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A Restudy of the Ingletonian Series of Yorkshire [1]

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(PLATE V)

Abstract

A description of the Ingletonian Series is given, with special reference to the sedimentary structures which occur and their use in determining the nature of the folding of the beds ; this is shown to be isoclinal. The age of the series is discussed, and it is considered to be in all probability Pre-Cambrian.

Introduction

THE name Ingletonian Series was given by Rastall to a group of unfossiliferous slates and grits occurring in the West Riding of Yorkshire at Ingleton and Horton-in-Ribblesdale. The formation is unconformably overlain by the Carboniferous Limestone, and on the south is faulted against Lower Palaeozoic rocks. In the present work the evidence of current and graded-bedding has been applied to the determination of the structure of the series. As yet, no undisputed fossils have been described, and the age of the series is uncertain ; new evidence bearing upon this is discussed.

The most important exposure of the Ingletonian rocks occurs in the valleys of Chapel-le-dale and Kingsdale, near Ingleton, and most of the present description applies to this area. In the lower parts of the two valleys there are continuously exposed river sections, but above the farmhouse of Beezleys, in Chapel-le-dale, the outcrops are scattered and discontinuous, although a good section is exposed in the Ingleton " Granite " Quarry.

Lithology

A comprehensive petrographical account of the Ingletonian rocks has been given by Rastall (1906), who has distinguished three main rock types, namely slates, grits, and conglomerates. On the accompanying map of the Ingleton Inlier (Pl. V) we have used the term greywacke, in preference to the indefinite term grit, and have distinguished the following lithological divisions of the series, (i) predominantly greywacke, (ii) predominantly slate, (iii) undifferentiated greywacke and slate. There are all transitions from massive greywacke into finely laminated slate. Banded series of slates and greywackes, with the individual beds only a few inches thick, form transitions between groups (i) and (ii). Coarse greywacke beds occur in many parts of the inlier, rarely more than a few feet thick ; an exception to this is the

[1] Since this paper was written we have learnt that Dr. G. Bond has been working on the Ingletonian and has reached conclusions similar to our own. He has kindly withdrawn his claims in our favour.

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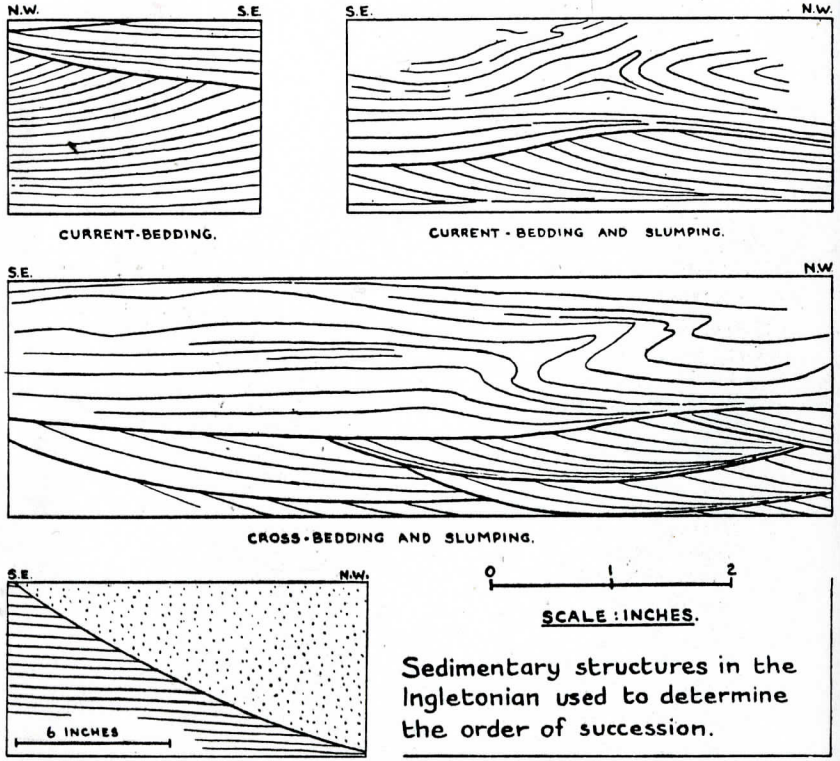
coarse greywacke in the Ingleton " Granite " Quarry, which is up to 100 feet in thickness.

