Late Ordovician communities from North America

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Abstract: The study aims to reconstruct the palaeoenvironments and faunas from six different localities in the area of Cincinnati, USA. The Upper Ordovician consists of limestones with intercalating mudstones. The faunas are rich and very diverse. The taxonomic composition and taphonomic indications are briefly described. The palaeoenvironment and faunal communities are reconstructed and compared to Bretsky (1969). The six faunas were, in most cases, similar to either the Sowerbyella - Onniella Community or the Zygospira - Hebertella Community of Bretsky. The fauna belonging to the Sowerbyella - Onniella Community is dominated by depositfeeding Cryptolithus and the brachiopod Sowerbyella. The three faunas belonging to the Zygospira - Hebertella Community has a varied faunal composition, but occurring species are the brachiopods Zygospira and Hebertella, and the bivalve Caritodens demissa, and these faunas are all bryozaan dominated. The two remaining faunas are less varied, one consisting mainly of Rafinesquina brachiopods and the other of crinoids. They might also belong to the Zygospira - Hebertella Community.

Keywords: North America, Cincinnati region, Upper Ordovician, Cincinnatian, Fossil Communities, Palaeoenvironmental reconstructions.


The Upper Ordovician strata are well exposed in the Cincinnati region and the sediments are often excellently rich in fossils. Stig Bergström, and others, donated several fossils and fossiliferous slabs from this region, to the Department of Geology, at Lund University (Sweden). Although this was done in the 1960ies, most of the material has not been examined until now.

The fossils have been identified as far as possible with the use of Cumings (1908); Davis (1985); Shimer & Shrock (1947); Moore (1955, 1959, 1961, 1965); Moore & Teichert (1978).

The samples have been studied with a binocular microscope (maximum magnification, 40 times). The lithology, degree of abrasion, fragmentation and orientation of fossils, etc. have been used in the interpretation of taphonomic processes and environment. For determination of the age of the samples from the different localities, the time-ranges of the organisms have been used. The community reconstructions are based on comparison of the fossil assemblages and the community reconstructions of Bretsky (1969) and McKerrow (1978).

McKerrow presented communities from the Cambrian to the Cenozoic, based on fossils found in the British Isles. Although based on local species the communities are still usable as comparison with other fossil assemblages, community structure being more important than community species. Bretsky’s work is a study of the faunal associations in the Upper Ordovician strata of the Central Appalachians, an area not too far from the Cincinnati region. Bretsky recognised three kinds of faunal communities. The Orthorhynchula - Ambonychia Community lived in nearshore areas with clastic sediments (sands and silts). It was dominated by brachiopods and bivalves. The Zygospira - Hebertella Community lived in the inner to outer infralittoral zone and the Sowerbyella - Omiella Community lived in the outer infralittoral, on muddy bottoms. The area in Bretsky’s study being closer than the Cincinnati area to the palaeo-shoreline, the community living closest to the shore is not represented in the fossil material of this study. The other two communities are both represented, as will be discussed below.

Palaeogeography and geologic history of the Cincinnati region
The Cincinnati region comprises the eight counties Butler, Clermont, Hamilton and Warren Counties in Ohio, Boone, Campbell, and Kenton Counties in Kentucky and Dearborn County in Indiana. Being situated where the three states Ohio, Kentucky, and Indiana meet, this area is also called the Tri-State. (See Fig. 1.)

The Cincinnati region was in the Late Ordovician situated on the shelf of an epeiric sea, which was covering the interior of the North American plate (Weir et al. 1984). The continent was situated on the equator (Scotese et al. 1979) and conditions were warm and favourable for a high carbonate production. Land existed to the east of the area, where the Taconic orogeny was pushing up the margin of the North American plate (Weir et al. 1984). Coarser sediment from this land area rarely reached the Cincinnati region. The lithologies in the region mainly consist of shales and limestones, with all their intermediates.

The Taconic orogeny also created a foreland bulge beyond the land area (Potter 1996; the following information is also from this source unless otherwise indicated) and this bulge was probably the beginning of the Cincinnati Arch, one of three arch structures that are responsible for the out-cropping of Upper Ordovician strata in this region. The arch has been active
several times and has now lifted up the Upper Ordovician strata through the younger layers in adjacent areas.

The base of the Cincinnatian Series (see Fig. 2) is defined by the base of the Kope Formation - a thick shale unit. The shales are almost always calcareous, and contain some silt. They are usually but poorly laminated.

