

A POSSIBLE CHRONOMETRIC SCALE FOR THE GRAPTOLITE BEARING STRATA.

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Geologists at once recognised the importance of BARON DE GEER's time calculations based upon the deposition of the Varve Clays. In the present paper an attempt will be made to show the possibility of utilising the Baron's method, taken in connexion with the changes in the graptolitic faunas of the Lower Palaeozoic rocks.

The Bannisdale Slates of the Lake District of England belong to the Lower Ludlow division of the Silurian System. They consist chiefly of leaden-grey beds with conspicuous striped bands, consisting of alternations of fine mudstone and fine sand; with several alternations in the thickness of a centimetre. The rhythmic regularity of the alternations strongly favours the view that their existence is due to periodic changes, such as those which occur diurnally and annually.

The stripes seem to be too thick for diurnal deposition and on the whole, annual deposition seems the most probable as in the case of the Varve Clays. Dr. D. STAMP has suggested the same explanation in the case of striped Tertiary beds in India.

The striped structure ranges fairly generally throughout the deposits. There are variations indicating intercalation of grit beds, but these are of little importance.

These specimens have been examined from two localities. One of these shewed 6 pairs of stripes to a centimetre, over a thickness of five centimetres, each pair consisting of one mud and one sand stripe. Another specimen from a different locality shewed 44 pairs to 23 centimetres and the third from the same locality 33 pairs to 7.7 centimetres. The average of the three specimens is 4.3 pairs to 1 centimetre, *i. e.*, each centimetre represents 4.3 years of sedimentation.

The officers of the Geological Survey estimate the thickness of the Bannisdale Slates as 1600 metres, which, at the rate of sedimentation estimated for the above 3 specimens, would indicate a period of 688,000 years for the accumulation of the whole, *i. e.*, approximately 700,000 years.

The Bannisdale Slates contain two graptolitic zones; the lower recently discovered by my colleagues Mr. KING and Miss ELLES is that of *Mono-graptus tumescens* and the upper that of *M. leintwardinensis*. The graptolite of each of these zones would therefore exist for a period of a 350,000 years.

This estimate is itself in favour of the idea that the stripes indicate annual changes. If they were due to secular changes of longer periods, the duration of a graptolite species would necessarily be much longer, probably some millions of years, which is unlikely.

The latest list of the British Graptolite Zones is given by Miss ELLES (Geological Magazine, 1925, Vol. LXII, p. 337).

The number of zones in the Ordovician (including Tremadoc beds) and Silurian is as follows: —

Silurian	{	Ludlow	5
		Wenlock	6
		Llandovery	10
Ordovician	{	Ashgill	2
		Caradoc	3
		Llandeilo	4
		Arenig	4
		Tremadoc.	3

If each graptolitic zone represents a period of a quarter of a million years, this gives four million years for the deposition of the Ordovician rocks and five and a quarter for the Silurian to the base of the Upper Ludlow, or allowing another quarter of a million years, for the formation of the Upper Ludlow, five and a half million years.

We may check these results by a comparison of the British zones with those of Scandinavia, given by Dr. J. C. MOBERG (Sven. Geol. Undersökn. Ser. C, No. 229). He enumerates 16 zones in the Ordovician and 17 in the Silurian. This would indicate that the duration of the two was nearly equal, and approximately $4\frac{1}{2}$ million years each.

There are obviously many disturbing factors affecting the calculations; some known, others unknown.

I may mention the possible over-estimate of the thickness of the Bannisdale Slates, the occurrence of some beds which do not exhibit the stripes, the unknown periods of time marked by prominent bedding planes, and the few measurements made of the number of stripes in a given thickness, which may not indicate the average.

As regards the graptolite zones, that of *Monograptus tumescens* may start in beds below the Bannisdale Slates, and, a very important point, it is almost certain that the graptolites characteristic of different zones existed for very different lengths of time, for some beds and especially the Llandovery strata have been recently divided into a much greater number of zones than those originally defined by LAPWORTH. This disturbing factor is probably responsible for the calculation that the deposition of the Silurian occupied a longer period of time than that of the Ordovician.

Many of the disturbing factors are no doubt operative in contrary directions, and will neutralise one another.

With all these possibilities of error I think that the method of calculation here advocated, will give us some idea of the order of magnitude of time-intervals in the graptolite bearing deposits, and that should the method be pursued in greater detail, it may give fairly trustworthy results from this aspect, and may further be applied to other rocks such as those containing Ammonoidea.

I have therefore written this brief paper as possibly suggestive of a line of work which may well be pursued further.

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