FAUNAL ANTICIPATION IN THE LOWER LLANDOVERY OF THE OSLO REGION, NORWAY

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Study of brachiopod faunas in two sub-zones of the Lower Llandovery of the Oslo Region illustrates the dangers of using these faunas for correlation. Evidence is put forward for a diachronous relationship between the faunas, and depth is suggested to be the most likely control on their distribution.

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Introduction

Study of Lower Llandoverian sediments and faunas on the Malmøya group of islands in the Oslo region has revealed a relationship between non-drifted and drifted brachiopod assemblages (life and death assemblages of Boucot, 1953) which may have general application. Malmøya lies 5 km south of Oslo city centre in Bunnefjorden, the southerly trending extension of Oslofjorden. Silurian sediments are extensively exposed on Malmøya and were described in detail by Kiær (1908). Kiær used the 'Etasje' or stage system of classification which has been developed in the Cambro-Silurian deposits of the Oslo region, the Silurian succession of Malmøya being placed in stages 6 to 9. The two lowermost stages, 6 and 7, are thought to be equivalent to the British Llandoverian; Spjeldnæs (1957) suggested that stage 6 is more fully developed on Malmøya than elsewhere in the Oslo region. Kiær established the thickness of stage 6 in the Malmøya area as approximately 150 metres, and defined three zones (6a up to 6c) each with two sub-zones (denoted by the suffices alpha and beta). He based this zonation on faunal variation and listed the characteristic fossils of each sub-zone with rough estimates of their relative abundance (e.g. common, rare). The problems inherent in Kiær's apparently precise zonation and correlation with other areas in the Oslo region will be illustrated by considering the sub-zones 6bα ('the *Dicoelosia osloensis* shale', approx. 20 m thick) and overlying 6bβ ('the *Protatrypa malmoeyensis* shale', approximately 30 m thick).

Brachiopod assemblages

In both sub-zones an immediate distinction can be made between the mode of occurrence of fossils in the shales, which constitute 85% of the succession,

and that of fossils in thin calcareous siltstone bands (usually 2 to 5 cm thick) which occur within the shales.

The main features of the shale faunas of 6bα and 6bβ are shown in Table 1. In 6bα the fauna is limited both in species and individuals, and brachiopods occur in small pockets a few centimetres in diameter along a restricted number of horizons. The shale fauna of 6bβ is richer and more diverse, but is still restricted to certain horizons where fossils tend to occur concentrated in lenses (apparent diameters up to 60 cm, thickness 2 to 3 cm). The very high articulation ratios of all brachiopod species in both sub-zones indicate a non-drifted origin for these assemblages; however most of the brachiopods show a great disparity in numbers of brachial and pedicle valves among the single valves that do occur. Because of this it is thought that these assemblages should strictly be termed winnowed or residual non-drifted assemblages (cf. Fagerstrom 1964, p. 1199) as the lighter brachial valves were probably drifted off the living colonies leaving the more dense pedicle valves behind. The only common brachiopod which does not show this phenomenon is *Protatrypa malmoeyensis,* in which the ratio of opposing valves is near parity in every sample studied. This feature may reflect the more equivalved form of this brachiopod relative to the other common species; orientation studies indicate that both valves of *P. malmoeyensis* have similar hydrodynamic properties.

In contrast to the shale faunas, brachiopod assemblages which occur in

Table 1. Mode of occurrence of common brachiopods in the shales of 6bα and 6bβ in the Malmøya area.

6bα	% of population	Pedicles : brachials	Articulation ratio (%)
Leangella triangularis (= *Leptaena transversalis* var. *minor* of Kiær, 1908)	75	7.9 : 1.0	84
Dicoelosia osloensis (= *Bilobites biloba* of Kiær, 1908)	12	8.5 : 1.0	86
Skenidioides lewisii (= *Skenidium Lewisii* of Kiær, 1908)	6	7.0 : 1.0	89
6bβ			
Protatrypa malmoeyensis (= *Atrypa reticularis* of Kiær, 1908)	64	1.2 : 1.0	94
Eoplectodonta duplicata (= *Leptaena transversalis* var. *major* of Kiær, 1908)	14	6.1 : 1.0	81

Table 2. Mode of occurrence of common brachiopods in siltstones of 6bα.

	Pedicles : brachials	Articulation ratio (%)
Leangella triangularis	2.0 : 1.0	24
Dicoelosia osloensis	2.8 : 1.0	8
Eoplectodonta duplicata	0.6 : 1.0	6

6bα on the bases of siltstone bands contain very few articulated shells (see Table 2). Also, unlike the shale faunas, any identifiable specimens always occur in a matrix of shell sand and the vast majority of specimens in the siltstones are highly fragmented. It is interesting that ratios of opposing single valves in the siltstone assemblages are more equal than those of the shales (differences both in articulation ratios and in ratios of opposing valves between the siltstones and shales are statistically significant). This parity of opposing valves in the siltstones apparently contradicts my interpretation of the siltstone faunas as drifted assemblages (see criteria of Boucot 1953). However, it has already been suggested that brachial valves were drifted off living communities in preference to pedicle valves; such a process would be expected to lead to a relative enrichment of brachial valves in the resultant drifted assemblages, and this is observed. An absolute majority of brachial valves is not usually seen, presumably as the above process would be counterbalanced to some extent by the preferential breakage of the more delicate brachial valves during transport.

