

STRATIGRAPHICAL DISTRIBUTION OF CRINOIDS AND BLASTOIDS IN THE LOWER CARBONIFEROUS

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ABSTRACT

The turnover of crinoid and blastoid genera for stratigraphical divisions of the Lower Carboniferous (equivalent to Mississippian) has been analysed by evaluation of the number of first and last occurrences of genera that have been recorded for each division. Rather similar patterns of change of faunal turnover apparently are revealed by this method of analysis where different taxonomic groups of crinoids and blastoids are compared, and where North American and European blastoid and crinoid faunas are analysed separately.

The data, interpreted at face value, show that the Mastarian division (Kinderhookian of North America), the Ivorian/Chadian (equivalent to the Meppen through to the end of the Burlington), the Arundian (equivalent to the Keokuk), the Brigantian (equivalent to the Ste Genevieve to the Hombergian), the Pendleian/Arnsbergian (equivalent to the Elvirian) each contain significant numbers of originations or extinctions, or both. The Holkerian and Asbian (equivalent to the Warsaw to the top of the St Louis) divisions, in contrast, show little faunal turn over.

The interpretation of the records of first and last occurrences is made difficult by the geographically, and possibly stratigraphically, biased sample, uncertainties in the temporal duration of stratigraphical divisions and taxonomic artefacts.

INTRODUCTION

This paper is a contribution to the search for 'natural' biostratigraphical subdivisions of the Lower Carboniferous (equivalent to Mississippian) that, if they exist, may form the basis for internationally agreed, formal chronostratigraphic units. 'Natural' biostratigraphical units, in the sense used here, refers to stratigraphical intervals with boundaries characterized by greater than normal rates of taxonomic origination or extinction.

The ossicles of several different echinoderms are abundant in Carboniferous rocks. Only crinoids and blastoids, however, are common enough as at least partly articulated, and therefore identifiable, specimens to provide evidence of faunal turnover. Very few species of Carboniferous crinoids or blastoid have been reported as being geographically widespread, so our investigation is

restricted to genera of these two groups. Although many disarticulated ossicles, particularly columnals, of Carboniferous crinoids have been described (for example, by MOORE & JEFFORDS 1968), they are not used in this analysis because in most cases their relationship to taxa based on more complete crinoids is not known.

The principal sources of data used in this study are charts recording the distribution of genera of European and American Lower Carboniferous camerate crinoids (LANE & SEVASTOPULO, 1987) and of disparid, cladid and flexible crinoids (LANE & SEVASTOPULO, in press); and a compilation of the ranges of all known Lower Carboniferous genera of blastoids, made by J.A. WATERS (Fig. 1). It should be noted that the international correlations used in this paper differ in part from those in the papers by LANE & SEVASTOPULO. BROADHEAD (1982) has carried out a similar analysis of turnover of crinoids across the Lower/Middle Carboniferous boundary.

LIMITATIONS OF THE DATA

The conclusions that may be drawn from the data presented below (Fig. 1; Tables 1 - 6) are tentative for the following reasons.

Geographical and stratigraphical coverage

Lower Carboniferous crinoid and blastoid faunas are known principally from North America and Northwest Europe, particularly Britain and Ireland. Few crinoids (apart from taxa based on columnals) or blastoids have been recorded from the Soviet Union (YAKOVLEV & IVANOV 1956); almost none are known from China; a few faunas have been described from Australia (CAMPBELL & BEIN 1971). Several faunas are known from North Africa (for example, PAREYN 1961). The latter are of considerable interest because they show that some camerate crinoid genera which appear to have become extinct in the medial part of the Lower Carboniferous in North America and Northwest Europe, were thriving in North Africa during the late Lower Carboniferous. It is probable that the geographical bias of the crinoid data used in our analysis will have resulted in bias of the results.

As shown below, the documented generic diversity of Lower Carboniferous echinoderm faunas at different stratigraphical levels is also very uneven. This may not truly reflect fluctuations in diversity through time: the occurrence of Lazarus taxa in some of the stratigraphical intervals with high diversity suggests that the record for some divisions in which diversity is low is incomplete. Also fluctuations in apparent diversity are likely to be, in part at least, artefacts resulting from variations in taxonomic practice.

Stratigraphical ranges

The stratigraphical ranges of echinoderms in North America have generally been recorded in terms of the 'standard Mississippian section'. The Northwest European record is couched in terms of chronostratigraphical stages. The shortcomings in the records of stratigraphical occurrences lead to several problems.

