ELSEVIER

Palaeogeography, Palaeoclimatology, Palaeoecology 121 (1996) 53–64

PALAEO GEOGRAPHY CLIMATOLOGY ECOLOGY

Early–Middle Jurassic ostracod migration between the northern and southern hemispheres: Further evidence for a proto Atlantic–Central America connection

Ian Boomer [a], Sara Ballent [b]

[a] *School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK*
[b] *Departamento Paleontologia Invertebrados, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*

Received 8 July 1994; revised and accepted 3 May 1995

Abstract

Early to Middle Jurassic marine ostracod assemblages from the southwestern part of the British Isles, North African continental margin and South America have yielded taxa which are not known from other parts of Britain and Europe. We discuss the palaeogeographical and stratigraphical distribution of these taxa, here arranged into ten informal "groups", from which we infer that benthonic podocopid Ostracoda successfully migrated between Northwest Europe and the eastern part of Tethys during the Early and Middle Jurassic, not through the main Tethyan seaway but via a proto Atlantic–Central America route supporting previous observations based on macrofossil evidence ("Hispanic Corridor" of Smith, 1983). Furthermore, the fact that these taxa are absent from contemporary European sequences suggests the existence of physical and/or chemical barriers limiting benthonic faunal exchange between the western part of the British Isles and the rest of north-western Europe, particularly during the Late Pliensbachian through to Aalenian interval.

1. Introduction

The Early Mesozoic witnessed some of the earliest phases of rifting that would eventually lead to the opening of the Atlantic. From palaeobiogeographical studies of marine invertebrates it has been possible to date the earliest marine connections along the lines of tension faulting. Smith (1983) and Hallam (1983) considered that a Central American "Hispanic Corridor" provided a sporadic, intermittent and restricted level of faunal exchange between the eastern Pacific and western Tethys from the Early Pliensbachian based on palaeobiogeographical studies of marine invertebrates. At this time the European epicontinental sea was situated at the north-western end of the Tethys sea-way which extended through southern Europe and the Middle East into Australasia (Smith et al., 1981). This route has been recognised as a major migration pathway for the exchange of taxa between the northern and southern hemispheres.

Hallam (1973) stated that by the Pliensbachian there was a marine link between the Arctic region and Europe. In a later work Hallam (1977) suggested, from the known distribution of the ammonite genera *Welya* and *Bouleiceras*, that a narrow sea-way must have existed between Argentina,

0031-0182/96/$15.00 © 1996 Elsevier Science B.V. All rights reserved
SSDI 0031-0182(95)00049-6

Antarctica and southern Africa during the Toarcian. Howarth (1981) noted that outcrops of Jurassic sediments, of varying ages, can be found across the Gulf of Mexico to Cuba witnessing an incursion from the eastern "Pacific" Tethys.

Recently, Stanley and Beauvais (1994) studied an Early Jurassic (Sinemurian) reef in British Columbia, Canada, which yielded coral species previously known from Morocco, Great Britian, Italy, Peru and Chile; these authors hold that the Hispanic Corridor may have played an important role during that time. The most obvoius mechanism promoting intermittent dispersal would be sea-level fluctuations concomitant with rifting along the corridor (Westermann and Riccardi, 1985; Smith and Tipper, 1986). This route is known to have been adopted by several groups of invertebrates, for example, the Dicoelitia belemnites (Jeletzky, 1980), *Stylothalamia* sponges (Hillebrandt, 1981), ammonoids (Smith, 1983; Riccardi, 1991), bivalves (Damborenea and Manceñido, 1979, 1988; Hallam, 1983) brachiopods (Manceñido, 1978; Manceñido and Dagys, 1992) and corals (Beauvais, 1992; Stanley and Beauvais, 1994). Similarily, marine reptiles were widely distributed during the Early and Middle Jurassic, particularly in Tethyan latitudes, and were able to disperse along the Hispanic Corridor (Bonaparte, 1981; Gasparini, 1985, 1992).

The recognition of this migration route also explains the close faunal similarities which have been observed between the Pliensbachian foraminifera from the Grand Banks, Portugal and North Africa region and Argentina (Exton, 1979; Exton and Gradstein, 1984; Riegraf et al., 1984; Ballent, 1987b).

2. Early Jurassic ostracod distribution

Studies on Early Jurassic Ostracoda from European marine sequences detail the initial colonisation of the epicontinental sea, following the global rise in sea level during the latest Triassic. This event led to the establishment of many new marine habitats or biotopes initially occupied by low diversity faunas. Subsequently, a series of successive diversity explosions and crashes led to the establishment of, what was later to become, the typical marine assemblages of the Jurassic and Cretaceous. The ancestry of many later Mesozoic marine ostracod genera can be traced back to this Early Jurassic diversification.

Over the past fifty years a large number of publications have appeared which comprehensively document the evolution of Early and Middle Jurassic marine Ostracoda from Northwest Europe. As a result the faunas from these sequences are well known. Our knowledge of ostracod assemblages outside NW Europe during that time (i.e., a Tethyan fauna) is less well known. Recent works have widened our knowledge of Late Triassic and Early Jurassic faunas from other regions of the world including, the southern European Alps (Kristan-Tollmann, 1971), the Himalayas (Kristan-Tollmann and Gupta, 1987), the Middle East (Kristan-Tollmann et al., 1980), North Africa (Bate et al., 1984), south-east Asia (Kristan-Tollmann et al., 1987; Kristan-Tollmann and Hasibuan, 1990) and South America (Ballent, 1987b, 1992 and Ballent in: Riccardi et al., 1990). Lord et al. (1993) described early Jurassic ostracod assemblages from three cores from offshore Western Australia adding to our knowledge of the circum-Pacific fauna at this time. Kristan-Tollmann, in a number of papers (1977 et seq.), has detailed the Triassic and early Jurassic Ostracoda from Tethyan sequences. Lord (1988) in his review of the Liassic Ostracoda of the Tethyan Ocean referred to the proto Atlantic embayment between north-west Africa and eastern North America but considered that (based on Scott, 1984, p. 51) there was no connection to the Gulf of Mexico and thus no connection between Europe and the "Pacific" Tethys to the West. In the following we hope to provide evidence for such a western link with Tethys.