Sedimentary Structures

Three sedimentary structures of special importance will be described, namely current-bedding, graded-bedding, and slump-folding.



Text-fig. 1.

Current-bedding.

Current-bedding occurs throughout the Ingletonian strata, but is best developed in the medium-grained greywacke beds. The commonest type may be termed recurrent-diagonal bedding, in which the foreset laminae of each bed are cut off at the base of an overlying, and asymptote against the underlying, stratum. Torrent-bedding is sometimes seen in which the truncation occurs against the upper and lower strata. Cross-bedding simulating aeolian bedding on a small scale is frequently seen. Text-fig. 1 shows typical examples of the above types

of current-bedding ; attention should be drawn to the small scale of the structure.

Graded-bedding.

Graded-bedding has been seen in a few coarse greywacke beds distributed sporadically in the Ingletonian. In the typical case there is a transition from coarse greywacke, up through finer greywacke, to slate. The coarse greywacke bed in the Ingleton " Granite " Quarry has a basal conglomerate containing rounded and angular pebbles of finer-grained greywacke ; this is an example of graded-bedding on a large scale.

Contemporaneous slump-folding.

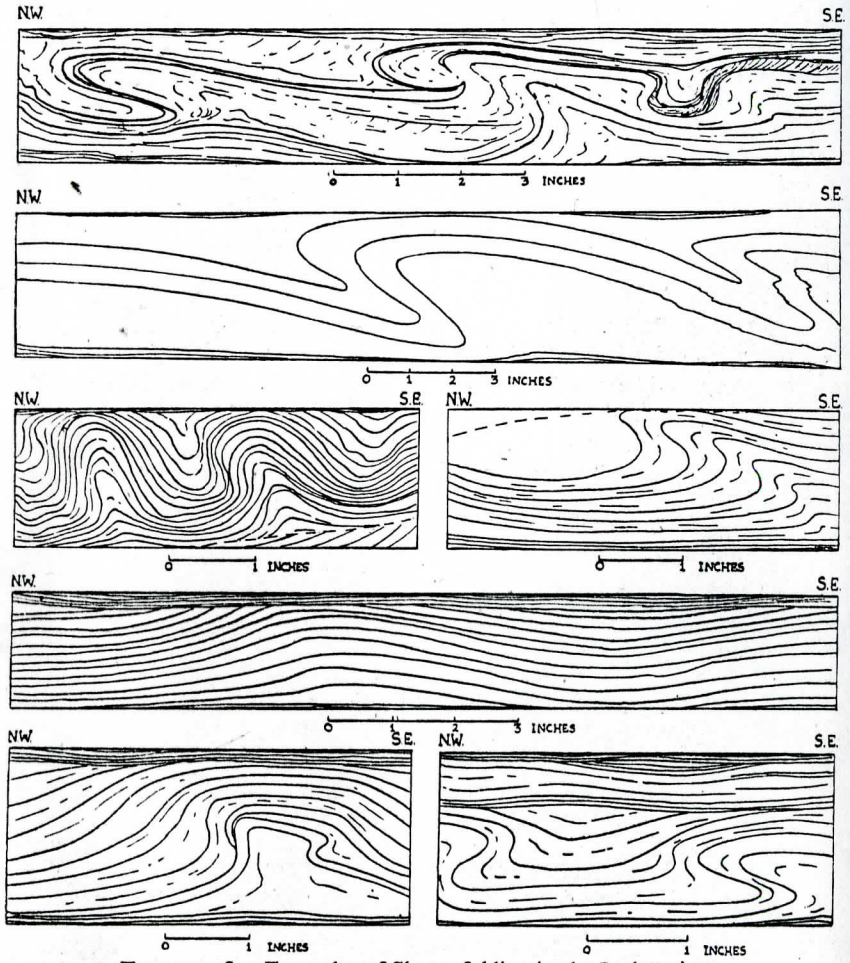
Slumping of unconsolidated sediment has occurred throughout the Ingletonian Series. It is particularly well seen in greywacke beds, rarely more than a few inches thick, interbedded with slate. Good exposures of slumping can be seen in the slate quarry near Snow Falls and in the river sections at Beezley Falls. There are all transitions from mere undulations in the slumped beds to recumbent folds. The slumping is not accompanied by any brecciation, and the folds are often truncated against the overlying strata. The slumping appears to have taken place down a plane of deposition having a general north-westerly dip. Typical examples of slumping are shown in Text-fig. 2.

