June 6, 1878.

The Annual Meeting for the election of Fellows was held this day.

Sir JOSEPH HOOKER, K.C.S.I., President, in the Chair.

The Statutes relating to the election of Fellows having been read, Major-General H. Clerk and Dr. G. Johnson were, with the consent of the Society, nominated Scrutators to assist the Secretaries in examining the lists.

The votes of the Fellows present having been collected, the following candidates were declared duly elected into the Society.

John Gilbert Baker, F.L.S.
Francis Maitland Balfour, M.A.
Rev. Thomas George Bonney, M.A.
Prof. James Henry Cotterill, M.A.
Sir Walter Elliot, K.C.S.I.
Rev. Canon W. Greenwell, M.A.
Thomas Hawksley, C.E.
John Hopkinson, M.A. D.Sc.
John Hughlings Jackson, M.D.
Lord Lindsay, P.R.A.S.
Samuel Roberts, M.A.
Edward Albert Schäfer, M.R.C.S.
Hermann Sprengel, Ph.D.
George James Symons.
Charles Sissmore Tomes, M.A.

Thanks were given to the Scrutators.

June 20, 1878.

Sir JOSEPH HOOKER, K.C.S.I., President, in the Chair.

In pursuance of the Statutes, notice of the ensuing Anniversary Meeting was given from the Chair.

The Presents received were laid on the table and thanks ordered for them.

The Right Hon. William Henry Smith, Mr. John Gilbert Baker, Mr. Francis Maitland Balfour, Prof. James Henry Cotterill, Sir Walter Elliot, Rev. Canon W. Greenwell, Mr. Thomas Hawksley, Dr. John Hopkinson, Mr. Samuel Roberts, Mr. George James Symons, and Mr. Charles Sissmore Tomes, were admitted into the Society.

The following Papers were read:—

I. "Notes on Physical Geology. No. V. Mr. George H. Darwin's Comments on Note No. III." By the Rev. SAMUEL HAUGHTON, M.D. Dubl., D.C.L. Oxon, F.R.S., Professor of Geology in the University of Dublin. Received May 20, 1878.

In the "Proceedings of the Royal Society," 14th March, 1878, p. 179, Mr. George H. Darwin has published a criticism on my proposed method of finding a limit to the duration of certain geological periods, published in the "Proceedings of the Royal Society," 20th December, 1877, p. 534.

My paper, of 20th December, consisted of two parts:—1st. A discussion of the rate at which a "wabble" of the earth's axis of rotation, caused by a want of coincidence between the axis of figure and the axis of rotation, would be destroyed by the friction of the ocean against its bed. 2nd. Speculative inferences from the solution of this problem, as to the duration of geological periods, depending on hypothetical geological assumptions as to the method in which Europasia was manufactured.

These assumptions were three in number, and none of them very probable, viz. :—

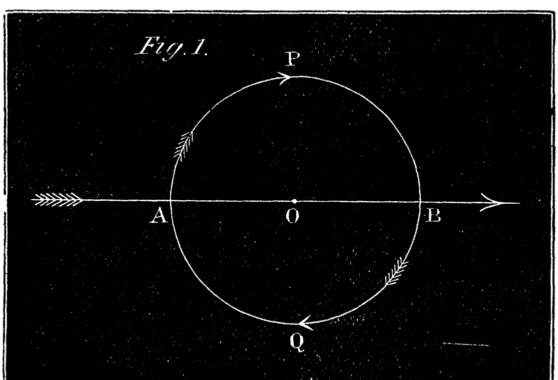
(*a.*) An instantaneous formation of the continent;

(*b.*) Its formation by means of 69 equal convulsions, with an interval of time between each, sufficient to reduce the radius of the wabble from one mile to five feet;

(*c.*) Its formation, by a number of small shocks, each displacing the axis of figure by such an amount that tidal friction would be able to render the axes of figure and rotation again coincident in the period of a single wabble.

In discussing the two latter hypotheses, I naturally timed my shocks so as to produce the maximum wabble. For this assumption I have, of course, no authority; and I readily admit that any conclusions drawn from the earth's wabble can have no more value than the probability of the hypothesis we may make as to the method of formation of Europasia.

In general, let AOB, fig. 1, be a portion of the path described by the axis of the figure, let AO be the displacement produced by any single shock, and let APBQ be the circle described by the axis of rotation in the first wabble after the occurrence of the shock.