The above publications have afforded us the opportunity to investigate the global occurrence of early Jurassic Ostracoda. Kristan-Tollmann (1990) illustrated the Tethys-wide distribution of some Late Triassic and earliest Jurassic ostracod species while Lord (1988) reviewed the known distribution of the early Jurassic Ostracoda from the Tethyan Ocean. Tethys was the major oceanographical feature at this time. It divided the eastern

half of the Pangea land-mass. At its western end was the relatively shallow water but extensive epicontinental sea which covered much of north-western Europe and it is assumed that oceanic conditions persisted at its eastern end.

Whatley and Ballent (in press) reviewed the bi-hemispherical distribution of Jurassic Ostracoda. They demonstrated that during the Early Jurassic, notwithstanding the Eurocentric nature of Jurassic ostracod studies, there were as many species migrating from the southern to the northern hemisphere as there were vice versa. During the Middle and Late Jurassic, however, all migration took place in a north to south direction. Whatley and Ballent (ibid.) suggested that there may have been migration via the Pacific Coast of South America and into Tethys through the straits of Panama. Indeed, from the following evidence, such a route seems likely to have existed during the early Jurassic.

2.1. *Palaeogeographical setting of D.S.D.P. Site 547*

Bate et al. (1994) described a Late Triassic to Late Jurassic sequence of ostracods from D.S.D.P. (Deep Sea Drilling Project) Site 547 off North Africa. Although many of the ostracods they recorded were clearly related to European assemblages a number of species were new and some could not be easily be assigned to known genera. Lord (1988) commented that there were no taxa in the D.S.D.P. material which he considered to be of Tethyan origin (i.e. *Ptychobairdia hahni* Lord and Moorley; *Hermiella* spp.). Early Jurassic "Tethyan" assemblages have been described from southern Germany (Malz, 1975) and Timor (Kristan-Tollmann et al., 1987), neither of those papers recorded taxa similar to those considered here (Fig. 1).

The earliest samples from Site 547 yielded Ostracoda which they interpreted as representing latest Triassic/earliest Jurassic freshwater to marginal marine environments (e.g. *Lutkevichinella* sp.). This can be equated with similar records in Northwest Europe at this time (Anderson, 1964; Boomer and Ainsworth, in press).

Winterer and Hinz (1984) interpreted the early

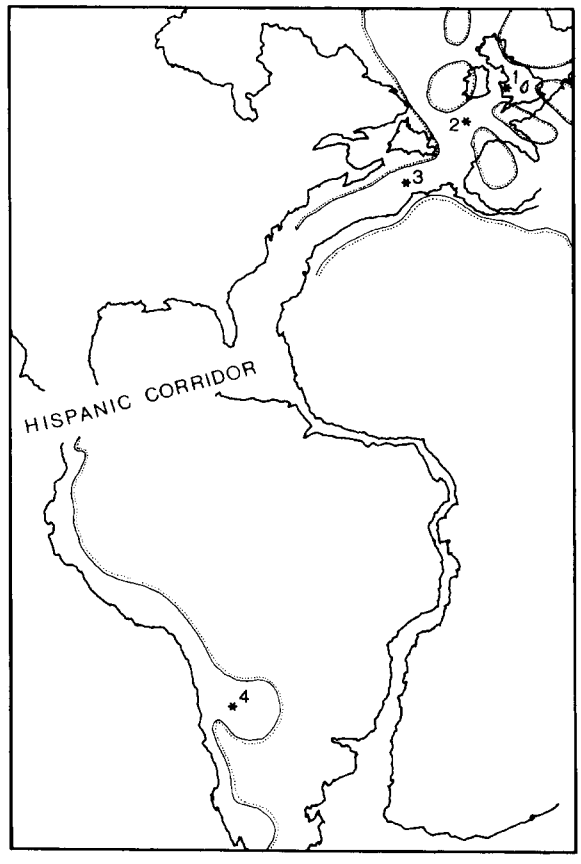


Fig. 1. Palaeogeographical location of samples discussed in the text, Early Jurassic shoreline inferred. *1* = Mochras Borehole, West Wales. *2* = Fastnet Basin. *3* = D.S.D.P. Site 547. *4* = Neuquen Province, Western Argentina. The fine line indicates the paleoshoreline with the dotted side indicating land, enclosed circles indicate islands. Palaeogeographical reconstruction after Smith et al. (1981).

Mesozoic history of this region beginning with rifting during the Triassic, possibly the incipient Atlantic rifting. This created a series of basin and swell features. The basins initially accumulated sediments from the surrounding highs until, at the end of the Triassic, a sequence of evaporitic sediments were deposited across a rift valley system which may have extended Northwest to the Nova Scotian shelf (then perhaps only 200–250 km away).

Subsequent drowning during the early Jurassic led to the accumulation of marine sediments in water depths of up to 200 metres. This echoes the

story seen in many Northwest European sequences where marginal and non-marine, latest Triassic, sediments are succeeded by Early Jurassic cyclical, shallow marine and restricted marine carbonates (Ziegler, 1981).

