ON DIFFERENTIAL EARTH-MOVEMENTS DURING CARBONIFEROUS
TIMES, AND THEIR SIGNIFICANCE AS FACTORS IN
DETERMINING THE LIMITS OF THE YORKSHIRE, DERBYSHIRE,
AND NOTTINGHAMSHIRE COALFIELD.

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I.—INTRODUCTION.

The theory generally accepted as explaining the occurrence of Coal Measures in detached basins is that after the deposition of these rocks a series of earth movements, post-Carboniferous in time, took place, certain ridges were upheaved, and after these had suffered denudation the remaining portions of the Coal Measures would survive in the basin-like depressions formed by the upheaved margins. Of late years, however, evidence has been accumulating which seems to suggest that

the older theory does not accurately represent the complicated series of earth-movements that were in progress during Carboniferous times, nor the part they played in determining the present limits of the British coalfields. In this paper it is proposed to briefly discuss the effects of these movements so far as the Yorkshire, Derbyshire, and Nottinghamshire coalfield is concerned, and to determine, so far as is possible, their sequence and character. For the sake of brevity the area under discussion will be called the Yorkshire coalfield.

II.—THE PRE-CARBONIFEROUS FLOOR UNDER STRESS.

If we knew more about the structure of the old Silurian floor it is very possible that we should find the present form of the coal basins indicated, and that in no very vague form either. When its various beds were subjected to the tangential stress that marked the post-Silurian era, the stressed rocks found relief in plication and fracture, with the resulting formation of its characteristic ridges and hollows. When equilibrium had been established, it is clear that the more normal phase of earth-movements came into operation, and the Silurian floor became affected by differential subsidence. That it was really a subsidence is indicated by the vast thickness of sediments laid down. That it was differential is evident from the variations in the age and character of the sediments laid down in different areas. It will suffice to mention that in South Wales* there is an uninterrupted sequence of deposits from the base of the Old Red Sandstone to the top of the Coal Measures, while in Yorkshire the Carboniferous basement conglomerate rests on the upturned edges of the truncated Silurian folds. A discussion of other areas would serve to disclose other differences in the rate of subsidence. The chief exposures of pre-Carboniferous rocks in Yorkshire are in the neighbourhood of Ingleborough, and it is suggestive that their strike displays a marked tectonic relationship with the Charnian axis, and this suggests that, like that ancient ridge, the exposures in Yorkshire might be a complex of rocks older than Silurian. The significance of this relationship will be pointed out later. The coming into operation

* A. Strahan. *Geology of South Wales Coalfield*, Part I., p. 1.

of the Craven faults during the Carboniferous Limestone* period served to sharply differentiate the rocks north and south of the faults, and proving that subsidence was greater in the southern area. It seems established, therefore, that after the Silurian floor had found relief from the tangential stresses by which it had been affected, it came under the influence of normal gravitational stresses acting in a vertical plane, but differential in their effect on the rate of subsidence.

III.—DATUM LINES FROM WHICH TO MEASURE VERTICAL MOVEMENTS.

There is often some difficulty in deciding whether earth-movements in a vertical plane were positive or relative, or even to decide on the direction in which the movement took place, with the result that descriptions of earth-movements are often not so clear as could be desired. When possible, of course, it is desirable to decide positively whether the motion, in the case of vertical movements, was towards or from the geometrical centre of the earth. Lack of data renders this difficult sometimes. The author therefore sought for some datum line in the Coal Measures themselves by which the character and extent of the movements affecting those rocks could be determined. He took the more persistent coal seams, such as the Barnsley and Kents Thick, and assumed, as seems generally accepted,† that they were laid down in marshes or lagoon-like areas, and that during formation they were approximately in a horizontal plane. If this be granted, then we have at our disposal an approximate datum line from which to measure vertical movements. If we take the Barnsley seam, use it as a datum line, and, neglecting the faults, plot down the position which the older seams then occupied, it becomes very evident that sedimentation had been accompanied by differential subsidence, as will be seen on reference to Fig. 4, Plate LI, while several interesting modifications are seen towards the margins.