The above sedimentary structures have been employed in the determination of the structure of the Ingletonian since they give the direction in which a group of strata is " younging " (Bailey, 1934, p. 469). It must be emphasized that the interpretation of current-bedding in the Ingletonian is attended by several difficulties, of which the following are the most important : (i) the beds are extensively fractured, with the fractures commonly inclined to the bedding at low angles ; (ii) torrent-bedding may be confused with current-bedding in the case of imperfect exposures ; (iii) the current-bedding is on a small scale ; and (iv) it is usually necessary to clean rock surfaces to observe current-bedding.

The evidence from the bedding and lithology demonstrates that the Ingletonian was deposited in fairly shallow water subject to current action. As deduced from the current-bedding, the prevalent direction of the currents supplying the sediment was from a general south-easterly direction. The series is lithologically comparable with parts of the lower Torridonian, and may be compared to this group of strata in its mode of deposition.

THE INGLETONIAN OF HORTON-IN-RIBBLESDALE

Greywackes and slates of the Ingletonian Series are seen in a few exposures near Horton-in-Ribblesdale, where the strike is nearly east–west and the beds are steeply inclined southwards. In the railway



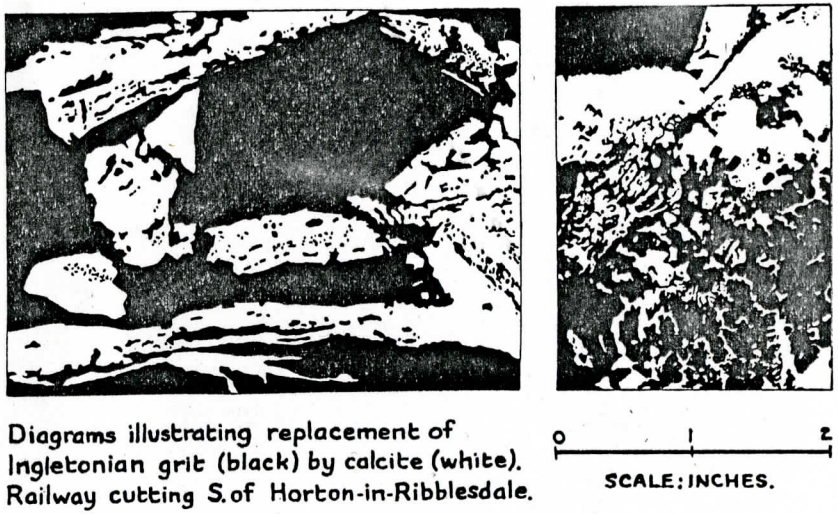
TEXT-FIG. 2.—Examples of Slump-folding in the Ingletonian.

cutting south of Horton station there are two good exposures of greywackes and slates which are particularly interesting on account of the associated calcareous rocks.

At the northern end of the south exposure in the cutting a breccia consisting of angular fragments of greywacke in a matrix of crystalline

limestone occurs. This exposure has been re-examined and clear evidence for replacement of the greywacke by calcite on a large scale has been obtained. It is believed that this breccia is to a large extent a replacement breccia.

At the southern end of the cutting a 3 ft. band of fossiliferous crystalline limestone occurs, more or less conformable to the bedding, and from which King (1932) has obtained an Ashgillian fauna. He has presented convincing evidence that this band represents a neptunean



TEXT-FIG. 3.

dyke. However, part of the band, that part described by King as poorly fossiliferous, is in part due to replacement of greywacke by calcite.

