaciation are derived from Arctic shells ; from flora and fauna and their migrations, clay deposits, etc.

Depths of ice-sheet during the Glacial Epoch are variously estimated: *e.g.* in Britain, 4,000 feet ; in North America, 9,000 feet (a mean) ; in one centre, Keewatin, the inferred thickness was 18,000 feet. In Antarctica the *average* thickness is estimated at 5,000 feet now ; *maximum* thickness in the Ice Age would therefore be vastly greater.

Referring again to the chart, please note what I would call the *throw of the ice factories*, due to the centrifugal effect of the daily rotation ; the outward throw from the Poles. Possibly it may be insignificant ; but, be it small or large, it will surely be greater away from than toward the Poles. From Greenland one would expect the throw to be principally southward, delivering ice-

bergs to the Atlantic and glaciation to Canada, while Scandinavia and Scotland would tend principally to throw southward over Europe and into the Atlantic. The south polar cap would, of course, throw northward in every direction.

The chart shows no glaciation in Siberia. This is a defect, as recent research shows glaciation of fairly large areas. Still the fact remains that there are not the same evidences of general glaciation as elsewhere, and, so far, no satisfactory explanation has been offered. May I, with all diffidence, suggest what may supply the basis of an explanation in the fact that, whereas the long northern strip of Siberia is low-lying and generally flat, there is no northern *ice factory* along the coast, or between it and the Pole, capable of "delivering the goods." Scandinavia could not do it, and Greenland is on the wrong side of the Pole; while the local mountains in Northern Asia are neither large enough nor suitably situated to feed a general glaciation; their effect could only be local.

Must we then conclude that Siberia had no part or lot in the general glaciation? Not quite that, but, in place of a vast moving ice-sheet on the northern plains, I suggest that we should look for heavy snowfalls in winter, followed by meltings and excessive floods in summer, and local glaciations.

So much, in brief, for evidences of the Glacial Epoch; now for the Astronomical cause. But before proceeding further, I will illustrate some movements of heavenly bodies by gyroscope. We are favoured to-day in having the use of a very fine instrument lent for this demonstration by Mr. A. E. Mundy, who has come himself, most kindly, to help us. The flywheel of the gyroscope is mounted in ball-bearings, and when spun at 15,000 revs. a minute it will run for some hours. We could spend a long and profitable evening playing with this beautiful toy, but I must confine myself to briefest possible employment.

First, notice its extraordinary behaviour as I hold it in its carriage and seek to turn it round; it resents the movement and turns a somersault rather than submit. *Next*, notice how it will balance itself on these two stilts and carry on quite happily if left alone. I will now mount it on this pedestal and attach a long vane, as a sort of semaphore, to its North Pole, and a counterweight to its South Pole, when, in addition to its *rapid rotation* on its polar axis, it will add a *second, very slow rotation*, round the vertical axis of the pedestal—a motion that, in astronomical circles, goes by the name of *precession*.

I want you to notice carefully that, if I try to push the Pole down, the gyroscope objects, and runs away sideways to avoid it. Or if I try to push it up, it does its "flank march" in the opposite direction. Even if I hit it hard on the head I can make very little impression.

Now, however, please notice that, if instead of pushing at the Pole, I merely touch the trunnions either way, the gyro., most obligingly, does all I want. Thus, if I hustle the precession, the Pole rises as if in protest, while if I gently retard the precession the Pole drops in acknowledgment. This experiment I am going to repeat, as it is invaluable. I rudely bear down on the gyro., and even hit it on the head, and it resents such treatment with every fibre of its mechanism. Now, however, with consummate tact and this little bit of string, I put gentlest pressure on the trunnions, and lo! the gyro. bows its head in graceful response as if before a royal personage. The moral is obvious and very beautiful: "Gently does the trick."

Now, as we slow it down—while still pursuing its first motion of rapid rotation, and its second motion of slow precession—it will illustrate for us a third motion called *Nutation* or "nodding." All three motions we will find exemplified in the *Solar System*, to which we will now refer (Fig. 1). Here a few definitions will refresh our memories and ensure a common background to our thoughts.

The Sun in Fig. 1—which, of course, is bigger than all the planets put together—has had, for reasons of space, to be shown as a mere dot in the centre. Otherwise the Planets are shown more or less in their right proportions and in their several orbits at varying distances from the Sun, the order of the principal ones being as follows, working outward:—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. Their orbits are not circular but elliptical, the Sun being in one or other focus. Ellipticity of the Earth's orbit is not great. For convenience the orbits are all shown as if in the same plane as the Earth, but the planes of the orbits really differ, Mercury's, for example, being inclined at 7 degrees, the greatest. The plane of the Earth's orbit is termed the *Ecliptic*, because it is in this plane that eclipses of the Sun and Moon must occur; when the Moon is above or below this plane it cannot eclipse the Sun or be itself eclipsed by the Earth.

For convenience I will refer to the *Ecliptic* plane as horizontal, and its axis, so to speak, as vertical; the terminal points of this

imaginary axis, above and below, are known as the Poles of the Ecliptic.

Now, taking a bird's-eye view and looking down from above, we will find that all the Planets revolve around the Sun in direction against the hands of a watch. Likewise each Planet rotates on its own axis in direction against the hands of a watch, or from West to East. The picture is too small to show the Moon, our satellite, properly, but it also revolves around the Earth, and rotates on its own axis from West to East.

Again, the picture is too small to show the inclination of each Planet to its orbit, but the artist has contrived to show Jupiter as nearly vertical, and Saturn with a considerable tilt, which is as it should be.

Turning now to Fig. 2, here in the middle we have a representation of the Seasons, as the Earth takes its annual course round the Sun. You will at once notice the tilt of about $23\frac{1}{2}$ degrees: this is termed the Obliquity of the Ecliptic (O.E.), being the angle between the Ecliptic plane and the plane of the Earth's Equator. It is the tilt that is responsible for the Seasons, it being summer in the north when the Sun is north of the Equator, and *vice versa*. It is really very simple, reminding one of the schoolboy's howler, who, when asked to give an illustration of expansion and contraction due to heat and cold, replied: "The days are longer in Summer and shorter in Winter."

Next you will note that when the Sun is actually crossing the Equator, it is either Spring as in the lower phase, or Autumn as in the upper, the actual instants of crossing being termed the Vernal and Autumnal Equinoxes.