Exton (1979) and Exton and Gradstein (1984) correlated ostracod and foraminiferal assemblages from late Pliensbachian and Toarcian sequences from the Lusitanian Basin, western Portugal and the Grand Banks offshore eastern Canada. Significantly the Lusitanian assemblages and those from the Iberian Cordilleras (Arias, 1991; Arias and Comas-Rengifo, 1992) show closer affinities with those of the central European region. This is clearly shown in Arias (1991; fig. 6) where the number of species in common between the Iberian sections and those of Germany, France and southern Britain are detailed. Arias (ibid.) also recorded a low degree of similarity between the Iberian and Zambujal sequences (Lusitanian Basin; Exton, 1979). This is probably due to the low diversity recorded by Exton. Indeed that sequence is particularly notable for the abundance of *Polycope* specimens, a feature not observed in any contemporary European sections and the significance of this feature is unclear (Boomer et al., in press). Suffice to say that none of the key taxa under discussion in the present paper have been recorded from the Iberian Peninsula.

2.2. *Palaeogeographical setting of the Mochras and Fastnet Basin sections*

It has long been a matter of debate as to whether a Welsh land-mass existed during the early Jurassic. The unexpected discovery of an extensive Lower Jurassic siltstone/mudstone sequence at a depth of 600 metres in the Mochras Borehole (an almost complete, Hettangian to Toarcian, 1300 m section) faulted against Lower Palaeozoic sediments did not, solve this question (Woodland, 1971). Cope (1984) suggested from the presence of a series of peripheral Mesozoic basins around Wales, that "...it is tempting to interpret (Wales) as a positive or swell region flanked by Basins" (p. 373). The sediments of the Fastnet Basin are of a similar lithology.

The Lower Jurassic sequence at Mochras rests unconformably on brecciated carbonate sediments of Late Triassic age. Sedimentological and faunal evidence indicate that the Lias sediments at Mochras must have accumulated in a shelf, and probably an outer shelf, situation where fault controlled subsidence kept pace with sediment accumulation. The Mochras Borehole lies at the northeastern extent of a series of NE–SW trending fault bounded basins (Ziegler, 1981) and Ainsworth (1986, 1987, 1989) has recorded the Early Jurassic ostracods from the Fastnet Sea and Celtic Sea basins at the southwest end. A detailed examination of early Jurassic Ostracoda recovered from the Mochras Borehole, Wales (Boomer, 1989, 1991) has revealed that, although many elements of the assemblages are typical of other European sites, the strongest faunal similarities are with contemporary material described by Ainsworth.

The Mochras assemblages can be distinguished by the absence or in some cases the rare occurrence of taxa which are commonly recorded in other, contemporary, sequences across Europe, this is particularly true for the Pliensbachian interval. These rare taxa (which include species of *Pleurifera, Gramannella, Wicherella*, abundant in the sequences of the southern North Sea Basin and the Dorset Coast, UK) are also almost entirely absent from the Fastnet Sea, Celtic Sea Basins, Site 547 and Argentina. Boomer (1991) considered that these differences resulted from isolation, either physically or environmentally controlled. The Mochras assemblages are particularly distinct in that they possess a great number of previously undescribed cytherurid taxa. Although the Hettangian and Sinemurian ostracod assemblages from Mochras are comparable to those from elsewhere in Europe, the Pliensbachian assemblages differ, in their faunal composition, from those of the Dorset Coast section (Field, 1968; Park, 1985) as do the Toarcian assemblages from Ilminster (Boomer, 1992) and the East Midlands in the UK (Bate and Coleman, 1975).

The uniqueness of the Mochras assemblages may have been due, in part, to the presence of a Welsh landmass at this time, it may also suggest deeper water conditions than the majority of the other European sites examined. Many of the European sequences are influenced by regressive

and transgressive events producing condensed sequences, coarse grained sedimentation and unconformities, these features are all but absent at Mochras. Boomer and Whatley (1993), however, noted that fluctuating sea levels may have affected dissolved oxygen levels during the Toarcian and, thereby, the ostracod assemblage compositions.

2.3. *Palaeogeographical setting of Neuquen, Argentina*

A number of the D.S.D.P. taxa have been recorded from Early to Middle Jurassic sediments in Argentina (Ballent, 1987b, 1991). Palaeogeographical reconstructions of the South American region record much of that continent as belonging to the Pangean landmass but with the eastern margin experiencing marine conditions. Neuquen is situated within an embayment of that coast, this coastline opens on to the main Tethys ocean to the west. The embayment probably witnessed shallow water conditions. Indeed, the overall microfossil assemblage composition is similar to those of the European shelf sea although lower in diversity (Ballent, 1987a). The sequences are dominated by fine grained calcareous sediments with subordinate coarse-grained and limestone horizons.

3. Distribution of ostracoda along the proto atlantic

In the following we have erected ten species groups whose distribution in the study areas supports the presence of a palaeoceanographical connection between Northwest Europe and South America during the Early Jurassic. Many of these species have not yet been formally described although we are confident of our taxonomic consistency. Poor preservation of much of this material, particularly of internal features, does not permit a detailed discussion of thier taxonomy in this work. A number of taxonomic notes accompany the discussion of each species group and alludes to their affinities. We have only figured specimens from areas where that group occurs but has not previously been illustrated. The geographical and stratigraphical range of each group is outlined. The geographical distribution of each group is summarised in Table 1.

To date, the taxa which we discuss below have not been recorded from contemporary European or western Tethyan sites and it is implied, therefore, that their migration did not occur via the Northwest European epicontinental sea, through the main Tethyan ocean, but by a proto Atlantic route. We recognise that each of the three regions discussed below yielded some species which are present in contemporary sequences from Europe; those taxa, however, are not the subject of this work.

The taxa considered in this work are known only from three regions:

—SW British Isles: Mochras Borehole (Boomer, 1989, 1991; Hettangian to Toarcian), Fastnet Sea Basin (Ainsworth, 1986; Toarcian and Aalenian).

—North Africa: D.S.D.P. Leg 79, Site 547 (Bate et al., 1984; Rhaetian?/Hettangian to Pliensbachian).