Firstly, ranges of individual genera are recorded as beginning at the lower boundary of the stratigraphical division in which they first occur and ending at the upper boundary of the division in which they last occur. This almost always will have extended the observed ranges. Furthermore, by clustering originations and extinctions at the beginnings and ends of stratigraphical units, a false impression of episodic faunal turnover may be given. Perhaps more importantly, where ranges are extended in this way the apparent magnitude of faunal turnover is likely to be strongly correlated with the duration of the stratigraphical divisions which are used in the analysis: all other factors being equal, short intervals of time are likely to span fewer extinctions and originations than long intervals.

Secondly, there are severe problems of stratigraphical correlation. These are of two types: national and international. National problems are particularly acute in assessing the North American record. This is because of the historical use of the essentially lithostratigraphical 'Mississippian standard section' in reporting echinoderm ranges and because it is clear that the boundaries between some of the units (for example, the Fern Glen and Burlington (Fig. 1); LANE 1978) are diachronous. Without further information, it is not possible to determine whether the range of an echinoderm genus reported from the Fern Glen overlaps the range of a genus reported from the Burlington. Correlation between North America and Northwest Europe also presents problems. These are probably more severe in the Viséan of Northwest Europe and its equivalents in North America than in the Tournaisian where conodont biostratigraphy provides a common yardstick (SANDBERG *et al.* 1978, LANE *et al.* 1980). In particular, the ages of units within the interval from the upper part of the Burlington to the top of the St Louis (Fig. 1) in terms of European stages are poorly understood. These problems are discussed further below.

THE DATA AND THEIR ANALYSIS

The number of first and last occurrences of genera within each stratigraphical unit are tabulated in Tables 1- 5 for camerate, disparid, cladid and flexible crinoids and for blastoids. The data for taxa restricted to North America and for those restricted to Europe, have been tabulated separately using the appropriate 'local' stratigraphical units. The data for genera common to both areas and the amalgamated data for each order of crinoids, for all orders, and for crinoids and blastoids combined (Table 6) are shown against a

common stratigraphical scale which uses, for convenience and without prejudice, a hybrid terminology from Western Europe.

The correlations are based largely on the work of BAXTER & BRECKLE (1982). The Hastarian Stage of Belgium (CONIL et al. 1976) is correlated fairly securely with the Kinderhookian of North America. The late Tournaisian (Ivorian Stage of Belgium) and lowermost Visean (Via of earlier Belgian literature and approximately the Chadian Stage of Britain and Ireland; George et al. 1976) have to be combined because of uncertainties of correlation of the Tournaisian/Visean boundary within the Burlington, which contains exceptionally rich crinoid and blastoid faunas. The Keokuk is treated here as equivalent to the Arundian Stage of Britain and Ireland following discovery of archaediscid foraminifera within it (BRECKLE et al. 1982). It should be noted, however, that there is no strong evidence to identify the horizon in the Keokuk with which the base of the Arundian should be correlated and also that the relative stratigraphical position of reported Keokuk crinoid faunas and the horizon with archaediscid foraminifera is not known. The Warsaw and Salem of North America are combined and tentatively equated with the Holkerian Stage of Britain and Ireland, and the St Louis tentatively with the Asbian Stage. For the purposes of this analysis, the Ste Genevieve and the lower and middle part of the Chester (Gasperian and Hombergian) are correlated with the Brigantian Stage of Britain and Ireland, and the Elvirian with the lower two stages of the Namurian, the Pendleian and Arnsbergian; it is recognized that the lower part, or indeed all, of the Ste Genevieve may be better equated with the Asbian, and that the base of the Namurian may fall at an horizon in the lower part of the Elvirian.

PATTERNS OF ORIGINATION AND EXTINCTION OF GENERA

All crinoids (Table 1)

The tabulation for all crinoids (referred to hereafter as the total crinoid data set) apparently reveals uneven levels of origination and extinction of genera through the Lower Carboniferous. The Hastarian division shows a substantial number of first occurrences and fewer, but still numerous, last occurrences. The highest number of originations and very many extinctions apparently occurred in the Ivorian/Chadian division. Extinctions appear to have exceeded originations in the Arundian division, but both were substantially greater than in the Holkerian and Asbian when faunal turnover appears to have been very low. The Brigantian division is marked apparently by a particularly high level of faunal turnover, with originations slightly exceeding extinctions. In the succeeding Pendleian/Arnsbergian division there also appear to have been many extinctions, but rather few originations. These data, taken at face value, suggest that certain divisions, such as the Brigantian, are characterized by major faunal turnover, while others, such as the Holkerian and Asbian, apparently show very low levels of faunal

turnover. However, interpretation of the raw data is subject to the caveats entered above.