Localities on the Earth are fixed by the Co-ordinates of Latitude and Longitude, latitude cutting the Earth in slices parallel to the Equator, while longitude cuts it in segments like an orange, from pole to pole. Certain parallels of latitude serve also to divide the Earth into its Zones, Torrid at the Equator, Frigid at the poles, and Temperate in between.

Will you now please observe these four globes of Fig. 3, resembling four Spanish onions, each with its stem and its taproot. They are intended to represent any heavenly body with its imaginary north and south poles, heeling over at various angles of tilt. The Sun you must suppose to be on the right.

The globe on the right is vertical, the next one is tilted at 30 degrees, the third at 60 degrees, while the fourth is at 90 degrees. Now notice that, in each case, the tilt is the exact measure of

the obliquity and *vice versá*. But notice, further, that both alike determine precisely the position of the polar circles, *vide* the second globe. Thus, if tilt and obliquity are 30 degrees, the polar circles must come down exactly 30 degrees, from the poles; if 60 degrees, the polar circles must come down 60 degrees. In the right-hand globe, the axis being vertical, the polar circles are reduced to geometric points; while in the left-hand globe they expand to 90 degrees and meet at the Equator.

Now, bearing in mind that the polar circles mark the limit of the North and South *Frigid Zones*, try and think out the implications: if the globe is vertical, frigid zones simply do not exist; if it is horizontal, its entire northern hemisphere (or southern) is a frigid zone, and is subject to intense cold in winter, followed by intense heat in summer; while, between these extremes of the vertical and horizontal axes, each differing angle of tilt furnishes you with a differing depth of frigid zone for its poles.

Please now examine Fig. 4, depicting five of the principal Planets inclined to their orbits, as they actually are ascertained to be at the present time: JUPITER on the right, with a tilt of 2 degrees; the EARTH next, with its tilt of $23\frac{1}{2}$ degrees; MARS, with a tilt of 25 to 28 degrees; VENUS heeling over at 75, and URANUS at 80 degrees. Now put two and two together. The obliquity or tilt determines the polar circles and frigid zones, therefore, other things being equal, the obliquity will determine the polar ice-caps. If no obliquity, no frigid zones and no ice-caps; but, given a large obliquity, you are bound to have equally large frigid zones, and, *other things being equal*, you ought to expect correspondingly large ice-caps. I have italicized the qualification, since local conditions must always differ, and polar caps can hence rarely, if ever, correspond in size and shape.

Another factor making for inequality is the eccentricity of the Planet's orbit. If very eccentric, it is clear that one Pole will gain advantage over the other, or the reverse, according to whether it, or the other, enjoys the closer approach to the Sun in summer.

We now arrive at the question: "Has the Earth ever had a greater obliquity than now in common with some other Planets?" To answer it we will have to go somewhat deeper into Astronomy.

Fig. 5 will help us to understand what is termed the Celestial Sphere. The Heavens are deemed to be a great hollow sphere of infinite radius, on the surface of which stars are set out and Sun and Planets move to and fro in their appointed courses.

The Earth is deemed to be at the centre of the sphere. The plane of the Equator, produced to the great sphere, is termed the Equinoctial, and the angle between Equinoctial and Ecliptic is simply our old friend the obliquity. The point P, where the Earth's axis cuts the great sphere, is termed the Pole of the Heavens. The point E, vertically above the centre of the Ecliptic, is the Pole of the Ecliptic; S represents a star, etc. In the great sphere, stellar positions, etc., are determined, as in the Earth, by co-ordinates similar to latitude and longitude, but termed Declination and Right Ascension. The intersections of the Equinoctial and Ecliptic give the Vernal and Autumnal Equinoxes, and it is from the Vernal Equinox that Right Ascension is measured in hours, just as we measure our longitudes from Greenwich in degrees. I may add that distances on the great sphere are measured, not by linear measure, but by degrees of the angles subtended at the centre of the sphere: an hour corresponds to 15 degrees.

Now, recalling the gyroscope and its precessional movement, think of the Earth as a gyroscope rotating on its axis once every 24 hours, and performing, in addition, a secondary rotation or precession. Imagine the vertical axis terminating in E to be the vertical axis of the gyroscope pillar; then, just as the gyroscope precessed round the vertical axis, so the Earth, with its polar axis terminating at P, should, one would think, precess around the vertical axis which terminates in E. In other words, the point P will very slowly describe a circle around E as centre, with a radius of $23\frac{1}{2}$ degrees. And, further, just as the gyro. varied its precessional motion by a little nodding motion termed Nutation, so the Earth, under the pull of the Moon, will vary its precession by Nutation, which will cause the pole to trace a wavy line, as illustrated in Fig. 6, in place of the smooth circular arc one would expect. Each nod of the Nutation movement takes 19 years to complete, and for purpose of calculation the pole is assumed to trace the smooth circular arc, correction being made for Nutation as necessary. The precession is supposed to take 25,868 years to complete.

This precessional movement, however, was at the outset loosely defined and confusion has resulted. Sir John Herschel in his *Outlines of Astronomy*, Art. 316, at first stated that the pole "describes a circle in the heavens around the Pole of the Ecliptic as a centre, keeping constantly at the same distance of $23^{\circ} 28'$ from it in a direction from East to West, and with

such a velocity . . . that the whole circle would be described by it . . . in 25,868 years." But, later on, in Art. 640, he showed that it had long been recognized by astronomers that the obliquity (which is the same thing as the Earth's tilt) was decreasing, *i.e.* the radius of the precessional circle was decreasing and could not therefore be constant.

Some 60 years ago, Capt. A. W. Drayson, F.R.A.S., who was for 15 years Instructor in Astronomy at Woolwich, was challenged by a Cadet as to the meaning of the contradiction, *a constant radius that continually diminished*, and from that day he set himself, by hard work of investigating, to clear up the mystery. It would take too long to describe his method in detail—I have here a leaflet giving particulars, of which any who desire may have a copy—but a brief reference to Fig. 7 will help. Drayson first procured all the old star catalogues he could, going back 1,400 years or more; then he prepared a very large plan, on which he traced the assumed course of the pole round E, the Ecliptic Pole, as centre. Then by selecting stars that for the time being did not vary their distance from P, he obtained a number of intersections, and, after "trial and error" extending over five years of intensive study and observation, he ascertained without doubt that, in place of tracing its circle round E as centre, the pole had been, for the past 1,400 years, tracing a circle round a point C, 6 degrees away from E, and with a constant radius of $29^{\circ} 25' 47''$. This he tested over and over again, till satisfied that it represented a true fact of Science. His figures are available to any who may desire them.