—Argentina: Neuquen Province, West-central Argentina (Ballent, 1987b; late Pliensbachian) Neuquen Province, West-central Argentina (Ballent, 1991; Aalenian to Bajocian). The presence of common taxa in the three areas does not, in itself, imply a Proto-Atlantic palaeoceanographical connection between Europe and South America. However, when one takes into consideration the absence of the same taxa from the many, well documented, sequences of the Northwest

Table 1
Geographical distribution of the ten groups discussed in the text. + = Indicates presence of a particular group in each region

	British Isles	North Africa	Argentina
Group 1	+	+	+
Group 2	+	+	+
Group 3	+	+	
Group 4	+	+	
Group 5	+	+	
Group 6		+	+
Group 7	+		+
Group 8	+		+
Group 9	+		+
Group 10	+		+

European Lias and the Tethyan sites known to date, we must assume that some more direct link other than the Tethyan seaway must have existed between the northern and southern hemispheres during this time.

Of the ten groups discussed, two are recorded from all three regions (groups 1 and 2), three from the British Isles and North Africa (groups 3–5), one from North Africa and Argentina (Group 6) and four from the British Isles and Argentina (groups 7–10) (see Table 1). We do not intend to produce a taxonomic review of the material although in most cases some taxonomic notes are given for clarification. Only those taxa which have not previously been figured in the literature are illustrated in Plate I. Most of the generic and specific names used are those used in previous publications and we do not necessarily agree with that nomenclature. We have not been able to study the specimens figured by Bate et al. (1984) although some of the assemblage slides from that sequence have been kindly loaned to us by Prof. A.R. Lord (University College London).

3.1. Group 1

Oligocythereis? cf. *O? mochrasensis* Boomer, Plate I, 1.
Oligocythereis? sp. A. Plate I, 2,3.
Oligocythereis? sp. B. Plate I, 5.
1984. Gen. Indet D. Bate, Lord and Riegraf, pl. 5, fig. 9.
?1984. Gen. Indet D. Bate, Lord and Riegraf, pl. 5, fig. 11.
1991. *Oligocythereis*? *mochrasensis* sp. nov. Boomer, pl. 1, figs. 2–4.
1991. *Oligocythereis*? sp. Boomer, pl. 1, fig. 6.
1991. *Ostracodo* C. Ballent, pl. 4, figs. 11–12 (note that in the original plate description, fig. 12 was erroneously assigned to *Ostracodo* D).
Distribution: British Isles (Mochras, Late Pliensbachian and Toarcian), North Africa (Pliensbachian) and Argentina (Aalenian/Bajocian).
Remarks: This group consists of at least three species. No similar species are known from contemporary sequences and it is possible that these taxa may constitute a new genus. They almost certainly belong to to the family Cytheruridae and may be the earliest representatives of the subfamily Paracytherideidae. *Oligocythereis? mochrasensis* Boomer, was described from the late Pliensbachian and early Toarcian of Mochras. Boomer (1991) also referred to sparse records of a similar species occurring in the late Toarcian of the same sequence. These younger specimens are distinguished by their more elongate carapace and shallow punctae on the lateral surfaces and one example (*Oligocythereis*? cf. *O. mochrasensis*) is illustrated in Plate I, 1. Boomer (1991) also figured another species, tentatively assigned to the same genus, from the late Pliensbachian and Toarcian interval at Mochras, *Oligocythereis?* sp.

Bate et al. (1984) figured two specimens which they assigned to Gen. Indet. D (ibid., pl. 5, figs. 9,11). The latter figure bears strong similarities to the same view of *O. mochrasensis* figured by Boomer (1991, pl. 1. fig. 2) and the two are almost certainly related. However, the lateral view of a left valve also assigned to Gen. Indet. D and figured by Bate et al. (pl. 5, fig. 11) does not appear to be related to the Mochras species.

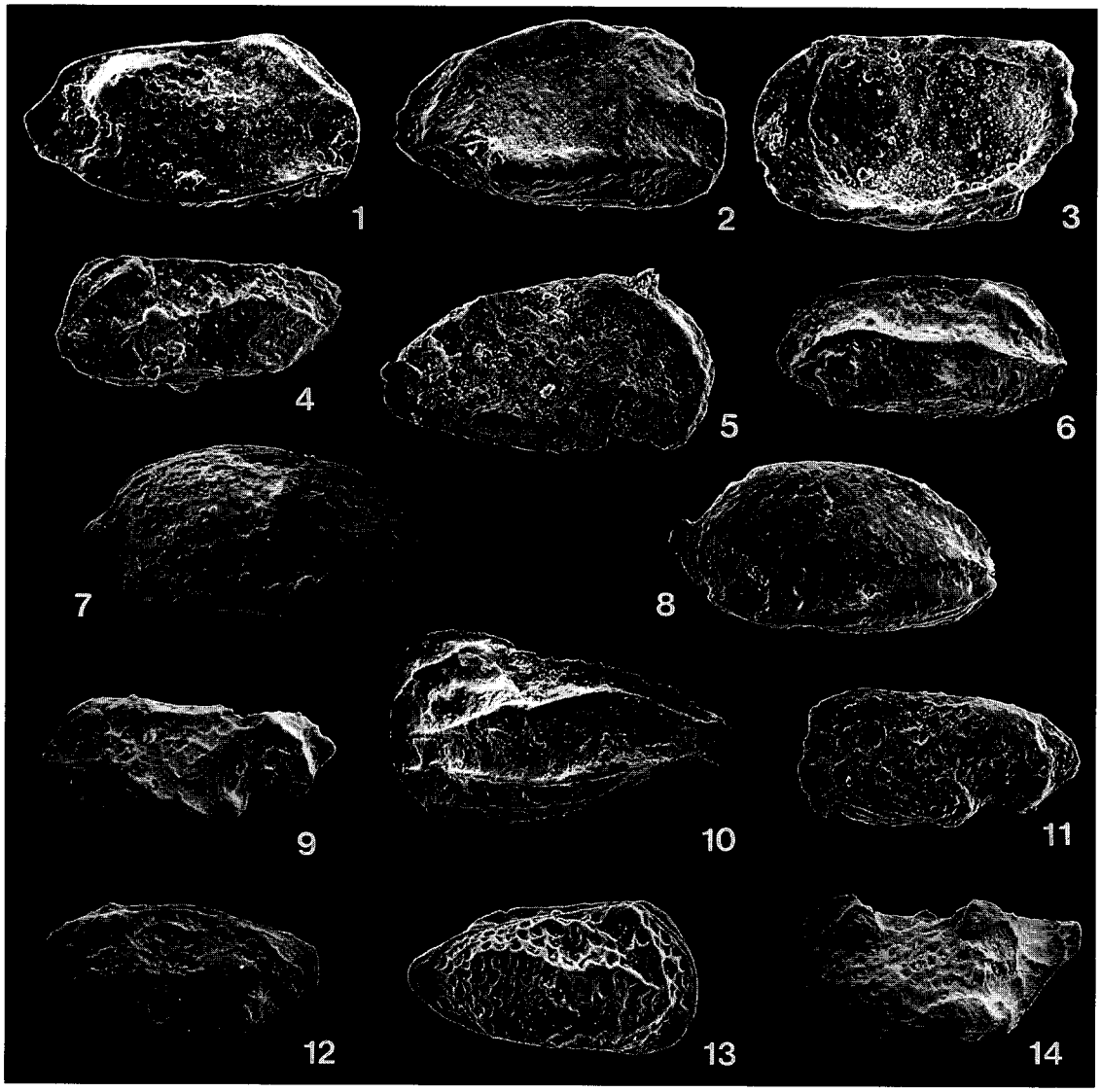
We have recovered Pliensbachian specimens from the D.S.D.P. residues which are very similar to *O?. mochrasensis* Boomer (this work, Plate I, 2,3) and suggest that the two specimens figured by Bate et al., as Gen. Indet. D are not conspecific. Included in the specimens we have observed from the D.S.D.P. residues are individuals comparable with *Oligocythereis*? sp. sensu Boomer, 1991 (Plate I, 5).

