Lithofacies-influenced ostracod associations in the middle Ordovician Bromide Formation, Oklahoma, USA

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ABSTRACT - The Bromide Formation of southern Oklahoma was deposited in a linear basin and on the adjoining platform during a marine transgressive-regressive event in the middle Ordovician. The formation displays wide lateral (platform-basin) and vertical (transgressive-regressive) sedimentary facies variation. From the prolific and diverse ostracod fauna present in the Bromide Formation two facies-influenced ostracod associations can be defined: a geographically and stratigraphically widespread Anisocycamus Association, occupying subtidally deposited marine sediments; and a Leperditella Association, which is restricted to marginal marine environments. The ostracods of the Bromide Formation demonstrate that the group can be utilized in the Ordovician as a tool to help establish palaeoenvironments and differentiate palaeoshorelines. J. Micropalaeontology, 15(1): 69–81, April 1996.

INTRODUCTION AND GEOLOGICAL SETTING
This paper aims to assess the relationships between lithofacies patterns and the stratigraphical and geographical distribution of ostracods in the Bromide Formation of Oklahoma, USA.

The Bromide Formation is the youngest of five formations comprising the Simpson Group (Fig. 1; see Decker & Merritt, 1931) and forms part of the thick intracratonic succession of Ordovician rocks exposed in the Arbuckle Mountains and Criner Hills of southern Oklahoma. The formation is divided into a lower Mountain Lake Member and an upper Pooleville Member and, based on conodont stratigraphy (Sweet & Bergström, 1976; Ross et al., 1982; Sweet, 1984), is considered of late Whiterockian–early Mohawkian age. In terms of the British Ordovician ‘Series’ this equates with the late Llandeilo to early Caradoc.

The Bromide Formation was deposited within a major linear basin (the Southern Oklahoma Aulacogen; Shatski, 1946) and on the adjoining platform during a marine transgressive-regressive event (Fig. 2). The formation displays wide lateral (platform–basin) and vertical (transgressive-regressive) facies variation, having marginal marine to basinal types of lithofacies, and contains one of the most prolific and diverse ostracod faunas recorded from the Ordovician of N. America. Some 48 genera and 83 species of ostracods are documented from the formation (Harris, 1957; Williams, 1990), thus providing an appropriate sequence from which to investigate the patterns and possible controls of the distribution of ostracods, particularly with respect to prevailing lithofacies.

Detailed palaeoenvironmental studies of Ordovician ostracods are rare. Several authors (especially Berdan, 1969, 1976, 1984) have noted the co-occurring relationship between leperditiocone-dominated ostracod faunas and marginal marine lithofacies in the Lower Palaeozoic in general. Copeland (1982) documented bathymetrically controlled ostracod assemblages from the middle Ordovician Lower Elbataaitine Formation of Canada and, on the basis of published work of other authors, attempted to recognize similar assemblages in other N. American sequences, including the Bromide Formation of Oklahoma.

The ostracod faunas of the Bromide Formation were originally documented by Harris (1931, 1957). Subsequent published research has addressed the taxonomy of a few species (e.g. Martinsson, 1960; Levinson, 1961; Guber & Jaanusson, 1964; Siveter & Williams, 1988a & b; Williams & Siveter, 1989a & b; Williams & Jones, 1990; Miller et al., 1990; Williams & Vannier, 1995). With the exception of the leperditiocones the entire ostracod fauna of the Simpson Group has recently been studied (Williams, 1990). Pending full publication of Williams’ revised study, with some modifications we have used herein the binomen of previous authors. Where herein the generic name is placed in inverted commas (e.g. ‘Ctenoholobina’ inflata Harris, 1957; see Pl. 1, Fig. 3) we consider the species to belong to a new, as yet unpublished, genus. Where both the generic and specific names (as used by a previous author) are placed in inverted commas (e.g. ‘Schmidtella affinis’ Ulrich sensu Harris, 1957; see Pl. 2, Fig. 5) we consider that both the genus and species are new (see Williams, 1990).