The data can be analysed in more detail by evaluating the contributions of the different taxonomic groupings of crinoids; and also by examining the patterns of first and last occurrences of crinoids restricted to North America, those known only from Europe, and those common to both areas.

Camerate crinoids (Table 1)

The pattern of first and last occurrences of camerate crinoids for the Hastarian and Ivorian/Chadian divisions is similar to that displayed by the total data set. During the Arundian division, extinctions apparently far outnumbered originations. This is a reflection of the demise of the Keckuk fauna of North America (Table 3). The Brigantian division shows a small number of originations, but a high level of extinction.

Disparid, cyathocrinine and dendrocrinine crinoids (Table 1)

The data for these groups are too few for analysis but the patterns they show are generally consistent with that shown by the total data set.

Poteriocrinine crinoids (Table 1)

Poteriocrinine crinoids exhibit a very similar pattern of first and last occurrences to the total data set. The only exception is for the Arundian division, in which they do not show the same large scale extinctions as the camerates.

Flexible crinoids (Table 1)

The data for flexible crinoids are too few for confident analysis. However, there is a general similarity of pattern with the total data set which extends to a significant loss of genera within the Arundian. The major loss of genera within the Pendleian/Arnsbergian of the total data set is not seen.

Crinoid genera common to North America and Northwest Europe (Table 2)

The data for these more cosmopolitan taxa reveal patterns of that show some similarities with those seen in the total data set (Table 1). In particular, the marked faunal turnover in the Ivorian and Chadian division, the high numbers of last occurrences in the Arundian, the insignificant faunal turnover in the Asbian and Holkerian are all features noted above. Faunal turnover in the Brigantian division was relatively high but apparently extinctions exceeded originations, the reverse of the pattern seen in the total data set.

Crinoid genera restricted to North America (Table 3)

The data reveal major faunal turnover during the Kinderhookian, particularly within the camerate crinoids. Generic diversity increased markedly during the Meppen/Fern Glen division. By the end of the Burlington, diversity had fallen slightly and it was further sharply reduced by the end of the Keokuk. These changes of diversity were largely a result of extinction of camerate crinoids, particularly in the Keokuk. The Warsaw/Salem and St Louis intervals are characterized by very low faunal turnover. During the Ste Genevieve there was a modest rise in diversity and faunal turnover. Large numbers of originations and extinctions apparently occurred during the Gasperian and Hombergian, mostly within the poteriocrinine crinoids. The Elvirian shows a major reduction in diversity caused by the extinction of many genera of poteriocrinine crinoids.

The patterns revealed by these data are generally similar to those seen in the total data set. This is not unexpected because genera restricted to North American account for over half the total number of genera analysed. However, the greater stratigraphical resolution (10 stratigraphical divisions as opposed to 7 in the total data set) suggests some refinement of the patterns seen in the latter. In particular, the major faunal turn over recorded for the Ivorian and Chadian division of the total data set (Table 1), is seen to be partly a result of the large increase in the number of American genera of camerate crinoids during the early part of the division and their disappearance during the later part. Similarly, the major faunal turnover within the Brigantian division appears to reflect high faunal turnover throughout the upper part of the division, rather than many originations at the beginning and many extinctions at the end.

Crinoid genera restricted to Western Europe (Table 4)

The data are too few for confident analysis, except for the Brigantian division which shows the same large faunal turnover noted in the total data set.

Blastoids (Fig. 1, Table 5)

The patterns of originations and extinctions of Lower Carboniferous blastoids have been discussed recently by AUSICH *et al.* (1988). Counts of generic diversity used by AUSICH *et al.* in their discussion include some undescribed taxa which are excluded in this analysis. Although, in general, blastoid genera have shorter ranges, both geographical and stratigraphical, than crinoid genera, the patterns of first and last occurrences revealed in Table 5 are surprisingly similar to those of the total crinoid data set, and particularly to those of camerate crinoids (Table 1). The Hastarian division is characterized by moderate numbers of originations and

several extinctions. The highest level of faunal turnover was in the Ivorian and Chadian division, reflecting the rich but short-lived fauna of the Burlington Limestone and its equivalents in North America. The Arundian (for which the great majority of data are from the Keokuk Limestone of North America) was also a time of major faunal turnover. However, in contrast to the pattern seen in crinoids, originations of blastoid genera exceeded extinctions during the Arundian. The Holkerian and Asbian show rather low levels of faunal turnover. The Brigantian also shows a low level of turnover which is in contrast to the pattern seen in the total crinoid data set. During the Pendleian and Arnsbergian, originations apparently almost matched extinctions, in contrast to the pattern seen in crinoids, which show a major decrease in diversity during that division.

