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RESEARCH ARTICLE

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Late Devonian benthic ostracods from western Junggar, NW China: Implications for palaeoenvironmental reconstruction

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This study focuses on the palaeoecology of the Late Devonian ostracods based on more than 4,500 carapaces and valves collected from stratal sections in western Junggar, NW China. According to the ostracod faunas from the Hongguleleng Formation, 3 ecological assemblages are proposed for open oceanic island arc context, that is, Ostracod Assemblage-1, Ostracod Assemblage-2, and Ostracod Assemblage-3. They characterize the foreshore, nearshore, and offshore environments, respectively. The water energy should be the first environmental factor controlling the composition of the ostracod assemblages from the Lower Member of the Hongguleleng Formation, and salinity fluctuations could be also involved.

KEYWORDS

Devonian, Hongguleleng Formation, ostracod, palaeoecology, western Junggar

1 | INTRODUCTION

Ostracoda are microcrustacea that first appeared in the Early Ordovician and are still developed today (Horne, Cohen, & Martens, 2002; Siveter, 2008). They are very sensitive to the ambient environment conditions and variations, such as salinity, bathymetry, temperature, hydrodynamics, oxygenation, and nutrients (Casier & Olempska, 2008; Jones, 2011; Maillet et al., 2013; Olempska & Belka, 2010; Racheboeuf et al., 2012). Ostracods may offer special insights into the characteristics and evolution of the Devonian global bioenvironmental events (Becker & Braun, 2008; Lethiers & Raymond, 1991; Song & Gong, 2017).

Until recently, most studies on the palaeoecology of Devonian ostracods have been conducted in the continental margins or epicontinental basin context, primarily in Europe and North America (e.g., Bandel & Becker, 1975; Becker, 1964, 1965, 1971, 2000; Becker & Bless, 1987; Casier, 2004, 2008, 2017; Maillet et al., 2013), as well as in South China (Wang, 1988, 2009). Casier (1987, 2004, 2008) proposed a novel ostracod assemblage denomination, that is, Eifelian Mega-Assemblage (=Assemblages 0-III), Thüringian Mega-Assemblage (=Assemblage IV), and Myodocopid Mega-Assemblage (=Assemblage V), which correspond to an environmental gradient from the nearshore to the deep basins. Similarly, five ostracod associations were recognized in the Palaeozoic strata of South China (Wang, 1988, 2009), that is, the leperditiid, palaeocopid, smooth-podocopid, spinose-podocopid, and entomozoacean associations. However, the palaeoecology of ostracods in the open oceanic setting far from continent-derived sediments remains poorly known. In this paper, all the samples of ostracods were collected from western Junggar, NW China, which was featured by the archipelgic context during the Palaeozoic (Gong & Zong, 2015). Studies of sedimentary petrology and trace element geochemistry indicate that the Late Devonian Hongguleleng Formation was deposited with intermittent periods of volcanic activities (Carmichael et al., 2016; Carmichael, Waters, Suttner, Kido, & DeReuil, 2014; Fan & Gong, 2016).

Therefore, the main aims of this study is to assess the influences of palaeoenvironmental changes in the open oceanic island arc context on the distribution and composition of the ostracod assemblage and to discuss the main factors controlling the distribution of ostracods in the Hongguleleng Formation.

2 | GEOLOGICAL SETTING AND SECTION DESCRIPTIONS

The western Junggar region is located in the north-west of Xinjiang Uygur Autonomous Region (referred to as Xinjiang), NW China (Figure 1), where the Kazakhstan, Siberia, and Tarim plates join. Western Junggar region is an important component of the Central Asian Orogenic Belt during the Palaeozoic (Cocks & Torsvik, 2007; Gong & Zong, 2015; Windley, Alexeiev, Xiao, Kröner, & Badarch, 2007). The western Junggar was located in a volcanic arc setting during the middle Palaeozoic (Xiao, Huang, Han, Sun, & Li, 2010), with widespread Palaeozoic sedimentary rocks and various types of volcanic rocks (Figure 1). The Late Devonian Hongguleleng Formation now cropping out in the Shaerbuerti Mountains was deposited in the back-arc basin of the Zharma–Saur arc (Figure 1), which yield abundant and diversified faunas and floras (e.g., brachiopods, bryozoans, conodonts, trilobites, and plants; Chen et al., 2009; Suttner et al., 2014; Wang et al., 2016; Windley et al., 2007; Xia, 1996; Xu, Cai, Liao, & Lu, 1990; Zong, Fan, & Gong, 2016) as well as trace fossils (Fan & Gong, 2016).

Field works were carried out in four sections, namely, the Wulankeshun, Bulongour, Gennaren, and Emuha sections (Figure 2a). The Late Devonian Hongguleleng Formation crops out well with abundant fossils in the first three sections, which have similar lithological and sedimentological features, especially for the Wulankeshun and Bulongour sections (Figure 2). Unfortunately, most of the Upper Devonian is missing in the Emuha section (Song & Gong, 2015). Therefore, this paper focused on the ostracods collected from the Wulankeshun and Bulongour sections, and the systematic palaeontology of ostracods in these two sections has been published (Song, Crasquin, & Gong, 2017).