The sea, at the time of deposition of the Kope Formation, was moderately deep, with weak currents along the bottom (Weir et al. 1984). Muddy sediment was supplied from the uplifted area along the eastern margin of the continent. The carbonate content increases towards the top of the formation, because of shallowing water.

The fauna, especially the brachiopods and ramose bryozoans, of the Kope Formation was usually more delicately built than the organisms of subsequent stages in the Cincinnatian Series. Well preserved articulated and oriented stems of crinoids have been found in the Kope Formation. Graptolites are also usually parallel oriented.

As the waters became shallower, the energy increased, and the Kope Formation was succeeded by the Fairview Formation which consists mainly of limestones with shale partings. In these limestones (coarse to medium grained packstones and wackestones) there are, among other structures, graded tempestites, ripple marks, crossbedding, and some hardgrounds. The fauna is more robust than in the Kope Formation, and there are horizons with large brachiopods, usually tightly packed and probably deposited in very shallow water.

Overlaying the Fairview Formation, is a thin shaly formation, the Miamitown shale, present almost exclusively in Butler and Hamilton Counties, Ohio. It is notable for its gastropod fauna. (Compare with the Lophospira sample of Todd's Fork.)

Above the Miamitown shale follows the Grant Lake Formation. In Indiana this formation is called the Dillsboro Formation, and in Kentucky it corresponds with the lower portion of the Bull Fork Formation. Grant Lake Formation is divided into three units: the Bellevue,
Corryville, and Mount Auburn members. In the Bellevue member the culmination of an ongoing regression, which began before or at the beginning of the Kope Formation, is followed by a transgression in the Corryville and Mt. Auburn members, with successively deeper waters and larger amounts of mud in the deposited sediment.

The uppermost part of the Cincinnatian Series consists of several formations, with different names in the different states. In Ohio they are the Arnheim, Waynesville, Liberty, Whitewater, and Drakes Formations. In Indiana the corresponding formations are the Dillsboro and Whitewater Formations, and in Kentucky they are called the Bull Fork and Drakes Forma-
tions. Note that the Bull Fork Formation also comprises the Grant Lake Formation.

Through these formations the lithology changes from limestone-dominated, through shale-dominated to tidal flat deposits and they record the shallowing of the sea due to a global regression caused by glaciation in what is now North Africa (Stanley 1993). The lowermost Silurian deposits rests unconformably on top of these layers.

The material
The material comes from six different localities within the Cincinnati region. Two of the investigated slabs come from the Grand View locality in Kentucky. The others come from the Aid's Run Creek, Todd's Fork, Stonelick Creek, Cowan Creek, and Elston Road localities in Ohio. This order is what I believe to be the chronological order, with the oldest (Edenian) samples coming from Grand View, and the youngest (Richmondian) from Elston Road. The remaining are probably all from the Maysvillian, and the correct chronological order is very difficult to ascertain, especially since most of the organisms have been identified only down to generic level (sometimes not even that far).

Taxonomic description
Grand View, Campbell Co., Kentucky
Fig. 3 A - D
Two slabs have been studied, the larger one containing the following fossils: The trilobite Cryptolithus tessellatus and the brachiopod Sowerbyella rugosa occur in abundance. There are also the trilobite Flexicalymene, crinoid columnals, gastropods (7-10 specimens), one orthocone, bryozoans, the brachiopods Zygospira modesta and Omiella multisepta, and possibly a few Cormulites. Several species of bryozoans, mostly ramose, with branches 2-4 mm in diameter. Identification is difficult, possible genera are among others Dekaya, Escharopora, and Callopora.

The smaller slab does not contain any different species from the larger one, but it lacks some of the above mentioned organisms, namely Flexicalymene, orthocones, and brachiopods, most notably Sowerbyella, which is abundant on the larger slab.

There are some lumps of coarser sediment on the large slab. These I have interpreted as either stomach contents or faeces of some organism. The lumps consists of quartz grains (about 1 mm in diameter) and dark or amber coloured smaller grains. These grains probably come from a sandy near-shore environment and have been transported to this locality, by some organism.

Time: (probably Upper) Edenian

Aid's Run Creek, near Decatur, Ohio
Fig. 3 E - G
One large slab and one smaller. The small one lacks information of collecting-locality and may be from an entirely different stratigraphic level, or geographic locality, but the two slabs seem, at a casual glance, very similar. However, there are some differences. The larger slab is described here.

