25. GEOLOGY of the ASHBOURNE & BUXTON BRANCH of the LONDON & NORTH-WESTERN RAILWAY :—CRAKE LOW to PARSLEY HAY.
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[PLATES XXII & XXIII.]

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I. INTRODUCTION.

In a previous paper read before this Society,¹ I gave a description of the geology of 6 miles of the new Ashbourne & Buxton Railway from Ashbourne to Crake Low. The sections described were in Bunter Sandstone, Boulder-Clay, shales and thin limestones (Yoredale Series of the Geological Survey), and volcanic tuff. The present paper is a continuation of the former one, and deals with the geology of the cuttings (Nos. 9 to 23) in the next 8 miles as far as Parsley Hay.

After passing through Yoredale Shales in the second cutting (No. 10), the railway enters the thick beds of Mountain-Limestone, in which it continues as far as Buxton. Several of the cuttings are of considerable length and depth; but, owing in some cases to the folded state of the beds, and in others to their nearly horizontal position, no very great thickness of limestone is seen.

It was not found possible to correlate the beds in the different cuttings. Although the limestones in the Cold-Eaton and Heathcote cuttings are somewhat similar in character and are divided up by intercalations of clay, we cannot be certain that they represent the same series of beds. The clay-partings do not in any way correspond. They are farther apart in the Cold-Eaton than in the Heathcote cutting. In the former six wayboards of clay are contained in 230 feet of limestone, and in the latter eight in a little more than 100 feet.

The chief points of interest brought to light by the sections in the cuttings are:

- (i) The numerous folds into which the massive beds of Mountain-Limestone have been thrown on the western side of this part of the Pennine Chain.

¹ Quart. Journ. Geol. Soc. vol. lv (1899) pp. 224-36 & pls. xvii-xviii.

- (ii) The granular and in part oolitic structure of some of the limestones.
- (iii) The probable thinning-out of the volcanic tuff in a northerly direction from the village of Tissington.

The cuttings between Parsley-Hay Station and Buxton were completed before my attention was called to the new railway, consequently they have not been carefully examined. The dip of the limestones is generally small, and the cuttings are of no great depth nor length. In one of them, the vesicular lava which is mapped by the Geological Survey near Haslin House (about 1 mile south of Buxton) was seen north-west of Staker Hill.

II. DESCRIPTION OF THE CUTTINGS.

9. Crake-Low Farm.

Separated by a bank of red soil from the Crake-Low cutting (No. 8 in my previous paper) is one in which a thickness of about 30 feet of limestone is seen. The beds are contorted, and form a small fold the axis of which runs nearly due north and south. They consist of cherty limestones, which are often dolomitized and separated by thin partings of shale.

10. Newton Grange.

The railway has been cut through a ridge or elongated dome, which forms a well-marked feature in the landscape. The longer axis runs north-north-west and south-south-east, while the cutting is parallel to the shorter axis, and shows a section with a fine anticline in the Mountain-Limestone. For the first, 80 or 90 yards the railway passes through shales and thin beds of limestone which are greatly contorted, then through a thick bed of limestone and alternations of shales and thin limestones, which mark the passage-bed from the Yoredale Series to the Mountain-Limestone. The dip is at first towards the east; with a few minor contortions, the beds roll over and settle to a south-easterly dip, which is maintained until we reach the centre of the dome, where the beds become horizontal, and then dip in a north-westerly direction.

The following measurements were taken from above downward. No attempt was made to measure or estimate the thickness of the contorted and rapidly-weathering shales at the southern end of the cutting. A well-defined bed of limestone, white and fresh on one side of the cutting, but brown and partly decomposed on the opposite side, was the topmost of the beds measured.

Section showing the junction of the Yoredale Beds and Mountain-Limestone at the southern end of Newton-Grange Cutting.