The blastoid data highlight problems of interpretation of the data from echinoderms as a whole, resulting from an inadequately known fossil record. A large number of blastoid genera are monospecific and are known from one or only a few stratigraphical horizons in a restricted area. It seems most unlikely that there are not many more faunas to be found in Asia and elsewhere. The effect of new discoveries on the patterns of originations and extinction can be seen in the two following examples. Firstly, the high level of faunal turnover in the Arundian has only become apparent as a result of recent collections and study of blastoids from Keokuk aged rocks (AUSICH & MEYER, 1988). Secondly, the relatively high diversity recorded for the Pendleian and Arnsbergian is a result largely of the fauna from Kazakhstan described by ARENDT et al. (1968).

DISCUSSION AND CONCLUSIONS

The data set for all genera of crinoids and blastoids (Table 6) exhibits the same pattern as for the crinoid total data set (Table 1). This is not surprising because crinoids contribute over 80% of the genera used in the analysis. The data show that the Hastarian (Kinderhookian of North America) is well characterized by its crinoid and blastoid fauna. Peak diversity and faunal turnover was attained in the Ivorian/Chadian division (equivalent to the Meppen through to the end of the Burlington). There were apparently large numbers of extinctions and a decrease in diversity during the Arundian (equivalent to Keokuk). The Holkerian and Asbian (equivalent to Warsaw up to the top of the St Louis) divisions show little faunal turn over. In contrast, the Brigantian (equivalent to Ste Genevieve to Hombergian) shows a level of faunal turnover exceeded only by the Ivorian/Chadian division. The Pendleian/Arnsbergian (equivalent to Elvirian) apparently shows a significant number of extinctions and a decrease in diversity.

Most of the many uncertainties which make interpretation of these data difficult have been outlined above. Critical questions which have to be asked and which are difficult to answer at present are as follows:

Is knowledge of the fossil record of Lower Carboniferous crinoids and blastoids good enough for confident interpretation of the recorded patterns of first and last occurrences? Data on the distribution of blastoids suggest that the interpretations should not be regarded as being more than extremely tentative.

Are improvements in the accuracy of stratigraphical correlation likely to result in major changes in the patterns discussed above? A change in correlation of the Keokuk division of North America could have a significant effect on the pattern of faunal turnover. If the lower part of the Keokuk is found to equate with the Chadian stage of northwest Europe and if some of the Keokuk echinoderm fauna is restricted to the lower part, Chadian extinctions would rise at the expense of Arundian extinctions. Other changes in correlation would lead to less significant changes in pattern. For example, if part of the Ste Genevieve were to be equated with the Asbian, there would be a decrease in the faunal turnover in the Brigantian division. Such changes are likely to be less significant than those caused by the discovery of new faunas, which improve the record.

Are the differences in faunal turnover recorded above a function of the temporal duration of the stratigraphical division used? It is very difficult to answer this question because of the generally poor quality of the radiometric dates for the Lower Carboniferous. From data in the compilation by JONES (1988), it does not seem likely that the Asbian division, for which faunal turnover is low, was much shorter in duration than the Brigantian, for which turnover was particularly high. Similarly, the duration of the Ivorian/Chadian division is not likely to have been so long in relation to the other divisions as to explain the high rate of faunal turnover.

We conclude tentatively that there are real differences in faunal turnover between the stratigraphical divisions analysed. The Hastarian (Kinderhookian of North America), the Ivorian/Chadian, the Arundian, Brigantian and Pendleian/Arnsbergian are distinctive in terms of their echinoderm faunas, whereas the Holkerian and Asbian are much less so.