The remains of the fauna are almost entirely made up of large brachiopod shells of the species Rafinesquina ponderosa. Except for these large Rafinesquina shells there are also fragments from this species, and from other organisms such as a small orthocone, one bivalve (Caritodenis demissa) and trilobites (Flexicalymene) and on the other side of the slab, thin ramose bryozoans (fragmented) and non-trilobite arthropod remains.

Time: Maysvillian (Fairview Fm or Bellevue mbr)

Todd's Fork, Morrow, Ohio
Fig. 3 H - I
From this locality there are one large and one small slab and in addition a "single species specimen" of a Callopora colony.

The large slab is dominated by ramose bryozoans. The brachiopods Zygospira modesta and possibly Hebertella and a few scolecodonts, conodonts and (non-trilobite) arthropod fragments also occur.
The small slab has relatively few fossils except several specimens of *Lophospira* gastropods all on one surface. On the other side there are fragments of trilobites, and small fossils, such as crinoid columnals, ostracodes, microgastropods and conodonts.

Time: **Maysvillian** (possibly from the Miami-town Shale)

**Stonelick Creek, near Newtonsville, Ohio**

Fig. 4

The material consists of one small and two relatively large slabs and in addition to these there are a few "single species specimens".

The fauna consists of the trilobites *Flexicalymene, ?Acidaspis* (or another odontopleu-
Fig. 4. Slabs from Stonelick Creek. A. The larger sample, carrying an interesting fauna of large bryozoans. B. The second largest sample from this locality - showing the more common kind of assemblage from this locality. C. The smaller slab, with a large orthocone. D. The opposite side of the sample in (C), with Flexicalymene thoracic segments.

...rid) and possibly fragments of yet another trilobite species. Crinoids, occurring almost exclusively as disarticulated columnals, probably of the genera Jocrinus and Glyptocrinus. This is deduced from columnal shape and comparison with the "single species samples" of well preserved and identified crinoids from this location. There are more than six gastropods on the larger of these two slabs, a large orthocone, and at least one bivalve (Caritodens demissa) on the smaller one.

Bryozoans make up the dominant part of the fauna with Graptodictya and ?Bythopora being the most common genera. Homotrypa occurs as well, and one of the "single species samples" consists entirely of a colony of these bryozoans.

The brachiopods are represented by one large shell, probably from Rafinesquina, and
several small ones from the ubiquitous *Zygospira modesta*. There are also non-trilobite arthropod fragments, at least one scolecodont element, and one *?Cornulites*.

The largest slab from Stone Lick Creek has one side very similar to the above mentioned slabs, and one side which differs from these. The side that probably has been facing upwards contains numerous large bryozoans, either ramoso or platform like. The platforms are the stabilising structures from which the branches grow. Otherwise the fauna is very much the same as for the other slabs. There are, on the downwards facing side, three *Rafinesquina* shells which implies that it was in fact *Rafinesquina* on the other slabs as well, although worse preserved and harder to identify. There is also a mould of a bivalve, possibly *Ambonychia*, on the same side as the large bryozoans.

Time: *Maysvillian* (prob. Bellevue member)
Cowan Creek, near Clarksville, Ohio

Fig. 5
The material consists of two slabs (and, in addition, one from Cowan Creek Lake with no difference in fauna except for a lot of small lumps that are probably bivalves).

The bryozoans dominate the fauna, with *Graptodictya* and *Bythopora* the most abundant genera (as in Stonelick Creek). The bryozoans are usually finely ramose, from less than one to about 2 or 3 mm in diameter, and fragments are up to 3 cm long. Ostracodes are also abundant, with one species on the larger one and three more on the smaller slab (which in other respects carry the same fauna). The most numerous ostracode is a byrychid. Of the others one is *Ceratopsis oculifera* and another is tentatively identified as *Primitia*.

There is one brachiopod species, *Hebertella ?simulata* (two pedicle valves), and several pits on one side of the large slab that may be fossil bivalves. These pits are oval to subcircular in outline, about 3 cm wide and 4-6 cm long. The pits are usually filled with matrix but where the lining can be observed it is dark and show striae as of growth rings. There is also a small specimen of *Caritodens demissa*. On the small slab there is a larger specimen of this bivalve species.

