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I

THE ROCKS BELOW THE RED CHALK OF LINCOLNSHIRE, AND THEIR CEPHALOPOD FAUNAS

BY HENRY HURD SWINNERTON, D.SC. A.R.C.S. F.G.S.

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[Plates I–IV]

Contents

of the ammonites they found in the Spilsby Sandstone to t Jurassic genus *Craspedites* and therefore concluded that t lower part of this sandstone must be pre-Cretaceous in a Dr. Spath had pointed out that they belong to the Cretaceo genus *Subcraspedites*. The Fordington specimens showed t genus just springing into being from some stock that is n *Craspedites*. This confirmed the view that a gap still exist between the Jurassic and the oldest known Cretaceous be of Lincolnshire.

I. Introduction

Though the rocks below the Red Chalk of Lincolnshire are of peculiar interest, the absence of exposures along the coast, together with the rarity and transitory character of inland excavations, have made it exceedingly difficult to build up a body of information that approaches, even approximately, that standard of detail and accuracy which characterizes modern stratigraphy. Any information that can be culled from borings is, therefore, of especial value.

In the early summer of 1932 the Alford Town Council sank a boring in search of water from the Spilsby Sandstone. After piercing a thick covering of boulder-clay, the boring entered the lower part of the Red Chalk and then passed through 200 feet of other strata before entering the Spilsby Sandstone. Fortunately, a long spell of dry weather preserved the core from that rapid disintegration which would have been produced by rain, and also enabled me to make the requisite number of journeys from Nottingham to Alford for effecting a careful examination of the core. My heartiest thanks are due to Mr. R. Bentham and to Mr. P. E. Kent, who accompanied me on most of the journeys and helped me with the laborious task of breaking up the rock and of making a thoroughly representative collection of specimens from all portions of the core.

Other borings have subsequently been put down at Maltby-le-Marsh, Fordington, and Skegness, but the use of the percussion method of boring, and other circumstances, have prevented me from obtaining more than fragmentary information from them.

In the Alford and Maltby borings a bed of light-coloured marl, situated below the Carstone Beds, was brought to light. The fossils yielded by this bed were of such exceptional interest that it was decided to make a search for this marl at the outcrop. Indications were found at a number of places; at one of these, situated near the village of Sutterby, $4\frac{1}{2}$ miles west of Alford, excavations were made during the month of August, 1932 and 1933. My thanks are due to the landowner, Mr. S. R. Wood of Firsby, and to the tenant farmers for permission to excavate. Mr. R. Crossland assisted me on both occasions, and I take this opportunity of expressing my deep appreciation of the invaluable help he rendered. As the work proceeded it became necessary to examine numerous specimens housed in the collections of the Geological Survey. My thanks are due to Sir John S. Flett, to the late Dr. F. L. Kitchin, and to other members of the Survey for facilities and ever-courteous help in conducting the examination. I am similarly indebted to Dr. W. D. Lang and to Dr. L. F. Spath of the British Museum (Natural History) who were not less generous in placing the

collections under their care, and their time and special knowledge, at my disposal.

The stratum mentioned above will be referred to hereafter as the Sutterby Marl.

The deposits described below have yielded a rich suite of fossils other than cephalopods. It includes numerous lamellibranchs, some foraminifers, a small number of gastropods, a few fragmentary echinoids, and fish remains. As much work still remains to be done in extracting them from the matrix, and in identification, these fossils will not be considered in this paper.

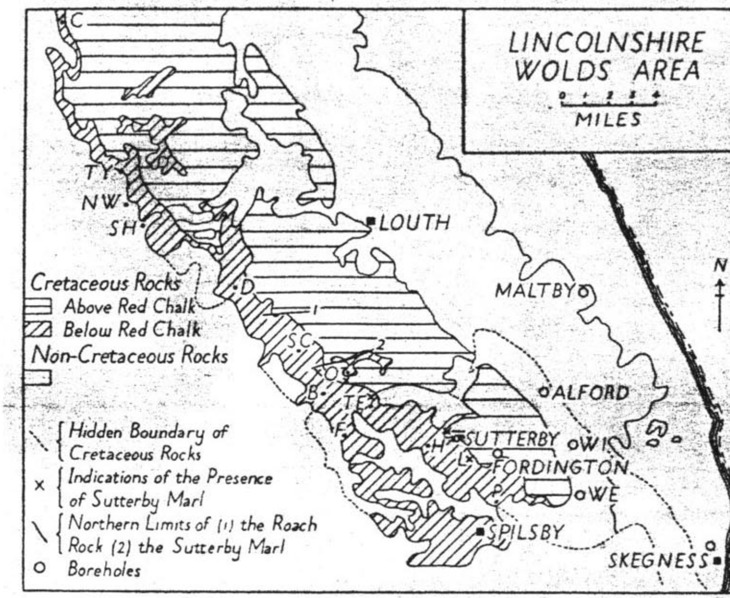

Fig. 1.

This map also shows the positions of the following places:—B. Belchford, C. Claxby, D. Donington, F. Fulletby, H. Harrington, L. Langton, NW. North Willingham, O. Oxcombe, P. Partney, SC. Scamblesby, SH. Six Hills, TE. Tetford, TY. Tealby, WE. Welton, WI. Willoughby.

(*Modified from map published by the Geological Survey.*)

II. Stratigraphical Summary

In consequence of the study of the various sections which are described below, it has been found necessary to revise and amplify the generally accepted succession of the strata found beneath the Red Chalk in Lincolnshire. It will be a help in the description and discussion, as well as the appreciation, of those sections if, at the risk of anticipating conclusions arrived at later, a summary of the newly established succession be given now. No alteration of existing names is made, but further subdivisions are inserted. The system of grouping under geographical headings is extended, and the new names are taken, as far as possible, from places or districts where some portion of the beds in question may still be seen in existing exposures. The following table gives the beds in descending order :—

LANGTON SERIES		
	Carstone Beds	Carstone grit
		Carstone sands and clays
		Sutterby Marl
TEALBY SERIES		
	Fulletby Beds	Upper Roach
		Roach Stone
		Lower Roach
	Tealby Beds	Upper Tealby Clay
		Tealby Limestone
		Lower Tealby Clay
	Claxby Beds	Upper Ironstone
		Lower Ironstone
SPILSBY SERIES		
	Spilsby Beds	Ferruginous grit
		Glauconitic sands
		Basement beds

III. Description of Borings and Sections

(a) The Alford Boring

(i) *Notes on the Core.*—The Alford boring, which was completed in June, 1932, was put down in the grounds of the pumping station. It descended to a depth of 332 feet below the surface. From a depth of 80 feet a core suitable for examination was obtained extending down to 286 feet, when the hard rocky cap of the Spilsby Sandstone was pierced, and soft running sand yielding an abundance of water was entered. Boring operations therefore ceased before the base of the sandstone was reached.

The theoretical length of the core was 206 feet, but owing to the loss sustained during the operations the actual length measured on the ground was only 165 feet; thus there was a difference of 41 feet, which may be accounted for in the following manner.

The 14 feet of core between 84 feet and 98 feet were represented by three heaps of loose sand which, of course, could not be measured. From 98 feet to 112 feet the deposits were sufficiently distinctive for the borer to make his log more detailed than usual. His measurements accord sufficiently closely with those recorded at Maltby and with others made by

me at Sutterby to be accepted as reliable. Of these 14 feet only 2 feet 9 inches were preserved in the core, and thus a loss of 11 feet 3 inches must have been sustained at this level. Comparison with other cores and boring records, combined with the borer's verbal statements and my own observations, show that about 16 feet were lost between the depths of 160 feet and 180 feet.

(ii) *The Boring Record.*—Under present-day conditions borers' records consist of very rough-and-ready descriptions which nevertheless yield some valuable information. As the borer's record was the datum to which measurements of the core had to be referred, it is given here together with the summary of my own descriptions and main divisions.

Borer's Record

	Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*
Hard clay	44	0	44	0
Sand and gravel	16	0	60	0
Red chalk and marl	24	0	84	0
Soft green sand	14	0	98	0
Blue clay	3	0	101	0
Grey marl	6	0	107	0
Blue clay	5	0	112	0
Hard green sand with thin clay beds	62	0	174	0
Blue silty clay	14	0	188	0
Grey marl	3	0	191	0
Blue clay	11	0	202	0
Grey marl with sandstone beds	16	0	218	0
Blue clay	34	0	252	0
Blue marl	6	0	258	0
Blue silty clay	8	0	266	0
Soft greensand	18	0	284	0
Sandstone	2	0	286	0
Greensand and soft running sand	46	0	332	0

Detailed Record of the Alford Boring

			Thickness		Depth	
			Ft.	*in.*	*Ft.*	*in.*
GLACIAL DRIFT		Hard clay	44	0	44	0
		Sand and gravel	16	0	60	0
RED CHALK		Red chalk and marl	24	0	84	0
LANGTON SERIES	CARSTONE BEDS	Coarse grit above passing down into medium and fine glauconitic sand	14	0	98	0
		Dark grey sandy marl with much glauconite	3	0	101	0
	Sutterby Marl	Light grey marl with occasional grains of grit and streaks of fine sand; glauconite rare	6	0	107	0
		Dark grey and black clay with streaks of fine sand; glauconite rare	5	0	112	0

Detailed Record of the Alford Boring—*Contd.*

Series	Beds	Division		Thickness Ft.	in.	Depth Ft.	in.
Tealby Series	Fulletby Beds	Upper Roach	Grey and green clay with patches of sand, numerous grains of oolitic iron ore, occasional flakes of iron ore, scattered grains of grit and small pebbles, especially in the upper portion	4	9	116	9
			Similar to the last but oolitic iron ore very abundant, hardened by calcite cement	4	6	121	3
		Roach Stone	Moderately hard fine-grained sandstone of light green or grey colour, with calcareous and ferruginous cement, scattered grains of grit, and patches rich in oolitic iron ore	13	0	134	3
		Lower Roach	Grey-green and buff clays with abundant oolitic iron ore and occasional flakes of iron ore	25	6	159	9
	Tealby Beds	Upper Tealby Clay	Grey and buff marly clay	3	9	163	6
			Estimated gap, probably in place of grey silty clay	16	4	179	10
			Light buff marl		6	180	4
			Grey silty clay	4	8	185	0
			Buff tinted grey clay	3	0	188	0
			Light buff clay	3	0	191	0
			Medium to dark grey clay with patches of sand rich in glauconite and containing some grains of oolitic iron and angular black pebbles		2	191	2
			Similar clay with less sand and glauconite	1	1	192	3
			Grey clay	7	11	200	2
		Tealby Limestone	Soft, light grey shaly rock consisting of shell and quartz sand with a few grains of glauconite and fewer of oolitic iron ore		8	200	10
			The same, hardened by calcareous cement		7	201	5
			The same, but darker, with some grit and small pebbles		7	202	0
			The same, but without iron ore or glauconite, some grit	2	4	204	4
			The same, hardened by calcareous cement		4	204	8
			The same		8	205	4
			The same, with buff tint, hardened by calcareous cement		6	205	10
			The same, with pyrites in the lower portion	2	8	208	6
			The same, hardened by calcareous cement	1	0	209	6
			The same		7	210	1
			The same, hardened by calcareous cement	1	5	211	6
			The same	1	6	213	0

Detailed Record of the Alford Boring—*Contd.*

Series	Beds	Division		Thickness Ft.	in.	Depth Ft.	in.
Tealby Series	Tealby Beds	Lower Tealby Clay	Grey clay with buff tint	2	4	215	4
			Light grey clay with laminæ of shelly foraminiferal sand, occasional grains of glauconite and oolitic iron ore, septaria near the base	8	0	223	4
			Very dark grey shale with light and buff patches and abundant glauconite; small nodules in the upper part and septarian nodules below	2	8	226	0
			Medium to dark grey silty clay with patches of quartzose and shelly sand rich in glauconite	2	6	228	6
			Medium grey silty clay, slightly glauconitic	1	0	229	6
			Line of phosphatic nodules including ammonite fragments		2	229	8
			Medium grey silty clay slightly glauconitic		8	230	4
			The same, with much glauconite		2	230	6
			The same, slightly glauconitic		4	230	10
			Dark drab-coloured clay, non-glauconitic	1	0	231	10
			Medium grey clay with little glauconite	3	0	234	10
			Light grey marl with much pyrites		3	235	1
			Medium grey clay with abundant glauconite	1	9	236	10
			Medium to dark grey clay with laminæ of shell sand, glauconite uncommon or absent	20	4	257	2
	Claxby Beds	Upper Ironstone	Dark grey to buff clay with angular phosphatic fragments	2	10	260	0
			Very dark clay with scattered grains of oolitic iron ore	2	0	262	0
			The same without oolitic iron ore	3	2	265	2
			Dark grey clay streaked with brown, oolitic iron ore common	3	0	268	2
			The same, but the clay matrix is pink or red where the oolitic iron ore is most abundant		10	269	0
			Greenish grey marl rich in oolitic iron ore, with occasional large grit grains and large rounded pebbles of buff and pink limestone		10	269	10
		Lower Ironstone	Mottled buff and pink limestone, with oolitic iron ore, passing down gradually into dark grey clay rich in oolitic iron ore; a few polished pebbles	1	0	270	10
			Dark drab clay with much oolitic iron ore; nodules at the base	4	8	275	6
			Dark drab clay with little oolitic iron ore	2	6	278	0
			Light grey fossiliferous clay		8	278	8
			Drab clay with much oolitic iron ore in its upper portions, less below	5	4	284	0

DETAILED RECORD OF THE ALFORD BORING—*Contd.*

				Thickness Ft. in.		Depth Ft. in.	
SPILSBY SERIES	SPILSBY BEDS	Ferriferous grit	Very hard coarse grey grit with polished grains and black pebbles, oolitic iron-ore grains and pyrites common in its upper portion .	2	0	286	0
		Glauconitic sands	Friable grey sand, fine grained and glauconitic	46	0	332	0

(iii) *Descriptive Comments.* The Carstone Beds.—Most of the material from this portion of the core was in the form of loose sand arranged in three heaps. These exhibited a change of grade and colour downwards from a coarse grit with a slightly rusty tint, which recalled the appearance of the Carstone as it is most frequently seen at the outcrop, through grey sand and fine, dark grey sand to black sandy marl.