From this fact flow vastly important issues. It will be obvious to anyone that such a disclosure must immediately modify many processes in Astronomy, and cut across some cherished theories. From the first, Drayson's discovery proved unwelcome, and to this day it has never had any official investigation worthy of the name. I merely state the fact, but will couple therewith the hope that ere long it will be made the subject of a genuinely scientific inquiry.

If you will refer to Fig. 8 now, two of the more obvious issues will appear. C is the centre of the Drayson arc; E the Ecliptic Pole and centre of the supposed precessional circle; P is intended to show, very roughly, the position of the pole at the present time. If it moved round E as centre, the pole would follow the dotted circle of $23\frac{1}{2}$ degrees radius, and would finish its round in 25,868 years; but, since the actual centre has been

established by strict geometry to be C, and not E, the pole will follow the larger circle of radius $29\frac{1}{2}$ degrees and take about 31,686 years to get round.

Now, however, you will note that E-P, $23\frac{1}{2}$ degrees, is our old friend the Obliquity, or tilt (you see it in elevation in the celestial sphere, Fig. 5). If, therefore, the pole really did follow the dotted circle, the Obliquity would remain constant (save for the very small effect of Nutation); but since it follows the larger circle, it will be obvious that the distance from E to P, as it moves round the larger circle, will vary continually. For instance, when P is at Z, in line with E and C, the distance E-Z or E-P will be a minimum (actually $23^{\circ} 25' 47''$); whereas when at W, the distance E-W or E-P will be a maximum, or $35^{\circ} 25' 47''$. The plain meaning of this is, that when the pole was at W, the far end of its beat, the Obliquity was nearly 12 degrees greater than it is at present.

Now do you begin to see the meaning of it all? The Obliquity, which is now about $23\frac{1}{2}$ degrees, must, at 13548 B.C., have been about $35\frac{1}{2}$ degrees: *i.e.* the Earth had 12 degrees more tilt, the Polar Circles were 12 degrees nearer the Equator, and the Frigid Zones were 12 degrees wider than now. The effect of this will be illustrated by the next slide.

Here, to help the eye, I have reproduced Fig. 8, with its two circles as before, and these two circles, the small and the large, I have applied to the two globes below, making them look uncommonly like Scottish thistles. The left-hand globe of Fig. 9 shows the kind of Frigid Zone the Earth would have if it precessed round E as centre; but the right-hand globe shows the expansion of that Frigid Zone when at maximum Obliquity, due to precessing round C instead of E. You see the difference.

Therein lies the chief (I do not say the only) cause of the Glacial Epoch, in the greatly intensified cold conditions of winter, spread over 12 degrees more of the temperate zones (North and South) than now, succeeded by greatly intensified heat of summer, causing melting and moving of the ice formed in winter. Both are essential, for without melting there can be no movement of the ice-sheet, or relatively little.

The next slide, that of the Eastern Hemisphere, shows us that at date 13548 B.C., the whole of Scotland, and of England down to Durham, was within the then Arctic Circle, which is amply confirmed by the facts of glaciation. The next, that of the

Western Hemisphere, shows the Arctic Circle as then including the whole of Hudson's Bay, which it undoubtedly did.

Turn now to another consideration. There is a word employed by astronomers to denote the fraction of incident sunlight which is reflected by a heavenly body. They call it the ALBEDO, a word I would like you to remember. It is a question of percentage. Thus, if sunlight be denoted by 1·00, the Albedo of a particular Planet might be ·5, say, or more or less. Standing in the lime-light, my face may possibly reflect 10 or 15 per cent. of it, and you could, if in a merry mood, say that was my Albedo. But if I were to deliver a ton of coal to your coal-cellar and trim up the mess afterwards, 1 per cent. would likely cover all you would see of my Albedo at the end of the business.

Now let us look at a few Planets in such slides as I have been able to get together :—

JUPITER,	with a tilt of 2 degrees,	has an Albedo of	·62.
MARS	„ 25 „ „		·22
			(notice the ice-caps).
SATURN	„ 27 „ „		·72.
VENUS	„ 75 „ „		·76.
URANUS	„ 80 „ „		·6.

You will notice that Venus is the most brilliant of all, having an Albedo of ·76, and you will appreciate the intensity of the light she reflects when you learn that it is nearly six times as bright as that of the Moon, the Albedo of which is only ·13. The figures are from Dr. Spencer Jones's admirable book on *General Astronomy*, and now I will read you what he says about it, in Art. 137 :—“The Albedo of Venus has the high value of ·76, which is about equal to the reflecting power of freshly fallen snow. As few, if any, rocks or soils have so high a reflecting power, the value would seem to indicate that the Planet is mostly or entirely cloud-covered.” Cloud-covered? and with Frigid Zones coming down to within 15 degrees of the Equator, and an Albedo of freshly fallen snow—conditions of extreme glaciation!

The same distinguished writer, referring to the ice-caps of MARS (Art. 139), says :—“These polar caps, whose interpretation as formed of ice and snow, can hardly be doubted, etc.” MARS, with a tilt of 25 degrees and undoubted ice-caps to correspond, has an Albedo of ·22 only. VENUS, with three times the

tilt and three and one-half times the Albedo, is thought to be "cloud-covered." Pray, why should it not be covered with ice and snow?

Dr. Jones has not hitherto been quite a protagonist of the Drayson doctrine. I welcome, therefore, the more readily this unconscious testimony to its correctness; though, to Major Marriott belongs the credit of first interpreting the brilliance of VENUS as a link in the chain of evidence of glaciation.

Please remember that word ALBEDO, and when you get home to-night, turn up 2 Cor. iii, 18, write Albedo in the margin and think about it.

Return now for a few moments to Fig. 8, and, regarding the larger circle as a "Great Year" divisible into four Seasons, you will have its mid-winter at W when the glaciation was at its height; autumn at A when it was beginning; spring at S when it was coming to an end; and we are now nearing the mid-summer period when, with Obliquity at its minimum, winter and summer contrasts will be least marked. This is in part confirmed by the researches of Dr. Ernst Antevs, of the University of Stockholm, in his recent publication entitled "The Last Glaciation" (American Geographical Society),* and, further, in a recent paper on "Historic Climatology," by Dr. C. E. P. Brooks, F.R.Met.Soc., who shows that as we go farther back, the range of temperature, winter and summer, widens out.