Ballent (1991) figured a species, *Ostracodo* sp. C. from the Aalenian–Bajocian boundary interval in Argentina. We consider this species to be congeneric with the material discussed above. Ballent did not record this species from Late Pliensbachian sediments in Argentina and we suggest, therefore, that it may have migrated into that region during the Toarcian–Aalenian.

3.2. Group 2

Eucytherura sp. A. Plate I, 4,6.
1984. *Palaeocytheridea* sp. Bate, Lord and Riegraf, pl. 5, fig. 2.
1991. *Ostracodo* A. Ballent, Pl. 4, figs. 6–8.

PLATE I



1. *Oligocythereis*? cf. *O.*? *mochrasensis* Boomer (Group 1). Toarcian, Mochras, adult RV, ×100.
2,3. *Oligocythereis*? sp. A (Group 1). Pliensbachian, D.S.D.P. Leg 79, Site 547, Core 11, core-catcher. 2. Adult RV, ×152. 3. Adult RV, internal view, ×117.
4,6. *Eucytherura* sp. A (Group 2). Sinemurian, Mochras. 4. Adult LV, ×112. 6. Adult RV, ×116.
5. *Oligocythereis*? sp. B (Group 1). Pliensbachian, D.S.D.P. Leg 79, Site 547, Core 11, core-catcher, adult? RV, ×132.
7. *Cytheropteron* sp. A (Group 5). Pliensbachian, Mochras, adult RV, ×145.
8. *Cytheropteron* sp. A? (Group 5). Pliensbachian, D.S.D.P. Leg 79, Site 547, Core 11, core-catcher, adult? RV, ×145.
9,11. *Procytherura* sp. (Group 7). Toarcian, Mochras 9. Adult LV, ×125. 11. Adult LV, ×111.
10. *Pleurocythere* sp. A (Group 4). Pliensbachian, Mochras, adult? LV, ×139.
12. *Procytherura euglyphaea* Ainsworth, (Group 10). Toarcian, Mochras, adult carapace, ×145.
13. *Grammanicythere*? sp. (Group 8). Toarcian, Mochras, adult carapace, ×105.
14. *Eucytherura* sp. B (Group 9). Toarcian, Mochras, adult?, LV, ×114.

Distribution: British Isles (Mochras, Sinemurian and Pliensbachian), North Africa (Pliensbachian) and Argentina (Aalenian/Bajocian).
Remarks: This group comprises a number of species characterised by elongate oval carapaces with longitudinal ribs along the ventro-lateral, mid-lateral and dorsal (flange) margins. These taxa also possess distinct eye nodes with a short oblique ocular rib produced anteriorly. The intercostal regions may be smooth or weakly reticulate. Representatives of this group have been recorded from the Sinemurian and Pliensbachian of the Mochras Borehole, Sinemurian of Site 547 and the Aalenian/Bajocian of Argentina (see also Group 4).

These taxa are almost externally similar to members of the genus *Pleurocythere* Triebel, which is distinguished by the presence of three distinct longitudinal ribs, recorded from Middle Jurassic sediments in Northwest Europe. The carapace outline and presence of a lophodont hinge suggests, however, that this species is best accommodated within thee Cytheruridae. Boomer (1991) illustrated two similar species which he assigned to *Pleurocythere* from the Pliensbachian and Toarcian of Mochras and these may also belong to the Cytheruridae, one of these is included in Group 4.