The grit consisted mainly of quartz grains with iron-stained and clean surfaces in equal proportions. The grains are usually rounded and often polished. Other constituents are lydian stone, fragments of greenish marl and of broken shells, occasional grains of oolitic iron ore, and, more rarely, grains of glauconite. A certain amount of pyrites appears in the finer sand, and dark glauconite becomes abundant in the dark grey sand. The marly matrix of the bottom layer is almost black. The similarity of the sandy constituents, together with the abundance of dark glauconite, leaves no doubt about the affinity of this deposit with the beds above. One striking new feature is the presence of large patches, as much as $1\frac{1}{2}$ inches long, of a bright green substance apparently glauconitic in constitution. No fossils were found in these beds.

The Sutterby Marl.—Though the borer recorded six feet of this marl only two were preserved in the core. From these a number of fossils were obtained, including the belemnite *Neohibolites ewaldi* (v. Strombeck) and the ammonite *Aconeceras nisoides* (Sarasin). With the marl may be associated the underlying dark grey, almost black, clay of which only three inches were seen, though five feet were recorded. This clay had the same constitution as the grey but contained patches of pyrites and yielded no fossils.

The Fulletby Beds.—These include deposits for which the term "Roach" was first used by the Geological Survey (Jukes-Browne, 1887, p. 19). They differ from the beds above in the rarity of the glauconite, and the presence of oolitic iron ore often in large quantities. The dominant matrix is clay or silty clay which is usually grey, though varying in

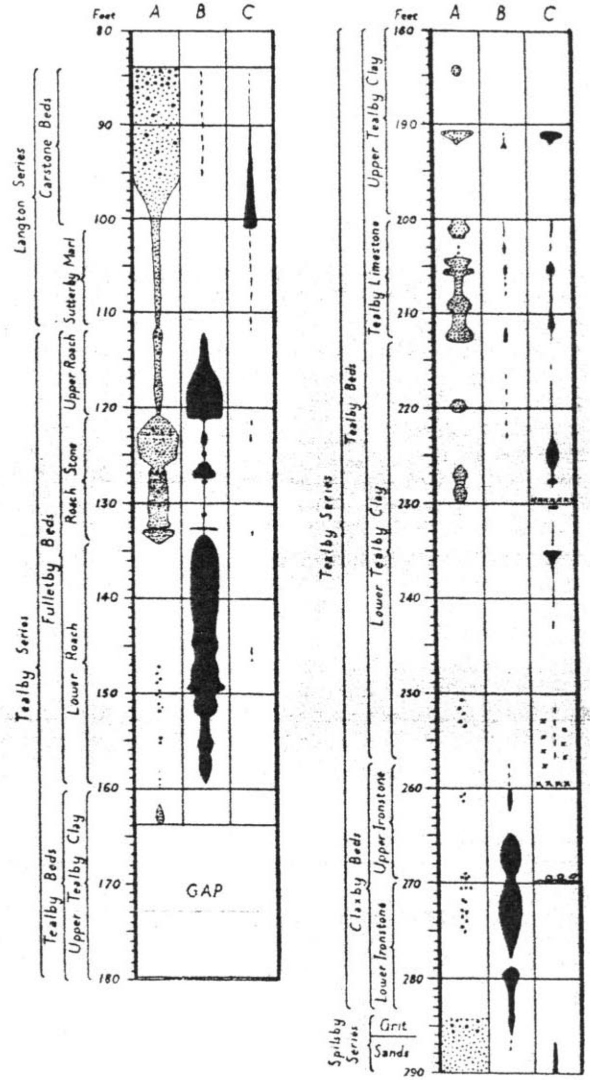

FIG. 2.—Section of the Alford boring showing the general distribution of sand and grit (A), of oolitic iron ore (B), and of glauconite (C) as determined by inspection of hand-specimens from more than a hundred different levels. The approximate proportion of each constituent in relation to the dominant clay matrix is indicated by the width of the column that is occupied by dotted or blackened area. In column C the occurrence of phosphatic nodules is indicated by crosses, and an erosion level is marked close to level 270.

depth of colour from very light to almost black, and frequently tinted with blue or green. Occasionally the colour is light to medium dark buff, tending to become pink or even red in patches where the iron ore is abundant. Arenaceous material is present at several levels, especially in the top five feet and from a depth of about 121 feet down to 134 feet. In the latter case some layers are essentially sandstones. The presence of calcareous and ferruginous cement made this section of the core a hard rock, which may be called the "Roach Stone".[1] It is further characterized by having a smaller quantity of oolitic iron ore than is found in the beds above and below. The latter are more like clay, though they may be indurated in patches owing to the sporadic occurrence of calcite cement. Large grit grains and small pebbles having polished surfaces are scattered throughout these beds.

Carbonized leaves and stalks occur throughout, and several woody fragments more than $2\frac{1}{2}$ inches in length were found. Animal remains, even in a fragmentary state, are uncommon, but well-preserved specimens of belemnites occur at intervals.

The most striking constituent of the Roach is iron ore. This is almost entirely in the form of oolitic grains, though large pisolitic grains and flakes are present. The colour of the ore varies from light ochre to dark rusty brown. The darker grains usually exhibit polished and often iridescent surfaces. The distribution and varying proportion of the oolitic iron ore are shown diagrammatically in Fig. 2. Where the ore attains its maximum development the grains lie almost in contact with one another and tend to mask the matrix. There appears to be a certain degree of relationship between the quantity of oolitic iron and the constitution of the matrix. Where, as in the Roach Stone, sand is present in an appreciable quantity the proportion of ore is small. Where the sandy constituent is negligible or absent the ore may be abundant.

Throughout considerable thicknesses the Roach has the appearance of a patchwork made up of every grade from pure clay, through clay with few oolite grains, to material which is richly ferriferous. While these patches usually have ill-defined and irregularly shaped boundaries, many of them are sharply outlined in round, oval, or strap-like forms, and have all the appearance of worm burrows into which the material from superposed layers has flowed. The general impression produced by the patchy appearance of the Roach is that it accumulated under conditions varying rapidly from those in which mud and silt were being laid down to others in which oolitic iron was also formed in changing proportions. As they were

[1] The term "Roach Rock," which was suggested when this paper was read, has been dropped because of its close similarity to the name of a well-known feature in Cornish geology. The paucity of iron ore precludes the use of the earlier term "Roach Ironstone".

being formed these deposits appear to have been subjected to some churning influence in which worms played a prominent part. That there was ample food for these organisms is proved by the abundance of plant fragments and the varying colour of the clay matrix.

The Tealby Beds.—These are distinguished from the beds immediately above and below by the common occurrence of glauconite, sometimes in considerable quantity, and the scarcity or usual absence of oolitic iron ore. The dominant constituent of the series is a silty clay which, apart from the absence of pink and red coloration, exhibits the same colour ranges as those already noticed for the matrix of the Roach.

Sand is present only in small quantities at occasional levels, except for a thickness of about 12 feet in the middle of the series, where it occurs in considerable quantities mixed with so much shell sand that it forms a highly calcareous deposit. This is cemented with calcite to form beds of hard sandy limestone varying in thickness from 6 to 18 inches, and alternating with soft uncemented layers of like thickness. It will be shown later that these sandy beds correspond with the Tealby Limestone of the earlier workers.

The clays which lie above the limestones are more varied in colour than those below. Buff-coloured clays are more common, and one bed (188–191 feet) forms a conspicuous feature. Down to the lower level mentioned glauconite appears to be absent. Immediately below this bed is one, only two inches thick, which consists of grey sandy clay with abundant glauconite and many large rounded and polished grains of quartz. This layer also yielded angular black phosphatic nodules and a few grains of oolitic iron.

In addition to the lithological constituents mentioned above, the Tealby Limestone contains glauconite in small quantities throughout, a scanty proportion of oolitic iron ore in its upper layers, and pyritous nodules an inch or more in diameter in the bottom beds.

The clays below the limestone differ from those above in having a more uniformly grey colour. Glauconite is present throughout, and occasional grains of oolitic iron occur in the uppermost portions. The presence of a clearly defined layer two inches thick (at 229 feet 6 inches), made up mainly of rounded and broken phosphatic nodules, deserves special mention.

At 235 feet a sharply defined junction occurs between a thin, light grey, almost white marl above, and a dark marl below which is rich in glauconite and contains large bright green patches like those occurring at the base of the Carstone Beds (p. 8). This junction is marked by the presence of an abundance of pyrites. From this level downwards, small nodules and septaria occur sporadically and pyrites in a finely divided state is often present, especially inside fossil shells.

The Claxby Beds.—These beds differ from the Tealby Beds and resemble the Fulletby Beds in the rarity of glauconite, in the presence of oolitic iron ore in considerable quantities, and in their churned appearance at certain levels. They differ from the Fulletby Beds in that the predominant colour of the clay matrix is buff or brown.

In these beds there are three horizons of special interest. The first is situated at 260 feet. Though phosphatic nodules occur immediately above and below this level they are here crowded together in a thin band and enclose fragments of phosphatized ammonites which, unfortunately, cannot be identified. The second horizon occurs at about 270 feet. Immediately above this level the deposit consists of normal material which, however, encloses large rounded pebbles as much as three inches long. Except for the presence in them of scattered oolitic grains of iron ore, these closely resemble pink or cream-coloured chalk, and have evidently been derived by erosion from the layer below, which is a hard mottled cream and pink limestone with a few scattered grains of oolitic iron and large well-polished grit grains. This layer is about five inches thick and passes down gradually into normal ferriferous clays. It will be shown later that this distinct break is in the vicinity of a not less distinct change of fauna. These facts suggest the advisability of dividing the Claxby Beds into lower and upper portions. The third level is situated at 278 feet 8 inches, where a non-ferriferous light grey clay occurs which contains many fossils and closely resembles normal Tealby Clay.

The Spilsby Beds.—The junction between the Claxby and Spilsby Beds is sharply defined. This is due to a rapid change in the colour of the clay matrix from brown to light grey, accompanied by a great increase in the quantity of sand and grit and a hardening of the rock by calcareous cementation. At 286 feet this very hard layer gives place to a friable fine grey sandstone in which grit is absent, oolitic iron rare and glauconite common.

(b) Notes on other New Borings

(i) *The Maltby Boring*.—A boring was put down by the Mablethorpe Urban District Council near the village of Maltby-le-Marsh, at a point situated 2½ miles south-west of Mablethorpe, alongside the main road from that place to Alford. In August, 1932, when I examined the core, the boring had reached a depth of 382 feet. Unfortunately, operations had been suspended and were not renewed until the autumn, when it was impossible for me to visit the site. After passing through a great thickness of chalk the boring entered the Carstone grit at a depth of 319 feet. The details are as follows :—

DETAILED RECORD OF PORTION OF THE MALTBY BORING

		Thickness Ft.	Thickness in.	Depth Ft.	Depth in.
RED CHALK	Red clay with layers of nodular red chalk	3	0	317	11
	Light clay mottled red, pink, buff, and grey	1	6	319	5
	Dark clay mottled red, buff, and grey, containing numerous rounded and polished grit fragments and a few grains of oolitic iron ore . . .		9	320	2
	Light brown ochreous clay with patches of mottled clay like the bed above, and lumps of light-brownish yellow clay, grit and iron ore as before .		9	320	11
CARSTONE BEDS	Coarse brown pebbly grit speckled with iron pyrites, clay matrix mottled red and grey	1	0	321	11
	Finer grey grit with fewer large polished grains, clay matrix light grey with brownish patches	2	4	324	3
	Estimated gap	11	3	335	6
	Dark grey glauconitic sandy marl with large bright green patches . .	5	0	340	6
SUTTERBY MARL	Gradual passage into light grey marl .	3	6	344	0
	Gradual passage into black marl . .	6	0	350	0
FULLETBY BEDS	Passing into Roach clay and rocks identical with those seen at Alford .	32	0	382	0

The borer's record of the beds below this provides no certain indication of the depths at which other stratigraphical horizons, recognized at Alford, occur, with the one exception of the top of the Spilsby Sandstone, which was evidently struck at a depth of 512 feet.

One feature of interest was the presence of a conglomeratic layer near the top of the Roach (353 feet 7 inches). This was three inches thick and contained polished pebbles as much as half an inch in diameter.

(ii) *The Fordington Boring*.—This boring was put down by the Boston Urban District Council. It is situated three miles south-west of Alford in the floor of one of those deep little valleys which are such a characteristic feature of the southern end of the Lincolnshire Wolds. Starting at 168 feet above sea-level it was taken to a depth of 266 feet. After passing through 18 feet of boulder-clay it entered the solid rock at a stratigraphical level which lay below the base of the Roach Stone. It ultimately entered the Spilsby Sandstone at 170 feet, and the Kimeridge Clay at 242 feet 6 inches. With the exception of several hard bands of rock which had to be cut by means of the rotary drill, the whole boring was done by percussion. Of the rocks above the Spilsby Sandstone only two recognizable samples were available for examination. One was from a bed 98–102 feet down described by the borer as "grey sandy clay with sand partings". This specimen closely resembled the softer beds of the Tealby Limestone at Alford. The second was from a bed 148–155 feet down. This was described as "brown sandy clay" and was typical Claxby iron ore. The Spilsby Sandstone here attains the greatest thickness hitherto recorded: namely, 72 feet 6 inches. It is fortunate that a core of the lowest layers of this sandstone was available, for it yielded a rich fossiliferous horizon.