SECTIONS STUDIED AND METHODS
The ostracods detailed in the present study were recovered from six logged sections which, taken together, embrace the entire Bromide Formation (Fig. 3). The sections are situated in the Arbuckle Mountains and Criner Hills of southern Oklahoma, USA. Section 1 is situated about 5 km south of Fittstown adjacent US Highway 99 (Fay et al., 1982, measured section 11a). Sections 2 and 3 are situated in Murray County adjacent to Interstate 35 (Fay et al., 1982, measured sections 16a and 16b respectively). Section 4 is situated adjacent to Interstate 35 in Carter County (Fay et al., 1982, measured section 3). Section 5 is situated on the Arbuckle Ranch (formerly the Johnston Ranch), Murray County (Fay et al., 1982, measured section 1). Section 6 is at Rock Crossing, Carter County, Criner Hills (Fay et al., 1982, measured section 15a). These sections were chosen in order to represent a platform–basin transect across the Southern...
Fig. 1. Stratigraphic setting of the Bromide Formation and its correlation with the ‘standard’ Ordovician series (adapted from Ross et al., 1982).

Oklahoma Aulacogen. Section 1 is considered to have been situated on the palaeo-platform and section 6 is situated near the centre (i.e. the presumed deepest marine parts) of the palaeo-basin. Sections 2–5 are thought to represent intervening and progressively deeper marine locations down a palaeoslope.

In general, the Mountain Lake Member of the Bromide Formation is well exposed in all 6 sections. The Pooleville Member of the Bromide Formation is well exposed in sections 1, 2 and 3; in section 4 only its top few metres is exposed; in section 5 its upper part is incompletely exposed and in section 6 the top of the member is periodically covered by river alluvium.

The ostracod distributions analysed herein are based on faunas recovered from 117 samples collected in the field (Williams, 1990). These samples represent all of the clastic and carbonate lithologies present in the Bromide Formation and, where possible, embrace the whole of the stratigraphic range of the formation exposed in the six sections studied. Section 1 presents the richest and best preserved ostracod faunas so far encountered in the Bromide Formation.

The ostracods of sections 1 and 6 were originally studied by Harris (1957, charts 3 and 4). Harris also studied lateral equivalents of our sections 4 and 5 (see Harris, 1957, charts 2 and 1 respectively). Where appropriate, ostracod data from Harris’ collections have been utilized in the present study. Account is also taken of the fact that the stratigraphy of the sections in question has been extensively revised (see Fay et al., 1982; Grahn & Miller, 1986; Williams, 1990).

Fig. 2. Palaeogeography of Oklahoma during the deposition of the Bromide Formation (after Longman, 1982).

Fig. 3. Location of sections sampled of the Bromide Formation: in the Arbuckle Mountains and Criner Hills, Oklahoma.
In order to recover ostracods from the Bromide Formation, shale samples were broken down in baths of 10% hydrogen peroxide and then wet sieved, dried and picked for ostracods. In order to prevent possible bias due to ‘facies sampling’ the limestones were also sampled in bulk, subsequently broken into small pieces in a rock crusher and then examined for ostracod valves. Specimens recovered in this way were prepared using a vibrotool.

SEDIMENTOLOGY AND PALAEOENVIRONMENTS
Longman (1976, 1981, 1982) clearly demonstrates a range of lithofacies in the Bromide Formation which, taken together, indicate a marine transgressive-regressive event (Fig. 4). A clastic shoreface sequence at the base of the Mountain Lake Member of the Bromide Formation overlies the subtidally deposited shales of the Tulip Creek Formation. This shoreface sequence is succeeded by subtidally deposited shales and limestones which form the bulk of the Mountain Lake Member. The overlying carbonate-dominated sequence of the Pooleville Member is interpreted as a phase of regression which, on the platform, culminated with the occurrence of a tidal flat environment. However, nearer to the geographic and bathymetric depo-centre of the Southern Oklahoma Aulacogen subtidal sedimentation persisted throughout the Pooleville Member.

The sedimentological variation from shelf to basin is discussed below first with reference to sections 1 and 6, the end-members of the transect. Further data on the relevant lithofacies are given in Longman (1982).

Section 1 (Fig. 5)
This section was situated on the northern palaeo-platform adjoining the Southern Oklahoma Aulacogen (Figs 2, 3). Here, lithofacies of the Bromide Formation are dominantly of shallow marine aspect. The Mountain Lake Member begins with a thick sequence of shoreface sandstones which are succeeded by thin, interbedded, subtidally deposited shales and limestones. Longman (1982) estimated that water depths of only 5 m prevailed during the acme of the marine transgression represented in this section. The succeeding Pooleville Member is dominated by shallow marine carbonate deposits; these culminate at the top of the sequence with the occurrence of birdseye micrites which are interpreted as the product of deposition in a broad tidal flat environment (Longman, 1982).