3.3. Group 3

1984. Gen. Indet. C. Bate, Lord and Riegraf, pl. 5, fig. 6.
1991. *Lophodentina striata* sp.nov. Boomer, pl. 2, figs. 7–8.
Distribution: British Isles (Mochras and Fastnet Basin, Latest Sinemurian and Pliensbachian) and North Africa (Pliensbachian).
Remarks: Bate et al. (1984) recorded Gen. Indet. C from the Pliensbachian of Site 547. Subsequently, Boomer (1991) described *L. striata* from the latest Sinemurian and Pliensbachian of Mochras where it defined an Ostracod Zone of that age. The ornamental features of this group bear similarities to the southern Hemisphere, Upper Jurassic genus *Mandawacythere* Bate, 1975 but the stratigraphical separation of these two taxa makes any direct evolutionary relationship unlikely.

3.4. Group 4

Pleurocythere sp. B. Plate I, 10.
1984. *Palaeocytheridea*? sp. Bate, Lord and Riegraf, pl. 1. fig. 8.
1984. ?*Palaeocytheridea* sp. Bate, Lord and Riegraf, pl. 5, fig. 5.
1991. *Pleurocythere* sp. B. Boomer, pl. 3, fig. 7.
Distribution: British Isles (Mochras, Latest Sinemurian to earliest Toarcian) and North Africa (Sinemurian).
Remarks: The taxa which we have referred to this group are morphologically similar to those of Group 2 described above. They can be distinguished in that the carapaces of the present group taper posteriorly and the ribs are less robust. Externally, the present species are similar to middle Jurassic species of *Pleurocythere* although their smaller size indicates a possible association with the Cytheruridae. The group is recorded from the Rhaetian?/Hettangian of Site 547 and from the Late Sinemurian to the Early Toarcian of Mochras.

3.5. Group 5

Cytheropteron sp. A. Plate I, 7.
Cytheropteron sp. A? Plate I, 8.
Distribution: British Isles (Pliensbachian and earliest Toarcian) and North Africa (Pliensbachian).

Remarks: No similar species are known from elsewhere in Europe. A number of closely allied taxa were have been recorded from the Late Pliensbachian and Early Toarcian at Mochras. Although Bate et al. (1984) did not figure any specimens belonging to this group, we have figured a specimen recovered from one of the D.S.D.P. assemblage slides loaned to us (Plate I, 8). The two specimens are almost certainly conspecific.

3.6. Group 6

(No representatives illustrated)
1991. *Procytherura bispinata* sp.nov. Ballent, pl. 2. figs. 8–11.

1984. Gen. Indet. B. Bate, Lord and Riegraf, pl. 5, figs. 12,14.

Distribution: North Africa (Pliensbachian) and Argentina (Aalenian/Bajocian).

Remarks: The group comprises two species. The North African species was recorded in the Pliensbachian interval (Bate et al., 1984) while Ballent (1991) recorded *P. bispinata* from the Aalenian–Bajocian sequence in Argentina. No representatives of this group have been recorded from the British Isles. These taxa are very similar to species such as *P. euglyphaea* Ainsworth (see Group 10). They differ in having greatly reduced lateral ornament and possess distinct postero-ventral projections.

3.7. Group 7

Procytherura sp. Plate I, 9, 11.

1991. *Ostracodo* B. Ballent, pl. 4, fig. 9.

Distribution: British Isles (Mochras, Toarcian) and Argentina (Aalenian/Bajocian).

Remarks: This group of species is recorded from the Late Toarcian of the Mochras Borehole where four allied species are recognised (Boomer, 1989). The group is characterised by strongly dimorphic elongate oval carapaces bearing ornamentation from fine punctae through to a mixture of ribbing and reticulation. The most distinctive features of the carapace are clearly illustrated in the species described by Ballent from the Middle Jurassic of Argentina. These taxa are characterised by their small carapace with straight ventral and slightly convex dorsal margins, a well developed ventro-lateral carina which is truncated or sharply rounded posteriorly. Above the posterior termination of the carina the carapace is depressed, a feature bounded dorsally by a lunate postero-dorsal rib or carina. All of these taxa are considered by the present authors to belong to the genus *Procytherura*.

3.8. Group 8

Grammanicythere? sp. Plate I, 13.

1986. Indet. Gen. 1. sp. A. Ainsworth, pl. 6, figs. 1–2,5.

1991. *Gramannicythere*? sp. Ballent, pl. 4, figs. 4–5.

Distribution: British Isles (Mochras, Fastnet, Toarcian to Aalenian) and Argentina (Aalenian/Bajocian).

Remarks: This group is characterised by species with elongate, quadrate carapaces bearing distinct caudal processes at about mid height. The valves are ornamented with three very strong ribs running dorsally, ventro-laterally and obliquely from postero-dorsal to the antero-ventral margin. Secondary intercostal ribbing or punctation is also present. We have followed Ballent (1991) in questionably assigning this species to the cytherurid genus *Gramannicythere*. The carapace shape and nature of the ornamnetation, however, suggests closer affinities with cytherideid genera such as *Ektyphocythere*. The group has been recorded from the latest Toarcian of the Mochras Borehole, the Toarcian/Aalenian of the Fastnet Basin and from the Aalenian/Bajocian of Argentina.

3.9. Group 9

Eucytherura sp. B. Plate I, 14.

1991. *Hemiparacytheridea* sp. Ballent, pl. 2, fig. 4.

Distribution: British Isles (Mochras, Late Pliensbachian to Early Toarcian) and Argentina (Aalenian/Bajocian).

Remarks: The specimens figured by Ballent, 1991 and the present authors are almost certainly conspecific. There is no evidence of similar taxa from the D.S.D.P. material. The species is distinguished by strong ocular, postero-dorsal and postero-ventral nodes. The latter forming the termination of a ventro-laterally inflated rib. The mid-valve region is markedly punctate. This species is best accommodated within the genus *Eucytherura*, similarly ornamented taxa are extant today.

3.10. Group 10

Procytherura euglyphea Ainsworth, Plate I, 12.

1986. *Procytherura euglyphea* sp. nov. Ainsworth, pl. 4, figs. 12–15.

1991. *Procytherura* cf. *P. euglyphea* Ainsworth. Ballent, pl. 2, fig. 6.