Time: (Upper?) Maysvillian

Elstun Road, Ohio

Fig. 6
Three quite small slabs of mudstone with a fauna that mainly consists of crinoids and graptolites of the genus *Climacograptus*. There are also a few fragments of bryozoans, for example *Proboscina autoporoides*, and the trilobite *Flexicalymene*.

There is one crinoid calyx with arms partly preserved. This crinoid is identified as *Ectenocrinus simplex* (see Fig. 6 B), based on the small calyx, the pentagonal shape of the column, arm morphology etc. By the look of the stems there are likely more than one species of crinoids in the sample.

Time: Richmondian

There is also a small sample from the same locality, with abundant, very small fossils, such as crinoid columnals, micro gastropods, and fragments of *Cryptolithus*. The sample looks very different from the crinoid mudstones. It is probably collected from an entirely different stratigraphic level. Judging by the occurrence of *Cryptolithus* it is probably older than the other samples, although these few fragments could be reworked material.

Time: ?

Taphonomic description

Grand View
There are few, if any, well preserved, complete specimens. The fossils all show corrosion to some degree.

It is notable that the preserved parts of *Cryptolithus* almost exclusively consist of more or less fragmented cephalas (see Fig. 3 D). On the large slab most of the cephalas rest on top of other fragments and are eroded so that only the fringes remain. On the small slab, on the other hand, the cephalas are usually partly buried and only the glabella is visible. The cephalas on the smaller slab are somewhat better preserved, probably as a result of more rapid burial. Probably the trilobites assembled here or nearby to moult, leaving the relatively heavy cephalas on the bottom of this area, while lighter exuvia, such as pygidia, generally were swept farther off shore. Almost all the fringes of the crypto lithids are oriented in a similar direction (within 180 degrees). It has been suggested that the fringes served to orient the animal, in the most stable position with regard to the current (Campbell 1975) - maybe the shed cephalic exuvia were likewise passively oriented towards the current.

It seems likely that the sedimentation was episodic with deposition and removal of finer sediment alternating. Removal being greater at the place of the larger slab, could explain the differential erosion. On the smaller slab there are also moulds with a dark covering - possibly collophane, a kind of phosphatic deposit (Weir et al. 1984).

These remains represents a time-averaged
community, with a mixed assemblage. The community, however, has not changed much during the time in question - thus it was a relatively stable environment. But the question regarding in situ organisms and organisms transported to or from the site, remains. Since there are no fossil crinoid holdfasts and the columnals show both sorting (larger on large slab, smaller on small slab) and "orientation", that is they are localised in a "string" on the large slab, their hard parts were probably transported into the area by currents. As a conclusion both current activity and time-averaging have been important in determining the appearance of this assemblage.

**Aid's Run Creek**

The *Rafinesquina* brachiopods of the large slab from this locality probably represent a life assemblage that has been redeposited by a storm-event. According to Brett & Baird (1986) pavements of brachiopods in convex-up position are due to storm generated currents, this orientation being the most stable. In life, these brachio-
pods are oriented convex valve down (Richards 1972). The shells range from 3 to 6 cm in width and the larger pedicle valves are more convex than the smaller ones, the convexity resulting from the mode of growth in the outermost part of the bigger shells. All seem to be oriented brachial valve down, although some pedicle valves are missing, showing the interior of brachial valves. It is impossible to deduce if all the other brachiopod shells are articulated or if they consist of only pedicle valves.

The robust shells of the brachiopods, together with the relatively large (as compared with the material from the other localities) fragments of both Rafinesquina and other organisms, implies that this was a high energy environment. Although Rafinesquina usually pioneered soft muddy substrates (Richards 1972), the large, strongly convex forms inhabited turbulent environments (Alexander 1975). Cracks in the shells are common, most probably because of tumbling against each other during reworking and deposition.

The shells from the small slab are more fragmented and parts of Rafinesquina are stacked through the sample. A couple of bryozoan attachments on one side of the slab (see Fig 3 G) and a shell possibly cemented to the seafloor, shows that this side has been facing upwards, but there are no large differences in the appearance of the two sides of the sample.

There are three main differences between the two samples: 1) The large slab carries relatively unbroken brachiopod valves while the shells on the small slab are more fragmented. The brachiopods of the smaller slab are covered by dots, punctae, made visible through abrasion of the shells. These dots are not visible on the shells of the larger slab. 2) The smaller sample has fragmented brachiopods throughout, while on the larger, shells are all on one surface 3) The matrix of the large slab consists of lime mud, while the matrix of the smaller are of quartz grains, i.e. silt. The slabs consequently must be from different localities or (more likely in this case) different stratigraphic levels, the smaller slab possibly representing an environment closer to the shore.