Although proportions of individual species are much more variable in the drifted assemblages than in the shales, the qualitative compositions of the drifted and non-drifted assemblages within 6bα are generally similar. However a significant exception is the top 5 metres of 6bα where drifted assemblages are rich in single valves and fragments of the 'typical' 6bβ species *Eoplectodonta duplicata* and *Protatrypa malmoeyensis,* while intercalated non-drifted assemblages in the shales at the same levels still contain a typical 6bα fauna dominated by *Leangella triangularis*. The boundary between 6bα and 6bβ is clearly seen a few metres higher where *E. duplicata* and *P. malmoeyensis* become characteristic elements of the *non*-drifted assemblages of 6bβ. In other words the drifted assemblages found at the top of 6bα 'anticipate' the non-drifted assemblages of 6bβ. This clearly shows that the boundary between 6bα and 6bβ is diachronous, as the faunas of each sub-zone must have lived in contemporaneous but different environments. Sporadic vigorous currents drifted elements of the 6bβ fauna into the life environment of the 6bα fauna in the Malmøya area, resulting in the juxta-position of the different faunas in drifted and non-drifted assemblages. At a later stage conditions on Malmøya changed, allowing the 6bβ fauna to replace the 6bα living communities.

Relationship between 6bα and 6bβ faunas

It is clear from these observations that these faunas are environmentally controlled, and cannot continue to be used as precise zonal indicators. The change in environment between 6bα and 6bβ is not reflected by any changes in the chemistry or petrology of the shales within which the non-drifted assemblages are found, but evidence of the relationship between the two faunas is given by sedimentary structures in the siltstones. Drifted assemblages occur on the bases of siltstone bands and three modes of occurrence are common. Of these, the most notable are infillings in the bases of cut-and-fill structures described by Whitaker (1965, Figs. 1 and 2) as groove casts. Broadhurst (1968, p. 35) called these structures priels, a term introduced by Martinsson (1965, p. 194). The term priel is used here as it is believed that these structures show several features quite different from those of common groove casts. Drifted assemblages also occur as sporadic braids of bioclastic material on the bases of siltstones, or as evenly developed thin layers of shell sand along the bases of planar siltstones. In all these cases the bioclastic material is overlain by normal siltstone, with a clear boundary between the two sediment types. As suggested by Broadhurst (1968), it is thought that deposition of the bioclastic material took place during the initial high energy stages of the currents responsible for siltstone formation. Confirmation of this is given by a close agreement between the preferred orientation of structures such as priels and of the fossils within their bioclastic infillings (e.g. stem bryozoans and *Tentaculites sp.*). In all cases a steady flow of currents carrying bioclastic material from the south-west is indicated, although siltstone deposition at a later stage in the formation of any one bed shows a more complex current pattern. From this a constant geographic relationship between the two faunas is suggested, the 6bβ fauna living to the south-west of Malmøya, which was inhabited by the contemporaneous 6bα fauna.

The anticipatory nature of the drifted assemblages containing 6bβ forms suggests that the constant north-easterly trending current regime was associated with a north-easterly shift of facies (Fig. 1). Such a constant current direction would be most likely to reflect the slope of the shelf on which these communities lived, so that the 6bβ faunas were drifted down-slope from their
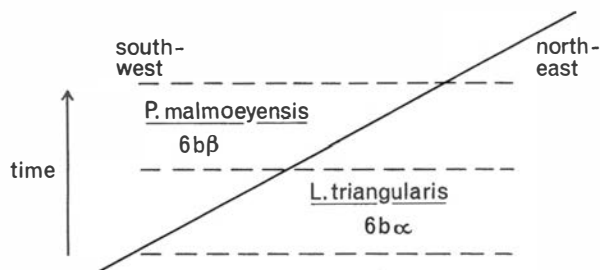