Section 6 (Fig. 6)
Section 6 is situated near the geographic and bathymetric centre of the Southern Oklahoma Aulacogen. Compared to the deposits of section 1, the lithofacies of the Bromide Formation in section 6 have a more deep marine aspect. As in section 1, the sequence begins with shoreface sandstones which are succeeded by interbedded shales and limestones. Longman (1982) estimated water depths of about 80 m for the acme of the transgression for the strata represented in this section. The lithofacies of the overlying Pooleville Member, comprising richly fossiliferous limestones and shales, show no evidence of regression, and were probably deposited in water depths well below normal wave base.

Sections 2–5
Sections 2–5 (Fig. 3) represent a gradual, intervening palaeoslope between the depositional settings of sections 1 and 6. Deposits of sections 2 and 3 were situated at the shelf-slope break (hinge line) of the Aulacogen and show a similar development of lithofacies to those of section 1, with regression evident in the Pooleville Member. Deposits of sections 4 and 5 were situated within the more basinal parts of the aulacogen, though apparently in an overall shallower marine setting than those of section 6. In section 4 the strata of the uppermost Pooleville Member are characterized by birdseye micrites, thus indicating that regression also occurred here.

OSTRACOD DISTRIBUTIONAL PATTERNS
A large quantity of data exists concerning the distribution of modern and fossil ostracods in marine environments (e.g. see Whatley & Maybury, 1990). Modern marine ostracods are predominantly benthic and generally show maximum abundance and diversity in shelf environments. Similar
patterns may be expected in the Palaeozoic. For example in summarizing the ecological ranges of Silurian ostracods Siveter (1984) noted that highest diversity among palaecocope-dominated ostracod faunas occurred on the midshelf to shelf upper slope and that reduced diversity was characteristic of both deeper marine and more nearshore high energy environments. A few ostracod taxa (myodocopes) had probably adopted to a pelagic life-style by the Silurian but most Silurian ostracods were apparently benthic (see Siveter, 1984; Siveter et al., 1991).

There are only a few previous attempts at characterizing Ordovician ostracods in terms of environments and lifestyles. Copeland (1982) identified bathymetrically controlled ostracod assemblages in the middle Ordovician Lower Esbatoottine Formation of Canada. He identified two ostracod assemblages: a widespread ostracod fauna ranging from shallow to deeper shelf marine environments and an ostracod fauna restricted to a deeper shelf marine setting. Using published data, Copeland (1982) attempted to recognize similar assemblages in other N. American sequences, including Oklahoma. He compared the ostracod faunas of the Lower Esbatoottine Formation to that part of

| Mountain Lake Member | Pooleville Member | Stratigraphy |
|----------------------|------------------|--------------|
| Shoreface            | Open marine      | Shallowing subtidal to tidal flat |
|                      |                  | Environments |
|                      |                  | Lithology    |
|                      |                  | L. auricula  |
|                      |                  | B. circulantis |
|                      |                  | H. labiosa   |
|                      |                  | S. excavata  |
|                      |                  | S. affinis   |
|                      |                  | L. varicata  |
|                      |                  | L. simplex   |
|                      |                  | G. nuculopsis |
|                      |                  | S. asymmetricta |
|                      |                  | D. macrocarinata |
|                      |                  | S. minutula  |
|                      |                  | S. crassimarginata' |
|                      |                  | K. calcini   |
|                      |                  | E. simpsoni  |
|                      |                  | C. gibbosum  |
|                      |                  | B. reticulata |
|                      |                  | A. elegans   |
|                      |                  | P. excava     |
|                      |                  | E. depressa   |
|                      |                  | E. socialis   |
|                      |                  | B. ovalis     |
|                      |                  | E. indivisa   |
|                      |                  | E. moorei     |
|                      |                  | Gen. n. A, sp. n. A |
|                      |                  | B. papillata  |
|                      |                  | M.? brevispinata |
|                      |                  | E. quadra     |
|                      |                  | P. quadra     |
|                      |                  | K. hybosa     |
|                      |                  | S. transversa |
|                      |                  | W. longispina |
|                      |                  | C. inflata    |
|                      |                  | Laccochilina sp. |
|                      |                  | L. jonesinoide |
|                      |                  | L. tumida     |
|                      |                  | C. alata      |
|                      |                  | C. abrupta    |
|                      |                  | L. rex        |
|                      |                  | Ningutella sp. |

