CONDITIONS OF SEDIMENTATION OF THE CYRTINA SEPTOSA BAND IN THE LOWER CARBONIFEROUS OF DERBYSHIRE

by

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Summary

Fourteen localities of the Cyrtina septosa Band were studied in the shelf facies of the Carboniferous Limestone in North Derbyshire.

Tracings of brachiopod shells were recorded from each locality and percentages of disarticulation and orientation of values and size of shells were calculated. Grain sizes were also measured. It was found that there was a random pattern in the sedimentation over the shelf and that there were no significant changes as the reef-complex was approached.

Introduction

The Carboniferous Limestone Series of this country has been divided into a number of zones and sub-zones based on brachiopods and corals and are recognised by the letters K, Z, C, S and D after the fossil names. These zones were originally applied to the Limestone succession in the Avon Gorge, Bristol (Vaughan, 1905) which since that time geologists have zoned other areas of Carboniferous Limestone, including much of Derbyshire. It is not always easy to map these zones in the field, as often the index fossils are not present and the limestone facies may change from one area to another, thus making correlation of individual beds very difficult.

Many fossils are, however, found in the Carboniferous Limestone although often they are very scattered. There are certain horizons where numerous fossils are present and these act as important marker bands in mapping the geology of limestone country. The occurrence of such concentrations of fossils suggests that conditions of deposition must have been very favourable for their accumulation and it is probable that there was a considerable break in sedimentation at the time of formation. The bands are often separated by

many feet of fine-grained unfossiliferous limestones much of which may have been chemically precipitated. It has been suggested (Broadhurst, 1964) that,in shales of the Coal Measures,sedimentation was very slow during the deposition of the fossil bands and faster when the thick inter-bedded unfossiliferous mudstones were laid down. It is possible that similar conditions were present during the Limestone formation.

One important fossiliferous horizon in the Carboniferous Limestone is the Cyrtina septosa Band,which was originally described by Garwood (1912) from the North West Province of the Lower Carboniferous where it can be traced for many miles at 80 - 100 feet below the top of D_1 subzone.

Cope (1936) recorded the Band from the standard (shelf) limestones of the Miller's Dale area where it occurs in the Chee Tor Beds 25 feet below the Lower Lava Flow and 150 feet below the D_1/D_2 boundary.

In 1958 Shirley described a fossiliferous band containing the brachiopod Davidsonina Cyrtina septosa (Phillips) near Grangemill; and Wolfenden (1958) mapped the Band behind the reef-complex in the Earlsterndale, Snelslow Hill and Castleton areas of Derbyshire.

The Cyrtina septosa Band usually consists of light-grey, very fossiliferous limestones containing the brachiopods D. septosa, Chonetes papilionacea Phillips, Gigantoproductus maximus (M'Coy) and Daviesiella aff. comoides (J. Sowerby), the corals Lithostrotion irregulare (Phillips), L. junceum (Fleming), Palaeosmilia murchisoni Edwards and Haime, Dibunophyllum bourtonense Garwood and Goodyear and Syringopora sp.; the gastropod Bellerophon sp., and the algae Girvanella sp.; and Koninckopora inflata (de Koninck).

The total thickness of the Band varies from 1 to 7 feet. Sometimes there may be as many as four well-defined layers of fossils making up the Band. These are separated by fine-grained unfossiliferous limestones.

The Band is found only in the standard (shelf) limestone facies and as the reef-complex is approached brachiopods characteristic of the reef-facies begin to appear. There is no Cyrtina septosa Band as such in the fore-reef facies although occasional specimens of D. septosa can be found.

Method of Study

Thirteen localities of the Cyrtina septosa Band have been studied from an area within a $5\frac{1}{2}$ mile radius of Buxton and one locality 4 miles west of Matlock (see Text-Figure 1), with a view to working out any lateral variation in the pattern of sedimentation at one particular horizon in the Lower Carboniferous.