TABLE 1

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
ALL CRINOIDS (196)									
FIRST	21	27	73	11	3	7	51	3	
LAST		11	42	35	3	7	46	17	35
CAMERATES (56)									
FIRST	4	14	29	1	3	1	1	-	
LAST		4	22	13	-	1	11	2	3
DISPARIDS (11)									
FIRST	4	2	3	1	-	-	1	-	
LAST		1	2	2	-	1	1	3	1
CYATHOCRININES (13)									
FIRST	2	-	6	2	-	1	2	-	
LAST		-	2	4	-	-	1	-	6
DENDROCRININES (6)									
FIRST	2	2	1	-	-	-	1	-	
LAST		2	1	2	-	-	-	-	1
POTERIOCRININES (88)									
FIRST	5	7	26	6	-	4	39	1	
LAST		2	12	8	3	3	28	11	21
FLEXIBLES (22)									
FIRST	4	2	8	1	-	1	4	2	
LAST		2	3	6	-	2	5	1	3

TABLE 2

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
ALL CRINOIDS (53)									
FIRST	12	13	19	-	1	2	6	-	
LAST		-	10	8	1	3	12	6	13
CAMERATES (14)									
FIRST	3	5	5	-	1	-	-	-	
LAST		-	6	2	-	-	4	-	2
DISPARIDS (5)									
FIRST	3	1	-	-	-	-	1	-	
LAST		-	-	-	-	1	-	3	1
CYATHOCRININES (6)									
FIRST	2	-	4	-	-	-	-	-	
LAST		-	1	2	-	-	-	-	3
DENDROCRININES (2)									
FIRST	-	1	-	-	-	-	1	-	
LAST		-	-	1	-	-	-	-	1
POTERIOCRININES (20)									
FIRST	2	5	7	-	-	2	4	-	
LAST		-	3	1	1	1	6	2	6
FLEXIBLES (6)									
FIRST	2	1	3	-	-	-	-	-	
LAST		-	-	2	-	1	2	1	-

TABLE 4

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9	10
ALL CRINOIDS (40)										
FIRST	1	1	5	7	-	-	4	20	2	
LAST		-	3	4	1	-	4	15	1	12
CAMERATES (6)										
FIRST	-	1	2	2	-	-	1	-	-	
LAST		-	1	3	1	-	1	-	-	-
DISPARIDS (1)										
FIRST	-	-	-	1	-	-	-	-	-	
LAST		-	-	-	-	-	-	1	-	-
CYATHOCRININES (4)										
FIRST	-	-	-	1	-	-	1	2	-	
LAST		-	-	1	-	-	-	1	-	2
POTERIOCRININES (21)										
FIRST	1	-	3	2	-	-	1	14	-	
LAST		-	2	-	-	-	2	9	1	7
FLEXIBLES (8)										
FIRST	-	-	-	1	-	-	1	4	2	
LAST		-	-	1	-	-	1	5	-	3

TABLE 5

1. ALL BLASTOIDS (48)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
FIRST	-	8	16	11	1	4	3	5	
LAST		2	17	8	5	3	5	6	2

2. BLASTOIDS COMMON TO NORTH AMERICA AND EUROPE (6)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
FIRST	-	4	2	-	-	-	-	-	
LAST		-	3	1	-	-	1	1	-

3. BLASTOIDS RESTRICTED TO NORTH AMERICA (27)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9	10	11	12
FIRST	-	4	1	10	10	1	-	1	-	-	-	
LAST		2	2	9	6	5	1	-	-	1	-	1

4. BLASTOIDS RESTRICTED TO EUROPE (9)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9	10
FIRST	-	-	1	1	1	-	4	2	-	
LAST		-	1	1	1	-	2	3	-	1

TABLE 6

1. ALL CRINOIDS AND BLASTOIDS (245)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
FIRST	21	35	90	22	4	11	51	8	
LAST		13	60	43	8	10	51	23	37

2. CRINOIDS AND BLASTOIDS COMMON TO NORTH AMERICA AND EUROPE (59)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9
FIRST	12	17	21	-	1	2	6	-	
LAST		-	13	9	1	3	13	7	13

2. CRINOIDS AND BLASTOIDS RESTRICTED TO NORTH AMERICA (130)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9	10	11	12
FIRST	8	17	31	22	21	3	1	6	11	9	1	
LAST		13	9	26	32	7	1	2	9	10	10	11

4. CRINOIDS AND BLASTOIDS RESTRICTED TO EUROPE (49)

STRATIGRAPHICAL DIVISIONS	1	2	3	4	5	6	7	8	9	10
FIRST	1	1	6	8	1	-	8	22	2	
LAST		-	4	5	2	-	6	18	1	13

CAPTION TO FIGURE

Fig. 1. Stratigraphical distribution of Lower Carboniferous blastoids. Thin lines are North American ranges; thick lines European ranges; and dashed lines, ranges of genera from Kazakhstan, Australia and Southeast Asia.