The Wulankeshun section (46°46′05.12″N; 84°54′43.98″E, hereinafter referred as WLS; Figures 1, 2) is located approximately 65 km west of Hebukesar Mongol Autonomous County. It exhibits a continuous outcrop from the Late Devonian to the Early Carboniferous (Wang, Zong, Gong, & Wang, 2015): series of the Zhulumute, Hongguleleng to Heishantou formations without major tectonic deformation (Figure 2). The Hongguleleng Formation (372.4 m thick) could be divided into three members: the lower member is made of grey, grey-yellow bioclastic limestones; the middle member consists of variegated fine-grained volcaniclastic rocks; and the upper member is composed of grey-green, grey-yellow bioclastic limestones and calcareous-pelitic clastic rocks (Figure 2).

The Bulongour section (46°45′10.26″N; 86°08′20.70″E, hereinafter referred as BLS; Figures 1, 2) is located in the north of Hoxtolgay, about 1.5 km north-west of the Bulongour Reservoir, and about 90 km east to the WLS. It is the stratotype of the Hongguleleng Formation and has been extensively studied (e.g., Chen et al., 2009; Suttner et al., 2014; Xu et al., 1990). In this study, the sampling is focused on the lower member of the Hongguleleng Formation in both sections for the well-preserved ostracod fossils found in the limestones.

Detailed conodont biostratigraphy (Wang et al., 2016), conondont biofacies, and microfacies (Wang, 2016), and sedimentology (Fan & Gong, 2016) of the Hongguleleng Formation are now available. In this paper, the palaeoenvironments of the lower member of the Hongguleleng Formation are adapted from Fan and Gong (2016) and Wang (2016). In summary, three palaeoenvironments could be

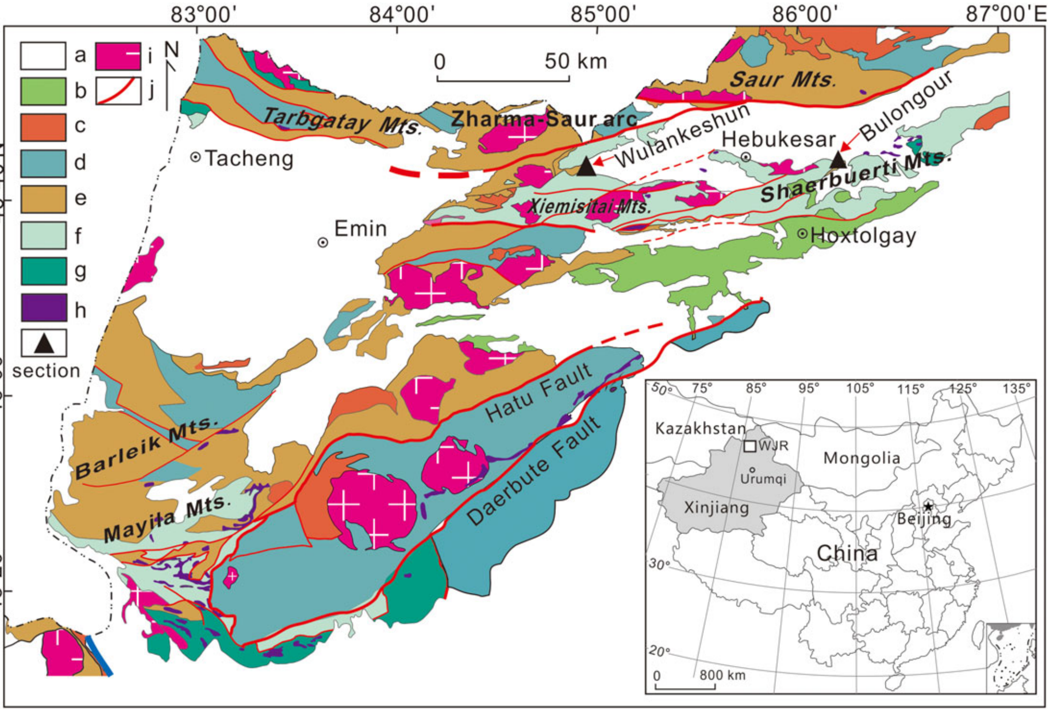


FIGURE 1 Location map of the studied sections and simplified geology of western Junggar, NW China (modified after Gong & Zong, 2015). (a) Quaternary; (b) Mesozoic; (c) Permian; (d) Carboniferous; (e) Devonian; (f) Silurian; (g) Ordovician; (h) Ophiolites; (i) Granites; (j) Faults [Colour figure can be viewed at wileyonlinelibrary.com]