That replacement has occurred in the above cases is clearly seen from the diagrams (Text-fig. 3). One effect of this replacement is seen in the development of angular fragments, previously considered to result from erosion brecciation and desiccation. In addition to the macroscopic evidence of corrosion and replacement, the grits are frequently seen to be permeated by calcite on a microscopic scale.

TECTONICS

Folding.

In Chapel-le-dale the Ingletonian beds show an apparent south-westerly dip at high angles over a distance of 2¼ miles. This has been taken to indicate that at least 10,000 feet of tilted strata are exposed (Gunn, 1890, p. 5), but Hughes (1902, pp. 325–6) expressed doubts

regarding this. He observed folds near Dale Barn and in the " Granite " Quarry, and therefore regarded the series as being isoclinally folded, and drew a hypothetical section to illustrate this view. Other observers either do not appear to have seen these folds or else have doubted their existence. It is now abundantly clear, from a study of the current and graded-bedding that the Ingletonian is isoclinally folded. The strike is almost exactly N.W.–S.E., and is very constant throughout the inlier. The beds are almost always inclined to the south-west at high angles, usually greater than 75°. In the Ribble Valley the Ingletonian strikes 10° N. of W., and the apparent dip is generally about 70° towards the south.

To illustrate the folding, sections in lower Kingsdale and Chapel-le-dale will be described in some detail. In Kingsdale the axis of a syncline is seen a few yards north of the uppermost of the Pecca Falls. The river runs along the axis for a distance of 80 yards. The dip of the north limb is as low as 40°, increasing rapidly upstream to 70° at Cuckoo Island and 85° at Thornton Force. The south limb of the syncline is inverted with an apparent dip downstream of 80°–85° ; at the axis, however, this limb dips upstream at a high angle. The folding is very sharp, and is accompanied by much fracturing.

The syncline appears again in Chapel-le-dale. The actual axis is not well seen, though there is a contrast in the dips on either side of it ; the presence of the axis is shown by a slight topographic depression which runs along it. The dips of the two limbs are similar to those seen in Kingsdale. The presence of the syncline is confirmed by evidence from current and graded-bedding determinations made in both valleys. Further evidence is obtained from the lithology ; upstream and downstream from the axis of the syncline occur two slate bands of closely similar thickness and lithology, which are sharply differentiated from the massive greywacke beds within the syncline. They outcrop at almost equal distances from the axis, and the slight difference which does occur is probably due to the asymmetric nature of the fold, the axial plane of which dips to the south-west at about 70°.

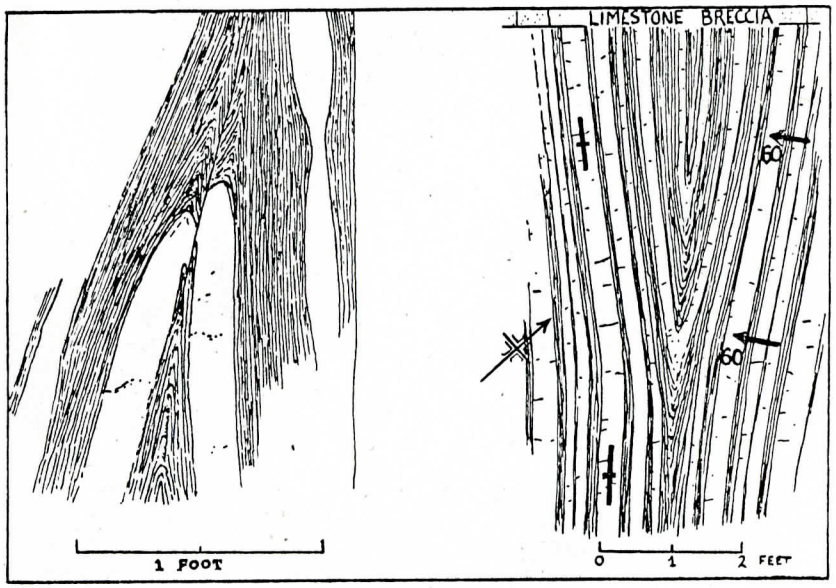
An anticline is seen in the river in Chapel-le-dale about 100 yards south-east of Beezleys and a few yards above the uppermost of the waterfalls. A sketch of the river section, showing the fold, is reproduced in Text-fig. 4. The presence of this anticline was proved by current-bedding determinations at places within 30 yards upstream and downstream from the axis. The dip of the south limb is 60°, whilst the north limb is essentially vertical.