At each locality the positions of at least forty brachiopods were noted by tracing the outlines of the shells directly on to sheets of paper placed against the rock face. In this way positions, size, disarticulation and orientation of the brachiopod shells were recorded accurately. The arrangement of the shells and their general alignment showed the presence or absence of any sedimentary features such as current-bedding or ripple marks.

The size, disarticulation and orientation of fossil shells are generally considered to be useful indices in helping to interpret the conditions of deposition. Well-preserved shells which are still articulated are probably in or near their original position of life, whereas shells which are abraded, fragmented and have their two valves disarticulated have probably been subjected to turbulent water (currents etc.) and are no longer in their life position. The valves may even be overturned so that the concave surface rests lowermost. This is considered to be a stable position of rest.

Valves which are not overturned but rest with their concave surfaces uppermost have probably accumulated in much quieter water (Shrock, 1948).

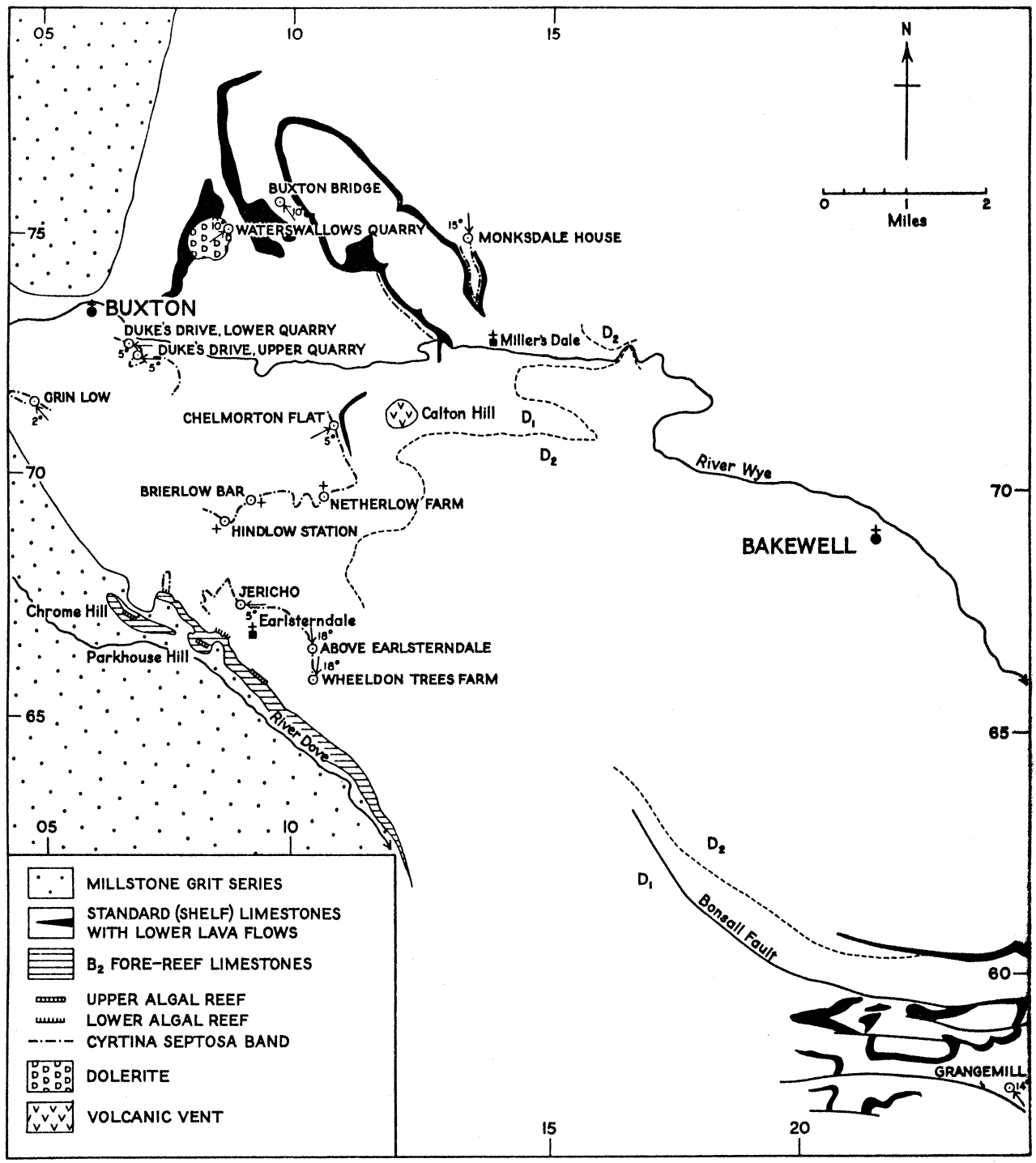

FIG. 1. Map to show the fourteen localities of the Cyrtina septosa band in Derbyshire which are described in the text.

An assemblage of disarticulated and overturned shell fragments is known as a death assemblage.

From these tracings percentages of (i) disarticulated shells, (ii) shells with their concave surface uppermost (iii) shells with their convex surface uppermost and (iv) size, were calculated. The shells were placed into three size groups, "small" (those less than 1 inch), "medium" (those between 1 and 3 inches) and "large" (those over 3 inches).

Thin sections were cut from specimens at each locality and acetate peels also taken in order to study the presence or absence of rounded and oolitic grains, and to measure the sizes of individual grains.

It was hoped to show from this study that the Cyrtina septosa Band showed obvious changes in sedimentation as the reef-complex or edge of the limestone "massif" was approached. It was expected that there would be evidence for an increase in the turbulence of water towards the reef-complex and a corresponding decrease in turbulence away from it, and that current directions, as shown by current-bedding, would indicate water flowing from the shallows of the shelf to the deeper water of the basin, or vice versa.