The worst phase of the Glacial Epoch would thus have run from about 21000 B.C. to about 5600 B.C., and you will readily understand that the piling up of these enormous ice-caps must have robbed the sea of a tremendous quantity of water, all of which had to be refunded. Thus the melting of snow and ice year after year, with cumulative effect, at or near 5600 B.C., must have furnished a very large quota to the universal deluge of Gen. vii, which may well have occurred any time after that date.

One more slide and we have done. We have recently had many references in the Victoria Institute to the structure of the Atom, which, on Sir Ernest Rutherford's hypothesis, resembles a Solar System in miniature, having a central orb or nucleus, composed of two kinds of particles, *protons* or units of positive electricity, held together, *i.e.* surrounded, by *electrons*, or particles of negative electricity, which circulate

* Particulars of confirmations from Antevs are given in the lecturer's reply (pp. 139 and 140).

round the nucleus in orbits, as Planets circulate round the Sun. Atoms are many and various, from the Hydrogen atom, a single proton with a single electron circulating round it as the Moon revolves round the Earth, to Uranium, with 238 protons, plus 146 electrons and 92 planetary electrons. Between these extremes we have as many varieties of atoms as there are elements, and hence as many varieties of solar systems in miniature, no two alike, all revolving at incredible speed in their courses, and, as we would judge, probably answering to the same laws as prevail in the greater systems, some of which are measurably demonstrated by this gyroscope.

Whether the little orbs have their winters and summers, their nights and days, their temperate and glacial epochs, we must leave to the imagination. But, one thing stands out clearly amid such inferences as we are able to draw, viz. that whether we survey the infinitely great, or study the infinitely small, we trace infallibly the design of Him who, though He contemplated His works from the beginning, "and behold they were very good," rested not content with any of His works of creation till He had come Himself and dwelt among us full of grace and truth. Well may we say with the Psalmist of old:—

"The heavens declare the glory of God ;
And the firmament showeth His handiwork,
Day unto day uttereth speech,
And night unto night showeth knowledge."

It is for us to hear, to heed, and to bow our hearts in wonder and adoring praise.

Addendum.

In the time at my disposal it has not been possible even to mention a large array of facts in support of Drayson's discovery: for particulars reference should be made to his own works:—COMMON SIGHTS IN THE HEAVENS (1862); THE LAST GLACIAL EPOCH OF GEOLOGY (1873); THE MOTION OF THE FIXED STARS (1874); THIRTY THOUSAND YEARS OF THE EARTH'S PAST HISTORY (1888); UNTRODDEN GROUND IN ASTRONOMY AND GEOLOGY (1890)—all of which are to be seen in the Library of the British Museum and other scientific libraries; and DRAYSONIA, by Admiral Sir Algernon De Horsey, K.C.B. (1911).

More recent publications are procurable in inexpensive pamphlet form as follow:—From Wm. Pollard & Co., Ltd.,

Exeter, THE DRAYSON PROBLEM, by A. H. Barley, Esq.; WARMER WINTERS AND THE EARTH'S TILT, by Maj. R. A. Marriott, D.S.O.; also from W. E. Baxter, Ltd., Lewes, Sussex, THE ICE AGE: ITS DATE, DURATION, AND ASTRONOMICAL CAUSE, by A. H. Barley, Esq., Maj. R. A. Marriott, D.S.O., Maj.-Gen. Sir Wm. Salmond, K.C.B., and others.

DISCUSSION.

The CHAIRMAN (Lieut.-Col. F. A. Molony) said: We have to thank Colonel Skinner for bringing to our notice a very intriguing subject, which he has presented with remarkable clearness. Those of you who have taken astronomical observations, for navigation or other purposes, will want to know what the *Nautical Almanac* says about it. I have taken out the obliquity from that impartial compilation at intervals of ten years, and find that for the last 100 years it has been decreasing with great steadiness at the rate of 4·7 seconds every ten years. Drayson published his theory in 1873. Our lecturer has told us, on p. 127, what Drayson based his prediction upon; as far as I can calculate he is now only 2 or 3 seconds of arc out. This is such a very small angle of arc that one cannot fairly say that Drayson is proved to be wrong. Reckoning that you would like to hear what professional astronomers have to say about the matter, I obtained an interview with one, and then wrote out the gist of what he told me. This he has very kindly corrected, and here it is:—

Views of Modern Astronomers on the Causes of the Ice Ages.

“It is believed that the very small diminutions in the obliquity of the ecliptic now taking place, are due to changes in the plane of the earth's orbit under planetary influences. The obliquity is not likely to have ever been so great as Drayson supposed, and has had very little effect upon the Ice Ages. Astronomers refuse to tie themselves to any definite theory about these, but some are inclined to believe that the changes in the eccentricity of the earth's orbit have had much to do with them. That is, that sometimes, and at very long intervals, the earth's orbit is more elliptical than at other times, this being due to planetary influence.

As the sun is at a focus, either the North or South Pole (but not both simultaneously) will experience extra cold for many winters in succession. Some think that the slipping of the earth's crust over its liquid core may have influenced the matter. This would cause the North Pole to lie, say, sometimes in Canada and at others in Siberia. This possible explanation would have to be considered if it could be proved by geological evidence that the Ice Ages in those two countries were not simultaneous."

These are the orthodox astronomical views. You will note that they say, "The obliquity is not likely to have ever been as great as Drayson supposed" (*i.e.* $35^{\circ} 25' 47''$). Now, our lecturer has reminded us that, whereas staid Jupiter only allows himself 2 degrees divergence from the perpendicular, giddy Venus rotates at well-nigh as great a difference from the upright as is possible (*i.e.* 75 degrees), compared with which Drayson's maximum heel-over is but small.

I hope that you also noted that the astronomers' theory that the Ice Ages are chiefly due to eccentricity of orbit is dependent on the ice-caps at North and South Pole *not* receding together, but there is much evidence that they *are* both receding at the present time.

Now geology confirms Drayson, as I shall presently show, but probably Drayson himself would not have claimed that he had propounded the whole truth in the matter. Geologists are demanding a cycle even greater than Drayson's, which shall throw the glacial epochs into groups of at least four each, and which may be due to alterations in the plane of the earth's orbit, while gyroscopic action keeps the pole steady.

I concur with our lecturer in claiming that geology confirms Drayson, who calculated that the last Ice Age was at its height 15,000 years ago. Swedish geologists, by counting annual darkenings in hardened mud, calculate that the glaciers near Stockholm *began* receding 12,000 years ago, while Canadian scientists reckon that Niagara has been receding for 7,000 years *since* the last glaciation, and American men give a somewhat larger figure. All this agrees with Drayson remarkably closely.