A detailed record follows of the boring through the bottom beds of the Spilsby Sandstone:[1]—

		Thickness Ft.	Thickness in.	Depth Ft.	Depth in.
Bed D.	Hard calcareous sandstone richly fossiliferous in its lower portion; a few phosphatic grains	1	0	240	5
,, C.	Very dark shaly sand with much glauconite, very fossiliferous; a few small phosphatic nodules	1	2	241	7
,, B.	Hard calcareous sandstone with numerous belemnites in its upper portion and many phosphatic nodules, which increased in quantity downwards		8	242	3
,, A.	Blue clay penetrated by tubes filled with sand and enclosing white calcareous nodular masses		3	242	6
	Blue shale	23	6	266	0

(c) Notes on Published Boring Records

(i) *The Willoughby Boring.*—Willoughby lies 2½ miles south-south-east of Alford. In 1887 a boring was put down by the East Lincolnshire Railway, now incorporated with the London and North-Eastern Railway. Jukes-Browne (1893, p. 469) wrote an account of this boring, relying for his information mainly upon details supplied by M. Staniland, who examined a series of samples taken from the core. These samples are now at the offices of the railway at Boston. I am indebted to Mr. G. B. Barton, the District Engineer, for permission to examine these samples and for the necessary facilities. No sample exceeded two inches in diameter, but the majority of them could be easily matched with material found in the Alford core. Arising out of this comparison the following points of interest may be noted.

The beds at a depth of 57–63 feet were represented by two samples of typical Roach clay; the base of the glacial deposits should therefore be put at 57 feet and not 63 feet.

The "dark clay" at 106–135 feet, referred to Tealby Clay, was represented by two samples both of which contain numerous grains of oolitic iron scattered throughout, as in the material from the depth 150–159 feet at Alford. The next sample, which had the figures 135 scratched upon it, was identical with the buff clay at Alford at the depth of from 188 to 191 feet. As the base of the Lower Roach clay lies 14 feet above this level it is probable that at Willoughby this horizon lies about the middle of the "dark clay," at about 120 feet. The two samples must therefore have been collected from above this level.

[1] The bottom six feet of the Spilsby Sandstone were exposed by road-widening operations at Partney in 1932. They yielded a fauna similar to that found at Fordington (p. 27).

The sample for the level 183–186 feet contained a large patch of bright green clay identical with that which occurs at Alford at the level 235–237 feet (p. 11).

The sample from the "sandy clay" (208–214 feet) is typical Claxby iron ore in which the matrix tends to become red where the oolitic grains are most abundant. The top of the Claxby Ironstone beds should, therefore, be put at 208 feet instead of 214 feet. This alteration brings the thickness of the Claxby Beds into close accord with that at Alford.

The sample from the level of 218–220 feet was partly made up of the same pink and cream-coloured material as that found at Alford at 270–271 feet.

There were nine samples from various levels in the Spilsby Series, which was entered at 232 feet. Eight of these samples accord closely with the variations of this rock seen at Fordington, but a sample from the level 244–245 feet is more like Claxby Ironstone. Jukes-Browne writing of this says, "I suspect, however, that this sample has been misplaced."

As the result of this re-examination of the Willoughby boring record the following re-interpretation is suggested:—

	Thickness Feet	Depth Feet
Surface deposits and glacial drift	57	57
Fulletby Beds	63	120
Tealby Beds	88	208
Claxby Beds	24	232
Spilsby Beds	18+	250

(ii) *The Welton Borings and Well.*—In 1904 the Skegness authority sank a boring at Welton (Woodward & others, 1904, p. 184). The samples were kept in the offices of the Skegness Town Council but were destroyed by fire. Samples taken during the sinking of a well close to the site of the boring, in 1928, are now in the possession of Mr. Percy Griffiths, and were generously placed at my disposal for examination. A series of specimens which had been selected from them and are now in the collections of the Geological Survey were also examined. Of these, only eight came from the Cretaceous beds. Four, belonging to the Roach, show that the Upper Roach and Roach Stone are absent and that the Lower Roach was entered at 40 feet and has its base at about 64 feet. The remaining samples were typical representatives of the Tealby Clay. The well was sunk to a depth of 126 feet. It is probable that, somewhere near the bottom, it penetrated the Tealby Limestone. Several fossils, from an unrecorded depth, were given to me by Mr. Griffiths. These included a large *Exogyra* imbedded in a matrix identical with that seen in the Alford boring at 209 feet (p. 20).

(iii) *The Skegness Borings*.—Three records of borings at Skegness have been published (Jukes-Browne, 1893, p. 473; Woodward & others, 1904, pp. 155–9). Of these only the two boreholes at the Waterworks on Burgh Road need be considered. A complete set of samples, which was kept at the offices of the Council, was unfortunately destroyed by fire, but a selected few are still preserved in the collections of the Geological Survey. In July, 1933, the Skegness Steam Laundry, which is only half a mile distant eastward, commenced sinking a boring by percussion. Immediately after the Red Chalk had been pierced at a depth of 110 feet 6 inches I was able to watch the operations closely for several days and to glean some scraps of information.

With so few samples for examination it is difficult to unravel the details of the published records for the purposes of comparison with the Alford boring, but the exceptional interest of the Skegness borings justifies the attempt. For this purpose the record for boring No. 1, which is the most detailed, will be used (Woodward & others, 1904, p. 155).

The Carstone (92–101 feet) is described in terms which indicate the same increase in fineness of texture downwards which has already been noticed at Alford (p. 8). The "red marl and sand" (84–92 feet) probably includes some of the coarse grit which usually occurs at the top of the Carstone. A sample from the laundry boring (110 feet 6 inches–120 feet 6 inches) contains much coarse grit with rounded and polished grains embedded in a matrix of light blue clay. The sample bears a close resemblance to the grey grit of the Maltby boring (324 feet).

Samples from the laundry boring show that the "loamy greensand" (100 feet–101 feet 6 inches) and the "hard light coloured clay" (101 feet 6 inches–108 feet) may be correlated with the levels at Alford described as "grey sandy marl with much glauconite" (98–101 feet) and the "light grey marl" (101–107 feet): that is, the Sutterby Marl.

The "sandstone and shale" (116–130 feet) accords well with the position of the Roach Stone at Alford (121–132 feet), which also yielded a quantity of water.

The "greenish clays" with "oolitic iron oxide" (130–226 feet) accord in character with the Lower Roach beds at Alford but they are 68 feet thicker.

The "bluish grey clay" and "green silt and clay" (226–286 feet) with indications of glauconitic development bear comparison with the Tealby Beds at Alford (164–258 feet), but in this case the proportionate thicknesses are reversed, for the beds at Alford are 34 feet thicker than those at Skegness. This reversal suggests an encroachment of the limonitic upon the glauconitic facies towards the south-east.

The sample from the 263-feet level is identical with the light buff marl at Alford (188–191 feet), while that from 269 feet is similarly matched by the richly glauconitic clays at Alford (191–192 feet 3 inches). The juxtaposition of these two deposits and their resemblance in character in the two borings creates a presumption in favour of the correlation of these levels with one another.

The grey, blue and pink deposits with iron ore (286–295 feet) may be compared with the Upper Claxby Beds. In the notes on No. 2 boring it is stated: "A sample from 297 feet was a hard oolitic marlstone with grains of iron-peroxide." If the rock here referred to may be correlated with the pink and cream-coloured limestone with oolitic iron ore at Alford (270 feet), then this comparison with the Upper Claxby Beds is strengthened.

The "stone band with iron pyrites" (318–319 feet) recalls the hard pyritous layer which caps the Spilsby Sandstone elsewhere, and may be taken as the top of the Spilsby Beds at Skegness. In this case, the beds from 297 to 318 feet can be regarded as equivalent to the Lower Claxby Beds. They appear, according to the record, to be non-ferriferous, and this feature may be the further development of a tendency already incipiently manifested at Alford at 280 feet, where there is a layer recalling the Tealby Clays in character.

The above considerations suggest the following re-interpretation of the Skegness boring record:—

			Thickness Ft.	Thickness in.	Depth Ft.	Depth in.
Langton Series	Carstone Beds		9	6	101	6
	Sutterby Marl		7	0	108	6
Tealby Series	Fulletby Beds	Upper Roach clay	8	0	116	6
		Roach Stone	13	6	130	0
		Lower Roach clay	96	0	226	0
	Tealby Beds		60	0	286	0
	Claxby Beds	Upper Claxby Beds	11	0	297	0
		Lower Claxby Beds	21	0	318	0
Spilsby Series	Spilsby Beds		20	0+		

(d) The Excavation at Sutterby

The discovery of a light grey marl, yielding specimens referable to the ammonite genera *Deshayesites* and *Aconeceras* and to the belemnite species *Neohibolites ewaldi* (v. Strombeck), between the Carstone and the Tealby Beds in the borings at

Alford and Maltby led to a search for this bed at the outcrop. Indications of its presence were found at several points, of which the one that seemed to be the most favourable for excavation was situated in a little valley lying immediately east of the hamlet of Sutterby. The floor of this valley is occupied by a large ploughed field, overlooked on the eastern side by a steep wooded bluff formed by the scarp edge of the Red Chalk and underlying Carstone. The lower slopes of the bluff were smothered under a thick covering of Chalk and Carstone rubble. At one point, however, ploughing operations parallel to the bluff had removed the rubble and turned up a

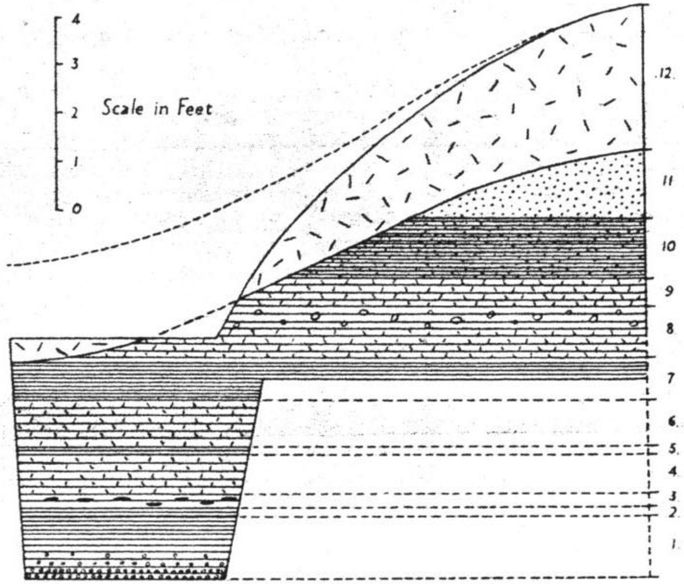

Fig. 3.—Section through the excavations at Sutterby.

grey marl which, with fragments of ammonites and belemnites, lay scattered about in the soil.

Excavations were made in August, 1932, and were renewed and extended in August, 1933. With a view to discovering the extent of the marl and elucidating its relationships to the beds above and below, a vertical cutting three feet wide was excavated into the lower part of the bluff and three trial holes, in line with the cutting, were made at intervals down the slope of the field. Acting on the information gained from these, a trench was made at right angles to the line of the cutting and along the ploughed margin of the field. This was 16 feet long, 4½ feet wide, and from 4½ to 5 feet deep. The fossils obtained

from these excavations will be described later. The details of the beds examined are given in the accompanying table.

Record of the Section excavated at Sutterby

		Thickness Ft.	in.
12.	Waste from the Chalk and Carstone	3	0
11.	Fine brown sand	1	6
10.	Green clayey sand		2
	Green sandy clay streaked brown and black		8
	Green clay tending to buff colour		4
	Very dark grey, almost black, silt		1
9.	Dark buff marl with dark grey patches; some belemnites		7
8.	Blocky yellow marl with harder nodular lumps up to two inches in diameter; a few belemnites		5
	Hard blocky grey to yellow marl, almost unfossiliferous		9
7.	Light grey and yellow clay, slightly fossiliferous		10
6.	Hard blocky grey and yellow marl, unfossiliferous	1	0
5.	Yellow clay with belemnites		2
4.	Blocky marl, light yellowish grey above, becoming darker below		10
3.	Blocky marl, still darker, containing phosphatic nodules and phosphatized ammonites		4
2.	Dark yellow and buff unctuous clay containing patches of rusty red and dark brown powder; a few fossils.		2
1.	Buff clay with black patches passing through flaky clay to black clay containing scattered grains of oolitic iron ore		7
	Typical Roach clay with small pebbles		6+

The phosphatic nodules were round to elongate-oval in form and when handled broke up into sharp angular fragments. Some formed as lumps in the umbilicus of small ammonites which, however, did not always share in the process of phosphatization. The ammonites were rarely completely phosphatized. In no case did they show signs of being rolled or bored.

Between the grey marl and the beds above and below there was no indication of a break in the sequence or of a sharp line of demarcation. On the contrary, the passage from one to the other, though rapid, was transitional in character. Within the grey marl the phosphatic nodules, though limited to a narrow zone near the base, did not lie upon a surface but were enclosed in the marl at different levels.

IV. Some Outstanding Stratigraphical Problems

(a) The Relationship of the Tealby Limestone to the Roach Ironstone (= Roach Stone)

There has been much uncertainty in the past concerning the precise relationship of the Tealby Limestone to the Roach Ironstone. In the field, the former produces a prominent feature at the outcrop in the north, and the latter an equally marked one in the south. These two features do not, however, occur together in any one area. On the contrary, they are both absent in the intervening region which extends for a few miles south of Donington. Previous workers, from Judd (1867, pp. 244–6; see also Jukes-Browne, 1887, pp. 21, 22) onwards, have linked the two features together, and have concluded that the two rocks are equivalent.

In describing the Alford boring particular attention was given (p. 11) to the sandy and calcareous beds which occur between the levels 200 and 213 feet. If the record and description be compared with Judd's description of the Tealby Limestone at North Willingham, and with the section given by the Survey for the pits at Six Hills (Ussher and others, 1888, p. 99), the closeness of the similarity will be evident. In the latter, the clay bands are described as being full of comminuted shell. This corresponds with the term "shell sand" used by me for these beds at Alford.