Distribution: British Isles (Mochras, Fastnet, Toarcian to Aalenian) and Argentina (Aalenian/Bajocian).

Remarks: This small cytherurid species is easily distinguished by the nature of the ribbing, particularly the oblique, somewhat inflated, lateral rib. The species is present in the Late Toarcian of Mochras, the Toarcian to Aalenian of the Fastnet Basin and the Aalenian/Bajocian of Argentina.

4. Conclusions

Ten distinct groups of species are recognised from sites to the southwest of the British Isles, off Northwest Africa and in South America. These groups are not known from the well-documented shelf deposits of the North West European Lias. A link has therefore been established between the northern and southern hemispheres other than via the Tethyan seaway. This supports the previous observations of many workers (e.g. Smith, 1983; Hallam, 1983) that a proto Atlantic "Hispanic Corridor" (Fig. 1) must have existed to allow such faunal transfer. It is presently unclear as to why these groups are unknown from contemporary deposits in the adjacent epicontinental sea. It is possible that they inhabited somewhat deeper water than those of the European shelf sea or the Alpine carbonate platform and that these assemblages are also facies controlled. There is inconclusive proof that the assemblages described above are restricted by facies or by water depth, the Mochras and Fastnet material originating in fault bounded basins (mid to outer shelf), the palaeodepth reconstruction for Site 547 is about 200 m while the South American material is probably from a shallow water embayment. It is more likely that the faunal similarities arise from their partial isolation from the European continental shelf faunas and the migration opportunity afforded by the presence of the Hispanic Corridor.

Acknowledgements

Our thanks to Robin Whatley for his comments on an early draft, R. Jones for SEM and David Griffiths (both Aberystwyth) for photography. Thanks also to the reviewers A. Hallam, M. Maceñido and N. Morton and the editor P. De Deckker for their many helpful suggestions. This paper is a contribution to IGCP 322 Jurassic Events in South America.

References

Ainsworth, N.R., 1986. Toarcian and Aalenian Ostracoda from the Fastnet Basin, offshore south-west Ireland. Geol. Surv. Ireland Bull., 3: 277–336.

Ainsworth, N.R., 1987. Pliensbachian Ostracoda from the Fastnet Basin, offshore southwest Ireland. Geol. Surv. Ireland Bull., 4: 41–62.

Ainsworth, N.R., 1989. Rhaetian, Hettangian and Sinemurian Ostracoda from the Fastnet Basin offshore Southwest Ireland. Geol. Surv. Ireland Bull., 4: 169–200.

Boomer, I. and Ainsworth, N.R., in press. The Early Jurassic. In: J., Athersuch et al. (Editors), A Stratigraphical Atlas of British Ostracoda. 2nd Ed.

Anderson, F.W., 1964. Rhaetic Ostracoda. Bull. Geol. Surv. G.B. 21: 133–174.

Arias, C.F., 1991. Asociaciones de Ostracodos del Domeriense superior y Toarciense inferior de la Cordillera Iberica. Coloq. Paleontol., 43: 79–97.

Arias, C.F. and Comas-Rengifo, 1992. Ostracodos del Ostracodos del Domeriense superior y Toarciense inferior de la Cordillera Iberica. Rev. Esp. Micropalaeontol., 24 (3): 111–155.

Ballent, S., 1987a. Biostratigrafia y edad de las microfaunas del Jurassico inferior de Argentina. In: 4th Congr. Latinoam. Paleontol., Bolivia, 1, pp. 331–342.

Ballent, S., 1987b. Foraminiferos y Ostracodos del Jurasico inferior de Argentina. Rev. Mus. La Plata (N.S.) Paleontol., 9 (53): 43–130.

Ballent, S., 1990. In: A.C. Riccardii et al., Lower Jurassic of South America and Antarctic Peninsula. Newsl. Stratigr., 21 (2): 75–103.

Ballent, S., 1991. Ostracodos del Jurasico medio (Limite Aaleniano-Bajociano) en La Provincia del Neuquen, Centro-Oeste de Argentina. Rev. Esp. Micropalaeontol., 23 (3): 21–56.

Ballent, S., 1992. Metacopina (Ostracoda) del Hettangiano superior en el sudoeste de la Provincia de Mendoza, Argentina. Ameghiniana, 29(2): 153–157.

Bate, R.H. and Coleman, B.E., 1975. Upper Lias Ostracoda from Rutland and Huntingdonshire. Bull. Geol. Surv. G.B., 55: 1–42.

Bate, R.H., Lord, A.R. and Riegraf, W., 1984. Jurassic Ostracoda from Leg 79, Site 547. In: K. Hinz, K. Winterer et al., Init. Rep. DSDP, 79: 703–710.

Beauvais, L., 1992. Corals of the circum-Pacific region. In: G. Westermann (Editor), The Jurassic of the Circum-Pacific. Cambridge Univ. Press, pp. 324–327.

Bonaparte, J., 1981. Inventario de los vertebrados jurásicos de América del Sur. In: W. Volkheimer and E. Musacchio

(Editors), Cuencas sedimentarias del Jurásico y Cretácico de América del Sur. Buenos Aires, 2, pp. 661–682.

Boomer, I.D., 1989. The temporal and spatial distribution of Lower Jurassic Ostracoda from North-West Europe. Thesis. Univ. London, 389 pp. (unpublished).

Boomer, I.D., 1991. Lower Jurassic ostracod biozonation of the Mochras Borehole. J. Micropalaeontol., 9 (2): 205–218.

Boomer, I.D., 1992. Lower Jurassic Ostracoda from Ilminster, Somerset. J. Micropalaeontol., 11: 47–57.

Boomer, I., Ainsworth, N.R. and Exton, J., in press. A re-examination of the Pliensbachian and Toarcian Ostracoda of Zambujal, west-central Portugal. J. Micropalaeontol.