Those who wish to go into the mathematics of Drayson's theory should study *Draysonia*, by Admiral Sir Algernon de Horsey, published by Longmans. Be Drayson right or wrong, it seems clear that the last Ice Age was ending only 5,000 years B.C. Archbishop

Usher puts the Deluge at 2448 B.C., but we do not tie ourselves to his datings. It is clear that ice-meltings may have had much to do with that flood; but I doubt if the connection is as our lecturer gives it, and for two reasons: I reckon that the rise in the oceans would only be an inch or so per year, even when the melting of the polar ice-caps was at its maximum. Suppose that this calculation is wrong, and that the rise was 20 or 30 feet a year, still it would be annual, would begin gradually, and would be expected, and therefore not likely to endanger life. But, as Marriott points out, the general melting would cause the sudden bursting of glaciers which had formed lakes by damming up valleys, and these would cause very destructive river floods. The little Marjolen See, in Switzerland, is held up by a glacier whose crevasses allow the water in the lake to lower itself at times which cannot be foreseen; these floods have caused so much damage in the valley of the Rhône below, that an expensive tunnel has been cut to lower the level of the lake permanently.

We were all much interested lately in hearing about the damming by a glacier of the Shyok, a tributary of the Indus. We were told that so sudden a flood was expected whenever the dam should burst, that the great Attock bridge might be endangered. Also that a Sikh army was once overwhelmed in Cashmere by a flood similarly caused. Now, at the head of the waters of the Tigris is Lake Van, of 1,500 square miles, with mountains 11,000 feet high to the south of it. It has no outlet, but a slight rise would cause its waters to flow out through a gorge at its west end. A rise of 460 feet would allow of its waters finding outlet by the Bitlis gorge, a few miles west of the first. A further rise of 525 feet would send the outlet to the south-east corner of the lake, 52 miles away.

When these topographical conditions prevail, geologists argue that the gorges were temporarily blocked by glaciers similar to the block which we lately heard of at the head-waters of the Indus, thus compelling the water to cut other outlets. Some of the Swiss glaciers to-day push their way down to a lower level than Lake Van, so it seems clear that a much smaller alteration of climate than Drayson proves might bring a glacier down to that lake. If the gorges south-east of Lake Van were thus blocked, when the dam broke it would send down from 200 to 400 *cubic miles* of water, and

as the height of the lake is 5,270 feet, the water would not be long in finding its way down to the great plain of Mesopotamia. Some 60 miles north-west of Mosul, or Nineveh, the Tigris comes out of the hills, and from there to 20 miles south of Mosul the contoured map shows low rounded hills all rising to about the same graded plane, and looking very much as though they were made of the silt deposited by some tremendous flood.

In short, it seems to me to be certain, reasoning on scientific data only, that a terrible and unexpected flood or floods swept over the great plain of Mesopotamia between the years 7000 and 2000 B.C. If caused in the way I have suggested, it would naturally happen during the rainy season.

The Biblical account, by stating that all the fountains of the great deep were broken up, hints that the flood was not caused by rain only. Gen. vii, 11, says that the flood began on a definite day. The Babylonian version says, "A whole day long (the flood descended), swiftly it mounted up." The Bible says that it took many months to run off, but this is not counter to the foregoing explanation, if we remember how flat the great plain of Iraq is.

Permit me again, in your name, to thank Colonel Skinner for his extremely interesting paper.

Major-General Sir WILLIAM SALMOND, K.C.B., said: Colonel Skinner has shown how the second rotation of the earth, as proved by General Drayson to exist, has necessarily brought about glaciations in the past, and will continue to do so in the future, unless different conditions should come into force: such, for instance, as a change in the position of the centre of gravity of the earth. Colonel Skinner has explained that great meltings must have occurred during the period 2600 to 2100 B.C.

I have found corroboration for this in reliable Egyptian records covering those years. They were published in English in 1863, in a book which I have in my hand. It is entitled *Hekekyan Bey on Egyptian Chronology*. At p. 15 the author says: "The Memphis Astrological Observatory, which is still in function, and is known by the appellation of The Mekias or Nilometer of Roda (a small island near Cairo), counts the year A.D. 1861 as the 7,563rd Nile inundation, observed and recorded." A continuous and reliable record like

that, over so many years, has a special value in relation to the effects on the earth itself when journeying through the 32,000 years' cycle called The Great Year. On p. 96, Hekekyan Bey gives the date, in Nile years, of the Deluge. This date, when adjusted to the value of present-day years, works out to be 3232 B.C. If we consider Fig. 8, as shown on the screen, in the light of a clock-face, and assume that the earth, having started from Z (zero year) on its 32,000-year travel, has arrived at S (which would be 6 at the bottom of our clock), it will then enter the last 8,000-year lap of the cycle. In about 6 clock-minutes, *i.e.* at about 6.36 by our clock, the earth will pass through the years of great meltings, *viz.* 3232-2600-2100 B.C. 6.36 on our clock will be about the end of April in the Great Year.

Here, then, we have a detail which tends to corroborate Drayson's curve for the 32,000 years of the Great Year. So far as I know, Drayson was the first man to envisage—as he has done—the cause of the climatic conditions of the earth in the past and as they will be in the future. I submit that Drayson deserves well of his country.

Colonel J. B. STRACEY-CLITHEROW, C.B.E., said: Drayson's discovery has been so amply described by Colonel Skinner, and extended by General Salmond, that I will not dwell on this part. All I wish to say is, that for those who like to study Drayson's theory it does help them to understand the true movement of this earth, and to realize what has taken place, is taking place, and likely to take place in the future. I will just give you one instance of what I mean. On October 18th, 1923, I wrote a letter to the *Yorkshire Post*, on the erosions that are taking place round our coasts, and pointing out that the cause of this was the annual decrease in the obliquity of the axis of our earth with its orbit. As the decrease in the angle takes place, so does the mean level of the sea increase, from the melting of the ice at both poles, an average of nearly a mile a year of ice off the circumference of the poles.