Fig. 5. Stratigraphy, lithology and ostracod ranges for the Bromide Formation at section 1. Anisocycamus Association ostracods are above the double line, Leperditella Association ostracods are below the double line. Log thickness measurements are given in metres from below the contact between the Pooleville Member and the overlying Viola Group as this is an easy datum plane to establish in the field. For key to lithologies see Fig. 4.
### Lithofacies-influenced ostracod associations

| Mountain Lake Member | Pooleville Member | Sample horizon |
|----------------------|-------------------|----------------|
| Shoreface            | Open marine       | Thickness (m)  |
|                      |                   | Stratigraphy   |

| Environments          | Lithology          |
|-----------------------|--------------------|
| Open marine           | S. 'asymmetrica'   |
| Open marine           | Gen. n. A, sp. n. A|
| Open marine           | B. reticulata      |
| Open marine           | E. simpsoni        |
| Open marine           | A. elegans         |
| Open marine           | K. depressa        |
| Open marine           | S. affinis         |
| Open marine           | S. crassimarginata'|
| Open marine           | C. gibbosum        |
| Open marine           | D. macrocarinata   |
| Open marine           | K. calvini         |
| Open marine           | Hithis sp.         |
| Open marine           | H. parisspinosa    |
| Open marine           | H. nodosimarginata |
| Open marine           | E. socialis        |
| Open marine           | K. bailyna         |
| Open marine           | H. circulanis      |
| Open marine           | P. rugosus         |
| Open marine           | K.? spinantis      |
| Open marine           | H. labiosa         |
| Open marine           | P. minima          |
| Open marine           | B. papillata       |
| Open marine           | E. ventrosa        |
| Open marine           | E. moorei          |
| Open marine           | S. millepunctata   |
| Open marine           | B. deckeri         |
| Open marine           | K. arcuata         |
| Open marine           | E. quadrunata      |
| Open marine           | B. weverini        |
| Open marine           | S. excavata        |
| Open marine           | K. induvisa        |
| Open marine           | L. auricula        |
| Open marine           | Karinutilia? sp.   |
| Open marine           | P. minuta          |
| Open marine           | E. bispinata       |

*Fig. 6. Stratigraphy, lithology and ostracod ranges for the Bromide Formation at section 6. All ostracods are of the *Anisocyamus* Association. Log thickness measurements as for Fig. 5. For key to lithologies see Fig. 4.*

The Bromide Formation present at the Highway 77 locality (see Harris, 1957). Copeland concluded that the ostracod faunas of the Bromide Formation (Decker’s beds 8–15) of the Highway 77 locality (see Harris, 1957) correspond quite closely to the deeper shelf marine ostracod assemblage of the Lower Esbastaottine Formation.

Of the 83 ostracod species currently recorded from the Bromide Formation (Williams, 1990), 65 are present in the sections 1–6 discussed herein. The distributional patterns of ostracods in the Bromide Formation is herein presented based on presence/absence data. No statistical analysis has been made, partly in the knowledge that field sample size and sampling interval varied in order to maximize the number of ostracods recovered. Two lithofacies-related associations, of what are presumed to be benthic ostracods, can be clearly recognized within our six sampled sections: the *Anisocyamus* Association and the *Leperditilla* Association. The term ‘association’ is here used with respect to the Bromide Formation for a recurring, discrete group of ostracods which occupy a defined range of lithofacies (palaeoenvironments) and which are taxonomically distinct from ostracod faunas (associations) which occur in other, different lithofacies.

*Anisocyamus* Association (Pls 1–3; Fig. 7)