**Todd’s Fork**

The lithology of the large slab is limestone, but clay sediment on both sides show that it derives from a laminated mudstone - limestone. The fossil material of this sample is not well preserved. Some fragments are better preserved indicating time-averaging and slow sedimentation. The bryozoans of the larger slab are usually fragmented in pieces of about 2 cm length.

Mud sedimentation, slow burial and time-averaging, and the fossils showing no preferred orientation implies that this was a low energy environment. The fragmentation of hard parts was due to long exposure on the seafloor rather than mechanical abrasion. The organisms present must therefore have lived at the locality but not all at exactly the same time.

The smaller sample with the Lophospira gastropods on the other hand, shows a none-averaged assemblage. The gastropods are preserved as inner moulds and are mostly complete. Most of the breakage is Recent and no breakage can with certainty be assessed to have taken place before burial, which was probably rapid. (See Fig. 3 1.)

**Stonelick Creek**

The large bryozoans on the large slab (Fig 4 A) are probably *in situ*. This is indicated by: 1) fragments of the same species are usually located next to each other; 2) different sizes/lengths of broken branches implies lack of sorting; 3) there are (smaller) bryozoans attached to other bryozoans, and to brachiopod and bivalve shells; 4) they show no preferred orientation.

This community could possibly be referred to as a "bryozoan forest". The environment was probably of medium high energy level, with currents bringing in nutrition for the bryozoans and perhaps removing finer fragments. Most branches are 5-10 mm in diameter but some are finer. (There is one very fragile bryozoan but it lives encrusting the platform of another bryozoan and therefore it can withstand a turbulent environment.) However current activity did not disable mud deposition completely. It is likely that there was first a soft muddy substrate
subsequently stabilized by skeletal debris and perhaps accompanied by a change to more energetic environments, in which the large bryozoa thrived.

As mentioned in the section of taxonomic composition the other side of this slab is not very different from the other samples. The material is bioturbated and on the "bryozoan slab" most organism remains larger than 2-5 mm are fragment to this size. The crinoid columnals are also of this size. Most bryozoans are ramose with branches 1-5 mm in diameter and broken in 2-4 cm long pieces. On the large slab they show parallel orientation. All this implies reworking and sorting of material. On the other slabs the material is not equally fragmented, but it consists of completely disarticulated multi-element skeletons.

There are also some samples with only crinoids and one with a bryozoan colony from this locality. The bryozoan colony is rather large and therefore probably preserved in situ, and the exceptional preservation of the crinoids shows that they are in situ buried as well. One calyx is preserved complete, and in an upright position in the mudstone, indicating a momentary burrying. The other calyces are preserved in limestone, and are slightly disarticulated, indicating moderately high sedimentation rates or bioturbation. (However, there are no obvious traces of bioturbation.)

**Cowan Creek**

On the large slab the surface is undulating, showing older, more abraded organism-remains in patches between sediment with better preserved specimens. This possibly implies different rates of sedimentation at different times.

The bryozoans are usually finely ramose, from less than one to about 2 or 3 mm in diameter, and fragments are up to 3 cm long. It seems that most of the bryozoans were very thinly ramose, and those that are more robust seem to have been deposited at a later time. The latter ones also show more of a preferred orientation, which the smaller fragments lack.

The brachiopod shells are broken and on one, there is encrusting bryozoa. It is not likely that they have been transported very far by currents, being so much larger than any other object in the assemblage. The encrustation again suggests that there were times of no or very slow deposition of sediment.

If the pits on one side of the sample are indeed bivalve shells they are poorly preserved. The ostracodes on the other hand are usually well preserved. The bivalve *Carriodens* on the small sample is much abraded, but not very fragmented. This implies long exposure in a calm environment.

The sample from Cowan Creek Lake consists of limestone with thin mud horizons. It is very much like the large slab except for the unidentifiable small bivalve "lumps".

**Elstun Road**

The crinoids are preserved as up to almost 1 dm long pleurocolumnals, but mostly the stems are 2-5 cm. Most of them are very fine, being about 1.5 mm in diameter, and the few that are more robust never exceeds 2.5 mm. The visible part of the calyx is rather well preserved although the arms are partly missing.