Results

From the results of the investigation it appears, however, that there is a random pattern in the sedimentation of the Cyrtina septosa Band.

Sedimentary structures such as current-bedding are only occasionally seen. They consist of piles of shell, crinoid and coral debris arranged in the form of current-bedding units such as those found in sandstones.

Fairly well preserved current-bedding can be seen at Grangemill in the south east corner of the area studied (SK 24115762). Here the current-bedding units appear to indicate currents flowing in a westerly direction, that is, at right angles away from the reef margin at Matlock.

Poorly developed current-bedding is also found at Jericho, near Earlstemdale (SK 08956750) where the units have a length of 15 inches and a height of 4 inches. They appear to indicate currents flowing in a west-south-west direction towards the reef-complex.

Very poorly developed current-bedding is also present at Brierlow Bar (08946968). In the upper band here, the currents probably moved in a westerly direction, while in the lower band there is no evidence for any current action at all. Conditions of sedimentation obviously changed in the period of deposition of the Band.

No other localities show any evidence of current-bedding though the occasional piling up of shells may indicate periodic flurries of water movement rather than a persistent current being present.

The most convincing evidence for turbulent water comes from Chelmorton Flat (10667130). In a small outcrop ¼ mile west of the farm a very fossiliferous outcrop of the Cyrtina septosa Band can be found. Here 97% of the brachiopod shells are disarticulated and 79% are found with their convex surface uppermost. Both these figures are high in comparison with the other thirteen localities,where disarticulation figures average 75% and orientation figures show approximately the same numbers of shells oriented with their concave and convex surfaces uppermost. Small limestone pebbles are present in the matrix and many of the coral colonies have been overturned. In thin section,many rounded grains are present and these often show canals left by boring algae on their surfaces. There is no current-bedding at this locality, such as might have been expected in a deposit formed in turbulent water. The accumulation of shell and crinoid debris behind a simple coral lying on its side may indicate, however, that currents flowed in a north-easterly direction.