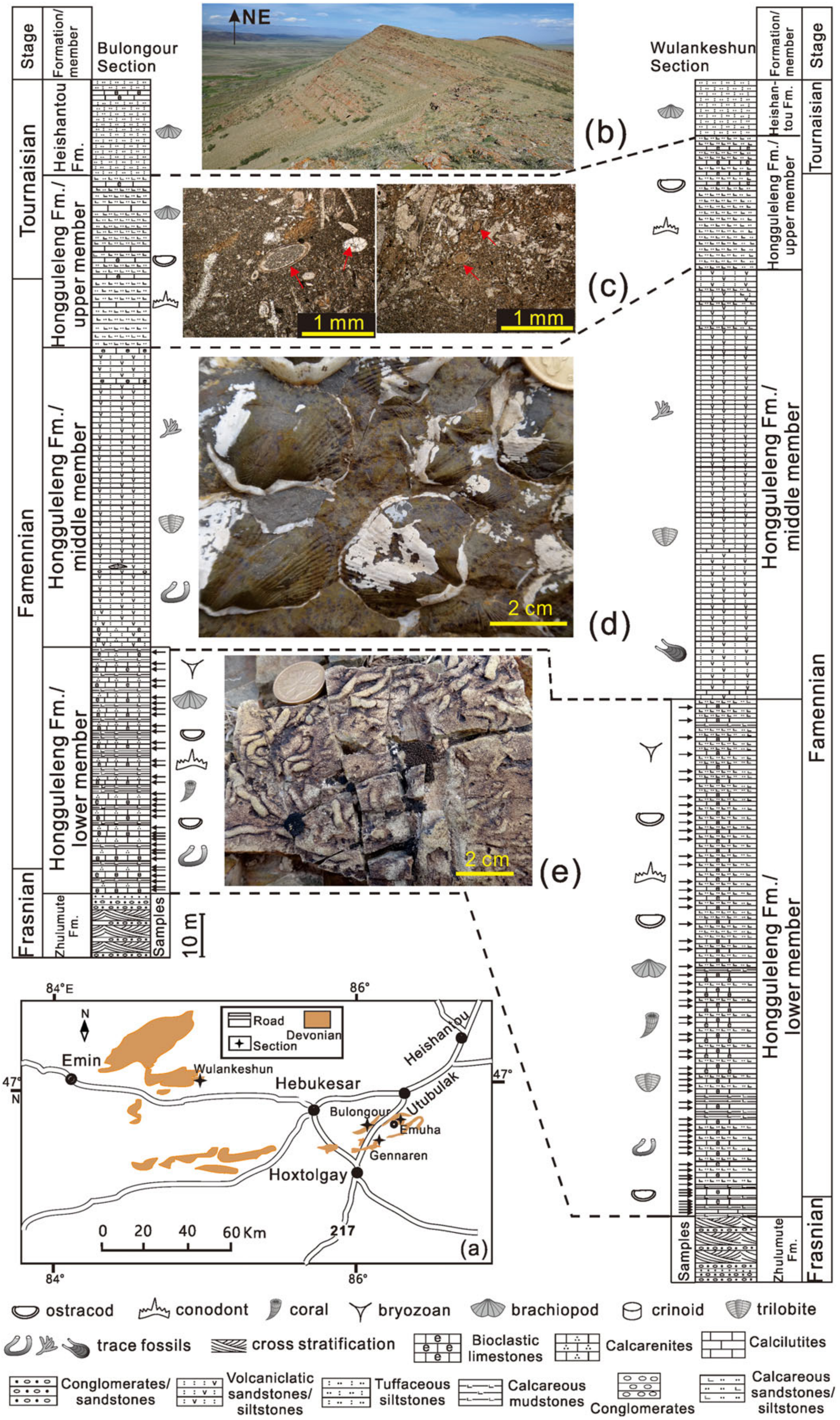


FIGURE 2 Correlations between the Wulankeshun and Bulongour sections in western Junggar, NW China (modified after Song et al., 2017). (a) Locations of the sections; (b) view of the lower member of the Hongguleleng Formation in the WLS; (c) thin sections of packstone showing ostracods (red arrows) from the Hongguleleng Formation in the BLS; (d) brachiopods in the lower member of the Hongguleleng Formation in the WLS; (e) ?*Planolites* isp. in the upper member of the Hongguleleng Formation in the WLS. WLS = Wulankeshun section; BLS = Bulongour section [Colour figure can be viewed at wileyonlinelibrary.com]

recognized from the bottom to top in the lower member of the Hongguleleng Formation, that is, foreshore (bed 18 of WLS and bed 1A of BLS), nearshore (bed 19 and beds 22–23 of WLS, bed 1B and bed 3 of BLS), and offshore (beds 20–21 of WLS and bed 2 of BLS).

3 | MATERIALS

Two hundred and thirteen samples were collected from the Wulankeshun, Bulongour, and Gennaren sections from 2011 to 2016. More than 4,500 carapaces and valves of ostracods were extracted from limestones by hot acetolysis (Crasquin-Soleau, Vaslet, & Le Nindre, 2005; Lethiers & Crasquin-Soleau, 1988). Among them, about 2,500 and 1,900 specimens were obtained from the BLS and WLS, respectively. In total, 53 species belonging to 31 genera were recognized (45 species belonging to 29 genera from the BLS and 49 species belonging to 28 genera from the WLS) (Song et al., 2017). The ostracod faunas from the lower member of the Hongguleleng Formation are dominated by Metacopina (i.e., Bairdiocypridoidea, Healdioidea, and Quasillitoidea), Podocopida (i.e., Bairdioidea), Palaeocopida (e.g., Hollinoidea, Primitiopsoidea, and Paraparchitoidea), Platycopida (Kloedenelloidea), and Myodocopida (Entomozoidea; Song et al., 2017; Table 1). The taxonomic classification of Liebau (2005) was used in the paper.

4 | ECOLOGY OF OSTRACOD ASSEMBLAGES FROM THE HONGGULELENG FORMATION

4.1 | Ecological assemblages of ostracods

The ostracod assemblages from the lower member of the Hongguleleng Formation vary with the sedimentary environments, and three ecological assemblages of ostracods can be defined as follows (Figures 3, 4).