CAPTIONS TO TABLES

TABLE 1. First and last records for all genera of North American and Northwest European crinoids. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St. Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous.

TABLE 2. First and last records for all genera of crinoids common to North America and Northwest Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St. Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous.

TABLE 3. First and last records for all genera of crinoids restricted to North America. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Kinderhookian; 3 - Meppen and Fern Glen; 4 - Burlington; 5 - Keokuk; 6 - Warsaw and Salem; 7 - St. Louis; 8 - Ste Genevieve; 9 - Gasperian; 10 - Hombergian; 11 - Elvirian; 12 - Post-Lower Carboniferous.

TABLE 4. First and last records for all genera of crinoids restricted to Northwest Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian; 3 - Ivorian; 4 - Chadian; 5 - Arundian; 6 - Holkerian; 7 - Asbian; 8 - Brigantian; 9 - Pendleian and Arnsbergian; 10 - Post-Lower Carboniferous.

TABLE 5. First and last records of genera of Lower Carboniferous blastoids, including those from Kazakhstan, eastern Asia and Australia. (i) All genera, including those from Kazakhstan, eastern Asia and Australia. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St. Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous. (ii) Genera common to North America and Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington;

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TABLE 2. First and last records for all genera of crinoids common to North America and Northwest Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St. Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous.

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4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous.

(iii) Genera restricted to North America. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Kinderhookian; 5 - Meppen and Fern Glen; 4 - Burlington; 5 - Keokuk; 6 - Warsaw and Salem; 7 - St Louis; 8 - Ste Genevieve; 9 - Gasperian;

10 - Hombergian; 11 - Elvirian; 12 - Post-Lower Carboniferous.

(iv) Genera restricted to Northwest Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian;

3 - Ivorian; 4 - Chadian; 5 - Arundian; 6 - Holkerian; 7 - Asbian; 8 - Brigantian; 9 - Pendleian and Arnsbergian; 10 - Post-Lower Carboniferous.

TABLE 6. First and last records of genera of Lower Carboniferous crinoids and blastoids.

(i) All genera. Stratigraphical divisions as follows:

1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous. Note that this data set includes Manillacrinus from Australia.

(ii) Genera common to North America and Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian/Kinderhookian; 3 - Ivorian and Chadian/Meppen to Burlington; 4 - Arundian/Keokuk; 5 - Holkerian/Warsaw and Salem; 6 - Asbian/St Louis; 7 - Brigantian/Ste Genevieve to Homberg; 8 - Pendleian and Arnsbergian/Elvirian; 9 - Post-Lower Carboniferous.

(iii) Genera restricted to North America. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Kinderhookian; 5 - Meppen and Fern Glen; 4 - Burlington; 5 - Keokuk; 6 - Warsaw and Salem; 7 - St Louis; 8 - Ste Genevieve; 9 - Gasperian; 10 - Hombergian; 11 - Elvirian; 12 - Post-Lower Carboniferous.

(iv) Genera restricted to Northwest Europe. Stratigraphical divisions as follows: 1 - Pre-Carboniferous; 2 - Hastarian; 3 - Ivorian; 4 - Chadian; 5 - Arundian; 6 - Holkerian; 7 - Asbian; 8 - Brigantian; 9 - Pendleian and Arnsbergian; 10 - Post-Lower Carboniferous.

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K'HOOK.		OSAGEAN				MERAMECIAN			CHESTERIAN		MISSISSIPPIAN	
HANNIBAL	CHOUTEAU	MEPPEN	FERN GLEN	BURLINGTON	KEOKUK	WARSAW	SALEM	ST LOUIS	GENEVIEVE	GASPER		HOMBERG
<p> Pentremblastus Pyramblastus Strongyloblastus Tanaoblastus Orophocrinus Phaenoblastus Phaenoschisma Hadroblastus Mesoblastus Xenoblastus Katoblastus Pentremites Cryptoblastus Globoblastus Arcuoblastus Auloblastus Decemboblastus Lophoblastus Monoblastus Orbiblastus Schizoblastus Dentiblastus Ellipticoblastus Gongyloblastus Deliablastus Euryoblastus Peritoblastus Xyeleblastus Ambolostoma Carpenteroblastus Granatocrinus Tricoelocrinus Metablastus Cribroblastus Ptychoblastus Acentrotremites Monoschizoblastus Astrocrinus Orbitremites Codaster Heteroblastus Diploblastus Nymphaeoblastus Artuschisma Dolichoblastus Kazakhstanoblastus Mastoblastus Nodoblastus </p>												
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