LETTERS TO THE EDITORS

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NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 713.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

Kinematical Relativity and the Geological Time-Scale

IN a recent paper, a detailed analytical theory of time-keeping has been developed on an axiomatic basis[1]. Starting from the existence of a temporal sequence for events at any given observer and the existence of a 'substratum of equivalent observers', it has been found that amongst all possible graduations of the clocks of a substratum two families stand out with special properties, namely, the family τ, according to which the substratum is described by each of its members as static, and the family t, according to which it is described as uniformally expanding from a point origin. By deriving the equation of motion of a free particle, it has been found that if we identify the smoothed-out universe of extra-galactic nebulæ with a substratum, then the uniform time of dynamics is to be identified with τ-time[2], which gives an infinite 'age' to the universe, whereas the uniform time of optics and atomic vibrators is to be identified with a t-time[3], which gives 2×10^9 years as the 'age of the universe'.

It is well known that this 'age of the universe', as derived from Hubble's law, is of the same order as the 'age' assigned to the oldest rocks on the earth's surface by analysis of their uranium-lead ratio. This result, by itself, cannot be taken as conclusive evidence that this is the earth's 'age' because, as Holmes remarks[4], "Hutton's oft-quoted dictum that he could find 'no vestige of a beginning' remains true of geology to this day. Geological time dates from the deposition of the oldest known sediments, and whatever their age may be that of the earth must be still greater". However, strong corroborative evidence for the significance of this figure comes from recent investigations of the helium ratio of iron meteorites, about 70 per cent of which are now believed to reach our planet from outside the solar system[5]. These again lead to a greatest 'age' of the order 2×10^9 years.

These investigations of rocks and meteorites are based on the Rutherford-Soddy law of radioactive decay, which states that if N is the number of atoms of a particular radioactive element present in a specimen at a given epoch, and if δN is the number of these atoms which disintegrate in the subsequent interval δt, then

$$-\delta N = \lambda N \delta t,$$

where λ has been found to be independent of temperature, pressure, etc. 'Ages' are then assigned by this law on the 'assumption' that λ is invariant for change of epoch. This, of course, is simply a *definition* of the particular uniform time of radioactive decay of a given element. Since different elements and methods lead to consistent results, we have good reason for believing that there is a unique uniform time of radioactive decay, and the agreement between the 'ages' assigned to the oldest rocks and meteorites with the 'age' assigned to the universe by Hubble's law makes it extremely plausible to identify this time with the uniform t-time of optics.

If, therefore, we regard the dates assigned to geological epochs as t-scale dates, it becomes of interest to compare them with the corresponding dates on the τ-scale, given by[6]

$$\tau = t_0 \log (t/t_0) + t_0,$$

where t_0 is the present t-epoch, since this is the scale which has been identified with the uniform time of dynamics. It is readily seen that if t_1 is any past t-epoch and τ_1 is the corresponding τ-epoch (the two scales agree on the value of the present epoch, t_0) then

$$t_0 - \tau_1 = t_0 \log (t_0/t_1).$$

We can, therefore, immediately compile the following table to illustrate the difference between the t- and τ-periods assigned to geological eras, all figures being in millions of years.

Geological period	t_1	$t_0 - t_1$	$t_0 - \tau_1$
Present	2,000	0	0
Base of Eocence Rocks	1,930	70	71
Base of Cretaceous Rocks	1,900	100	102
Base of Triassic Rocks	1,800	200	210
Base of Devonian rocks	1,700	300	325
Base of Ordovician rocks	1,600	400	445
Base of Cambrian rocks	1,500	500	575
Laurentian rocks	1,000	1,000	1,400
Oldest European rocks	500	1,500	2,800
Oldest rocks (Manitoba)	250	1,750	4,200
'Creation'	0	2,000	∞

We observe that the t- and τ-measures of the whole fossil period (Cambrian age to present) differ by about 15 per cent of the t-measure, which is not much greater than the probable error in assigning epochs by the present radioactive methods. Moreover, when we go back a thousand million years on the t-scale, that is half way back to 'creation', we find that the τ-measure of this period is not more than fourteen hundred million years.

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[1] Milne, E. A., and Whitrow, G. J., *Z. Astrophys.*, 15, 263 (1938).
[2] Milne, E. A., *Proc. Roy. Soc.*, A, 154, 69 (1936); 157, 324 (1937).
[3] Whitrow, G. J., *Quart. J. Math. (Oxford)*, 7, 271 (1936).
[4] Holmes, A., "The Age of the Earth", 30 (1937).
[5] Holmes, A., "The Age of the Earth", 230.
[6] Milne, E. A., *Proc. Roy. Soc.*, A, 158, 337 (1937).