This association, which derives its name from two characteristic primitiopacean species (*Anisocyamus elegans* and *Anisocyamus bassleri*; see Siveter & Williams, 1988a, b) is present in all six sections (Table 1). The *Anisocyamus* Association includes the majority of ostracod species (56) documented in the six sections studied and is dominated by palaeocope (see Pls 1–3; Fig. 7) and leiocope ostracods (see Pl. 2). However, overall diversity is high, with eridostracan, binodicope and podocopid ostracod taxa also being
present (see PIs 2, 3; Fig. 7). Many of the species belonging to the *Anisocyamus* Association (e.g. *Bromidella reticulata*, *Cryptophyllus gibbosum* and *Eridoconcha simpsoni*) have long stratigraphic ranges, occurring in the Mountain Lake and Pooleville members of the Bromide Formation and also in the underlying Tulip Creek Formation. Within the *Anisocyamus* Association there also appears to be some cross-basin variation in the geographical ranges of individual species, although some of this variation may be related to sampling bias in individual sections. A total of seven species (e.g. *Schmidtella* ‘minuta’, *Kayina hybosa*) appear to be present only in the shallow marine subtidal deposits of section 1. Six species (e.g. *Baltonotella parspipinosa*, ‘*Primitiopsis* minuta’) appear to be restricted to the deeper marine sediments of section 6 (Table 1). More significantly, however, most species of the *Anisocyamus* Association have wide geographical distribution: for example, 20 species of this association are common to sections 1 and 6 and a further seven species are common to sections 2 and 6 (Table 1).

**Leperditella Association** (Fig. 7)

This association, which derives its name from two characteristic leperditiacean species (*Leperditella rex* and *Leperditella tumida*), is present only in the upper part of the Pooleville Member and does not occur in all the sections studied. Significantly, the *Leperditella* Association is absent from section 6. By contrast, the *Leperditella* Association is best developed, both in terms of species diversity and number of individuals, in section 1. The *Leperditella* Association is poorly developed in the uppermost part of the Pooleville Member at both sections 3 and 4. The *Leperditella* Association is characterized by leperditiocope ostracods which occur in limestone beds generally 10–50 cm in thickness; however, in the intervening shales (generally 2–10 cm thick), palaeoepice ostracods, particularly leperi- ditiaceans, predominate. Significantly, none of the (nine) ostracod species which comprise the *Leperditella* Association are present in the *Anisocyamus* Association.

**FACTORS INFLUENCING OSTRACOD DISTRIBUTION**

The distribution of the two named ostracod associations is clearly closely related to the distribution of the lithofacies of the Bromide Formation. Deposits of sections 1 and 6, which record sedimentation on the palaeo-platform and in the palaeo-basin respectively, clearly demonstrate this pattern of occurrence (Figs 5, 6). The most characteristic ostracods recorded from these two sections and belonging to the *Anisocyamus* and *Leperditella* associations are illustrated in Plates 1-3 and Fig. 7. In section 6 where, after the deposition of the basal shoreface sandstone sequence, sedimentation occurred in a subtidal marine setting throughout the Mountain Lake and Pooleville members, only the *Anisocyamus* Association is present (Fig. 6; see also Harris, 1957, chart 4). The *Anisocyamus* Association is absent from lithofacies characteristic of very shallow or marginal marine environments, in that it occurs only in the upper part of the Pooleville Member in the platform sequences. Where deeper water sedimentation persisted throughout the Pooleville Member (i.e. section 6, Fig. 6) the *Leperditella* Association appears to have tolerated a wide range of water depths; it is estimated that relevant marine subtidally deposited sediments of sections 1 and 6 were deposited in water depths of 5 and 80 m respectively (Longman, 1982).

By contrast, the *Leperditella* Association is restricted to lithofacies characteristic of very shallow or marginal marine environments, in that it occurs only in the upper part of the Pooleville Member in the platform sequences. Where deeper water sedimentation persisted throughout the Pooleville Member (i.e. section 6, Fig. 6) the *Leperditella* Association is absent. The *Leperditella* Association seems to be only completely developed where both limestones and shales were deposited (i.e. section 1). Where only limestones are present (i.e. section 4) only leperditiocope ostracods are present (data of Harris, 1957, chart 1). This suggests that in addition to water depth, substrate was also a factor influencing the distribution of the Bromide Formation ostracods.

The *Leperditella* Association (comprising nine species)
and the *Anisocyamus* Association (comprising 56 species) of the six sections studied in the Bromide Formation have no ostracod species in common. The *Leperditella* Association presumably represents a fauna specifically adapted to marginal marine environments from which the *Anisocyamus* Association was apparently ecologically excluded (Fig. 8).