In seeking to elucidate the problem every exposure mentioned by previous writers, as far north as Caistor, has been examined. Though these are now much obscured, the rock is sufficiently exposed at a number of points to make direct comparison possible. This work has confirmed the impression that the beds referred to in the Alford boring are the strict equivalent of the Tealby Limestone. J. W. Judd makes special reference to the presence of one layer containing large specimens of *Exogyra sinuata* and other lamellibranchs. A similar layer occurs in the boring at a depth of 209 feet. The fauna of these beds has not yet been worked out, but the state of preservation of the shells is strikingly alike in the boring and at the outcrop. At Acre House, the Tealby Limestone is 14 feet thick (Lamplugh and others, 1920, p. 211). It is therefore not appreciably thicker than at Alford. Nevertheless, the individual beds of limestones are thicker and harder and the intervening clays are thinner. This fact accounts for the greater prominence of the feature produced by the Tealby Limestone outcrop in the north, and its insignificance or absence in the south.

In the previous correlation of the Tealby Limestone with the Roach Ironstone the "Fulletby Rock" has played an important part because it has provided the most northerly exposure of the ironstone (Jukes-Browne, 1887, p. 22). This rock can still be seen exposed in a deep excavation near Fulletby which is no doubt one of the old ironstone workings referred to by Judd (1867, p. 245). Though the sides of this excavation are now much obscured the following section can be made out :—

	Estimated thickness *Ft.*	*in.*
Glacial gravel with much Carstone grit, enclosing pockets of Sutterby Marl in its lower layers		
Clay with oolitic iron ore	2	6
Hard, fine-grained calcareous and ferruginous sandstone	6	0
	3	6

The hard rock seen in this section is identical with that which occurs in the Alford boring at 121–134 feet. It is unlike the Tealby Limestone, which at Alford is situated 80 feet lower down.

The evidence which has thus been culled from the outcrop and the borings accords with the view that the Tealby Limestone and the Roach Ironstone are not equivalent but are situated upon separate stratigraphical horizons.

(b) The Constitution and Stratigraphical Relationships of the Carstone

That the Carstone passes up without a break into the Red Chalk, as pointed out by Strahan (1886, p. 487), is confirmed by details given above for the Maltby boring (p. 13).

Concerning the relationships of the Carstone to the beds below, Strahan shows that it rests upon the Tealby Limestone at Acre House and upon the Roach clays in the Otby valley, and is, therefore, unconformably related to the Tealby Series. This view he supports by reference to the constitution of the Carstone, which consists largely of material derived from the Tealby Series, such as oolitic grains, flakes of iron ore, and phosphatic nodules. The last-mentioned, in addition to being scattered through the Carstone, forms a bed at the base six inches thick. That these nodules are derived is further indicated by the fact, emphasized by the Survey (Ussher and others, 1888, p. 85), that they are well rolled and include fragments of ammonites which, despite the uncertainty of their identification, have evidently been derived from different horizons. Unfortunately, the sections referred to by Strahan are now almost completely obscured, but in so far as the evidence on the ground is still accessible it confirms his observations. In describing the borings above, reference is made to the presence of grit grains at numerous horizons (Fig. 2) in the Tealby Series. These grains closely resemble much of the Carstone material, which was probably provided by the destruction of these beds (see Strahan, 1886, p. 487).

While there is no doubt that in the north the Carstone rests unconformably upon the beds beneath, there appears to be little or no evidence of such unconformity in the south. In the first place, the deposits, which lie between the base of the Red Chalk and the top of the Roach clays, are on the whole much finer grained and the coarse grit facies is limited to their uppermost portions. As already shown in the Maltby boring and in the excavations at Sutterby, these beds pass without a break up into the Red Chalk above and down into the Roach clays below. It is unfortunate that in the borings the beds between were not shown intact. This deficiency is, however, largely rectified by the existence of a sand-pit in these beds near to Langton Hall, which lies one mile south-east of Sutterby.

The Survey (Jukes-Browne, 1887, p. 25) in describing this section also give an account of the beds which were passed through in the making of a well near the entry to the pit. The sequence at Langton can be summarized as follows :—

Beds in borings and excavations	Beds at Langton	Approximate thickness
	In the pit	*Ft.*
Carstone grit	Sand with pebbles and rolled phosphatic nodules	10
Glauconitic sands and clay	Sand	18
	In the well	
Ditto	Grey and white sand	15
Sutterby Marl	Soapy fuller's earth	?

In this section there appears to be no distinct indication of a break. If one exists, it would probably be situated at the bottom of the layers with phosphatic nodules.

Though the exposures of the base of the Carstone are practically non-existent in the central part of the Wolds area : that is, between Fulletby and North Willingham, a few field observations have been made which throw light upon its relationships to the beds beneath.

In searching along the outcrop for the Sutterby Marl, positive evidence of its presence was found at the following points (Fig. 1) : on Harrington Hill close to the point where the road from Alford joins that from Harrington to Brinkhill ; in a roadside trench north of Tetford ; at the base of the drift near Fulletby ; and in the fields on the scarp face due north of Belchford. According to a gamekeeper's statement, a light marl full of "lucky stones" (belemnites) was found whilst digging post-holes in the farm-yard at Oxcombe. Since this spot is correctly situated for the occurrence of the Sutterby Marl, there is little doubt that this is what was seen. North of the latitude of Oxcombe, careful search in the neighbourhoods of Scamblesby, Donington, and North Willingham has yielded no trace of it, and it is highly probable, therefore, that the Sutterby Marl is absent north of that latitude. This marl, seen at such widely separated points as Skegness, Tetford, and Fulletby, is so constant in character and so lacking in signs of lateral change towards deposits of a shallow-water origin that it must originally have extended much farther north than its present boundary. Its absence in that direction may be ascribed to erosion.

The erosion plane thus indicated appears to transgress northwards successively across the truncated outcrops of the lower beds. The Roach Stone feature, so prominent on the face of the main scarp in the South Wolds, becomes indistinct (Ussher and others, 1888, pp. 97, 98) and finally disappears three miles south of Donington. North of Donington the Tealby Limestone produces a distinct feature separated by a long slope from the Red Chalk–Carstone feature. This slope can only be the outcrop surface of the Lower Roach and Upper Tealby clays. East of North Willingham the Tealby Limestone is comparatively well exposed in the fields on the northern side of the road, where it forms a wide platform which comes distinctly nearer to the Red Chalk–Carstone feature. According to published records, the beds between the Carstone and the limestone in the Otby valley are only 25 feet thick, while at Acre House the Carstone rests upon the limestone (Ussher and others, 1888, p. 100 ; Judd, 1870, p. 331). This series of observations, while substantiating Strahan's conclusion (1886, p. 489) that the Carstone rests unconformably upon the beds below, shows that it is a stronger unconformity than he thought ; for the Roach Stone, instead of being truncated in the form of the Tealby Limestone north of Acre House, is truncated south of Donington.

Though no marked evidence of erosion has been forthcoming for the South Wolds area, indication that erosion was going on not far away is provided by the presence in the Carstone grit of material washed out of the lower beds farther north. It will be shown later that species of the ammonite genus *Deshayesites* occur in situ in the phosphatic nodule bed near the base of the Sutterby Marl. As already noted (p. 21), rolled fragments of *Deshayesites* have been found in the Carstone of the North and Central Wolds. These fragments, while furnishing testimony to the original more northerly extension of the Sutterby Marl, also provide evidence that the uplift in the north which led to the break in the sequence took place during the interval of time represented by the Carstone sands and clay.

V. Palæontology

(a) The Cephalopod Faunas

(i) *Introduction.*—For the purposes of correlating the Lincolnshire succession with rocks of the same age elsewhere, the belemnites and ammonites have already been proved by earlier workers to be invaluable. Fortunately, well-preserved belemnites occur at frequent intervals throughout the Alford boring. On the other hand, ammonite remains are rare and are usually badly preserved or seriously damaged. In the excavations at Sutterby and in the lower part of the core at Fordington, ammonites in a relatively good state of preservation were more common. It is natural, therefore, to attach more importance to the belemnites for the purpose of establishing the major faunal subdivisions of the rocks below the Red Chalk. Where identifiable ammonites occur, however, they give a definiteness and precision to the levels at which they are found that cannot be provided by the belemnites.

(ii) *Historical.*—Lamplugh showed in 1891 (pp. 808–9) that the series of faunal subdivisions based upon belemnites which he established for the Speeton Beds holds also for the Lower Cretaceous of Lincolnshire. Owing to the fragmentary nature of the exposures in Lincolnshire, the limits of those subdivisions were not clearly defined. This deficiency can now be largely made good.

Lamplugh (1922, p. 15) introduced another subdivision between the *minimus* marl and the *brunsvicensis* beds: namely, the *ewaldi* marl. As will be shown below, this new subdivision is well represented also in Lincolnshire.

In conjunction with Pavlov, Lamplugh also correlated horizons at which ammonites had been found in Lincolnshire with corresponding beds in the Speeton series (Pavlov and Lamplugh, 1891, p. 28). Greater precision has been given to this aspect of the subject by Dr. Spath's very careful work upon the specimens from various exposures now preserved in several museums (Spath, 1924B).

(iii) *The Fauna of the Red Chalk.*—Many good specimens of *Neohibolites minimus* (Lister) and of its variations were found in the Red Chalk of the Maltby boring, where they ranged down into the mottled clays which immediately overlie the Carstone grit.

(iv) *The Fauna of the Carstone Beds.*—The next level at which fossil remains were found occurred in the Maltby core in the glauconitic clays overlying the Sutterby Marl. The specimens were unfortunately so fragmentary that precise identification was out of the question. Such features as were exhibited by the belemnite fragments point to affinity with the *ewaldi* rather than the *minimus* group of species of the genus *Neohibolites*. With these fragments were associated shattered unidentifiable pieces of a large ammonite.

(v) *The Fauna of the Sutterby Marl.*—As the result of excavation, the Sutterby Marl yielded upwards of 500 good specimens of belemnites and a considerable number of fragments of ammonites, including a few that were sufficiently complete for the purposes of reliable identification. While the belemnites occurred throughout the whole thickness of the marl, the ammonites were almost restricted to the phosphatic nodule layer. This yielded the following specimens which, with few exceptions, were phosphatized: *Deshayesites fissicostatus* (Phillips), *D.* aff. *læviusculus* (v. Koenen), *D. multicostatus* sp. nov. (see p. 31), *Aconeceras nisoides* (Sarasin), *A. sp.*, *Cheloniceras*, *Tonohamites*?, and fragments of an unknown genus.

The following, which were not phosphatized, came from the blocky marl of the Maltby boring: *Aconeceras nisoides* (Sarasin) and *Ancyloceras*.

This fauna fixes the position of the phosphatic nodule layer

as being about the middle of the Lower Aptian, at the bottom of the *deshayesi* zone in the *bodei* subzone (cf. Stolley, 1911, p. 220; Spath, 1923, p. 148).

The characteristics and distribution of the belemnites from the Sutterby Marl are discussed in detail below. The following is a summary of the results reached:—

Neohibolites ewaldi (v. Strombeck) occurs throughout.
—— —— fusiform variety occurs in beds 2, 3.
—— —— claviform variety occurs in beds 2–5.
—— —— inflexiform variety occurs throughout.
—— *spicatus* sp. nov.[1] is rare in beds 2–5.
Hibolites minutus sp. nov. occurs in beds 2, 3, but is rare in beds 4, 5.
Oxyteuthis aff. *brunsvicensis*.

The belemnites found in the Sutterby Marl have been compared with the specimens collected by Danford (1906) from the *ewaldi* marl at Speeton and now preserved in the Museum of the Geological Survey. Every variety of *N. ewaldi*, together with the *Hibolites minutus* sp. nov. referred to above as found at Sutterby, has its counterpart in the Speeton collection, a fact which would seem to establish the lower part of the Sutterby Marl as the exact equivalent of the *ewaldi* marl. The recorded position of the ammonites in relation to the horizon of this varietal assemblage of belemnites calls for comment. Lamplugh records a black clay (with "*Amm.* cf. *deshayesi*") below the *ewaldi* marl at Speeton. Spath, with greater precision of identification, records the presence in these clays of *Deshayesites* (*Parahoplitoides*) *fissicostatus* of the *bodei* subzone. He also refers to the presence in the upper B beds of other species belonging to the *bodei* assemblage. The records for Speeton thus seem to imply that the *bodei* subzone lies below the *ewaldi* subzone, whereas at Sutterby it lies not only within but definitely above the bottom of the *ewaldi* subzone.

E. Stolley gives *Neohibolites ewaldi* as characteristic of the two subzones above the *bodei* subzone: that is, the *weissi* and *deshayesi* (Spath's *hambrovi*) subzones. He indicates the presence in the *bodei* subzone only of rare examples of *N.* cf. *ewaldi*. This arrangement resembles that recorded for Speeton. On the other hand, Stolley (1908, p. 215) mentions the presence in the *bodei* subzone of a small club-shaped representative of the *jaculum* group, which is quite absent from the *weissi* and *deshayesi* subzones. This form—*Hibolites minutus*—occurs at Sutterby in the lowest parts of the marl along with numerous specimens of the *ewaldi* varieties and with the *bodei* ammonite fauna. These facts suggest that the absence of *ewaldi* from

[1] See p. 30.

the *bodei* subzone at Speeton and its rarity at the same level in Germany is due to faunal failure. This suggestion is strengthened by the presence at this level of occasional specimens of a belemnite closely allied to *B. brunsvicensis*.

(vi) *The Fauna of the Fulletby Beds.*—As already indicated, the Fulletby Beds are not very fossiliferous. Nevertheless, well-preserved specimens of *Belemnites (Oxyteuthis) brunsvicensis* were found at various levels in the Alford core. The highest occurrence was at 134 feet, which is 27 feet below the base of the Sutterby Marl. The lithological unity of the beds above this level up to at least 112 feet, together with the presence of rare but closely allied belemnites in the lower part of the Sutterby Marl, leaves no doubt about the reference of the upper portions of these beds to the zone of *brunsvicensis*. The lower portions must also be referred to the same zone, for this belemnite ranges down into the Tealby Clays below.