Ostracod Assemblage-1 (OA1) is found in foreshore deposits (Figure 4), featuring ostracods from the bed 18 of the WLS and the bed 1A of the BLS. This ostracod fauna is moderately diversified (i.e., 18 species in the WLS and 15 species in the BLS), mostly occurring in low abundances. The assemblage is dominated by Hollinidea Swartz, 1936, including two families, Hollinidae and Pribylitidae. Specifically, the Palaeocopida, that is, Hollinoidea (*Hollinella* Coryell, 1928, *Parabolbinella* Adamczak, 1968, *Pribylites* Pokorný, 1951), Paraparchitidae (*Guerichiella* Adamczak, 1968), Primitiopsidae (*Paraparchites* Ulrich and Bassler, 1906, *Samarella* Polenova, 1952), Amphissitidae (*Amphissites* Girty, 1910), Youngiellidae (*Moorites* Coryell and Billings, 1932), and Cryptophyllidae (*Cryptophyllus* Levinson, 1951) show a significant advantage in OA1 and represent more than 50% and 70% of the total number of species in the WLS and BLS, respectively. Among them, the first five families/superfamilies occur in the two sections, whereas the Crytophyllidae only appeared in the BLS. In addition to the dominant superfamily Hollinoidea (about 25% and 32% of total number of species in the WLS and BLS, respectively), the Paraparchitidae shows a relatively high abundance and diversity (about 15% of total number of species). The Metacopina accounts for 30–40% of the total number of species (WLS: 33%; BLS: 37%), which is mainly made up of Healdioidae (i.e., *Arcuaria* Neckaja, 1958, *Cribroconcha* Cooper, 1941; about 13% of the total number of species) and a few Bairdiocyprididae (*Praepilatina* Polenova, 1970) and Pachydomellidae (*Microcheilinella* Geis, 1933). Moreover, rare platycopids (Kloedenelloidea) of OA1 only found in the bed 18 of the WLS, account for 8% of the total number of species. Notably, Bairdioidea is not present in OA1. The endemic taxa (Song et al., 2017; e.g., *Pribylites wulankeshunensis* Song and Crasquin, 2017, *Pribylites junggarensis* Song and Crasquin, 2017, *Microcheilinella hoxtolgayensis* Song and Crasquin, 2017, *Microchelinella bulongourensis* Song and Crasquin, 2017, *Arcuaria hebukesarensis* Song and Crasquin, 2017, and *Cribroconcha honggulelengensis* Song and Crasquin, 2017) are common and abundant in OA1.

Morphologically, Palaeocopida are characterized by the straight dorsal border. They could survive in high-energy environments as crawlers with small sizes and thick carapaces (Wang, 1988). Similarly, some genera of Metacopina (such as *Praepilatina* Polenova, 1970 and *Microcheilinella* Geis, 1933) are also essentially benthic crawlers with small sizes (length of carapaces is less than 0.95 mm; Becker, 1971) and thick shells.

On the whole, OA1 dominated by Palaeocopida and without any Bairdioidea is similar to the "Eifelian Mega-Assemblage-I" from Europe

TABLE 1 Numbers of species per bed in the Bulongour and Wulankeshun sections (summarized from Song et al., 2017)

Order	Superfamily/ Family	Bulongour			Wulankeshun					
		Bed 1	Bed 2	Bed 3	Bed 18	Bed 19	Bed 20	Bed 21	Bed 22	Bed 23
Palaeocopida	Beyrichioidea	0	0	1	0	0	0	0	0	0
	Hollinoidea	5	4	2	4	6	4	5	3	3
	Primitiopsoidea	1	1	1	1	1	1	1	1	1
	Kirkbyoidea	0	1	1	1	1	0	1	0	0
	Cryptophyllidae	1	0	0	0	0	0	0	0	0
	Paraparchitoidea	2	2	2	3	2	1	1	1	0
	Youngielloidea	1	1	1	0	1	1	1	1	1
Platycopida	Kloedenelloidea	3	4	2	2	2	3	3	2	0
Podocopida	Bairdioidea	1	11	5	1	10	10	8	6	4
Metacopina	Bairdiocypridoidea	3	7	10	1	8	8	9	7	4
	Quasillitoidea	0	0	1	1	0	0	0	0	0
	Healdioidea	2	4	3	2	3	4	3	2	2
Myodocopida	Entomozoidea	0	1	0	0	0	1	1	0	0

and North America (e.g., Bandel & Becker, 1975; Becker, 1971, 2000; Casier, 2004, 2008, 2017) and the "Palaeocopid association" from South China (Wang, 1988, 2009; Figure 5). However, compared with the two ostracod assemblages above, most taxa in OA1 are smooth small-sized, and the dominant and common taxa are different. For example, beyrichiids, cavellinids, and leperditiids, which are common and abundant in both Eifelian Mega-Assemblage and Palaeocopida association, whereas are absent in OA1.

Ostracod Assemblage-2 (OA2) is located in the nearshore (Figures 3, 4), characterized by ostracods from the bed 19 and beds 22–23 of the WLS and the bed 1B and bed 3 of the BLS. The assemblage is dominated by Bairdiocypridoidea, including two families, that is, Bairdiocyprididae and Pachydomellidae. The diversity and abundance of ostracods in OA2 are higher than that in OA1, and 27 species and 29 species are present in the WLS and the BLS, respectively. Bairdiocypridoidea (*Bairdiocypris* Kegel, 1932, *Healdiacypris* Bradfield, 1935, *Praepilatina* Polenova, 1970, and *Pseudobythocypris* Shaver, 1958) and Bairdioidea (*Bairdia* McCoy, 1844, *Fabalicypris* Cooper, 1946, and *Acratia* Delo, 1930) are about 35% and 25% of the total number of species, respectively. Palaeocopida (20–25% of the total number of species) is dominated by Hollinoidea (*Pribylites* Pokorný, 1951) and Paraparchitidae (*Guerichiella* Adamczak, 1968) but with lower abundance and diversity. Platycopida (i.e., Kloedenelloidea, about 20% of total number of species) is more abundant in OA2 than in OA1.