	<i>Thickness in feet inches.</i>	
Contorted shales, not measured	—	—
Limestone with <i>Productus</i>	2	0
Shale	0	10
Thin limestones and shales	3	0
Shale	2	6
Thin limestones with shale-partings	5	0
Do. Do. Do. (1045) ¹	4	0
Yellow tuff, the greater portion decomposed to a clay, but in places less weathered and blue in colour (1046)	6	0
Shale	1	3
Thin limestones	1	6
Soft black shale	2	3
Thin limestones	2	0
Shale	0	3
Limestone with <i>Productus</i>	1	4
Limestone and shale	3	10
One of the limestones thins out, and is replaced by shale a few feet away on the same horizon. }		
Laminated limestone (1047)	0	8
Shale	0	2
Fossiliferous limestone	0	6
Shale	0	2
Limestones with shale-partings	3	0
Shales, mostly black	9	0
Blue limestone (1049)	3	6
Chert-band	0	2
Blue limestones, with bands of chert and shale-partings	30	0
Blue limestone	4	0
Yellow limestone	1	0
Blue limestone and chert, with very thin shale-partings	16	0
Blue limestone with chert-band, shale almost absent	16	0
Blue limestone with chert-bands, lowest beds reached	28	0
Total thickness of beds seen	147	11

In the northern limb of the anticline the following beds were measured :—

	<i>Thickness in feet.</i>
Grey encrinital limestone, the encrinites being larger and more numerous near the top	47
Blue limestones with chert-bands	60
Total thickness of beds seen	107

The beds of limestone at the northern end of the cutting are, therefore, about 40 feet below the lowest of the shale-beds seen at the southern end. At the centre of the anticline the beds were seen

¹ The numbers in parentheses throughout this paper refer to those of the rock-slides in my collection.

to bend over in a south-easterly and north-westerly direction, and to dip at angles of 30° and 15° respectively.

No definite proof was found of volcanic detritus in the limestones associated with the shales above the Mountain-Limestone.

The bed of tuff, 6 feet thick, may represent the thinned-out portion of the tuff-bed that reaches a thickness of about 140 feet in the Tissington cutting. If this opinion be correct, the tuff in the cuttings nearer Tissington occurs on a horizon about 60 feet above the main mass of Mountain-Limestone; and, since the limestones for 80 feet above the thick tuff-bed contain volcanic detritus, volcanic action in this part of the country must have continued until between 100 and 200 feet of Yoredale rocks had been deposited.

11. Moat Low.

In this cutting, which is a short one, the beds dip 20° in a south-easterly direction. About 30 feet of limestone with bands of chert are seen. The beds in the immediate neighbourhood dip in the same direction as those in the cutting. In an old quarry east of the cutting and on the footpath to Parwich Lees encrinital limestones, with chert-bands in the limestones below them, are seen to dip south-eastward at an angle of 20° . In another old quarry, near O. D. 889.2, beds of massive limestone dip south-eastward at an angle of 30° . Near the 5th milestone from Ashbourne dolomitized limestones, with limestones containing *Productus* and encrinite-stems, are seen dipping south-eastward at an angle of 20° ; while at the south-eastern end of the cutting and lower down the hill, cherty limestones are seen dipping 40° in a south-easterly direction. There is, therefore, a syncline between the Newton-Grange and Moat-Low cuttings, with its axis nearly parallel to the anticlinal axis of the Newton-Grange cutting.

12. New Inns (South).

In this cutting from 20 to 30 feet of limestone may be seen. The beds are at first nearly horizontal, and traversed by numerous calcite-veins. They then dip 20° in a north-westerly direction, and at the northern end are much broken up by joints, which are inclined at an angle of 50° to 90° to the horizon. These limestones contain encrinite-stems.

13. New Inns (North).

The beds consist of thin limestones which, on the whole, dip nearly due south or south-south-east, so that, as we proceed towards Buxton, we pass through successively lower beds in the series. There are a few small folds, and several good examples of lenticular beds of thicker limestone among the thinner ones.

14. Alsop-en-le-Dale. (See Pl. XXII, figs. 1 & 2.)

While this cutting was in progress, some very good sections of contorted strata belonging to the Mountain-Limestone were seen. Some of the best are now covered by a wall and a bridge, over which the turnpike-road passes.

The bearings of three of the anticlinal axes were taken, and found to be north-north-west and south-south-east, which is the same direction as the longer axis of the Newton-Grange dome.

The beds at first dip south-east by east, roll over in an anticline, and dip north-west by west; where the bridge has been erected they are bent into a sharp syncline and anticline. A sharp anticline follows, the beds then roll over into a more gentle anticline, are bent into a sharp syncline, and after passing through a short anticline and syncline, roll over a longer anticline and dip gently about 20° a little north of west. The beds contain chert, and are often dolomitized and traversed by veins of calcite; a fissure about 3 feet wide, on the south-western bank (down-line), is filled with clay.

Rough measurements of the beds show that a thickness of about 85 feet of limestone is seen in the cutting; and that, owing to the numerous folds into which the beds have been thrown, the difference in horizon of the beds at opposite ends of the cutting amounts only to about 10 or 15 feet.