Between this anticline and the previously described syncline two further folds have been proved by current-bedding. They consist of an anticline and a syncline, and the former can be observed in the river 60 yards upstream from the slate quarry near the Snow Falls. The

synclinal axis must fall in the middle of the slate band outcropping up the Baxengill Gorge, and this precludes its recognition in the field.

In view of the nature of the outcrops north of Beezleys, in Chapel-le-dale, it is impossible to map accurately all the folds which must occur. A synclinal axis crosses the valley near Dale Barn (Text-fig. 4) and a syncline occurs in the Ingleton " Granite " Quarry, though the actual axis is not well seen, owing to intense fracturing in the greywacke beds.

Summarizing, we may briefly state that the Ingletonian Series of the Ingleton Inlier is isoclinally folded into a succession of anticlines and



TEXT-FIG. 4.—Left: Sketch of section of anticline above Beezley Falls. Right: Plan of syncline near Dale Barn.

synclines, which have axial planes dipping south-west at about 70° (Pl. V, section). The southern limbs of synclines and the northern limbs of anticlines are therefore inverted. It would appear that the main direction of pressure came from the south-west. A relatively small thickness of strata outcrops over the 2¼ miles of the exposure in Chapel-le-dale.

Fracturing.

The Ingletonian rocks are intensely fractured on both a large and a small scale. The lack of distinctive beds within the series makes it impossible to determine the nature of the fracturing accurately. A large

fault is exposed at the northern end of the Ingleton " Granite " Quarry and a brecciated zone about 5 feet wide occurs. The fault plane is horizontally slickensided and is parallel to the bedding, which dips at 65°. Small faults with a few inches displacement are common. The shear fractures are usually inclined to the strike at small angles. Tension fractures are very common in the greywacke beds and have been infilled with quartz. They trend approximately N.N.E.–N.E., and are inclined to the south-east at high angles. Quartz veins with this trend are rarely more than a few inches thick. Veins trending approximately with the strike are not uncommon, and may occur up to 2 feet in width.

Basic Dykes

A pair of basic dykes cut the Ingletonian in Chapel-le-dale. Exposures of these dykes occur in the slate quarry near the Snow Falls and in the river immediately below the quarry, and also further downstream at the head of Twisleton Glen, on the left bank of the river. The dykes are a few feet apart and are 1 foot and 3 feet wide at Snow Falls. Their trend is N.N.E.

In thin section the dykes are seen to be much altered, and consist of chlorite, calcite, plagioclase, secondary quartz, leucoxene, and ore. Large pseudomorphs of chlorite and calcite after olivine occur. A determination of the quartz content was made by R. W. Grimshaw, by measuring the β to α quartz thermal energy change, and the result showed that 13·2 per cent of secondary quartz is present.

The dykes have been sheared subsequent to their intrusion and are typical members of the greenschist facies.

Regarding their age, these dykes may be related to the early Ordovician basic intrusions of the Cross Fell Inlier (Hudson, 1937, pp. 396–8).

Age Relationships of the Ingletonian

In the lower part of Chapel-le-dale and Kingsdale a narrow outcrop of much crushed Coniston Limestone occurs. The junction with the Ingletonian is regarded as being faulted (Wood, 1948). It is now known that the Ingletonian is inverted immediately north of the Coniston Limestone outcrop, and there can be little doubt that no conformable passage exists between the two formations.