At the end of my letter I added, "I fear we have in the near future to look forward to many serious erosions on our coast-line, and also up our arterial rivers. How long will it be before the waters of the Thames top the Embankment? Personally, I should be sorry to give it anything like fifty years." The London papers took

this latter part up, and went to the Meteorological Bureau to ask if there was this danger to the waters of the Thames. They replied that there was no danger of this happening; if there was more water in the oceans in one place, there was less in another. That, of course, is quite true with regard to tides, but was no answer to my point. Owing to the decrease in the obliquity of the axis, there was an increase in the mean height of the seas. We all know what did happen five years later, on January 6th, 1928, when the waters of the Thames came over the defences of the river, and went almost as far as Victoria Street, Westminster, when several people in their basements were drowned. So I think I may say that my prophecy came true, which was entirely worked out on Drayson's theory, that the true centre of the Pole of the Heavens is 6 degrees removed from the Pole of the Ecliptic.

Major R. A. MARRIOTT, D.S.O., said: I attended this afternoon's lecture for the purpose of replying to any points that might be raised adverse to the facts so ably explained by the lecturer, but as there seems to be no opposition, I will show how this present campaign in favour of Drayson's discovery started.

After reading *Thirty Thousand Years of the Earth's Past History*, by Drayson, I was convinced that it was an important discovery; and in 1911, when I found that Scott, after his first expedition, reported that the ice was retreating in the Antarctic, and being aware of the retreat of the Arctic ice in this hemisphere, I bethought me that Sir Robert Ball had written, in his book on the subject, that if the Ice Ages in both hemispheres could be shown to be contemporaneous, the astronomical theory (Croll's) would have to be *forthwith abandoned*.

I wrote a small pamphlet pointing this out as in every way favourable to Drayson, and that glaciers were receding all over the world, thinking that it would set geologists agog to bring pressure on astronomers to investigate Drayson's theory. Unknown to each other, Admiral Sir Algernon de Horsey published his *Draysonia*, the very same month, dealing with the astronomical side. We were, however, equally unsuccessful in producing scientific interest in the matter.

On writing to two late presidents of the Geological Society, I was met by the contention that even the 80,000 years of astronomers was not sufficiently long ago for the Ice Age to have passed away, and on pointing out to another leading geologist that Dr. Holst's computation of the Swedish evidence gave almost *exactly* similar dates for the duration of the last Ice Age as did Drayson, the reply was, "I have just come from Stockholm, and think they are right about Sweden, but it does not apply to the British Isles!"

I also wrote to Dr. G. F. Wright, a leading "glacialist" of North America, and was encouraged by his reply: "Your theory is correct and most welcome." In spite of this, in a book published two years afterwards, *The Ice Age in North America*, he went out of his way to say that astronomy could lend no aid to geology in this question.

Again, Dr. Holst, the Swede, though I pointed out to him Drayson's exact agreement with him as to dates, said, "If Drayson is right, there have been many glaciations, and I maintain there has been only one." He came to London some years after and propounded his doctrine, but met with no active opposition. Having found traces of a recent Ice Age all over the world, my difficulty was to find some evidence in my own country. It was only after perceiving this difficulty that I discovered that we had all round our coasts the submerged forests, which supplied as strong evidence of a recent glaciation as did any land relics. In fact, the geological evidences, which I have not time to go into, are numerous enough without the aid of astronomy. Drayson's discovery throws light on other sciences as well.

THE LECTURER'S REPLY.

I desire to thank the Members, Associates and friends for their most kind appreciation of the paper. Our hearty thanks are due to Sir William Salmond for his presence here, as well as for his interesting and valuable note on Nile chronology; to Colonel Stracey-Clitherow also, whose original research with regard to the continued rise of sea-level must surely ere long receive the attention so serious a disclosure demands; also to Major Marriott for reminding us of Scott's south polar confirmation of the general retreat of the ice; and to Colonel Molony, alike for his able handling of the

meeting, his own most valuable contributions to the discussion, and, in particular, for having obtained the views of a qualified astronomer, Dr. W. M. Smart, M.A., F.R.A.S., of Cambridge Observatory, whose courtesy in meeting Colonel Molony's request places us under a very real obligation.

From Dr. Antevs' recent work it would appear that, allowing for the difficulties and uncertainties of long-distance correlation, he is satisfied that the glaciations in Europe, Asia, and North America were simultaneous; while, in the southern hemisphere, he finds in Australia and South America like evidences of two or three Pleistocene glaciations that clearly suggest synchronism. Relating the southern hemisphere to the northern, while unable to say that synchronism is definitely proven, he finds it, nevertheless, on the available evidence highly probable.

As to this I submit that more weight may safely be attached to the undoubted simultaneous retreat of the ice in Arctic and Antarctic at the present time than is usually accorded to that fact. If retreat of the ice be due, as Drayson affirmed, to the decreasing obliquity, one has only to reflect that such retreat will be continuous throughout the whole period between maximum obliquity and minimum. To put it another way, the Ice Age, though shorn of its former impressiveness, is still with us, and, strictly speaking, cannot be said to terminate till a definite point is reached when the obliquity is either stabilized at a minimum, or starts on another increase. Thus viewed, the waning of ice at the poles is no other than the last lingering phase of the great retreat, and this fact of simultaneous shrinkage is thus, I submit, decisive for confirmation.

In this connection it is reasonable to ask, "Why should synchronism ever be in doubt? Is there any *evidence* in disproof?" Are we not rather hypnotized by the pure assumptions of the past, the legacy of the early theory of glaciation being due to former great eccentricity of orbit; a theory which, though it places the Ice Age 100,000 years farther back than modern glacialists can allow, is still employed as an argument against the Drayson thesis?

Antevs, it is true, puts the last glaciation several thousand years farther back than does Drayson's ideal cycle, illustrated in Fig. 8; but as to this, there is more elasticity and possibility of adjustment than appears on the surface: in all his works Drayson adumbrated

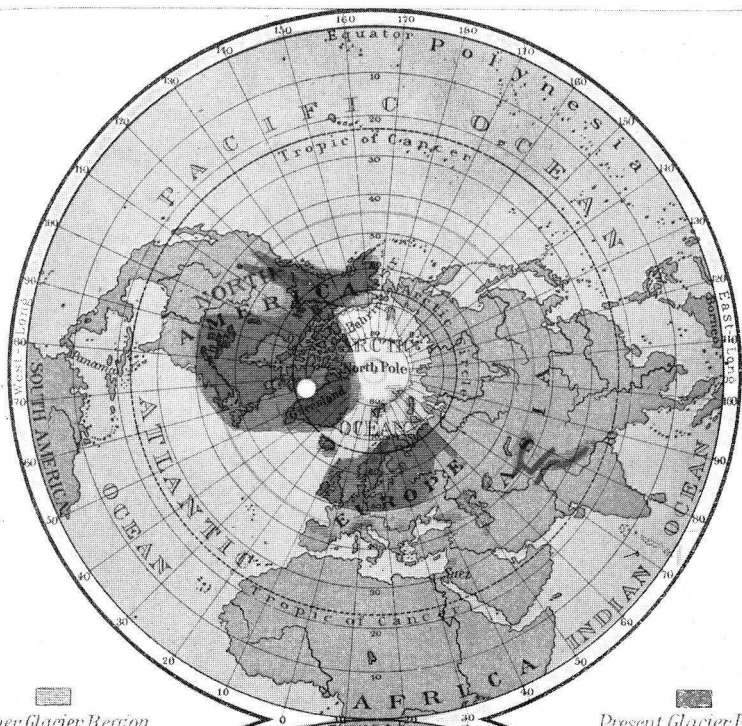
possible variations from the ideal, and a somewhat wider range of dates.