(vii) *The Faunas of the Tealby Beds.—Belemnites brunsvicensis* extends downwards into the Upper Tealby Clay and the Tealby Limestone. In the former it is accompanied at 191 feet by *B. absolutiformis* (Sinz), and *B. speetonensis* (Lamplugh). In the limestone its lowest occurrence is at 209 feet, where it is associated with a small specimen of *B.* (*Hibolites*) *jaculum* Phillips. At 215 feet, immediately below the last limestone band, large specimens of *B. jaculum* occur alone. Bearing in mind this definite evidence of the overlap of the two zones, the lower limit of the *brunsvicensis* zone may be placed at the bottom of the Tealby Limestone. It may be noted in passing that Lamplugh (1896, p. 212) included the Tealby Limestone as well as the Roach beds in this zone. *Belemnites jaculum* occurs at frequent intervals throughout the Lower Tealby Clays. Ammonites are of rare occurrence in these beds and consist chiefly of unidentifiable fragments. One recognizable specimen of *Simbirskites* occurred at 226–228 feet.

(viii) *The Faunas of the Claxby Beds.—Belemnites jaculum* ranges below the Tealby Clays into the Claxby Beds, where its lowest occurrence is at 266–269 feet. On the other hand, *B.* (*Acroteuthis*) *subquadratus* (Roemer) occurs at 273 feet and at intervals down to the bottom of these beds. As this species belongs to the *lateralis* fauna, the boundary between the two zones may be placed somewhere in the intervening four feet. The erosion level which occurs at 271 feet seems to be the most suitable position, and the beds above and below it may be referred to as the Upper and Lower Claxby Beds respectively.

The Upper Claxby Beds yielded a fragment of the ammonite genus *Distoloceras* and an almost complete specimen of *Lytoceras oxygonium* (Neumayr and Uhlig). The Lower Claxby Beds yielded small specimens of *Dichotomites* and *Polyptychites* at 279 feet.

The description given above accords with that of Lamplugh

(1896, p. 202) for the Claxby Beds at Acre House. There he found that belemnites of the *lateralis* group ranged throughout the workable ironstone, but that *B. jaculum* was to be found in the valueless iron-bearing clays which must have come from the roof of the ironstone.

(ix) *The Faunas of the Spilsby Sandstone.*—In the Alford boring only the top two feet of the Spilsby Sandstone were brought up in the form of a core, and these were unfossiliferous. The remainder was washed up in the form of loose sand by an extraordinary uprush of water, and yielded only unidentifiable fragments of fossils.

The core from the base of the sandstone at Fordington (p. 14), on the other hand, yielded a rich fauna which included the following species :—

Belemnites

Acroteuthis lateralis (Phillips)
—— *subquadratus* (Roemer)
—— cf. *subquadratus* (Roemer)
—— *mosquensis* (Lamplugh)

Ammonites

From bed D.
Subcraspedites primitivus sp. nov.[1]
—— *precristatus* sp. nov.
—— *cristatus* sp. nov.
—— *subundulatus* sp. nov.
—— *undulatus* sp. nov.
—— *parundulatus* sp. nov.
—— *subpressulus* (Boghoslovsky)

From bed C.
Subcraspedites cf. *precristatus* sp. nov.
—— cf. *subundulatus* sp. nov.
—— *preplicomphalus* sp. nov.
Paracraspedites stenomphaloides gen. et sp. nov.
—— *bifurcatus* sp. nov.
?*Paracraspedites trifurcatus* sp. nov.

It is unfortunate that the precise horizon at which the ammonites hitherto recorded from the Spilsby Sandstone were found is unknown. The record of *Subcraspedites* aff. *subditus* (Pavlov *non* Trautschold) from the Claxby Ironstone at Claxby (Spath, 1924B, p. 79), together with the fact that *Subcraspedites subpressulus* (Boghoslovsky) is the only form in the Fordington boring which can be closely associated with any of the previously recorded forms, suggests that the latter all belong to higher horizons. The more primitive character of the members of the Fordington faunas supports this view and strengthens the impression that these are the oldest cephalopod faunas which have up to the present time been found in the

[1] The new species here recorded are described on pp. 32–40 of this paper.

Lower Cretaceous of Lincolnshire, and indeed of Britain. It will be shown later that thay have some affinity with the fauna of the Russian Riasan Beds.

(b) Notes on the Belemnites

Genus NEOHIBOLITES Stolley

NEOHIBOLITES EWALDI (v. Strombeck). Pl. I, figs. 3–8

This species is abundant in the Sutterby Marl, especially in the bottom 18 inches. Though the oncoming of rainy weather hindered a careful zonal collecting of belemnites from the bottom of the excavation in 1932, several hundreds of specimens were obtained, the examination of which revealed a wide range of variation. In 1933 the work was renewed with a view to ascertaining whether this richly fossiliferous horizon had a homogeneous fauna.

The variations exhibited by this species may be referred to two groups, one in which the characteristics of the species are variously emphasized (Pl. I, figs. 3–5), the other in which features peculiar to other species tend to be manifested (figs. 6–8). An outstanding characteristic of the species is the tendency towards the assumption of a cylindrical form in the upper part of the guard. This is due to the slight diminution in calibre from the zone of maximum thickness, situated about the middle of the guard, to the alveolar end. The diminution amounts in a normal specimen to less than 20 per cent of the maximum thickness. Almost every gradation may be recognized, from short stout forms in which the maximum thickness is one-sixth of the length to long slender forms in which it is one-ninth of the length. In the former, the diminution towards the alveolar end takes place more rapidly than in the latter, with the result that one type tends to be spindle-like in outline while the other is almost parallel-sided in its upper half. The acme in numbers and size is attained by forms in which the relation of diameter to length is 1 : 7 and 1 : 7·5. A consideration of the accompanying table showing the distribution of these variations is of interest. It is evident that the *N. ewaldi* stock had become definitely established before the deposition of the lowest layers of the Sutterby Marl, and that whilst these were being deposited the stock was in a state of wide variability. During the deposition of the remainder of the marl the tendency towards the cylindrical form became more marked. The phosphatic nodule layer and the one below it are characterized by the presence of spindle-shaped forms, while the beds above are distinguished by the general absence of such forms and the dominance of those in which the cylindrical condition is definitely marked. The median forms attain the largest size.

DISTRIBUTION OF THE VARIATIONS OF *NEOHIBOLITES EWALDI* IN THE SUTTERBY MARL. (See Fig. 3.)

Progressive variations of the normal *N. ewaldi* (v. Strombeck).

Breadth : length.	1 : 6	1 : 7	1 : 7·5	1 : 8	1 : 9	Total.
Beds 6–9 . .		11	12	15	5	43
Beds 4–5 . .	3	17	28	23	11	82
Bed 3 . .	33	35	62	22		152
Bed 2 . .	41	43	18	2		104

Divergent variations towards *N. clava* (1 : 5) and *N. inflexus* (1 : 8).

Breadth : length.	1 : 5	1 : 6	1 : 7	1 : 7·5	1 : 8	Total.
Beds 6–9 . .				7	1	8
Beds 4–5 . .		2	2	19	9	32
Bed 3 . .	6	22	35	11	10	84
Bed 2 . .	1	8	10			19

In specimens collected from the top few inches of the marl, the alveolar end is not so perishable as in those from the beds below; consequently, portions of the alveolus may be preserved. This feature is one which distinguishes the species *N. wollemanni* from *N. ewaldi*, and its presence may perhaps be taken as a slight indication that the zone of *N. wollemanni*, which Stolley (1911, p. 20) places at the base of the Albian, is being approached.

In the second group of variations of *N. ewaldi* there is a tendency for the zone of maximum thickness to approach more nearly towards the apex, and to lie about one-third of the way up the guard. On the other hand, the alveolar end becomes relatively much thinner than in the normal *N. ewaldi*. Stolley recognized two varietal types leading towards *N. clava* and *N. inflexus* respectively. As will be seen in the table, the former in its extreme condition is rare and, like the spindle forms mentioned above, tends to disappear above the phosphatic nodule layer. The more slender *inflexus*-like variety exhibits a wide range both of form and distribution. It is more common than the *clava*-like variety but is less abundant than the normal *N. ewaldi*. The relative increase of the more slender varieties above the phosphatic nodule layer suggests an approach towards the Upper Aptian which, according to Stolley, is characterized by the presence of *N. inflexus*. It is, however, an interesting comment upon the use of belemnites for precise zoning that at Sutterby the claviform varieties apparently disappear while as yet *N. ewaldi* is dominant, for according to Stolley (1911, p. 20) there is a zone of *N. clava* between that of *N. ewaldi* and *N. inflexus*.

NEOHIBOLITES SPICATUS sp. nov. Pl. I, figs. 9a, b

Description of the Holotype.—Guard a deep brown colour; moderately elongate, at least eight times as long as broad. Maximum thickness situated about one-third of the length below the alveolar end; from thence the guard tapers gradually and almost regularly towards the apex. Ventral sulcus moderately deep at the alveolar end and distinct for more than half the length of the guard; disappears in the lower half; lateral furrows absent.

Slightly compressed at the alveolar end where the dorso-ventral is greater than the transverse diameter. Throughout the greater part of the length the transverse diameter is slightly larger. Alveolus extends to a depth of about one-third the length of the guard; margins show only a slight tendency to scale off.

Measurements.—Length 108 mm.; transverse diameter at alveolar end 11·5 mm., at maximum 13 mm.; vertical diameter at alveolar end 12·5 mm., at maximum 13 mm.

Horizon and Locality.—Rare form apparently limited to layers 3–5 of the Sutterby Marl, Sutterby, Lincolnshire.

HIBOLITES MINUTUS sp. nov. Pl. I, fig. 2

Description of the Holotype.—Guard a light yellow colour, translucent, at least six times as long as broad. Maximum thickness in the lower quarter of the length; from thence the guard tapers regularly towards the alveolus and rapidly towards the apex. Sides slightly flattened in the upper half. Alveolus destroyed by scaling.

Measurements.—Length 23 mm.; transverse diameter at alveolar end 2·3 mm., at maximum 3·7 mm.; vertical diameter at alveolar end 2·3 mm., at maximum 3·7 mm.

Horizon and Locality.—Sutterby Marl, beds 2–5. Sutterby, Lincolnshire.

Remarks.—The specimens of this species were distributed as follows: in bed 2, 15 specimens; in bed 3, 17 specimens; in beds 4 and 5, 4 specimens in all.

(c) Notes on the Ammonites [1]

Genus DESHAYESITES Kazansky, 1914 (Spath, 1930, p. 424)

DESHAYESITES FISSICOSTATUS (Phillips)

Fragments, especially of the body chamber, of this species are abundant in the phosphatic nodule band of the Sutterby Marl. The diameter of the most complete specimen is 47 mm. One individual, exhibiting the innermost whorls, shows that the first three are smooth and unornamented. Ribs appear on the latter half of the fourth whorl as low undulations which become sharply defined subsequently. On the fifth there are 23 ribs. At the sixth whorl the shell becomes less involute, so that the outer secondary ribs can also be seen. The diameter of the umbilicus at this stage is 7 mm. The degree of coarseness of ribbing exhibited by the Sutterby material is intermediate between that of specimens from Timmern in the British Museum (B.M. Nos. 14367, 14368) and Phillips's holotype of this species (B.M. No. C. 24718).

[1] All type specimens described in this section have been deposited in the British Museum (Natural History).

DESHAYESITES aff. LÆVIUSCULUS (v. Koenen)

Fragments of a species closely similar to *D. læviusculus* are common, but less so than those referable to *D. fissicostatus*. One specimen, consisting only of the inner whorls, resembles that figured by von Koenen (1902, p. 224, pl. viii, fig. 4a). Its dimensions are: diameter 33 mm.; height of whorl 18 mm.; thickness 8 mm. Other specimens are merely fragments of the outer whorls. The estimated diameter of the largest is 85 mm. This resembles the specimen figured by von Koenen from the Aptian of Mastbruch (1902, pl. xxxix, fig. 3a) more closely than that from Timmern (1902, pl. viii, fig. 5), in that its surface is marked by unbranching folds and that the external saddle is narrow.

DESHAYESITES MULTICOSTATUS sp. nov. Pl. I, figs. 1a–c

Description of the Holotype (B.M. No. 36366).—Involute, umbilicus narrow. Whorl compressed and moderately elevated. Sides at first gently rounded, later flattened on the inner half; elevation increases correspondingly; venter arched. Ribs well developed, slender, gently sigmoidal; at first bifurcating, later intermediaries appear. Suture line more deeply incised than in *D. fissicostatus*.

Measurements.—Dimensions: S52 mm., 47, 28, 28.[1]

Horizon and Locality.—Phosphatic nodule layer in the Sutterby Marl, Sutterby, Lincolnshire.

Remarks.—The outer whorl increases so rapidly in elevation that its height is nearly doubled in the last half whorl—from 13·5 mm. to 24·9 mm. At the same time it becomes more compressed, for its thickness relatively to its height diminishes from 73 to 56 per cent.

Specimens from Hunstanton preserved in the British Museum (C. 35763) resemble this specimen in pattern, number of the ribs, and in the suture; but they differ in that the

[1] Diameter in millimetres; whorl height, whorl thickness, and umbilicus in percentage of diameter.

costæ are not so strongly developed, the suture is less deeply indented, and there is a less marked tendency towards an increased elevation of the outer whorl. That whorl, also, is not so stout.

Genus SUBCRASPEDITES Spath (1924A, p. 17)

SUBCRASPEDITES PRIMITIVUS sp. nov. Pl. II, figs. 1a–c

Description of the Holotype (B.M. No. 36350).—Moderately involute, inner whorls visible. Umbilicus increasing regularly, fairly narrow. Whorl compressed, slightly inflated towards the umbilical shoulder, side flattened, curving gradually into the round venter. Dorsum impressed to a depth equal to half the height of the whorl.