* R. H. Tiddeman. Brit. Assoc. Rep., 1889, p. 600.

† Strahan. Brit. Assoc. Rep., 1900, p. 746.

IV.—SIGNIFICANCE OF THE THINNING OF THE COAL MEASURES TOWARDS THE MARGINS.

That the Coal Measures thin, sometimes with rapidity, towards their margins has long been known. The case of the famous Dudley seam formed by the measures between the coal seams of the South Staffordshire coalfield thinning out to nothing against the Silurian rocks is perhaps the most striking instance. In the Yorkshire coalfield the thinning is very marked towards its southern boundary. We have already seen that the central area was characterised by differential subsidence; if now we consider the southern boundary to have been an axis of relative stability, we are enabled to explain the known facts. This explanation, too, would be in harmony with movements in other portions of the area under discussion, and is clearly brought out in Fig. 3. In other words, the downward movement was less rapid as the margin is approached, and might have been nothing at the axis itself. It is difficult to discover how much further back we must date the limiting action of this ridge, but it is suggestive that in South Wales* it was hinted "that there may be some connection in shape between the present Carboniferous basin and the area of subsidence in which the maximum development of the Carboniferous rocks took place." This would imply that the present configuration of the basin was determined by pre-Carboniferous movements, which we have already seen is rather clearly indicated in the Yorkshire coalfield. The significance of the thinning of the Coal Measures towards their margins lies in the evidence they afford that the present limits of the basins were determined, not by post-Carboniferous upheavals, but by a series of differential movements of inter-Carboniferous age.

V.—CHARACTER OF FAULTING.

In the Yorkshire coalfield the faults are normal ones, that is, they hade to the downthrow side. This of course involves extension of the strata affected, and indicates that there was

* The Geology of the South Wales Coalfield, Part II., p. 19.

an absence of tangential stress such as would be required if marginal ridges had been uplifted. They possess, too, the radial and peripheral characteristics so suggestive of a subsiding area. The almost complete absence of overthrusts and reversed faults in the area is a marked feature; while the fact that so many of the faults were intermittent,* in that, while having a large throw in the Coal Measures, they reappear with a smaller throw in the new rocks above, suggests that careful investigation might, in fact probably would, reveal instances of the faults having been progressive ones during Coal Measure times. This would show itself in a diminished throw in the upper seams. There seems to be some evidence of this, though convincing sections are not available.

VI.—RELATIVE AGE OF INCEPTION OF THE CHARNIAN AND MARKET WEIGHTON AXES.

It will be seen from Fig. 4 that the Charnian axis was relatively stable for some time before the Barnsley seam was formed. Its stability was but relative, and at times it partook of the motion of the adjoining area. Its function in determining the limits of the Carboniferous rocks in its direction probably dates back to post-Silurian times. In the case of the Market Weighton axis, it seems to be clear that it was only after the formation of the Barnsley seam that it became stable, for marked thinning only appears after that stage. There is evidence, too, in recent borings, unfortunately not available for publication, along a line normal to the axis, that this condition obtained through Triassic times. The Market Weighton axis therefore came into existence as a line of relative stability after the formation of the Barnsley seam, and is posterior in age to the Charnian axis.

VII.—THE AGE OF THE PENNINE RANGE.