Locality	Lithology and thickness of Band	Total number of shells counted	Disarticulation %	Oriented with concave side uppermost %	Oriented with convex side uppermost %	True Orientation unknown %	"Small" (under 1 inch) %	"Medium" (1-3 inches) %	"Large" (over 3 inches) %	Thin section description. Presence of current-bedding etc.	Distance from reef-complex or "massif" margin	Suggested water movement
Netherlow Farm (10456973)	Light grey, coarse calcarenite. 4 feet thick	109	78	53	28.5	18.5	37	63	0	No rounding of fragments. No current-bedding	2½ miles from reef-complex	Fairly quiet conditions
Duke's Drive, Buxton (Upper quarry) (06907262)	Light grey, fine calcirudite	75	74.5	38.5	28	33.5	54.5	45.5	0	No rounding of grains. Very poorly developed current-bedding	1 mile from edge of "massif"	Some water movement but not very strong
Grin Low, Buxton (04907170)	Brownish grey, medium calcarenite. 7 feet	52	73	34.75	32.75	32.5	29	57.5	13.5	Grains well sorted in size. No current-bedding. No rounded grains	½ mile from edge of "massif"	Fairly quiet conditions
Wheeldon Trees Farm (10356620)	Light grey, coarse calcarenite. 1¼ ft.	50	76	46	16	38	22	74	4	Rounded grains present. No current-bedding	½ mile from reef-complex	Considerable water movement but no constant current direction
Above Earlsterndale village (10256671)	Light grey, coarse calcarenite. 1½ ft.	69	68	26	29	45	19	76.5	4.5	Some rounded grains. No current-bedding	¾ mile from reef-complex	Some water movement but no constant current direction
Grangemill, near Via Gellia (24115762)	Pinkish grey, medium calcarenite. 4 ft.	195	97	17	26	57	67.25	32.75	0	Oolitic rims round grains. Fairly good current-bedding. Shells oriented parallel to bedding	4 miles from reef knolls of Matlock	Fast moving currents
Jericho, near Earlsterndale (08956750)	Yellowish grey, coarse calcarenite. 1½ ft.	100	93	32	28	40	42	56	2	Rounded grains. Poorly developed current-bedding	½ mile from reef-complex	Considerable water movement with currents flowing off the shelf towards basin
Monksdale House (13207533)	Light grey, medium calcarenite. 7 ft.	41	75.5	14.5	48.75	36.75	29.5	68	2.5	No rounded grains. No current-bedding	4 miles from "massif" margin	Very quiet water conditions
Duke's Drive, (lower quarry) (06727277)	Light grey, coarse calcarenite. 2½ ft.	130	95	14	22	64	76	24	0	No rounded grains. No current-bedding	1 mile from edge of "massif"	Fairly quiet conditions
Hindlow Station (08556920)	Light grey, coarse calcarenite. 2 ft.	50	76	42	30	28	64	36	0	Same as previous locality	1¼ miles from reef-complex	Fairly quiet conditions
Brierlow Bar (08946968)	Light grey, fine calcarenite. 2 ft.	95	77.5	44.5	17.5	38	45.25	53.75	1	Some rounding of grains. Very poor current-bedding	1½ miles from reef-complex	Fairly fast moving water, currents flowing west
Buxton Bridge (09707562)	Light grey, coarse calcarenite. 4 ft.	50	78	18	50	32	24	76	0	No rounded grains. No current-bedding	1¾ miles from edge of "massif"	Very quiet conditions
Waterswallows Quarry (08667511)	Light grey, medium calcarenite 4 feet	112	95.5	28.5	37.5	34	48	52	0	A few rounded grains. No current-bedding	1¼ miles from edge of "massif"	Some water movement
Chelmorton Flat (10667130)	Light grey, calcarenite. 6 feet	100	97	8	79	13	43	57	0	Many rounded grains. Many shells overturned. Shells oriented parallel to bedding. No current-bedding	3 miles from reef-complex	Fast moving water but apparently no constant current direction

Table 1. Details of the disarticulation, orientation and size of the fossil debris, and presence of sedimentary structures with suggested water movement, in the Cyrtina septosa band of North Derbyshire.