Although the smooth-podocopids dominate OA2, the percentage of Bairdioidea (about 40% of podocopid species) is much lower than that in "smooth-podocopid association" from South China (Wang, 1988; Figure 5), which is 80–90% of the total number of podocopids species. Moreover, the dominating taxa of OA2, some genera of Bairdiocyprididae, for example, *Praepilatina* Polenova, 1970 and *Pseudobythocypris* Shaver, 1958, show more frequent occurrences in deep water along with the "spinose-podocopids association" in South China (Wang, 1988), as well as the Thüringian Mega-Assemblage in Europe and North America (Becker, 2000; Casier, 2004) than in the shallow-water environment as the lower member of the Hongguleleng Formation.

Ostracod Assemblage-3 (OA3) is distributed in the offshore environment (Figures 3, 4), marked by ostracods from the beds 20–21 of the WLS and the bed 2 of the BLS. The ostracods of OA3 are highly diversified and abundant in both two sections, especially the WLS, where 43 species belonging to 26 genera have been recognized. The ostracod faunas of OA3 are dominated by the smooth Podocopida and Metacopina (about 60–65% of the total number of species), including Bairdioidea (*Bairdia* McCoy, 1844, *Fabalicypris* Cooper, 1946, *Acratia* Delo, 1930, and *Famenella* Polenova, 1953),

Wulankeshun Beds	Wulankeshun Conodont Biofacies	Micro-facies	Trace fossils	Sedimentary structures	Ostracod Assemblage	Sedimentary environments	Bulongour Beds
23	polygnathid biofacies	mf2/mf5	*Rhizocorallium commune*	symmetric ripples/ hummocky cross stratification	OA2	nearshore	3
22			? *Rhizocorallium commune*				
21	icriodid-polygnathid-ancyrognathid biofacies	mf3/mf4/mf6	?*Phymatoderma* isp.	lenticular bedding	OA3	offshore	2
20			*Nereites missouriensis*	local high bioturbation			
19	icriodid-polygnathid biofacies	mf5/mf6	*Nereites missouriensis*	hummocky cross stratification/ flaser bedding	OA2	nearshore	1B
18	icriodid biofacies	mf1/mf2		tidal bundle	OA1	foreshore	1A

FIGURE 3 Distribution of sedimentary environments and ostracod assemblages from the lower member of the Hongguleleng Formation in the WLS and BLS, western Junggar, NW China. Conodont biofacies are adapted from Wang (2016); trace fossils are adapted from Fan and Gong (2016); microfacies types (mf1-6) modified after Wang (2016), mf1-mudstone with fine-grained bioclasts; mf2-wackestone-packstone with fine-grained bioclasts; mf3-mudstone-wackestone with fine-grained bioclasts; mf4-wackestone with fine-grained bioclasts; mf5-packstone with bioclasts; e. mf6-grainstone with coarse-grained bioclasts