south-west north-east

P. malmoeyensis
6bβ

time

L. triangularis
6bα

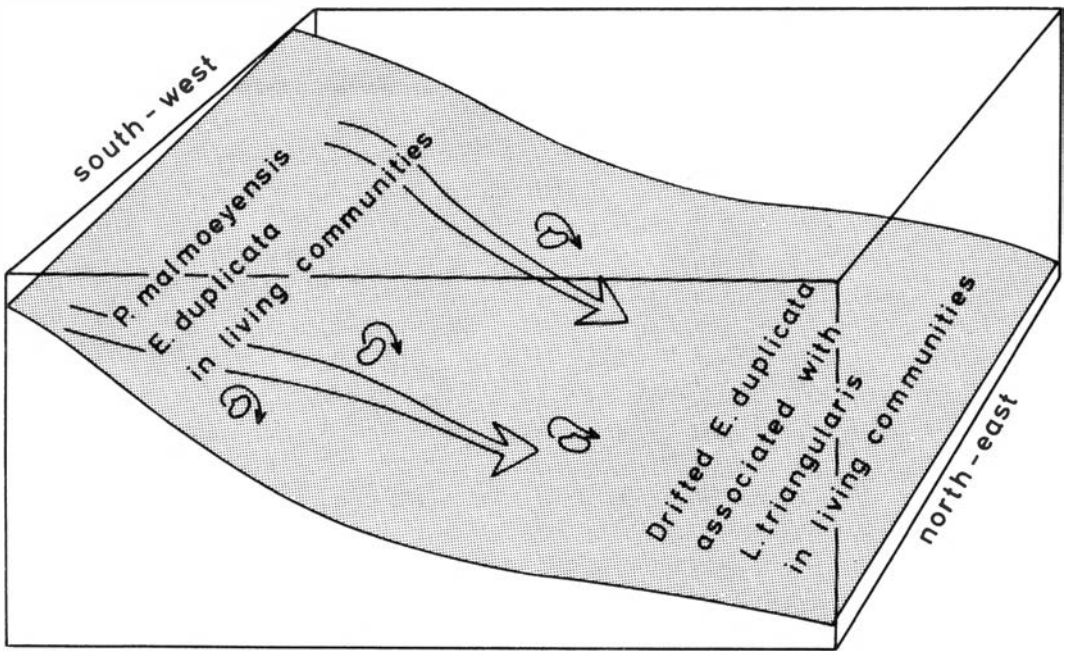Fig. 1. Schematic representation of suggested diachronous relationship between 6bα and 6bβ faunas.

Fig. 2. Suggested geographic relationship between 6bα and 6bβ faunas.

life position in shallower water, into the deeper 6bα environment (Fig. 2). In this case the north-easterly facies shift which caused the replacement of living communities typical of 6bα by those typical of 6bβ would be logically explained by shallowing conditions in the Malmøya area at the time.

Definite proof for this explanation would be provided if a distinctive siltstone band could be shown to transcend the 6bα/6bβ boundary as defined by changes in the composition of the non-drifted assemblages in the shales. Unfortunately this is not seen, probably because all the localities in the Malmøya area where the boundary is exposed lie approximately along the strike of the presumed continental slope, normal to the prevailing current direction. However, the constant preferred orientation of directional structures, and the similarity of the 6bα/6bβ boundary at all localities both indicate that a north-easterly shift of a shallow water environment is a logical explanation for the 'faunal anticipation' seen at the top of 6bα on Malmøya.

A notable feature of this anticipation is that the drifted assemblages at the top of 6bα are dominated by *Eoplectodonta duplicata,* whereas in the non-drifted assemblages of 6bβ, this brachiopod plays only a minor role (see Table 1). A close examination of the lenses in which the 6bβ non-drifted assemblages occur, suggests why this should be so; if samples are collected both from within these lenses and from the surrounding shale at the same horizons as the lenses, the fossil assemblages from the latter have a consistently and significantly lower articulation ratio. This suggests that the assemblages found outside the lenses contain shells which were drifted off

the living community (now represented by the lens) and strewn over the surrounding sediment. Relative to *Protatrypa malmoeyensis*, *Eoplectodonta duplicata* is approximately 4 times more abundant outside the lenses than within. Moreover, both inside and outside the lenses *E. duplicata* shows a lower rate of articulation than *P. malmoeyensis*. Thus *E. duplicata* appears to have been more susceptible both to disarticulation and to transportation, probably because of the lack of a pedicle in this brachiopod. By contrast, reconstructions of the life history of *P. malmoeyensis* figure this brachiopod firmly attached to the substrate by a pedicle (e.g. Seilacher & Meischner 1964, Fig. 7). Work by Fenton & Fenton (1934) and by Broadhurst (personal communication) goes further and suggests that the flanges seen along the valve margins of *P. malmoeyensis* may have been used to supplement the anchorage given by the pedicle by being thrust down into the substrate. Thus currents sweeping over living communities of *P. malmoeyensis* and *E. duplicata* would naturally carry with them a far higher proportion of the less stably attached shells of *E. duplicata,* regardless of the composition of the original community. From this, it is clear why the resultant drifted assemblages were dominated by *E. duplicata*.

Summary

In conclusion, this anticipation of non-drifted assemblages by drifted assemblages suggests, as in the British Upper Llandovery (Ziegler 1965), that the brachiopod faunas of the Lower Llandovery in the Oslo region are in some way depth controlled. As with the displacement of faunas by lava flows described by Ziegler, this phenomenon could be used more generally as a tool for distinguishing depth controlled faunas. Work is progressing in the Oslo region on the definition of brachiopod communities; it is hoped that a more comprehensive interpretation of the palaeogeography of the region during this period will result.

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