The ostracod associations of the Bromide Formation can be compared with Copeland’s (1982) middle Ordovician ostracod assemblages from the Lower Esbataotline Formation of Canada. The Lower Esbataotline Formation appears to have been deposited entirely within a marine subtidal setting (Copeland, 1982, p. 4). There are no marginal marine, peritidal or tidal flat depositional environments in the Lower Esbataotline Formation comparable to those of the Bromide Formation in Oklahoma. Correspondingly the *Leperditella* Association, which in the Bromide Formation is characteristic of lithofacies indicative of marginal marine environments, shows no relationships to the ostracod assemblages of the Lower Esbataotline Formation. By contrast, the *Anisocyamus* Association of the Bromide Formation has species in common with both the two ostracod assemblages of the Lower Esbataotline Formation. For example, *Eurybolbina bispinata* (Pl. 1, Fig. 12) is common to the *Anisocyamus* Association of the Bromide Formation and Copeland’s (widespread shallow to deeper shelf marine) ostracod assemblage 1. *Eohollina depressa* (Pl. 1, Fig. 13) and *Platyrrhomboides quadratus* (Fig. 7j) are common to the *Anisocyamus* Association and Copeland’s (deeper shelf marine) ostracod assemblage 2.

Copeland (1982) compared the Bromide Formation ostracod faunas of Harris (1957) with his assemblage 2 ostracod fauna (deeper shelf marine); it seems that the equivalent of Copeland’s Lower Eshataotline Formation ostracod assemblages cannot be clearly differentiated in the Bromide Formation and may be represented in the geographically widespread *Anisocyamus* Association.

**CONCLUSIONS**

Analysis of the geographical and stratigraphical occurrences of ostracods in the Bromide Formation implies the following patterns of their distribution and lithofacies correlation:

1. Ostracod faunas of the Bromide Formation can be characterized in terms of two associations which can be correlated with the distribution of their associated lithofacies. In sequences where subtidally deposited sediments prevail (i.e. section 6) only the *Anisocyamus* Association is present. However, at localities where sediments deposited in both subtidal and marginal marine environments occur (i.e. section 1) both the *Anisocyamus* and *Leperditella* associations are present but are mutually exclusive, the *Anisocyamus* Association characterizing the subtidal and the *Leperditella* Association the marginal marine environments.

2. Ostracod faunas, like the *Leperditella* Association, rich in leperditiscopae and leperditellacean palaeocopes, are present in marginal marine lithofacies in the underlying Joints, Oil Creek and Melish formations of the Simpson Group in Oklahoma (Williams, 1990). Such ostracod taxonomic groups are also recorded from similar ecological settings in the Silurian (Siveter, 1984). Thus, certain Ordovician and Silurian ostracod faunas appear to be useful tools for predicting proximity to palaeoshoreline and, therefore, may be used as an aid in the reconstruction of palaeogeography.

3. The *Anisocyamus* and *Leperditella* associations are broad indicators of palaeoenvironment in the Bromide Formation, describing marginal marine and marine subtidal depositional environments respectively. Ostracod species from both associations, particularly the *Anisocyamus* Association, occur in other middle Ordovician N. American sequences such as the Edinburg and Lincolnshire formations of Virginia, USA and the Lower Ebsatatline Formation of the District of Mackenzie, Canada. As such these species may have more