Lateral ribs arise as low ridges near the umbilical suture; apart from a slight backward curvature they lie in the direction of the radial line. About the middle of the whorl they become less distinct and break up into three branches, of which the middle continues the direction of the main rib; occasionally one of the branches exists as a separate intermediary. All peripheral ribs cross the venter with a gentle forward bend.

In the suture line the external saddle is wide and divided by a median lobe, the lateral lobe is similar in depth to the external lobe, lobe U2 is half as deep as the lateral. The remainder of the suture occupies more than one-third of the length of the radial line, slopes backwards, and touches the latter at the umbilical margin.

Measurements.—

Dimensions. S65 mm., 42, 31, 26.

Rib spacing :—[1]

Umbilical diameter,	7 mm.,	11 mm.,	17 mm.
Number of ribs,	20	23	18

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

Remarks.—A fragment of a larger individual (B.M. No. 36351) having an estimated diameter of 93 mm. exhibits the same whorl form and ornamentation. Its suture line (Pl. II, fig. 1c) is more advanced in that it is more deeply divided, its lateral lobe is deeper than the external lobe, and the portion of the suture which lies between U2 and the umbilicus has shortened to one-third of the radial line in length. The last-named two features become more marked in other species of this genus.

It is unfortunate that no portion of the outermost whorl of this species has been found. Without that it cannot be known whether in later life the species exhibits that rapid increase in width of spacing and coarse development of the lateral ribs which is so characteristic of the other species. On the other hand, the closeness of its affinity to the stock from which they arose is indicated by the great similarity of its whorl shape and ornamentation to the inner whorls of the other forms. It may be regarded as representing a more stable branch of that stock.

SUBCRASPEDITES PRECRISTATUS sp. nov. Pl. III, fig. 3

Description of the Holotype (B.M. No. 36358).—Inner whorls moderately involute tending to become more evolute after the umbilicus has attained a diameter of about 12 mm. Whorl as broad as high, maximum inflation near the umbilical shoulder, dorsum impressed to a depth of only one-fifth of the height. Lateral ribs arise a little distance from the umbilical suture and follow a straight course obliquely forward across the flank to a point beyond the centre, where they branch. In the early half of the outer whorl branching is bifurcate, later it becomes trifurcate or bifurcate with single intermediaries. The ribbing is close and moderately fine until the last quadrant of the outer whorl, where the lateral ribs rapidly become widely spaced and rise into coarse, sharply marked ridges having a maximum height in the middle and declining to the point of branching. Peripheral ribs exhibit no such abrupt increase in coarseness or spacing and cross the venter with a gentle forward bend.

Measurements.—

Dimensions : S49 mm., 30, 31, 43.

Rib spacing :—

Umbilical diameter,	9 mm.	19 mm.
Number of ribs,	22	13

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

SUBCRASPEDITES CRISTATUS sp. nov. Pl. III, figs. 4a–c, 5

Description of the Holotype (B.M. No. 36355).—Whorl shape (Pl. III, fig. 4b) between the ribs slightly higher than wide, and oval in section. Lateral ribbing increases in coarseness to an extraordinary degree on the outer whorl, where the ribs form high, sharp, crested ridges separated by hollows so deep that the diameter of the whorl is here 20 per cent less than that measured from crest to crest. At a point slightly nearer to the periphery than to the umbilicus the crests sink rapidly to the general level of the whorl surface and trifurcate into feeble, almost imperceptible ribs which arch forward as they cross the venter; two or three intermediaries may be present.

The suture line (fig. 4c) has low saddles and shallow lobes,

[1] Changes in the spacing of the ribs and in the time of onset of change are features of importance in the group of ammonites described here. The facts are expressed in terms of the diameter of the umbilicus at different stages of growth and of the number of lateral ribs shown upon the half-whorl subtended by that diameter.

feebly frilled; the lateral lobe is apparently deeper than the external, lobe U2 half the depth of the lateral. The remainder of the suture occupies nearly one-half of the length of the radial line and inclines gently backward until it touches the latter at the umbilical margin.

Measurements.—

Dimensions: S68 mm., 34, 35, 35.
Rib spacing: umbilical diameter, 24 mm.; number of ribs, 7.

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

Remarks.—A specimen (B.M. No. 36365) from the bottom six feet of the Spilsby Sandstone at Partney (see p. 14) is a young individual of the same species (Pl. III, fig. 5). Its dimensions are as follows: S37 mm., 35, 45, 39. Its umbilicus is relatively wider and the thickness of the whorl relatively greater than in the holotype, which was apparently more involute. The inner whorls are finely ribbed until the umbilicus has a diameter of 10 mm. From this point the widening of the space between the ribs is so rapid that at an umbilical diameter of about 14 mm. the number of ribs is only nine. At this stage the ribs are already high and crest-like. Each rib trifurcates towards the periphery into well-developed branches; single intermediaries are also present.

This species differs from *S. precristatus* in the earlier and more rapid oncoming of coarse, widely spaced ribbing and greater thickness of the whorl.

The ammonite fragment found by Pringle (1919, p. 50) in the Donington boring and referred by him to *Craspedites nodiger* belongs to this species.

SUBCRASPEDITES SUBUNDULATUS sp. nov. Pl. II, figs. 2a, b

Description of the Holotype (B.M. No. 36357).—Moderately wide umbilicus. Whorl, between the ribs, slightly compressed, inflated towards the umbilical shoulder. Dorsum impressed to a depth equal to only one-fifth of the height of the whorl.

The lateral ribs increase rapidly in coarseness and width of spacing on the last whorl after the umbilicus has attained a diameter of about 30 mm. On the inner whorls the moderately developed lateral ribs merge distally into two or three less distinct ribs which arch forward as they cross the venter. On the outer whorl the lateral ribs form high ridges; these trifurcate into feeble peripheral ribs which also arch forward. Occasional intermediaries are present.

The suture line is feebly incised; the external saddle is broad and divided by a median lobe. The lateral lobe is shallower than the external, and is situated at the centre of the radial line. Lobe U2 is half the depth of the lateral lobe, and is so near the umbilicus that the remainder of the suture occupies less than one-quarter of the length of the radial line, and lies some distance in front of this.

Measurements.—

Dimensions: S85 mm., 29, 28, 45.
Rib spacing:—

Umbilical diameter,	5 mm.	10 mm.	21 mm.	38 mm.
Number of ribs,	25	25	25	11

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

SUBCRASPEDITES UNDULATUS sp. nov. Pl. II, figs. 3a–c

Description of the Holotype (B.M. No. 36352).—Moderately evolute, umbilicus wide; whorls between the ribs slightly compressed, inflated towards the umbilical shoulder. Dorsum impressed to a depth of one-third of the height of the whorl.

The lateral ribs, which lie along the radii, increase in coarseness and width of spacing at an early stage, when the umbilical diameter is only about 12 mm. On the last whorl the ribs have the form of low rounded waves. In the middle of the flank they merge into groups of three faintly marked peripheral ribs with from one to three similar intermediaries. These ribs bend forward as they cross the venter.

The suture line is deeply incised, lateral saddle higher than wide and divided by a median lobe. The lateral lobe is not so deep as the external lobe but is twice as deep as lobe U2. The remainder of the suture lies some distance in front of the radial line and occupies more than one-third of the length of the radius.

Measurements.—

Dimensions: S95 mm., 36, 32, 53.
Rib spacing:—

Umbilical diameter,	12 mm.	36 mm.	50 mm.
Number of ribs,	18	10	9

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

Remarks.—One specimen (B.M. No. 36353) from the same horizon is very closely allied to, if not identical with, the above species (Pl. II, fig. 3c). Its inner whorls are less obscured than they are in the holotype. They are finely ornamented with as many as 24 ribs per half-whorl. The dorsum is impressed to a depth of only one-fifth of the height of the whorl.

SUBCRASPEDITES PARUNDULATUS sp. nov. Pl. IV, figs. 4a, b, and Text-fig. 4

Description of the Holotype (B.M. No. 36356).—Moderately involute with fairly wide umbilicus. Whorl slightly compressed, tending towards inflation near the umbilical margin

(Pl. IV, fig. 4b). Dorsum impressed to a depth of more than one-third of the height of the whorl.

Lateral ribs broad and wave-like, lying along the radial line, merging at the middle of the flank into groups of three faintly marked peripheral ribs with three or four intermediaries. The peripheral ribbing more clearly marked on the inner whorl. Ribs bend forward as they cross the venter.

The suture line moderately deeply incised, lateral saddle as broad as high, lateral lobe not so deep as the external lobe but twice as deep as lobe U2. The remainder of the suture lies

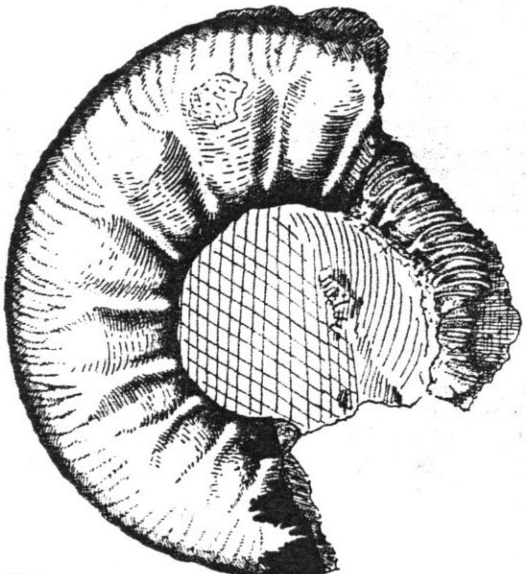

FIG. 4.—*Subcraspedites parundulatus* sp. nov. Holotype. Natural size.

some distance in front of the radial line and occupies about one-third of the length of the radius.

Measurements.—

Dimensions : S75 mm., 36, 32, 37.
Rib spacing : umbilical diameter, 28 mm. ; number of ribs, 9.

Horizon and Locality.—Bed D of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

SUBCRASPEDITES PREPLICOMPHALUS sp. nov.
Pl. III, figs. 1a, b, 2a, b

Description of the Holotype (B.M. No. 36364).—Moderately involute in the inner whorls, becoming more evolute after the

umbilicus has attained a diameter of about 20 mm. Whorl moderately elevated and compressed (Pl. III, fig. 1b), inflated centrally. Dorsum impressed to a depth less than one-third of the height of the whorl.

Lateral ribs arise with slight backward curvature on the umbilical margin but incline obliquely forward in front of the radial line as they cross the flank. At the inner ends they are low, but sharply marked, ridges. Externally they flatten out and merge into groups of three peripheral ribs without intermediaries. The ribs bend forward as they cross the venter.

Measurements.—

Dimensions : S105 mm., 34, 23, 42.
Rib spacing :—

Umbilical diameter,	9 mm.	17 mm.	44 mm.
Number of ribs,	25	16	11

Horizon and Locality.—Tip heaps made from the bottom six feet of the Spilsby Sandstone, Partney, Lincolnshire.

Remarks.—Specimens (Pl. III, figs. 2a, b) referable to the same species were collected from bed C of the Spilsby Sandstone in the Fordington boring. The following details from one specimen (B.M. No. 36361) amplify the description given above.

Measurements.—

Dimensions : S47 mm., 34, 23, 36.
Rib spacing :—

Umbilical diameter,	13 mm.	17 mm.
Number of ribs,	25	17

Dorsum impressed to a depth equal to about half the height of the whorl. Branching of the ribs is at first bifurcate but later becomes predominantly trifurcate.

Suture (fig. 2b) moderately deeply incised ; lateral saddle broad ; lateral lobe not so deep as the external lobe, but nearly twice as deep as the lobe U2, and situated close to the middle of the flank. The umbilical portion of the suture lies well in front of the radial line and occupies not more than one-third of the length of the radius.

This specimen closely approaches *Olcostephanus* (*Subcraspedites*) *spasskensis* (Boghoslovsky, 1897, p. 141, pl. ii, fig. 1a). It differs, however, from that species in having a wider umbilicus, a lower and narrower whorl, a much more deeply incised suture line with broader lateral lobe and saddles and shorter umbilical portion.

SUBCRASPEDITES aff. SUBPRESSULUS (Boghoslovsky)

Specimens closely related to *Olcostephanus* (*Subcraspedites*) *subpressulus* (Boghoslovsky, 1897, p. 142, pl. iv, fig. 3) were found in bed D of the Spilsby Sandstone in the Fordington boring. The following details taken from one specimen (B.M. No. 36354) amplify Boghoslovsky's description.

Measurements.—Dimensions : S62 mm., 40, 27, 37.

Among previously described British species of the genus *Subcraspedites* the one which most closely approaches this is *S. plicomphalus* (Sowerby, vol. iv, 1823, p. 145, pl. ccccıv). *Subcraspedites subpressulus* differs in the more complete enclosure of the inner by the outer whorls and in the finer ribbing upon the inner whorls.

Genus PARACRASPEDITES nov.

Genotype Paracraspedites stenomphaloides

This genus includes several species which differ from *Subcraspedites* in having coarse, moderately widely spaced lateral ribs on the inner as well as the outer whorls. The spacing does not show any marked or rapid increase during development. All peripheral ribs arise as branches of the main ribs, and are well defined both by greater prominence and by deeper furrows than in *Subcraspedites*. Intermediaries are absent. Ribs cross the venter without a distinct forward bend.

Paracraspedites stenomphaloides sp. nov. Pl. IV, figs. 1a, b

Description of the Holotype (B.M. No. 36363).—Moderately involute, umbilicus fairly wide, increasing regularly. Whorls compressed. Dorsum impressed to a depth equal to nearly half of the height of the whorl.

Lateral ribs arise near the umbilical suture and pass outwards with a slight forward curvature close to the radial line. Ribs stout and moderately widely spaced on the inner as well as the outer whorls. About the middle of the flank, and sometimes a little beyond it, each rib passes usually into three but sometimes into only two stout branches which cross the venter without a forward bend.

The suture line is imperfectly known. That shown in fig. 1b is taken from another specimen of the same species. It appears to be divided in a manner similar to that seen in the suture of *Subcraspedites*. It apparently has a marked forward swing in its umbilical portion.