15. Nettly Low.

This cutting is a small one, and only about 6 feet in depth. The beds dip as a rule nearly due east, towards the valley of the Dove.

16. Cold Eaton.

This cutting is in massive limestone with six clay-partings. The lower beds are at the Ashbourne end, and the dip is about 5° north-north-eastward. The lowest limestones below and up to the sixth or lowest clay-bed seen, consist of a white, granular and in part oolitic, limestone, with small pebbles of a previously-consolidated limestone. Other beds of limestone have the granular structure in most cases above and below a bed of clay. The clay-partings vary in thickness, and are sometimes variegated in differently-coloured layers. The upper beds of limestone contain a greater quantity of *Productus* than the lower, and are of a bluish-grey colour.

The following beds were measured :—

	Thickness in feet inches.	
Grey limestone, the upper parts containing <i>Productus</i> and passing down into a bluish-grey limestone. Dip 5° N.N.E. (1073)	110	0
First clay-parting, varying in thickness from 6 to 10 inches	1	5
Massive limestone	32	0
Carried forward	143	5

	<i>Thickness in</i>	
	<i>feet</i>	<i>inches.</i>
Brought forward	143	5
Second clay-parting	0	6
Massive limestone, granular in places.....	86	0
Third clay-parting	1	4
Massive limestone, upper portion white (954); but granular above Clay No. 4	39	0
Fourth clay-parting	0	6
Massive limestone, granular below Clay No. 4 and immediately above Clay No. 5 (953 & 1074)	19	6
Fifth clay-parting, in about twenty-one layers varying in colour (1075)	1	10
Massive limestone, granular.....	22	0
Sixth clay-parting.....	0	8
Massive white limestone, granular, with a few specimens of <i>Productus</i> , <i>encrinite</i> -stems, and small pebbles of limestone	29	0
	<hr/> 343	<hr/> 9

17. Cheapside.

The beds in this cutting dip 10° to 15° south-south-eastward. The following section was seen :—

	<i>Thickness in</i>	
	<i>feet</i>	<i>inches.</i>
Massive limestone.....	4	0
Clay-parting	0	5
Limestone	7	6
Encrinital limestone	5	6
Limestone, with stems of larger encrinites than those in the overlying bed	3	0
Limestone	10	0
	<hr/> 30	<hr/> 5

18. Bank House.

Only about 20 feet of strata can be seen in this cutting. The limestone is light-grey, with but a few traces of fossils. The beds are at first horizontal, and at the northern end dip 5° north-westward.

19. Heathcote.

At the southern end, and through a greater portion of the cutting, the beds dip 15° in a south-easterly direction, but at the Buxton end the dip decreases to an angle of 5°. There are several fissures, or pockets, in the limestone, filled with sand and clay. The sand is not a quartzose sand, but is probably derived from a decomposed dolomitic limestone.

The limestones in this cutting are, like those in the Cold-Eaton cutting, divided by wayboards of clay. They were not carefully examined for oolitic structure, as I was unable to visit the Heathcote cutting after I had found the oolitic limestones in the Cold-Eaton cutting.

The following beds were seen (the upper half was estimated, and the lower measured):—

	<i>Thickness in feet inches.</i>	
Limestones much broken up by joints about	25	0
Limestone with fossils about	40	0
Limestone with encrinurites, dolomitized, and contain- ing pockets filled with clay and decomposed dolo- mitic limestone at least	30	0
Massive limestone	40	0
First clay-parting	0	6
Limestone about	10	0
Second clay-parting	0	6
Limestone, granular (969)	30	0
Third clay-parting	0	5
Limestone	1	9
Fourth clay-parting	0	4
Limestone	8	0
Fifth clay-parting	0	6
Limestone	4	3
Sixth clay-parting	0	1
Limestone	12	0
Seventh clay-parting	0	6
Limestone	8	0
Eighth clay-parting	0	8
Limestone	30	0
	<hr/>	<hr/>
	242	6
	<hr/>	<hr/>

20. Hand Dales.

A thickness of about 30 feet of limestone was observed, the beds dipping 10° towards the Ashbourne end of the cutting.

The lowest beds consist of a white, finely-granular limestone (1092); above these may be seen 10 or 15 feet of a limestone containing encrinurite-stems, a few shell-fragments, and other small fossils not yet determined. Above this limestone the beds contain a few corals.