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**Explanation of Plate 2**

Figs 1–15. *Anisocyamus* Association (partim; see also Pls 1, 3; Fig. 7). Palaeocopes: hollinaceans (Figs 1, 4), an eurychilinacean (Fig. 7), leperditellaceae (Figs 3, 5, 11, 13). Leiocopes: aparchitaceans (Figs 2, 6, 8, 10, 14). Eridostracans (Figs 9, 12, 15). All specimens from the Bromide Formation, Simpson Group, middle Ordovician, Oklahoma, USA. **Fig. 1.** *Diceranella bicornis* Ulrich, 1894. Tectomorphic right valve, lateral view, ×48; MCZ4623. From Decker’s Bed 22 (see Harris, 1957), section 1. **Fig. 2.** *Saccelata millepunctata* (Ulrich, 1892). Carapace, left valve lateral view, ×36; MCZ4507. From Decker’s Bed 2 (see Harris, 1957), section 6. **Fig. 3.** *Schmidellia minuta* Harris, 1957. Carapace, right valve lateral view, ×83; MCZ4543. From Decker’s Bed 36 (see Harris, 1957), section 1. **Fig. 4.** *Diceranella macrocarinata* Harris, 1931. Heteromorphic left valve, lateral view, ×38; MCZ4448. From Decker’s Bed 8, Highway 77 locality (see Harris, 1957), section 6. **Fig. 5.** *Schmidellia affinis* Ulrich, 1894 sensu Harris (1957). Carapace, right valve lateral view, ×46; MCZ4532. From Decker’s Bed 32, Highway 77 locality (see Harris, 1957), section 1. **Fig. 6.** *Baltonoella ovulis* Harris, 1957. Carapace, left valve lateral view, ×62; MCZ4545. From Decker’s Bed 35 (see Harris, 1957), section 1. **Fig. 7.** *Eurychilina ventrosa* Ulrich, 1894 sensu Harris (1957). Heteromorphic left valve, lateral view, ×29; MCZ4629. From Decker’s Bed 32 (see Harris, 1957), section 1. **Fig. 8.** *Baltonoella circularis* (Harris, 1957). Carapace, left valve lateral view, ×46; BMNH OS13564. From the Mountain Lake Member, section 1. **Fig. 9.** *Cryptophyllus gibbosum* Harris, 1957. Right valve lateral view, ×53; BMNH OS13574. From the Mountain Lake Member, section 1. **Fig. 10.** *Baltonoella parvispinosa* (Kratis, 1962). Juvenile carapace, left valve lateral view, ×45; BMNH OS13567. From the Pooleville Member, section 6. **Fig. 11.** *Kayina hylosa* Harris, 1957. Carapace, right valve lateral view, ×52; MCZ4530a. From Decker’s Bed 36 (see Harris, 1957), section 1. **Fig. 12.** *Eridocochena simpsoni* Harris, 1931. Left valve lateral view, ×66; BMNH OS13477. From the Mountain Lake Member, section 2. **Fig. 13.** *Schmidellia transversa* Harris, 1957. Carapace, right valve lateral view, ×78; MCZ4547. From Decker’s Bed 34 (see Harris, 1957), section 1. **Fig. 14.** *Hyperchilarina nodosimarginata* Harris, 1957. Carapace; left valve lateral view, ×54; BMNH OS13562. From the Mountain Lake Member, section 6. **Fig. 15.** *Cryptophyllus nucalopsis* Harris, 1957. Carapace, left valve lateral view, ×74; MCZ4568. From Decker’s Bed 31, Highway 77 locality (see Harris, 1957).
Fig. 7. (c, e, f, j) *Anisocycamus* Association (paris. see also Pls 1–3). Palaeocopaces: leperditellaceans (c, f) and a palaeocopae (e). Podocopids (j), (a, b, d, g, h, i) *Lepidirilla* Association. Palaeocopaces: an eurychilinacean (a), a hollinacean? (b), leperditellaceans (d, g, h) and a monotopioplid? (i). All specimens from the Bromide Formation, Simpson Group, middle Ordovician, Oklahoma, USA. (a) ‘Coelochilina’ alata Harris, 1957. Carapace, left valve lateral view, ×1.45; BMNH OS13635. From the Pooleville Member, section 1. (b) ‘Ctenobolbina’ abrupta Harris, 1957. Tecomorphic right valve, lateral view, ×62; BMNH OS13533. From the Pooleville Member, section 1. (c) *Lomatopisthia* simplex (Harris, 1957). Teconomorphic left valve, lateral view, ×87; MCZ4641b. From Decker’s bed 36 (see Harris, 1957), section 1. (d) *Lepidirilla* tumula Ulrich, 1892. Carapace, right valve lateral view, ×28; MCZ4529. From Decker’s bed 4 (see Harris, 1957), section 1. (e) *Ectoprimoioideus* moorei (Harris, 1957). Carapace, left valve lateral view, ×71; BMNH OS13630. From the Mountain Lake Member, section 1. (f) *Lomatopisthia* auricata (Harris, 1957). Left valve lateral view, ×68; BMNH OS13611. From the Mountain Lake Member, section 5. (g) *Lepidirilla* rex Coryell & Schenck, 1941. Carapace, right valve lateral view, ×65; MCZ4526. From Decker’s bed 4 (see Harris, 1957), section 1. (h) *Lepidirilla* jonesioides Harris, 1957. Heteromorphic right valve, lateral view, ×39; BMNH OS13596. From the Pooleville Member, section 1. (i) *Ningiella* sp. Carapace, right valve lateral view, ×59; BMNH OS13555. From the Pooleville Member, section 1. (j) *Platyhomboides quadratus* Harris, 1957. Carapace, dorsal view, ×62; BMNH OS13632. From the Pooleville Member, section 6.