Measurements.—

Dimensions : S89 mm., 37, 27+, 34.

Rib spacing :—

Umbilical diameter,	15 mm.	25 mm.	30 mm.
Number of ribs,	15	12	13

Horizon and Locality.—Bed C in the Spilsby Sandstone in the Fordington boring, Lincolnshire.

Remarks.—This species resembles *Subcraspedites stenomphalus* (Pavlov) more closely than any other known form. It differs from it in the greater prominence of the peripheral ribs and the absence of the forward bend upon the venter. The inner whorls of the type specimen of *Subcraspedites stenomphalus* (B.M. No. 81062) are not known, so that no comparison of the ornamentation in youth can be made.

One specimen (B.M. No. 36359), from the same horizon and locality, is closely allied to but not identical with this species (Pl. IV, figs. 2a, b). It exhibits the following features :—

Measurements.—

Dimensions : S74 mm., 38, 26+, 28.

Rib spacing :—

Umbilical diameter,	6·5 mm.	8 mm.	13 mm.	21 mm.
Number of ribs,	12	12	12	16

These figures show that the ribbing is relatively widely spaced at a much earlier stage than any exhibited in the holotype. The branching of the ribs on the outer whorl is usually bifurcate, occasionally trifurcate, sometimes remarkably virgatite in character. Small specimens of this variety resemble *Olcostephanus subtzikwinianus* (Boghoslovsky, 1902, p. 125, pl. v, fig. 2). In the latter, however, all ribs exhibit a marked forward bend as they cross the venter.

Paracraspedites bifurcatus sp. nov. Pl. IV, fig. 3

Description of the Holotype (B.M. No. 36360).—Moderately involute, fairly wide umbilicus. Whorl slightly compressed. Dorsum impressed to a depth equal to one-quarter of the height of the whorl.

Lateral ribs stout; arising near the umbilical suture they pursue a straight course along the radial line and cross the venter without a forward bend. Ribs bifurcate into stout, well-marked branches at the middle of the flank. In the last quadrant of the outer whorl several unbranched ribs occur. The spacing of the ribs tends to increase slightly towards the outer whorl.

Measurements.—

Dimensions : S72 mm., 33, 28, 43.

Rib spacing :—

Umbilical diameter,	11·5 mm.	15 mm.	31 mm.
Number of ribs,	22	18	17

Horizon and Locality.—Bed C of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

Paracraspedites(?) trifurcatus sp. nov. Text-fig. 5

Description of the Holotype (B.M. No. 36362).—Moderately evolute, fairly wide umbilicus increasing regularly. Whorl compressed and slightly elevated. Dorsum impressed to a depth equal to more than half the height of the whorl. Lateral ribs arise a little distance from the umbilical suture and form stout ridges which follow the radial line. About the middle of the flank each rib passes into three coarse peripheral ribs which cross the venter without a forward bend. The middle

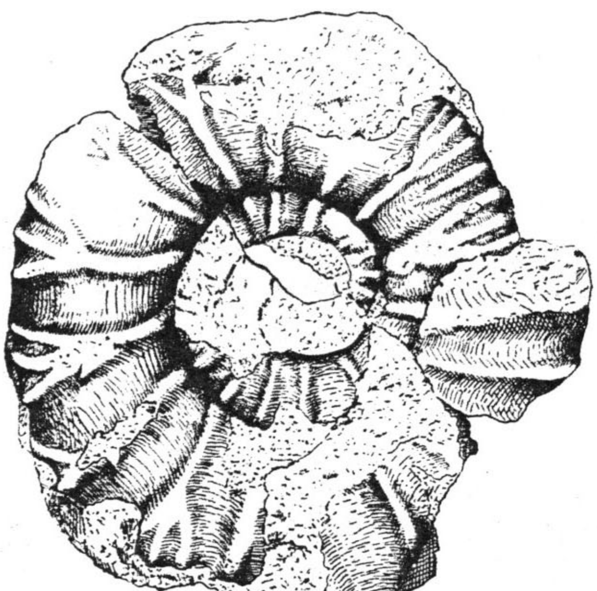

FIG. 5.—*Paracraspedites*(?) *trifurcatus* sp. nov. Holotype. Natural size.

branch continues the line of the main rib; intermediaries are absent.

Measurements.—

Dimensions : S75 mm., 32, 24, 44.
Rib spacing :—

Umbilical diameter,	18 mm.	33 mm.
Number of ribs,	9	9

Horizon and Locality.—Bed C of the Spilsby Sandstone in the Fordington boring, Lincolnshire.

(d) Remarks on the Faunas of Beds C and D of the Spilsby Sandstone

The two assemblages of ammonites just described present a remarkable general resemblance to that described by Boghoslovsky from the Riasan Beds of Russia (1897; 1902). This

is due to the presence in both regions of forms exhibiting the typical subcraspeditan ornamentation on the outer whorl, together with others which have that type of clear-cut ornamentation more usually associated with Jurassic ammonites. When this similarity is analysed it is found to be of family rather than specific grade. Specific identity is limited to one

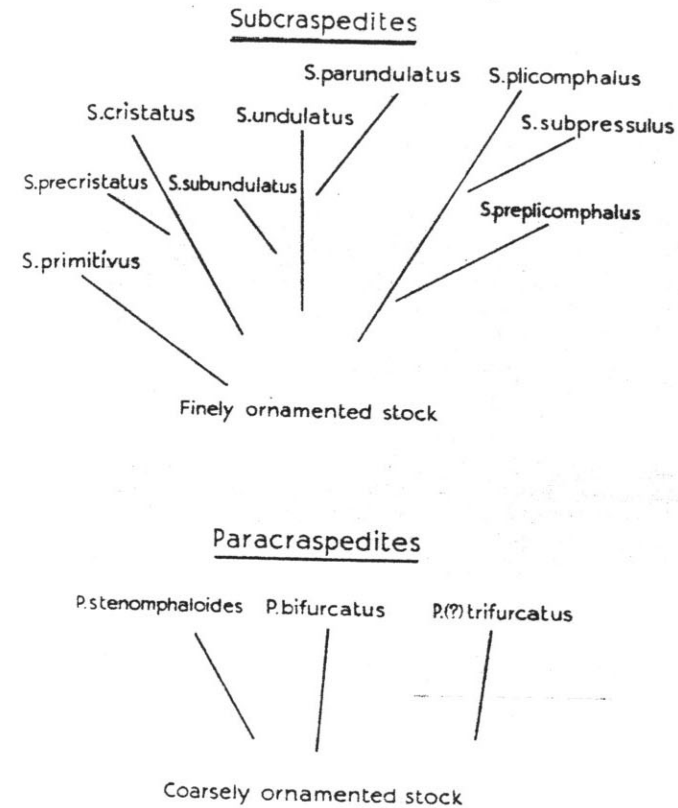

FIG. 6.—Diagram showing the morphological relationships to each other of the species of *Subcraspedites* and *Paracraspedites*.

species, *S. subpressulus*. An approach to specific similarity seems to be manifested also by *S. preplicomphalus* (see p. 36) and by *S.* aff. *stenomphaloides* (see p. 39). The Lincolnshire and Riasan areas evidently derived their faunas from the same northern source but were not themselves directly connected with one another. This view is strengthened by the presence in the Riasan fauna of a southern element not found in Lincolnshire, in the form of the berriasellid species *Riasanites rjasanensis* (Boghoslovsky) (Spath, 1923B, p. 306).

While in Lincolnshire the species of *Paracraspedites* and of *Subcraspedites* characterize, on the whole, separate horizons, the corresponding two elements appear to be mixed in the Riasan fauna. Whether this mixture is an accident of collecting or is natural is an open question.

The difference between *Paracraspedites* on the one hand and the young of the various species of *Subcraspedites* and the adults of *S. primitivus* on the other shows that the latter genus did not originate in the former, and that the faunas of beds C and D entered the area as independent invasions. The paracraspeditan invasion was made up of relatively disconnected representatives of some larger fauna. The subcraspeditan invasion, on the contrary, consisted of a compact assemblage of closely related forms, and evidently took place at a time when this genus was becoming differentiated from some finely ornamented and moderately evolute radical stock. The morphological relationships to one another of the species of *Subcraspedites* are indicated diagrammatically in the accompanying table (Fig. 6).

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EXPLANATION OF PLATES I–IV

Plate I

Fig. 1. *Deshayesites multicostatus* sp. nov. Holotype. 1a, side view, nat. size; 1b, ventral view, nat. size; 1c, suture line. Sutterby Marl. (See p. 31.)

2. *Hibolites minutus* sp. nov. Holotype. × 2. Sutterby Marl. (See p. 30.)

Figs. 3–5. *Neohibolites ewaldi* (v. Strombeck), varieties of the progressive series. 3, stout spindle-shaped variety; 5, slim cylindrical variety. Nat. size. Sutterby Marl. (See p. 28.)

6–8. *Neohibolites ewaldi* (v. Strombeck), varieties of the divergent series. 6, claviform type; 7, central type; 8, inflexiform type. Nat. size. Sutterby Marl. (See p. 29.)

Fig. 9. *Neohibolites spicatus* sp. nov. Holotype. Nat. size. 9a, ventral view; 9b, side view. Sutterby Marl. (See p. 30.)

Plate II

Fig. 1. *Subcraspedites primitivus* sp. nov. Holotype. 1a, side view, nat. size; 1b, suture line of holotype; 1c, suture line from a fragment of a larger specimen of the same species. Spilsby Sandstone, basement bed D. (See p. 32.)

2. *Subcraspedites subundulatus* sp. nov. Holotype. 2a, side view, × 0·75; 2b, suture line of holotype. Spilsby Sandstone, basement bed D. (See p. 34.)

3. *Subcraspedites undulatus* sp. nov. Holotype. 3a, side view, × 0·6; 3b, suture line of holotype; 3c, fragment of another specimen of the same species showing the inner whorls more clearly; nat. size. Spilsby Sandstone, basement bed D. (See p. 35.)

Plate III

Fig. 1. *Subcraspedites preplicomphalus* sp. nov. Holotype. 1a, side view, × 0·6; 1b, section across the whorl. Spilsby Sandstone, basement bed, Partney. (See p. 36.)
2. *Subcraspedites preplicomphalus* sp. nov. Paratype. 2a, side view of a fragment of another specimen of this species showing the inner whorls more clearly, × 0·8. 2b, suture line. Spilsby Sandstone, basement bed C. (See p. 36.)
3. *Subcraspedites precristatus* sp. nov. Holotype. Nat. size. Spilsby Sandstone, basement bed D. (See p. 33.)
4. *Subcraspedites cristatus* sp. nov. Holotype. 4a, side view, nat. size; 4b, section across the whorl; 4c, suture line. Spilsby Sandstone, basement bed. (See p. 33.)
5. *Subcraspedites cristatus* sp. nov. Paratype. Nat. size. Side view of a fragment of another specimen of this species showing the inner whorls more clearly. Spilsby Sandstone, basement bed, Partney. (See p. 33.)

Plate IV

Fig. 1. *Paracraspedites stenomphaloides* gen. et sp. nov. Holotype. 1a, side view, × 0·8; 1b, suture line. Spilsby Sandstone, basement bed C. (See p. 38.)
2. *Paracraspedites* aff. *stenomphaloides* sp. nov. Holotype. 2a, side view, nat. size; 2b, section across the whorl. Spilsby Sandstone, basement bed C. (See p. 39.)
3. *Paracraspedites bifurcatus* sp. nov. Holotype. Nat. size. Spilsby Sandstone, basement bed C. (See p. 39.)
4. *Subcraspedites parundulatus* sp. nov. Holotype (see Text-fig. 4). 4a, suture line; 4b, section across whorl.

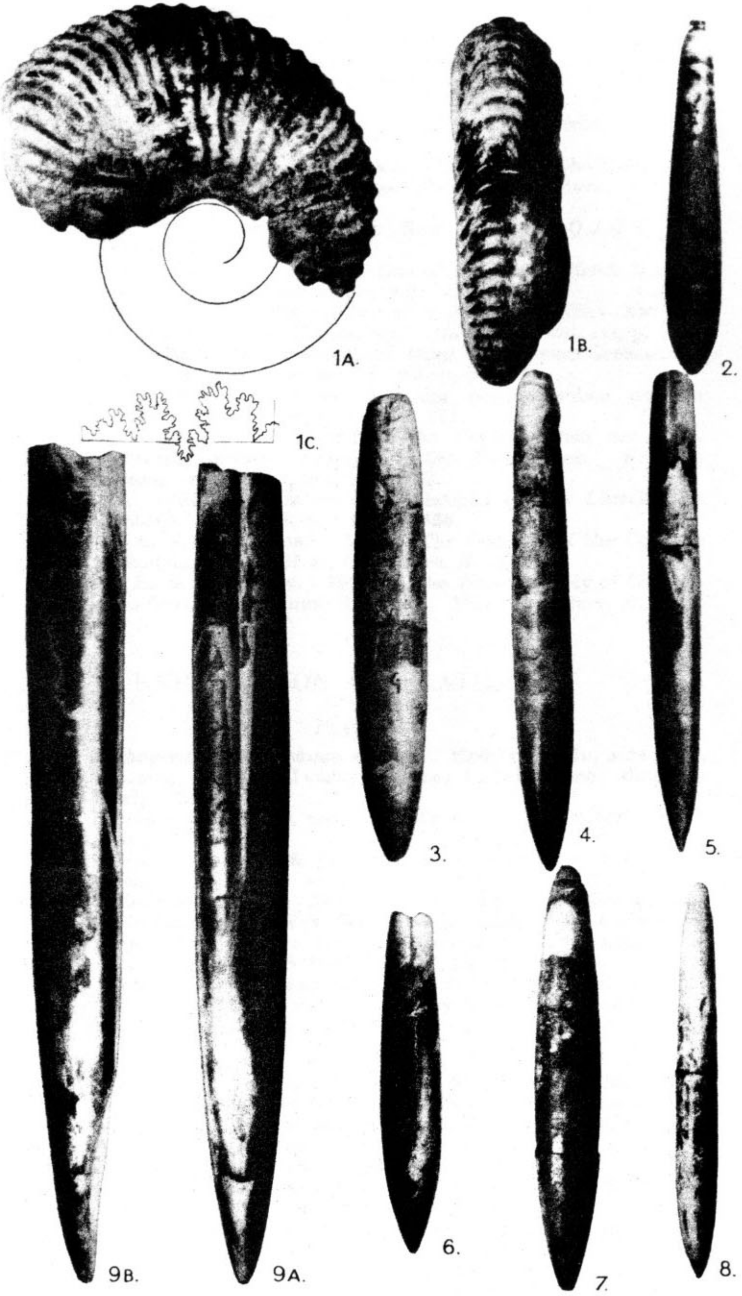
Note.—In Pl. III, figs. 1b, 4b, and Pl. IV, figs. 2b, 4b, the blackened areas show the amount of projection of the ribs. In Pl. III, fig. 1b, and Pl. IV, fig. 2b, allowance has been made for a slight lateral crushing of the specimen.