21. Caskin Low.

A thickness of about 40 feet of horizontal beds is seen in this cutting. The upper beds are very much broken up and weathered, but the lower are more massive. The latter are dolomitized in the upper parts, and pass into very fine-grained limestones with foraminifera. The lowest beds seen are granular, and contain amorphous pellets, a few small pebbles of limestone, and small fossils not determined.

22. Lean Low.

This is a shallow cutting on the eastern side of the hill-slope, south of Parsley Hay Bridge. The beds are nearly horizontal, and although the cutting is about 500 feet long, only a thickness of 18 feet of limestone is seen. The rock is bluish-grey, and contains *Productus* and a few corals.

23. Parsley Hay.

This cutting is in a massive white or light-grey limestone. A thickness of about 66 feet of strata is seen. At the northern end of the cutting the beds dip 10° north-eastward, and contain a few corals. Near the bridge they become horizontal. A brown dolomitized limestone occurs in irregular patches, and in vertical vein-like masses. The latter are due to dolomitization of the limestone along vertical joints. A hand-specimen (1096) from a vertical joint shows the junction between the dolomitized and the ordinary limestone. The dolomitized portion is brown, the unaltered part grey. The grey limestone near the junction contains numerous brown spots which consist of rhombohedra of dolomite.

The middle beds near the northern end of the cutting yield foraminifera (1097).

III. PETROGRAPHY OF THE ROCKS.

(1) Calcareous Tuff in Newton-Grange Cutting.

Thin slice 1046 (see p. 339). This is a bluish-grey tuff similar to some parts of the thick bed of tuff in Highway-Close Barn, described in my previous paper.¹ The irregular outlines and vesicular structure of the lapilli are easily seen in a hand-specimen of the rock. In a thin slice there are many vacant spaces, owing to the lapilli having dropped out in the process of grinding. Some lapilli are, however, left in the thin slice, and are altered to calcite. This rock was originally a calcareous tuff, consisting of vesicular lapilli in a cement of calcite or in a sediment containing calcium-carbonate.

(2) The Limestones.

The limestones may be conveniently divided into :

- (a) Crystalline limestones, either partly or wholly dolomitized.
- (b) Fine-grained limestones, partly crystalline.
- (c) Granular and, in part, oolitic limestones.
- (d) Encrinital limestones.

(a) Some of the dolomitic limestones consist of a more or less granular aggregate of dolomite and calcite with few, if any, rhombohedral outlines.

A thin slice (973) from the New-Inns cutting shows clearly-defined rhombohedral crystals of dolomite, with patches of iron-oxide and a few quartz-grains.

The grey limestone near its junction with the brown dolomitized limestone in the Parsley-Hay cutting (1096) consists of clear crystalline calcite polarizing in bright tints, in which are embedded idiomorphic rhombohedra and segregations or patches of brown dolomite.

¹ Quart. Journ. Geol. Soc. vol. lv (1899) p. 233.

(b) The fine-grained limestones (1095, 1049, & 1073) consist mainly of more or less crystalline calcite, which contains small circular bodies (probably *Calcisphaera*), foraminifera, small fragments of shells, encrinite-stems, lath-shaped prisms of calcite with jagged edges, and a few quartz-prisms.

(c) Granular or Oolitic Limestones.

Several thin slices of the granular limestone from the Cold-Eaton cutting, and one from the Heathcote cutting, were examined.

Nos. 953 & 1074 were taken from the limestone a few inches above the fifth clay in the Cold-Eaton cutting (see p. 342). Examined with a lens in a hand-specimen, the rock is seen to consist of small grains and to contain small pebbles of limestone. Under the microscope, it consists of oolitic grains and pellets and well-worn pieces of limestone in a cement of calcite.

The oolitic grains possess a concentric, and sometimes a radial structure. In a few cases they show a black cross in polarized light, but the majority consist of a brown non-crystalline substance. They are generally circular or oval in section, and the nucleus often consists of a foraminifer or a shell-fragment. (See Pl. XXIII, fig. 1.)

The pellets are amorphous, and possess no recognizable structure. A few of them contain iron-oxide, and polarize in a grey tint. A similar substance forms the nucleus of one of the oolitic grains, and is very much like that of which the clay in thin slice 1075 is composed. Some of the pellets probably represent small portions of rolled clay, which have been incorporated in the limestone immediately above it.