The tangential stress that plicated and rolled up the Silurian rocks before the laying down of the Carboniferous basement conglomerate was applied from the east. The tectonic relationship

* Geological Survey, Summary of Progress, 1902, p. 5.

existing between the Charnian axis and these pre-Carboniferous rocks exposed near Ingleborough has been mentioned, so that we may assume the possibility of an extension of the Charnian axis under the Pennines. The fracture of the Silurian floor that caused the Craven faults would destroy the stability of the ridge if it existed, and therefore the absence of any perceptible barrier between the Lancashire and Yorkshire coalfields up to the horizon of the Silkstone coal of Yorkshire (equivalent of the Arley Mine of Lancashire) is not surprising. The correlation of the seams up to this horizon in the North Staffordshire, Lancashire, and Yorkshire coalfields is convincing evidence that the Pennine barrier did not exist in Lower Coal Measure time. There is little or no evidence of thinning in the Middle Coal Measures on the Yorkshire side of the Pennines, but on the Lancashire side there is marked thinning of the Upper Coal Measures against the Pennines. There is additional evidence in the difference between the Permian rocks east and west of the great barrier, while the absence of Upper Coal Measures, of a type comparable to those of North Staffordshire and Lancashire, in the Yorkshire coalfield points distinctly to a barrier between the two great areas of subsidence, and dates the appearance of the Pennine Range at the close of the Middle Coal Measure period. At the same time it is very probable that it exercised some influence between the Silkstone or Arley Mine period and that of the close of the Middle Coal Measures. Great difficulty has been experienced in correlating the seams that lie above the Silkstone or Arley Mine bed in the Yorkshire and Lancashire basins. This might be taken to indicate that the buried pre-Carboniferous ridge was beginning to come into action and acted intermittently during Middle Coal Measure time, at the close of which it became a rigid barrier separating two subsiding areas. It has already been pointed out that there is an absence of evidence of tangential stresses having been applied in the Yorkshire basin during or since Coal Measure time. On the Lancashire side there is positive evidence of a thinning of the Upper Coal Measures towards their eastern margin, while the coal seams themselves are steeply inclined. The inference is that the

Pennine Range is a stable ridge that came into existence at a comparatively late period in Coal Measure time. That it acted as a barrier between two differentially-subsiding areas. The steepness on the Lancashire side is explained by the fact that this area was subsiding faster than the Yorkshire one, and obviates the necessity for calling in the assistance of a thrust from the east to explain the structure. The Pennines may be regarded as a range of the Uinta type,* formed by the coming into action of the deep-buried pre-Carboniferous ridge.

VIII.—CONCLUSIONS.

Briefly stated, the conclusions arrived at from the consideration of the limited data available of the tectonic features of the coalfield and its margins are as follows :—

- (a) The Charnian axis is an ancient ridge of relative stability dating back to at least post-Silurian time.
- (b) The Market Weighton axis was in existence as a relatively stable anticline during Middle Coal Measure time and soon after the formation of the Barnsley seam.
- (c) The Pennine Range is of the Uinta type, and the date of its appearance might be fixed not later than the close of the Middle Coal Measure period. The difficulty in correlating the Middle Coal Measure seams on both sides rather suggests that it was exercising some influence a little earlier.
- (d) The present limits of the Yorkshire, Derbyshire, and Nottinghamshire coalfield were determined, not by post-Carboniferous earth-movements, but as a result of the operation of a sequence of complicated movements commencing with the post-Silurian tangential stresses that crushed the pre-Carboniferous floor, and changing, after equilibrium had been established, into differential subsidence continued into post-Carboniferous times, when the margins referred to were denuded, and even later.

* Geology of Uinta Mountains, p. 201.

INTER-CARBONIFEROUS EARTH MOVEMENTS

YORKSHIRE, DERBYSHIRE and NOTTINGHAMSHIRE COALFIELD

It will be noticed that no attempt has been made to apply the same method of investigation to the eastern boundary. The recently-expressed views* of Professor Kendall seem the only possible ones in the present state of knowledge.

It is possible, if not probable, that similar conclusions would be arrived at by applying the same methods to some of the other British coal basins, and that of South Wales, from the larger amount of available data, owing to its margins being more exposed, would seem from a cursory examination to be a particularly promising area. In any case it would appear that to attribute the present limits of the British coal basins to the post-Carboniferous upheaval of their margins alone, does not explain all the known facts.

* Final Report of the Royal Commission on Coal Supplies, Part IX., p. 31.