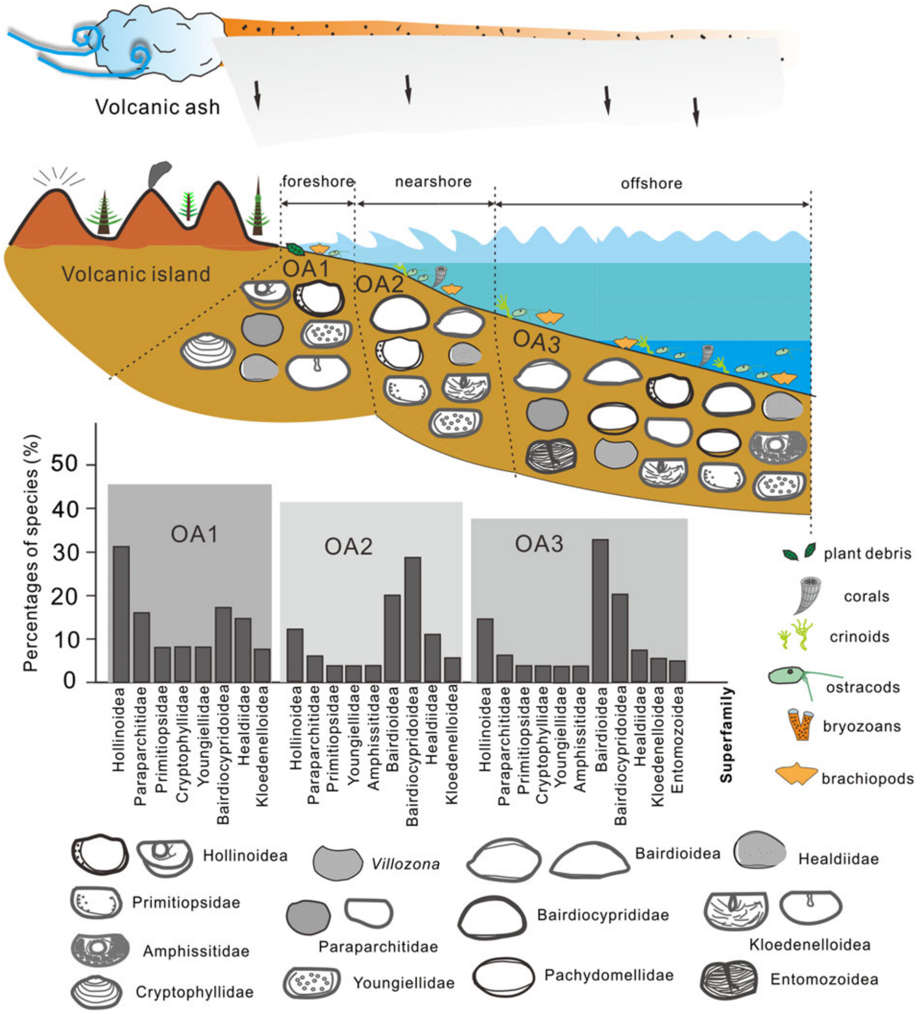
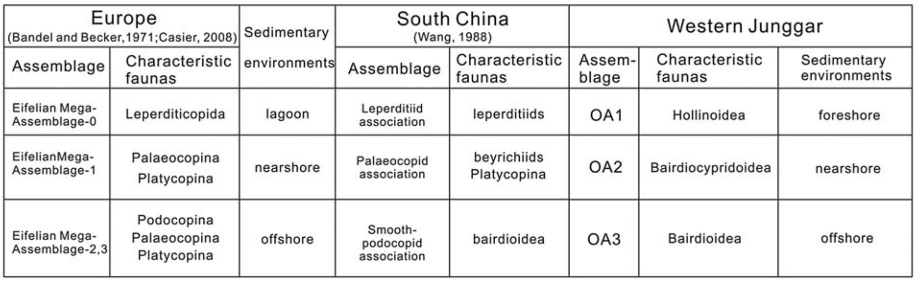


FIGURE 4 Palaeoenvironments and ostracod assemblages from the lower member of the Hongguleleng Formation, western Junggar, NW China [Colour figure can be viewed at wileyonlinelibrary.com]



Europe (Bandel and Becker,1971;Casier, 2008)		Sedimentary environments	South China (Wang, 1988)		Western Junggar		
Assemblage	Characteristic faunas		Assemblage	Characteristic faunas	Assem-blage	Characteristic faunas	Sedimentary environments
Eifelian Mega-Assemblage-0	Leperditicopida	lagoon	Leperditiid association	leperditiids	OA1	Hollinoidea	foreshore
EifelianMega-Assemblage-1	Palaeocopina Platycopina	nearshore	Palaeocopid association	beyrichiids Platycopina	OA2	Bairdiocypridoidea	nearshore
Eifelian Mega-Assemblage-2,3	Podocopina Palaeocopina Platycopina	offshore	Smooth-podocopid association	bairdioidea	OA3	Bairdioidea	offshore

FIGURE 5 Comparison of the ecological assemblages of neritic ostracods in the Palaeozoic from western Junggar, Europe, and South China

Bairdiocyprididae (*Bairdiocypris* Kegel, 1932, *Healdiacypris* Bradfield, 1935, *Praepilatina* Polenova, 1970, and *Pseudobythocypris* Shaver, 1958), and Healdioidae (*Bairdiocypris* Kegel, 1932, *Praepilatina* Polenova, 1970, and *Pseudobythocypris* Shaver, 1958) with high diversity and abundance, as well as a few Bufinidae (i.e., *Aurigerites* Roundy, 1926). Among them, Bairdioidea is presented in large numbers occupying more than 60% of the total number of podocopids specimens. Compared with OA2, Bairdioidea is more abundant in OA3, whereas Bairdiocypridoidea is lower in abundance in OA3. Palaeocopida makes up about 30% of the total number of species, which consists of Hollinoidea, Paraparchitidae, Primitiopsidae, Amphissitidae, Cryptophyllidae, and Youngiellidae. Hollinoidea is still dominating in the Palaeocopida of OA3 as in OA1 and includes four genera (*Hollinella* Coryell, 1928, *Parabolbinella* Adamczak, 1968, *Pribylites* Pokorný, 1951, and *Parasargentina* Zheng, 1982). Platycopida (including 3 genera, *Sargentina* Coryell et Johnson, 1939, *Quasiknoxiella* Tschigova, 1977, and *Knoxiella* Egorov, 1950) and Myodocopida are relatively rare in OA3, accounting for 5–10% and 5% of total number of species, respectively.