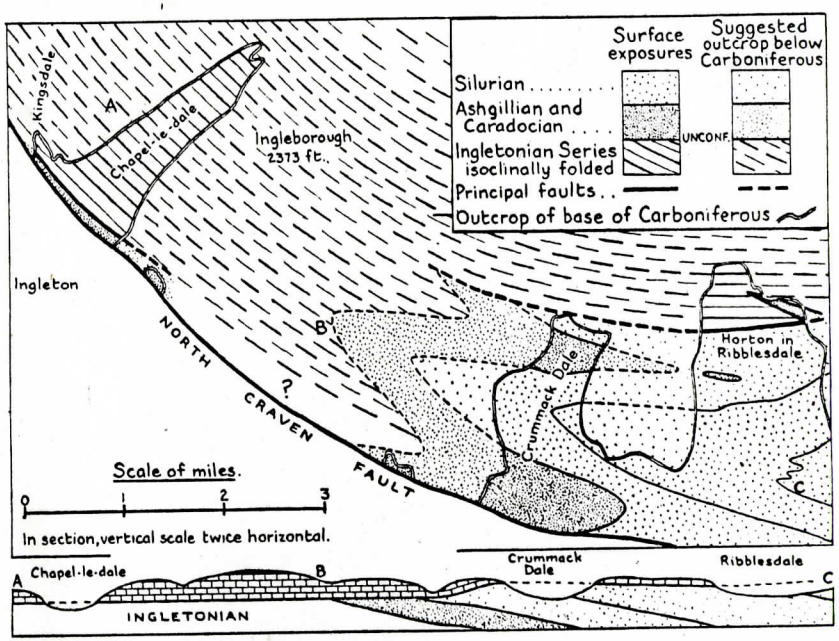
With regard to the age of the Ingletonian, there are three possibilities :—

(1) That the Ingletonian is of Ordovician age and passes up conformably into the Coniston Limestone Series ;

(2) that it is of Lower Palaeozoic age and is overlain unconformably by the Coniston Limestone ; and

(3) that it is Pre-Cambrian.

Green (1917) supported the first view. A correlation of the Ingletonian with the Ordovician strata of the Lake District and Wales was denied by Rastall, on petrographic grounds. Rastall and King considered the Ingletonian to be older than the Ordovician, and possibly of Pre-Cambrian age. Regarding the neptunean dyke at Horton-in-Ribblesdale, King states (1932, pp. 107–8) : " after the deposition of the Ingletonian, sufficient time elapsed to allow the grits



TEXT-FIG. 5.—Map and section showing relationship between the Ingletonian Series and the fossiliferous Lower Palaeozoic strata.

to become consolidated, tilted to a steep angle, and eroded . . . prior to Ashgillian times . . ." and as " no period of intense earth movement is known during the Ordovician or Cambrian it would appear . . . that the compressional movements . . . must belong to Pre-Cambrian times ".

The occurrence in the Ingletonian of isoclinal folding stands in marked contrast to the more open folding in the adjacent fossiliferous Lower Palaeozoic rocks of Crummackdale and Ribblesdale (King and Wilcockson, 1934). It is therefore considered that the former has been affected by at least two periods of folding of pre-Caradocian and Caledonian age, the latter also affecting the fossiliferous strata. It may be that all the folding in the pre-Carboniferous rocks was accomplished

at one period, the difference in intensity being due to some structural cause, but the neptunean dyke at Horton, to which reference has already been made, provides clear evidence that slates already existed in the Ingletonian Series in Caradocian times, which would seem to preclude this possibility.

The general relationships of the Ingletonian to the fossiliferous Lower Palaeozoic strata are shown in Text-fig. 5. An unconformity has been drawn below the Caradocian, and the outcrops have been tentatively continued below the Carboniferous. The easterly pitch of the fossiliferous strata at an angle of about 7° should be noted; this would account for the occurrence of the older Ingletonian rocks in the Ingleton area. Attention is also drawn to the general parallelism of the strike of the Ingletonian and the adjacent Lower Palaeozoic strata, and to the way in which the Craven Fault System follows this strike.

An unconformity occurs in the Lake District at the base of the Coniston Limestone, and there is evidence for slight pre-Bala folding. In the Cross Fell Inlier (Shotton, 1935) an unconformity has not been proved, but the Skiddaw Slates are more intensely folded than the post-Skiddavian rocks, and have therefore presumably been folded during an early Ordovician orogeny. In neither of these areas, however, does the pre-Caradocian folding appear comparable to that of the Ingletonian ; this fact, taken in conjunction with the absence of fossils within the series and the impossibility of correlating it with any of the North of England Lower Palaeozoic strata, seems to indicate that it is in all probability of Pre-Cambrian age.

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