**Explanation of Plate 3**

Figs 1-15. *Anisocycamus* Association (paris. see also Pls 1, 2; Fig. 7). Binoculaces (Figs 1, 4). Podocopids (Figs 2, 3, 5, 6, 8, 11, 14). Palaeocopaces: leperditellaceans (Figs 7, 10, 13), monotopiopids (Figs 9, 12) and a lomatopisthid (Fig. 15). All specimens from the Bromide Formation, Simpson Group, middle Ordovician, Oklahoma, USA. Fig. 1. Gen. n. A, sp. n. A. Right valve lateral view, ×71; BMNH OS13635. From the Mountain Lake Member, section 1. Fig. 2. *Batlicella* deckeri (Harris, 1931). Carapace, right valve lateral view, ×39; MCZ4636. From Decker’s bed 36 (see Harris, 1957), section 1. Fig. 3. *Punctiparichites* rugosus (Jones, 1858). Carapace, right valve lateral view, ×64; BMNH OS13634. From the Pooleville Member, section 6. Fig. 4. *Lomatopisthia* quadrate (Harris, 1957). Right valve lateral view, ×90; MCZ4586. From Decker’s bed 3 (see Harris, 1957), section 6. Fig. 5. *Kraussella* arcuata Ulrich, 1894. Carapace, left valve lateral view, ×33; BMNH OS13619. From the Pooleville Member, section 6. Fig. 6. ‘*Eoeprimita* baileyana’ (Jones & Holl) sensu Harris (1957). Carapace, right valve? lateral view, ×72; MCZ4649. From Decker’s bed 3 (see Harris, 1957), section 6. Fig. 7. *Schmidia* crusigenarju Harris, 1957. Left valve lateral view, ×48; BMNH OS13694. From the Mountain Lake Member, section 1. Fig. 8. *Kraussella* spinosa (Harris, 1957). Carapace, right valve lateral view, ×58; MCZ4652. From Decker’s bed 2 (see Harris, 1957), section 6. Fig. 9. *Pruvetoioidea* minimaria (Harris, 1957). Carapace, right valve lateral view, ×62; MCZ4527. From Decker’s bed 24 (see Harris, 1957), section 1. Fig. 10. ‘*Schmidia*’ extumata Harris, 1957. Right valve lateral view, ×69; MCZ4541. Bromide Formation, Mill Creek locality (see Harris, 1957; Williams, 1990). Fig. 11. *Kraussella* calbini (Kay, 1940). Carapace, right valve lateral view, ×36; MCZ4645. From Decker’s bed 26 (see Harris, 1957), section 1. Fig. 12. *Karunatelia* ? sp. Right valve lateral view, ×68; BMNH OS13597. From the Pooleville Member, section 6. Fig. 13. *Schmidia* asymmetry Harris, 1957. Carapace, right valve lateral view, ×39; MCZ4533. From Decker’s bed 31, Highway 77 locality (see Harris, 1957). Fig. 14. *Monocerealla* brevispinum Harris, 1957. Right valve lateral view, ×39; MCZ4638. From Decker’s bed 36 (see Harris, 1957), section 1. Fig. 15. *Lomatopisthia* auricula (Harris, 1957). Teconomorphic right valve, lateral view, ×93; BMNH OS13493. From the Mountain Lake Member, section 1.
Increasing diversity of benthic ostracod faunas

Leperditella Association; low diversity leperditidoo and leperditellacean dominated benthic ostracod fauna

Open shelf marine

Anisocyamus Association; high diversity palaeocope and leiocepe dominated benthic ostracod fauna.

Repositories for specimens figured in Plates 1-3 and Fig. 7 are: MCZ, Museum of Comparative Zoology, Harvard University; USA: USNM, United States National Museum, Washington DC, USA: BMNH, Natural History Museum, London, UK.

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Note added in proof: Since submission of this paper, Lundin et al. (1995: Journal of Paleontology, 69: 886-896) have referred 'Schmidella' asymmetrica Harris, 1957 to their new genus Loculocavata.

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Table 1. Species occurrence in the six studied sections through the Bromide Formation.

Open rectangles represent ostracods of the Anisocyamus Association (marine subtidal environments), black rectangles those of the Leperditella Association (marginal marine environments).
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