Overall, the OA3 are characterized by Bairdioidea and Bairdiocyprididae with large sizes (length of carapaces is more than 1.40 mm; Becker, 1971) and smooth shells, suggesting a benthic lifestyle. This assemblage resembles somewhat the "Eifelian Mega-Assemblage- II and III" (Casier, 2004, 2008, 2017) and the "smooth-podocopid association" (Wang, 1988, 2009; Figure 5). Nevertheless, what is noticeable is that some Entomozoidea were realized with relatively high abundance in OA3 from both the WLS and BLS, though by only one species (*Franklinella latesulcata* [Paeckelmann, 1921; Figure 6]). Moreover, more species of Entomozoidea (two species belonging to two genera; Figure 6) were discovered in relatively high abundance from the same offshore environment in the Gennaren section, which is not far away from the BLS. Previous studies have indicated that entomozoaceans (pelagic "finger-print" ostracods) prefer swimming in low-energy deeper waters (Bandel & Becker, 1975; Becker & Bless, 1987; Casier, 2004, 2008, 2017; Casier, Kasimi, & Préat, 1995; Lethiers & Casier, 1995; Olempska, 2002; Wang, 1988), the presence of which indicates deep-water basinal environments in general (Wang, 1988). As for biocoenoses, mixtures between the Eifelian and the Entomozoacean assemblages had been observed rarely in Europe or South China (Becker & Bless, 1990). *Villozona* Gründel, 1965 appeared in OA3 from the WLS (Figure 6), which was only known from basinal environments (Thuringia, Morocco, South China) previously (Becker, 2000; Gründel, 1965), and has never been reported in the shallow-marine environment yet. There are two possibilities for such an uncommon mixture of deep-water elements in the shallow-marine deposits. One is that some species of Entomozoidea and *Villozona* might be able to expand to the shallow waters from the slope or deep basinal environment under a particular environment such as the rapid changing water. The other explanation is that the complicated back-arc basin environment with narrow shelfs and steep slopes may offer the opportunity for the deep-water ostracods to disperse to the shallow waters. In this study, we are inclined to the second hypothesis on the basis of the sedimentary features and the general geological setting (Gong & Zong, 2015; Wang, 2016). Actually, the uncommon mixture of deep- and shallow-water ostracods reflect that the ecology of ostracods is more flexible and complicated in the open oceanic island arc context than that from the continental margins.

In general, the common species in the three ostracod assemblages are *Guerichiella* cf. *pulchra*, *Moorites copelandi*, and most of the endemic taxa (e.g., *Pribylites wulankeshunensis*, *Pribylites junggarensis*, *Arcuaria hebukesarensis*, *Cribroconcha honggulelengensis*, and *Microcheilinella hoxtolgayensis*; Figure 6). All of them are thick-shelled, small-sized,