Another theory in competition, Wegener's theory of a migrating pole—indicated by white dots on the polar chart—would seem to be ruled out altogether by Antevs.

Finally, as to the belief that "the very small diminutions in the obliquity of the ecliptic now taking place are due to changes in the plane of the earth's orbit under planetary influences," it need only be said that every movement of the ecliptic plane carries with it a corresponding movement of its pole; and thus, whatever may be the physical cause of decrease of the obliquity, the radius of the supposed—*i.e.* the orthodox—precessional circle must decrease *pari passu*. The vital fact, however, is, not that these decrements are small, but that they are known to have been in continuous operation for 1,400 years, with strong confirmations carrying it back another 6,000 or even 14,000 years, a period surely long enough to determine with accuracy the real arc, its centre, and its radius.

With regard to the Noachian Deluge, apart from the general rise of sea-level due to annual meltings, the most that can be argued from anything I have sought to establish in this paper is a partial contribution to the general Flood in the sudden release of enormous volumes of flood-water about the spring-time of the Great Year, a possibility well implemented by our Chairman in his study of Lake Van and its outlets. For a full explanation of the Deluge we must fall back upon the account given us in Gen. vii, 11, and accept it that, in addition to unprecedented rains, seismic disturbances of great magnitude in the ocean bed had caused tidal waves sufficient to engulf the entire land surface.

I may add that I am now in communication with a highly placed astronomer with regard to investigation of Drayson's claims. He is meeting me with heartiest good-will, and I feel hopeful that ere long the matter will be fully gone into.



Former Glacier Region

Present Glacier Region

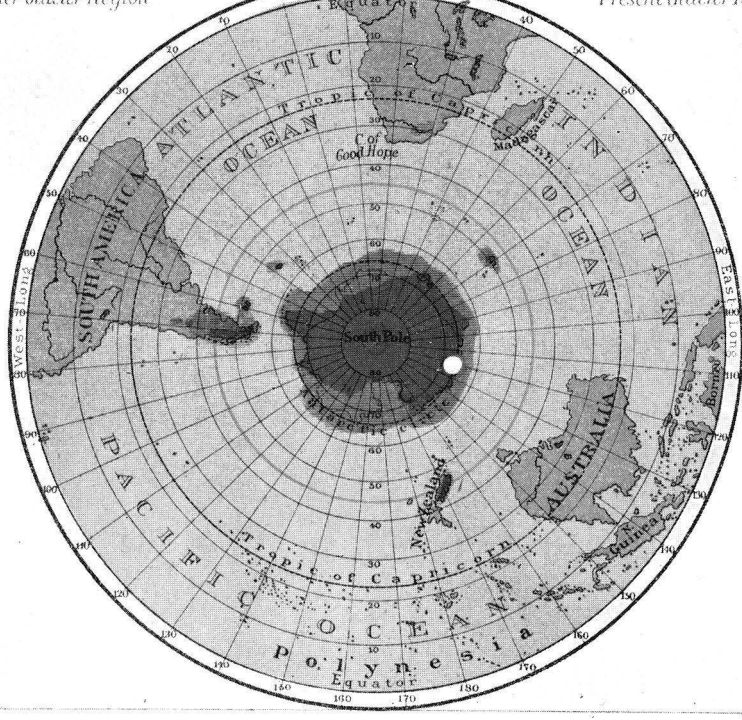
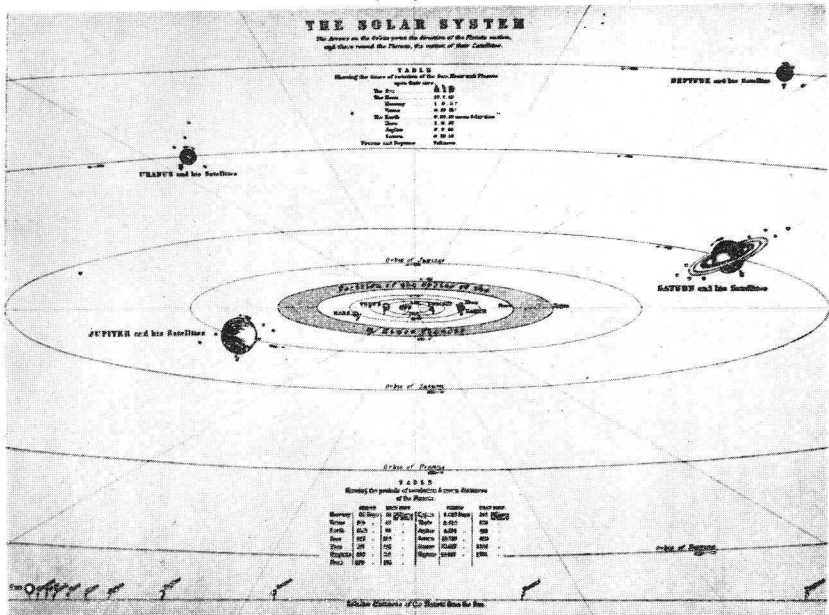


CHART SHOWING THOSE PARTS OF THE EARTH FORMERLY AND AT PRESENT COVERED BY GLACIERS.
(AFTER DR. ALBRECHT PENCK.)

FIG. 1.