The limestone-pebbles are well rounded, and contain foraminifera, fossil-fragments, and sometimes oolitic grains. They are often coated with a dark-brown amorphous substance, which is darker than the interior of the pebble. There is no doubt that they have been derived from a previously-consolidated limestone, and owe their well-rounded form to attrition. The oolitic grains, pellets, and pebbles are seldom in contact, but are cemented together by crystalline calcite. (See Pl. XXIII, fig. 2.)

No. 1076, below the sixth clay-bed in the Cold-Eaton cutting, and No. 969, below the second clay-bed in the Heathcote cutting, have a structure similar to the preceding, but are not in so fresh a condition. The majority of the oolitic grains either have been altered to a dark substance, or originally contained less calcium-carbonate. Amorphous pellets without any recognizable structure are present. The cementing-material is crystalline calcite.

The limestone above the fourth clay in the Cold-Eaton cutting is oolitic, but some feet higher in the series it loses its granular structure, and consists of shell-fragments, encrinite-stems, corals, and foraminifera (954).

(d) Encrinital Limestone.

Limestones with portions of encrinite-stems are common in the cuttings. They may be easily identified in hand-specimens, and in thin slices show the usual sections of these fossils.

(e) Clay-Parting.

(1075) A specimen of the soft clay from clay-parting No. 5, in the Cold-Eaton cutting (see p. 342), was kept in a drawer for several months. It was then sufficiently hard and dry for a thin slice to be made from it. Under the microscope it was seen to be amorphous, and contained iron-oxide. There were present a few needle-shaped crystals and prisms, with parallel extinction and positive double-refraction, polarizing in grey tints: these may be referred to quartz. Another small prism polarized in a yellowish-red, stood out in relief, had positive double-refraction, and may be assigned to zircon.

EXPLANATION OF PLATES XXII & XXIII.

PLATE XXII.

Fig. 1. Anticline and syncline in Mountain-Limestone, Alsop-en-le-Dale Cutting, London & North-Western Railway. (See p. 341.)

2. Anticline in Mountain-Limestone, same locality. (See p. 341.)

PLATE XXIII.

Fig. 1. Oolitic and pebbly limestone, $\times 50$, resting on the fifth clay-bed, Cold-Eaton Cutting, London & North-Western Railway. The oolitic grains show radial, and sometimes concentric structure. They are rarely in contact, and are separated by calcite, more or less crystalline, which exhibits very little structure or detail under the microscope (953). (See p. 345.)

2. Oolitic and pebbly limestone, $\times 25$, resting on the fifth clay-bed, same locality. The figure contains a pebble of fossiliferous limestone and small pellets (1074). (See p. 345.)

DISCUSSION.

The CHAIRMAN (Mr. TEALL) said that he was much pleased to know that the Author was continuing his excellent geological work in Derbyshire. In regard to the oolitic structures mentioned, he cited a paper recently published in the *Neues Jahrbuch*, where the results of an examination of recent oolitic grains showed that they were formed of aragonite, and so the inference had been drawn that all oolitic grains were aragonite to start with, and that the change to calcite had taken place in the process of fossilization. Moreover, it was found that if calcium-carbonate was precipitated from sea-water by the action of ammonium-carbonate on the calcium-sulphate spherules of aragonite were formed.

Prof. SOLLAS enquired whether the Author had discovered traces

FIG. 1.—ANTICLINE AND SYNCLINE IN MOUNTAIN-LIMESTONE.

FIG. 2.—ANTICLINE IN MOUNTAIN-LIMESTONE.

(From Photographs by H. H. Arnold-Bemrose.)

FIG. 1.

X50.

FIG. 2.

X25.

H. A. B., Photomicro.

Bemrose Ltd., Collo.

OOLITIC AND PEBBLY CARBONIFEROUS LIMESTONE.

of organisms among the oolitic rocks, and whether he attributed the oolitic structures to the growth of *Girvanella*. The best instances of oolite-formation at the present day occurred in closed salt-lakes ; he had never seen true oolitic structure in association with coral-reefs.

Prof. WATTS said that he was much impressed by the Author's microphotographs of dolomitic limestone. There was no more remarkable phenomenon than the growth of dolomite in rocks of this kind. The magnesia appeared sporadically in the midst of oolitic grains, and there was a most interesting zonary arrangement of impurities inside the dolomite-crystals.

The AUTHOR said that encrinite-stems occurred in some of the oolitic grains, and thanked the Fellows for the reception accorded to his paper.