The crinoid stems do not just occupy certain bedding planes or surfaces but are embedded in the matrix, throughout the sample. On one of the three slabs with crinoids (the one with the calyx) the stems show parallel alignment (Fig. 6 A). They have probably rolled along the bottom with their long axis transverse to the current, which is the normal behaviour of cylindrical objects (Brett & Baird 1986). However, this treatment causes rapid disarticulation of the echinoderms, and they must have been buried rather quickly.

The graptolites (sometimes pyritized) show no preferred orientation in any of the samples. Both degree of preservation and abundance vary between the three slabs.

From this locality is also a small piece with microgastropods. It is very dissimilar to the above mentioned slabs. The surface and interior of this piece is crowded with minute fossils, constituting the greater part of the sediment, as in a lithified calcareous sand. The microgastropods was probably living among the foliage of algal plants, some way above the sediment-water interface (Peel 1978).
Reconstruction and comparison of faunas

In reconstructing ancient faunas it is very important to remember that only a fraction of the organisms are preserved. Soft bodied organisms are hardly ever preserved, although activity by the organisms can be seen, e.g. burrows etc. The entire fauna can never be reconstructed in detail. According to Crame (1990) at least 50% of the original fauna, usually more, is not preserved in the fossil assemblage.

The following reconstructions (see Figs. 7-12) only include organisms which had preservable hard parts, and I have tried to take into consideration what is known of their living habits. For example *Rafinesquina* and other concavo-convex brachiopods usually live convex side down, although dead shells can be reoriented into the more stable convex-up position by currents (Richards 1972; Alexander 1975). *Zygospira modesta* has been found in life position attached in large numbers to bryozoans, and both *Onniella* and *Heberiella* live attached to the substrate by their pedicles with their "fronts" (that is, their commissures) pointing upwards, or away from the substrate (Richards 1972).

Comparing these six faunas it is clear that only the oldest one (from Grand View) has a dominating species that is not a suspension feeder. The trilobite *Crypitolithus* is restricted to moderately deep waters - about 30 m according to Shaw (1991) - and it is a deposit feeder (Campbell 1975). The remaining faunas are all dominated by suspension feeders (including filter feeders), such as bryozoans, crinoids, and brachiopods.

The dominating feeding type in a community can be used as an indication of water turbulence since it is controlled by the amount of nutrition available for the organisms in the sediment vs the water (Dodd & Stanton 1981). If the water mass is very calm the food particles in the water will soon settle on the sea bottom, with other sedimentary particles. Thus, in a calm environment, deposit feeders dominate over suspension feeders. If the water mass is turbulent on the other hand, the food particles will be kept in suspension for a longer time before settling, and

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**Fig. 7.** Reconstruction of the benthic community at Grand View (scale 1:3). Living in this community are the brachiopods *Sowerbyella* (S), *Zygospira* (Z), and *Onniella* (O). *Sowerbyella* lives lying on the bottom substrate, it’s form preventing sinking (Thayer 1975, referred to by Dodd & Stanton 1981; not seen by myself). *Zygospira* attaches itself to bryozoans, to reach a higher level in the bottom waters, while *Onniella* lives attached to grains by their pedicles, and with their commissures lifted above the bottom (Richards 1972). The trilobites *Cryptolithus* (C), and *Flexicalymene* (F), the latter rolled up for protection, e.g. from the predating orthcone (Or). There are also gastropods (G), and bryozoans (B). The faunal composition is very similar to that of Britsky’s (1969) Sowerbyella - Onniella Community, living on muddy silt bottoms of the outer infralittoral zone. This community can also be compared with the English, Middle Ordovician Trilobite - Onniella Community of McKerrow (1978), with a very similar faunal structure composed of trinucleids (*Onnia*), calymenids (*Onnicalymene*) and both orthid and strophomenid brachiopods.
so the fauna is dominated by suspension feeding organisms (Walker 1974; Dodd & Stanton 1981).

It is also notable, when looking at these faunas, that, again, the one from Grand View differs from the others, being a *Sowerbyella - Onniella* Community (in accordance with Bretsky 1969), while the others (when they can be assigned to any community) are *Zygospira - Hebertella* Communities. Further, the three communities of this latter kind, are the only faunas that are dominated by ramose bryozoans. As mentioned earlier Bretsky recognised one more community, dominated by brachiopods and bivalves, and living in sandy-silty environments, relatively close to the shore.