There is very little variation in the grain size of the limestones in the Cyrtina septosa Band. They vary from medium calcarenites (0.25 mm) through coarse calcarenites to fine calcirudites (4 mm) (Folk, 1959). The finer grained types are found at Waterswallows Quarry, (08667511) Grin Low, (04907170) Grangemill, and Monksdale House (13207533) while coarse grained limestones were recorded from Duke's Drive (upper quarry), (06907262) and Brierlow Bar. The remaining eight localities which occur at varying distances from the reef margin or edge of the limestone "massif" were limestones of the intermediate (coarse calcarenite) grade. There appears to be, therefore, no increase or decrease in grain size of the limestones as the edge of the "massif" is approached.

From a study of thin sections it can be seen that rounded grains occur occasionally in limestones of the Cyrtina septosa Band. They include (i) composite and (ii) simple grains (Illing, 1954) together with foraminifera, crinoid ossicles, algal and shell fragments. Many of the rounded grains, particularly shell fragments and crinoid ossicles, show canals left by boring algae which have subsequently been infilled with very fine-grained calcite. Rounded grains are found at three localities just behind the reef-complex; Jericho, Wheeldon Trees Farm (10356620) and above Earlsterndale village, as well as at two localities well away from the reef-complex, namely Grangemill and Chelmorton Flat. Oolites are completely absent from any of the limestones, although oolitic rims round some of the skeletal grains are seen at Grangemill.

The presence of rare oolitic rims and of occasional rounded grains in limestones of the Cyrtina septosa Band suggests that,at the localities mentioned,there was evidence for fairly turbulent water movement in order that the grains might be rolled around and abraded as they lay on the sea-floor. The presence of canals left by boring algae suggests that there was a pause in sedimentation to allow the accumulation of algal filaments around some of the grains.

A random pattern in the distribution of the various sizes of shell debris is also seen. Most localities show relatively good sorting in size with approximately half the shells falling into the "small" group and half in the "medium" group. Very few "large" shells were recorded, the highest figure, 13.5%, being found at Grin Low.

At some localities, however, three quarters of the shells are found to fall in the "medium" group and only one quarter in the "small" group. Examples of these figures are seen at Wheeldon Trees Farm and Buxton Bridge (09707562).

Disarticulation figures show remarkable constancy. Generally where there is a higher proportion of the species D. septosa the percentages of disarticulated shells are slightly higher than at other localities. This can be seen at Jericho,where 40% of the shells are D. septosa and the disarticulation figure is as high as 93%. At Waterswallows Quarry 25% of the shells are D. septosa and the disarticulation figure is 96%. Other high percentages of disarticulation are recorded at Grangemill (97%) and at Chelmorton Flat (97%). It is likely at these two localities, however, the high disarticulation figures are due to fairly turbulent water,rather than to the presence of large numbers of D. septosa. At the remaining ten localities the percentages of disarticulation range only from 68% to 79%, except at Duke's Drive (lower quarry) (06727277) where 95% was recorded.

The orientation figures show a random pattern in their distribution. Seven localities have more shells resting with their concave surface uppermost and the remaining seven localities show a greater number resting with their convex surface uppermost. The figures vary from 53% with their concave side uppermost at Netherlow Farm (10456973) where water conditions were probably fairly quiet to 79% with their convex side uppermost at Chelmorton Flat where there is sufficient evidence to suggest water conditions were fairly turbulent.

Conclusions

From the localities studied, there does not appear to be any significant pattern in the sedimentation of the Cyrtina septosa Band in Derbyshire. As the reef margin is approached there is some evidence for an increase in water movement,while some of the localities well away from the reef margin,appear to show very much quieter conditions. Localities away from the reef margin where there is evidence for stronger water movement,may represent the sites of fairly fast-moving currents flowing over the shelf,possibly with tidal oscillation and change of direction, although there is no evidence for any submarine channels such as the one found by the author at Castleton (Sadler, 1964).

Fossils probably became concentrated at this particular horizon due to a break in sedimentation , which allowed many animals to live in favourable conditions with plenty of food and oxygen. The shells were probably not transported far from their life positions,but may have been moved around considerably on the sea-floor by the ebb and flow of tidal currents before their final deposition.

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