THE SOLAR SYSTEM

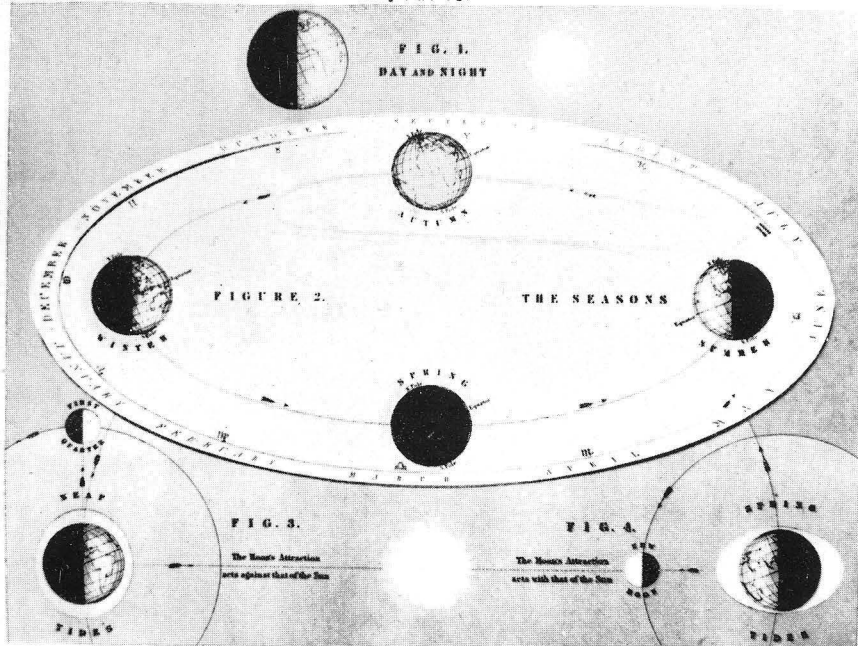
The planets on the orbits pass the direction of the Earth's motion, right there round the Sun, in the nature of their orbit.



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FIG. 2.

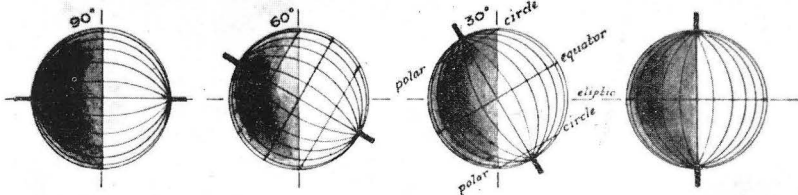
**FIG. 1.
DAY AND NIGHT**



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OBLIQUITY, TILT and POLAR CIRCLES

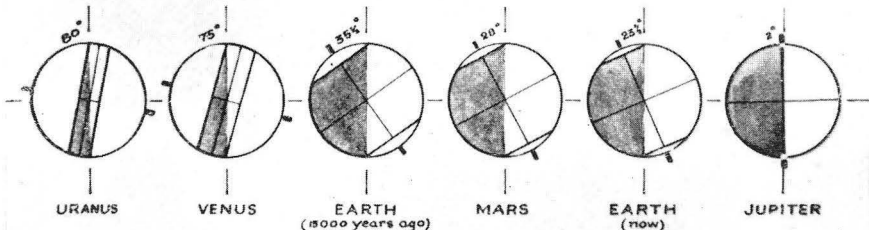
FIG. 3.



ANALOGY OF THE SOLAR SYSTEM

FIG. 4.

SOME PLANETARY TILTS

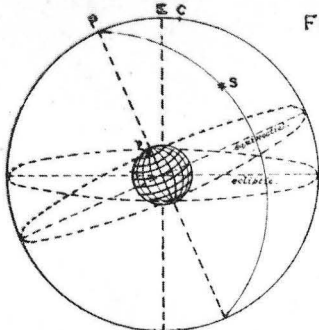


T.C. Shimmer (1914)

DRAYSON'S PRECESSIONAL CYCLE.

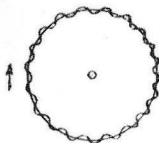
THE CELESTIAL SPHERE.

FIG. 5.



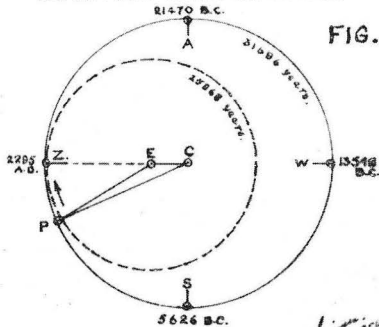
MUTATION.

FIG. 6.



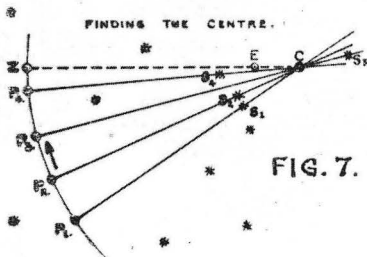
THE SUPPOSED CENTRE AND THE TRUE.

FIG. 8.



FINDING THE CENTRE.

FIG. 7.



T.C. Shimmer (1914)

FIG. 8.

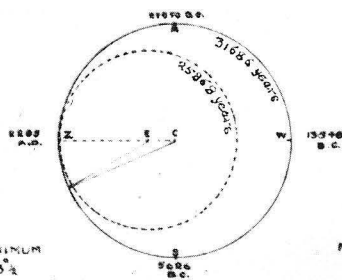


FIG. 9.

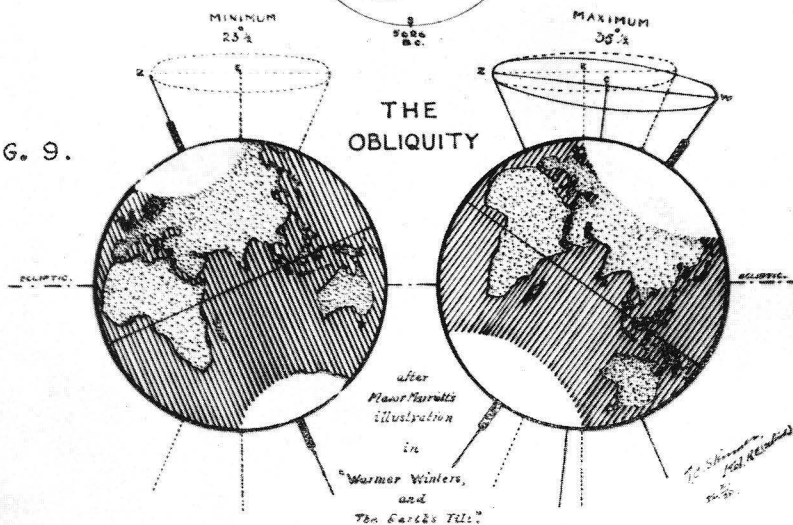


FIG. 10.