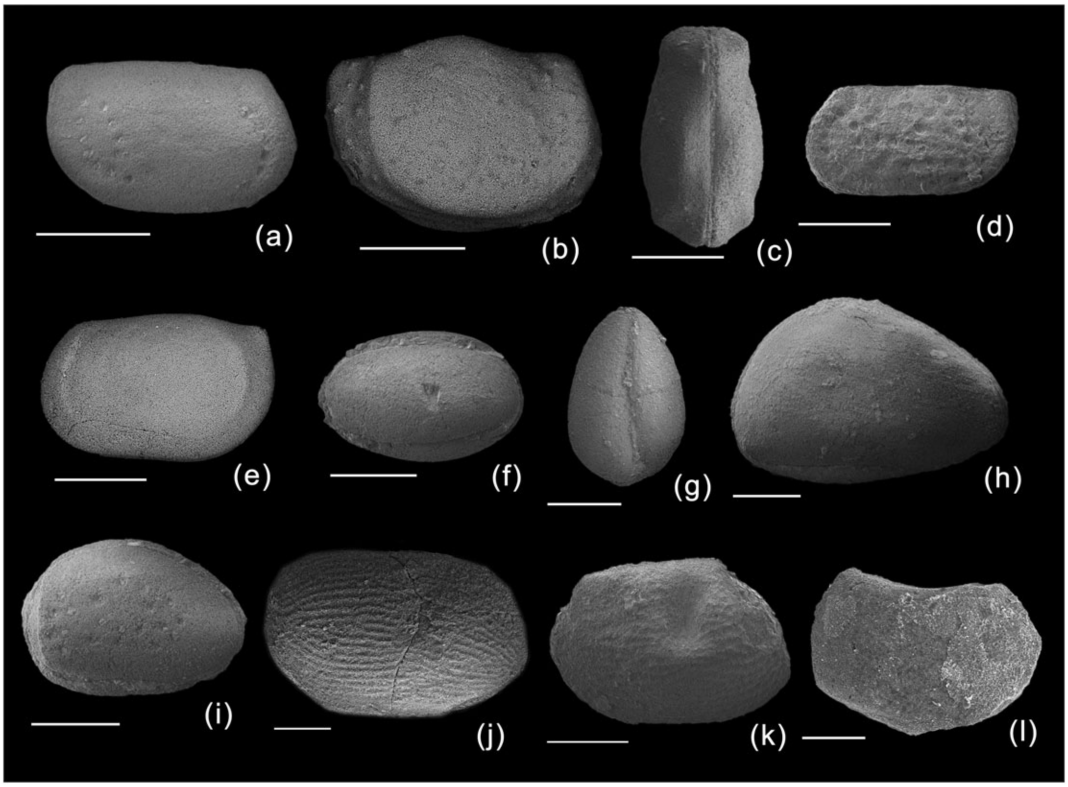


FIGURE 6 Common species of ostracods from the Upper Devonian Honggulelеng Formation of western Junggar, NW China (Song et al., 2017). (a) *Guerichiella* cf. *pulchra* Wei, 1988. Right lateral view of complete carapace, WZ15007. (b,c) *Pribylites wulankeshunensis* Song and Crasquin, 2017. Right lateral view and dorsal view of complete carapace, respectively, WZ15008. (d) *Moorites copelandi* Lethiers, 1981. Right lateral view of complete carapace, WZ15018. (e) *Pribylites junggarensis* Song and Crasquin, 2017. Right lateral view of complete carapace, WZ15011. (f,g) *Microcheilinella hoxtolgayensis* Song and Crasquin, 2017. (f) Right lateral view of complete carapace, WZ15050; (g) dorsal view of complete carapace, WZ15052. (h) *Arcuaria hebukesarensis* Song and Crasquin, 2017. Right lateral view of complete carapace, WZ15056. (i) *Cribroconcha honggulelengensis* Song and Crasquin, 2017. Right lateral view of complete carapace, WZ15059. (j) *Nehdentomis schmidti* Matern, 1929. Right lateral view of complete carapace, GN2015003. (k) *Franklinella latesulcata* (Paeckelmann),1921. External view of right valve, WZ15073. (l) *Villozona* sp. left lateral view of complete carapace, WZ15015. Scale bars represent 200 μm

and smooth or simply-ornamented (e.g., *Guerichiella* cf. *pulchra*, *Moorites copelandi*, and *Pribylites wulankeshunensis*), suggesting benthic crawlers or burrowers that survived in high-energy and great turbulence waters, which conform to the interpretation that the lower member of the Hongguleleng Formation was strongly affected by storms during deposition (Fan & Gong, 2016).

4.2 | Main factors controlling the distribution of ostracods from the Hongguleleng Formation

Becker (1969, 1971) considered various ecological parameters such as water salinity, temperature, depth, turbulence, oxygen content, and food supply in analysing the ostracod distribution in the Middle Devonian of the Eifel Region, Germany and concluded that the water turbulence was the most important factor controlling the distribution of ostracods. After Becker (1969, 1971), some works (e.g., Becker & Bless, 1990; Olempska, 1979) have shown that both the diversity and frequency of Devonian ostracods would increase when the water turbulence and turbidity decrease, especially for the large-sized smooth carapaces such as *Bairdia*. In most cases, increased turbidity would favour the survival of deposit-feeding ostracods, which mainly consist of Podocopida (e.g., Bairdiocypridoidea and Bairdioidea; Lethiers & Whatley, 1994) and a few of Palaeocopida (i.e., Beyrichioidea and Paraparchitoidea; Olempska, 2008), because they could catch coarser particles easily by their developed limbs (Horne, Brandão, & Slipper, 2011).

The storm-influenced depositional environment of the lower member of the Hongguleleng Formation should be habitable with adequate oxygen, abundant food supply, and suitable temperatures for sustaining rich and diversified shallow-marine (benthic) faunas (Wang, 2016). Therefore, in this study, we agree that the hydrodynamic condition is the dominant factor controlling the distribution of the ostracod assemblages in the Hongguleleng Formation. Compared with the offshore environments, the nearshore is higher in water energy and may be regularly more turbid due to the influence of storms. Additionally, the volcanic activity was intense and frequent for the volcanic arc context, especially in the upper part of the lower member and the middle member of the Hongguleleng Formation (Figure 2). For example, a number of volcanism-influenced deposits were preserved, such as the layered euhedral feldspars in medium- to coarse-grained tempestites in the bottom of the middle member of the Hongguleleng Formation (Fan & Gong, 2016). Thus, the water turbidity would probably increase significantly as storms burst with volcanic debris along with volcanic ash falls, causing the lower abundance and diversity of ostracods in OA2 (from the nearshore; Figure 4) than that in OA3 (from the offshore; Figure 4), especially for the Bairdioidea. However, the deposit-feeding imprint of OA2 (more than 75% of the total species) is more evident, which is about 65% of the total species in OA3.

Moreover, the salinity in the foreshore environment of the Hongguleleng Formation would fluctuate frequently because of runoff and it yields some euryhaline faunas (e.g., bivalves and serpulas; Wang, 2016). Some Platycopina and Paraparchitoidea ostracods are interpreted as euryhaline (Bennett et al., 2012), which corresponds with their occurrences in the foreshore (OA1), nearshore (OA2) even offshore (OA3) environments of the Hongguleleng Formation (Figure 4). In addition, a few large-sized species of the Hollinoidea (e.g., *Hollinella* Coryell, 1928 and *Parabolbinella* Adamczak, 1968) in OA1 generally characterize low-salinity environments such as the interdistributary bays, prodelta, and interdeltaic embayments (Crasquin-Soleau et al., 2005; Melnyk & Maddocks, 1988; Olempska, 1999). Therefore, salinity fluctuations may be another factor consider apart from the hydrodynamic condition, especially for the ostracods of OA1.

5 | CONCLUSIONS

1. Three assemblages of ostracods in the open oceanic island arc are first proposed based on ostracod faunas from the Hongguleleng Formation, that is, OA1, OA2, and OA3, which represent foreshore, nearshore, and offshore environments. They are more flexible and complicated than the ostracod ecological assemblages in the continental margins.
2. The common species from the lower member of the Hongguleleng Formation are small-sized and thick-shelled with smooth or simple ornamentation, which are adapted to living in the shallow waters with high energy and turbulence.
3. The hydrodynamic condition is considered as the major environmental factor controlling the composition of the ostracod assemblages from the Hongguleleng Formation. Ostracods are generally less abundant when the water turbulence and the turbidity increase, whereas the deposit-feeding ostracods seem to be more adaptable to high-energy environments. Salinity fluctuations may also influence the composition of the ostracod assemblages.

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