If the next shock which moves the axis of figure from O to B occurs when the axis of rotation is at A, the wabble will be doubled, and have the radius AB; but if the second shock be so timed as to occur when the axis of rotation is passing through B, the wabble will immediately cease, for the axes of rotation and of figure will coincide.*

If $\tau = 304{\cdot}75$ days, the wabble will be doubled if the next shock occurs at an interval denoted by $n\tau$, and will be destroyed if the interval is $(n + \frac{1}{2})\tau$.

If the shocks occur at irregular intervals, at the moment of shock the axis of rotation may be anywhere on the circle APBQ, and the mean effect will be found when the axis is at P or Q, which would be a more probable assumption than that made by me, when I placed the axis always at A. Let us now calculate the mean effect when shocks occurring at unknown intervals take place when the axis of rotation is at P or Q.

Let r denote the radius AO, then we have—

Radius of 1st wabble $= r$.
„ of 2nd „ $= r\sqrt{2}$.
„ of 3rd „ $= r\sqrt{3}$.
„ of nth wabble $= r\sqrt{n}$.

If $r = 5$ feet (the least observable wabble), n, the number of equal shocks required to displace the axis of figure through 69 miles, will be

$$n = \frac{69 \times 5280}{5} = 72{,}864,$$

and

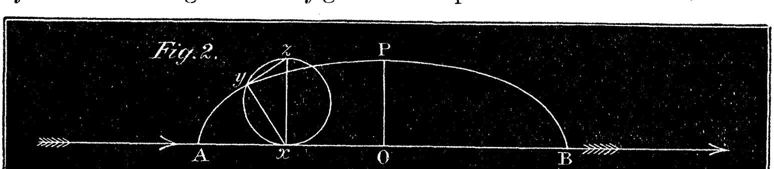
$$\sqrt{n} = 270.$$

This number should be substituted for A′ in equation 12 (Note iii, p. 543), when we obtain, for the number of years required by tidal friction to destroy the final wabble,

320,380 years.

This, as might be expected, is half the time required to destroy the final wabble, when all the shocks were additive at a maximum and occurred when the axis of rotation was passing through A.

Mr. Darwin has discussed at length the case of the axis of figure moving uniformly, and finds that the axis of rotation will move on a cycloid. I here give an easy geometrical proof of this theorem :—



Let AOB be a portion of the path uniformly described by the axis

* If AB be 69 miles, Europasia might have been manufactured in $152\frac{1}{2}$ days, by two equal shocks.

of figure; and let x be the position of the axis of figure at any moment, and y the corresponding position of the axis of rotation, then by the conditions of the problem, fig. 2,

Ax varies as the time,

The angle, Axy=yzx varies as the time.

But the angle yzx is proportional to the arc xy: therefore

Ax varies as arc yx,

but they are supposed to start together from zero, at the point A. Therefore Ax = arc xy, and the locus of y is the common cycloid, whose generating circle is xyz with diameter equal to the axis of the cycloid PO.

If the axis of figure therefore travels uniformly, the axis of rotation will describe a cycloid, and the two axes will coincide every $152\frac{1}{2}$ days, at the cusps, and the maximum radius of wabble will be OP, the diameter of the generating circle.

Mr. Darwin, finally, discusses the following problem:*

"I will now suppose that the geological changes begin suddenly from rest and proceed at such a rate that the variations in the position of the principal axis are imperceptible to astronomical observation. I will suppose, therefore, that the extremity of the instantaneous axis is never more than 5 feet distant from the extremity of the principal axis."

Mr. Darwin deduces from this that a displacement in the axis of figure, amounting to 69 miles, might be produced in 19,200 years, without ever producing an observable wabble.

My calculation of this problem is as follows:—

Since OP is 5 feet, the base of the cycloid, AB will be 5π, and as this length is described by the axis of figure in half a wabble, we have, if x be the number of years required to describe 69 miles,

$$5\pi : 69 \times 5280 :: \frac{304 \cdot 75}{2 \times 365 \cdot 25} : x.$$

From this I find—

$$x = \frac{69 \times 5280 \times 304 \cdot 75}{2 \times 365 \cdot 25 \times 5\pi} = 9675 \cdot 7 \text{ years.}$$

This result is half that obtained by Mr. Darwin.

My object in publishing the latter part of my paper, was to show that if geologists shall ever be in a position to give us exact information as to the mode of formation of a continent, under certain circumstances, conclusions of value as to geological time might be deduced from observations made on the wabble of the axis of rotation; but it is clear that, in the present state of our knowledge, such conclusions must be regarded as hypothetical.

* *Ante*, p. 182.