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**Fig. 8.** Reconstruction of the fauna of large *Rafinesquina* (R) brachiopods from Aid’s Run Creek (scale 1:2). It has no specific counterpart in Bretsky’s communities. But *Rafinesquina* occurs in both the *Zygospira - Hebertella* Community and the *Sowerbyella - Onniella* Community. Presumably these large brachiopods dominated the fauna completely with only occasional occurrences of infaunal pelecypods (P), locally and/or at certain times. They lived in a near-shore, turbulent environment as indicated by their heavy shells (Alexander 1975). They are shown in life position, resting on their convex pedicle valves and partly buried in the sediment (Richards 1972).

**Fig. 9.** Reconstruction of the community at Todd’s Fork. The large slab from this locality is dominated by suspension feeders, mainly finely ramose bryozoans (B), but there are also the brachiopods *Zygospira* (Z), and *Hebertella* (H), which lives in a similar way to *Onniella*, with the pedicle raising the animal above the sediment - water interface (Richards 1972). This fauna most likely corresponds with the *Zygospira - Hebertella* Community of Bretsky (1969). This community is often very diverse, particularly because of the diverse bryozoans. (Figure in natural size.)
Fig. 10. Reconstruction of the community at Stonelick Creek (scale 1:4). This community is dominated by suspension feeders like the crinoid Glyptocrinus (G), bryozoans (B), and the brachiopods Rafinesquina (R), and Zygospira (Z). There are also trilobites, e.g., Flexicalymene (F), and molluscs, like gastropods (Ga), orthocones (Or), and the bivalve Caritodens demissa (Ga). This community is probably more closely related to the Zygospira - Hebertella Community of Bretsky (1969) than with his Sowerbyella - Onniella Community. The former community lived somewhat closer to the shore, and the higher amount of suspension-feeding organisms also indicates higher turbulence (Walker 1974; Dodd & Stanton 1981).

Among the faunas included in this study, however, there are no similarities to this community, except possibly the Rafinesquina dominated assemblage from Aid's Run Creek. The community furthest from the shore was the Sowerbyella - Onniella Community, and the Zygospira - Hebertella Community. There are also abundant ostracodes (Os).

Fig. 11. Reconstruction of the community at Cowan Creek (scale 2:1). The bryozoan (B) fauna of this locality is very similar to that of Stonelick Creek, and the further presence of species like Hebertella (H), and Caritodens demissa (Ca) implies that this is also a Zygospira - Hebertella Community. There are also abundant ostracodes (Os).
ra-Hebertella Community was some intermediate between this and the Orthorhynchula-Ambonychia Community. This agrees with the observation that conditions were probably (at least slightly) more turbulent for the three bryozoan-dominated faunas.

If the faunas were indeed arranged in the correct chronological order, one might be tempted to assign this community-type distribution to a shallowing sea. But it is not enough having only two community types, and therefore only two "depth-indicators", to draw such a conclusion. However, the seas did in fact shallow generally, with several fluctuations, during the Cincinnatian period (Weir et al. 1984; Potter 1996).

Summary

The material studied show an abundant and diverse fauna dominated by bryozoans. The faunas also include brachiopods, trilobites, ostracodes, gastropods, bivalves, cephalopods and echinoderms. Soft-bodied organisms of the fauna are not preserved, but there are some dental elements from annelid worms (scolecodonts) and conodonts. (It is unusual to find this kind of fossils on the surfaces of slabs.) The material comes from six different localities, and most of them are limestone slabs which are very fossiliferous, though there are a few less fossiliferous mudstone samples.

Although the faunal assemblages at first seem far from alike, three of them in fact belong to the same Zygospira-Hebertella Community of Bretsky (1969). The differences between these three communities are explained by smaller regional and temporal variations in bottom topography, current velocities, water depth, etc. The only Edenian samples, from Grand view, contained species belonging to Bretsky's Sowerbyella-Onniella Community, a community belonging in a calmer environment than the Zygospira-Hebertella Community, which is concordant with the waters of the epicontinental sea covering the interior of North America, being deepest in the beginning of the Cincinnatian period (Potter 1996).

Two of the faunal assemblages carried more conspicuous faunas, not obviously belonging to any of Bretsky's communities. Both faunas were, however, dominated by suspension feeders, as in the Zygospira-Hebertella Community and they might just be extreme variations of this community.
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