Discussion

Mr. R. C. S. Walters thought the paper particularly welcome, as no work had been done in this area since the publication of the Geological Survey Memoirs. He was glad to learn how useful the Fordington borehole had been in completing the sequence of the lower part of the Spilsby Sandstone, which was penetrated in its entirety and probably at its maximum thickness. He showed a part of the core, a mass of ammonites and belemnites, from a position two or three feet above the junction with the Kimeridge Clay.

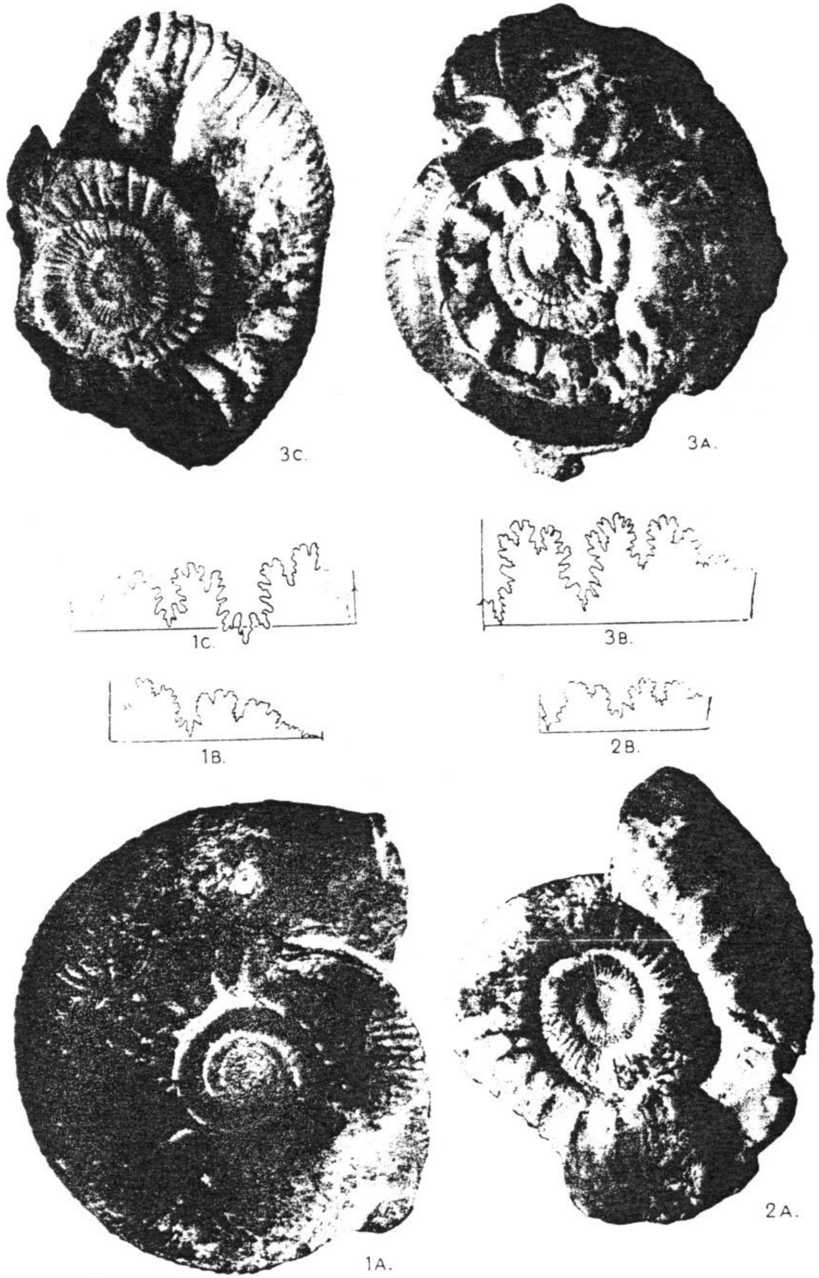
The thick beds of the Spilsby Sandstone at Fordington were very favourable for the large supply of water required by the Boston Corporation. The site had been approved by the late Dr. Herbert Lapworth. The boring was successful and another borehole was about to be put down. Another site was also being developed at Candlesby.

It was interesting to note the recent development of the Spilsby Sandstone as a source of water supply, and to find



W. Sutcliffe, *photo.*]

Lower Aptian Fossils from Lincolnshire



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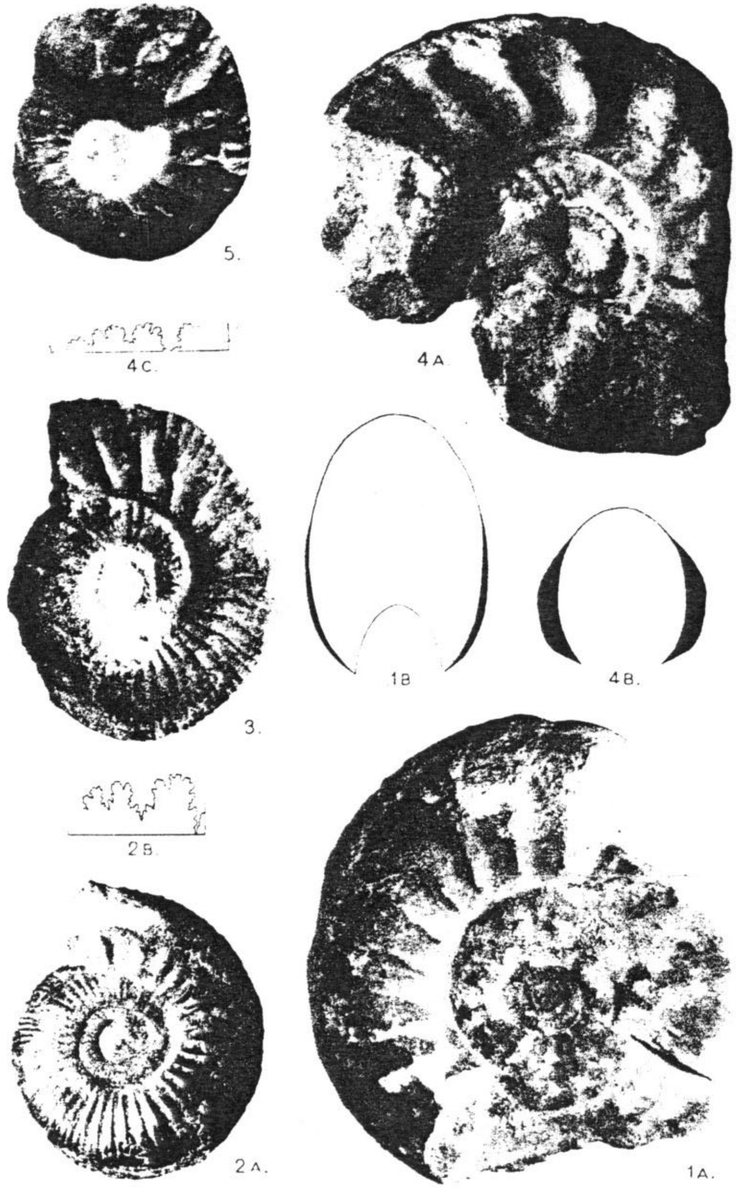
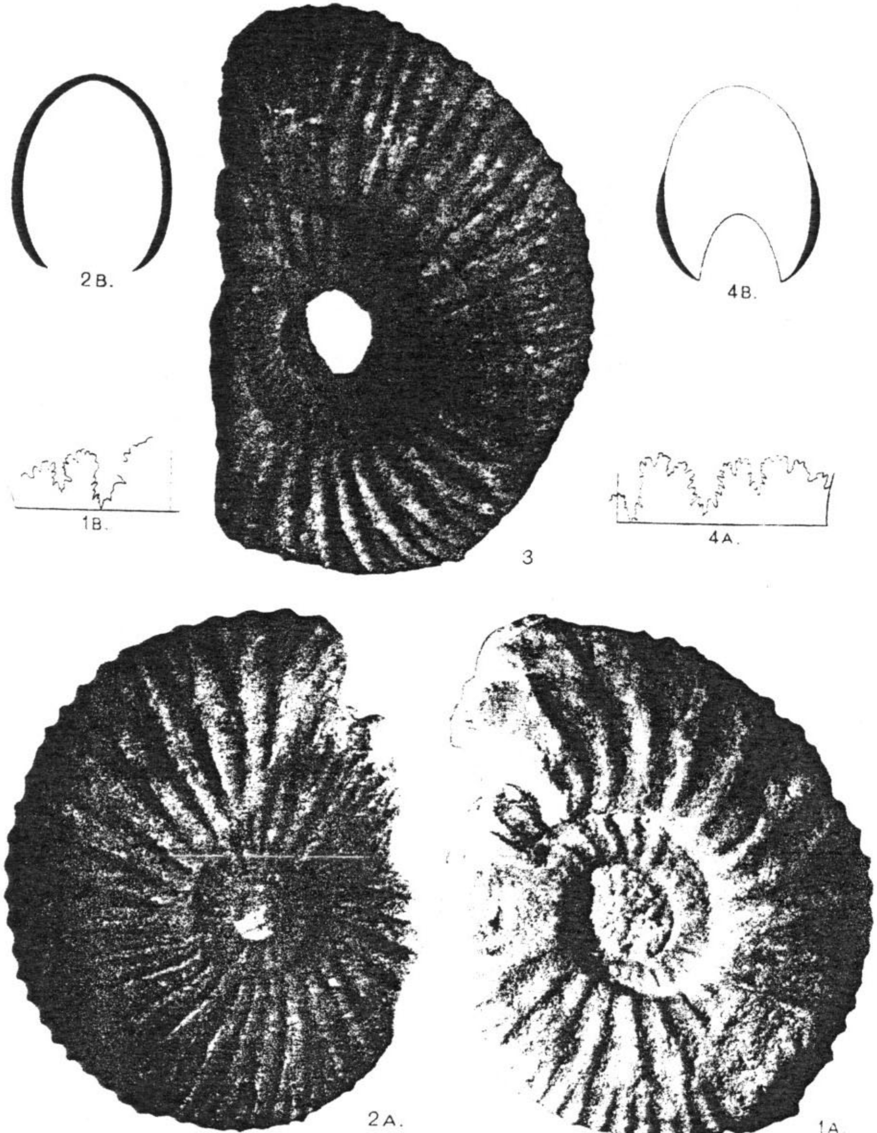
Ammonites from the Basement Beds of the Spilsby Sandstone



W. Sutcliffe, photo.]

Ammonites from the Basement Beds of the Spilsby Sandstone



Ammonites from the Basement Beds of the Spilsby Sandstone

that the water east of the Chalk outcrop at Maltby, Alford, Willoughby, and Welton had a hardness of between 2° and 10° (parts per 100,000), whereas at Fordington it was 22°.

Dr. L. F. Spath congratulated the author on his work and the Society on receiving this valuable contribution. He commented on the ammonites and emphasized the Cretaceous age of the two new faunas from the base of the Spilsby Sandstone. He said that there were ammonites at a much higher level at Speeton that had often been mistaken for Jurassic forms and resembled certain *Perisphinctes* far more than did the ammonites exhibited by the author. The stratigraphical gap below the Spilsby Sandstone was still as great as he had shown it to be in his Speeton paper, ten years ago.

Mr. E. E. L. Dixon inquired whether the author could throw any light on the conditions of deposition. The formations described included an unusually large number of interesting deposits. Not only were phosphates and glauconite recurrent, but there were iron ores in oolitic and other forms, and an abundance of sand grains that had been subjected to prolonged rounding and polishing. Had these grains been through desert conditions on the land from which they were derived, somewhat similar to the conditions inferred by Professor Bailey to have characterized the land bordering the Chalk seas? Or had they been rounded and polished by prolonged drifting to and fro on the sea-bottom, as suggested by Lamplugh?

The President observed that half a century ago the question had been put whether the lowest part of the Spilsby Sandstone was Cretaceous or Jurassic. The answer appeared to have now been obtained from the important new material described by the author, and it would be interesting if he would deal specifically with this point in his reply.

The Author, in replying to questions raised by previous speakers, said that the quality of the water obtained from the Spilsby Sandstone showed extraordinary and rapid variation in degrees of saltness and hardness, but he was unable to offer any explanation of this. The sporadic distribution of rounded and polished grit grains offered another unsolved problem. Their occurrence in a clay matrix, often without material of intermediate grade, pointed to some unusual mode of origin, whilst the presence of pebbles having the same surface peculiarities seemed to exclude transport by the wind. The grains of oolitic iron ore were often, but not always, glazed in a similar manner. They appeared to have been formed frequently in thin layers alternating with mud, and the whole subsequently churned up by worms. They must, therefore, have been glazed by some agency acting on the spot. The reference to the Jurassic appearance of the ammonites was not intended by the author to imply a Jurassic age for the rocks. Earlier workers referred certain