Boomer, I.D. and Whatley, R.C., 1992. Ostracoda and dysaerobia in the Liassic of Wales: The reconstruction of past oxygen levels. Palaeogeogr. Palaeoclimatol. Palaeoecol., 99: 373–379.

Boutakiout, M., Donze, P. and Oumalch, F., 1982. Nouvelles espèces de l'ostracodes du Lias moyen et supérieur du Jbel Dhar Nsour (Rides sud-rifianes, Maroc Septentrional). Rev. Micropaléontol., 25: 94–104.

Damborenea, S.F. and Manceñido, M.O., 1979. On the palaeogeographical distribution of the pectinid genus *Weyla* (Bivalvia, Lower Jurassic). Palaeogeogr. Palaeoclimatol. Palaeoecol., 27(1/2): 85–102.

Damborenea, S.E. and Manceñido, M.O., 1988. *Weyla*: semblanza de un bivalvo andino. In: Actas 5th Chilean Geol. Congr. 2: C13–25.

Exton, J., 1979. Pliensbachian and Toarcian microfauna of Zambujal, Portugal: systematic palaeontology. Carleton Univ. Geol. Pap., 79: 1–104.

Exton, J. and Gradstein, F.M., 1984. Early Jurassic stratigraphy and micropalaeontology of the Grand Banks and Portugal. In: G. Westermann (Editor), Jurassic–Cretaceous Biochronology and Palaeogeography of North America. Geol. Assoc. Can. Spec. Pap., 127: 13–30.

Field, R.A., 1968. Lower Jurassic Ostracoda from England and Normandy. Thesis. Univ. London (unpublished).

Gasparini, Z., 1985. Los reptiles marinos jurásicos de América del Sur. Ameghiniana, 22(1/2): 23–24.

Gasparini, Z., 1992. Marine reptiles of the circum-Pacific region. In: G. Westermann (Editor), The Jurassic of the Circum-Pacific. Cambridge Univ. Press, pp. 361–364.

Hallam, A., 1973. Distributional patterns in contemporary terrestrial and marine animals. In: N.F. Hughes (Editor), Organisms and Continents through Time. Spec. Pap. Palaeontol., 12: 93–105.

Hallam, A., 1977. Jurassic bivalve biogeography. Paleobiology, 3: 58–73.

Hallam, A., 1983. Early and Mid-Jurassic molluscan biogeography and the establishment of the Central Atlantic Seaway. Palaeogeogr. Palaeoclimatol. Palaeoecol., 43: 181–193.

Howarth, M.K., 1981. Palaeogeography of the Mesozoic. In: L.R.M. Cocks (Editor), The Evolving Earth. Cambridge Univ. Press, pp. 197–220.

Jeletzky, J.A., 1980. Dicoelitid belemnites from the Toarcian–middle Bajocian of western and arctic Canada. Geol. Surv. Can. Bull., 338: 1–71.

Kristan-Tollmann, E., 1971. Weitere Beobachtungen an skulptierten Bairdiidae (Ostracoda) der alpinen Trias. N. Jahrb. Geol. Paläontol. Abh., 139: 57–87.

Kristan-Tollmann, E., 1990. Tethysweite Verbreitung triadischer und liassischer Ostracoden. Geol. Paläontol., 24: 173–183.

Kristan-Tollmann, E. and Gupta, V.J., 1987. Anmerkungen zur Mikrofauna der rhätischen Kiotomergel von Kumaun, Himalaya. N. Jahrb. Geol. Paläontol. Monatsh., 8: 467–497.

Kristan-Tollmann, E. and Hasibuan, F., 1990. Ostracoden aus der Obertrias von Misol (Indonesian). Mitt. Österr. Geol. Ges., 82: 173–181.

Kristan-Tollmann, E., Tollmann, E. and Hamedani, A., 1980. Beiträge zur kenntnis der Trias von Persien. Mitt. Österr. Geol. Ges., 80: 163–235.

Kristan-Tollmann, E., Barkham, S. and Gruber, B., 1987. Potschenschichten, Zlambachmergel (Hallstätter Obertrias) und Liasfleckenmergel in Zentral Timor, nebst ihren Faunenelementen. Mitt. Österr. Geol. Ges., 80: 229–285.

Lord, A.R., 1988. Ostracoda of the early Jurassic Tethyan Ocean. In: T. Hanai et al. (Editors), Evolutionary Biology of Ostracoda. Kodansha, Tokyo, pp. 855–868.

Lord, A., Malz, H. and Apthorpe, M., 1993. Lower Jurassic Ostracoda from off Western Australia. In: K.G. McKenzie and P.J. Jones (Editors), Ostracoda in the Earth and Life Sciences. Balkema, Rotterdam, pp. 109–122.

Malz, H., 1975. Eine Entwicklungsreihe des "vallater" Ogmoconchen (Ostracoda) im S-deutschen Lias. Senckenbergiana Lethaea, 55(6): 485–503.

Manceñido, M., 1978. Studies of early Jurassic Brachiopoda and their distribution, with special reference to Argentina. Thesis. Dep. Geology, Univ. College Swansea, Univ. Wales, 481 pp. (unpublished).

Manceñido, M.O. and Dagys, A.S., 1992. Brachiopods of the circum-Pacific region. In: G. Westermann (Editor), The Jurassic of the Circum-Pacific. Cambridge Univ. Press, pp. 328–333.

Park, S.M., 1985. Lower Jurassic Ostracoda from around the Southern North Sea Basin. Thesis. Univ. London (unpublished).

Riccardi, A., 1991. Jurassic and Cretaceous marine connections between the southeast Pacific and Tethys. Palaeogeogr. Palaeoclimatol. Palaeoecol., 87: 155–189.

Riegraf, W., Luterbacher, H. and Leckie, M., 1984. Jurassic foraminifers from the Magazin Plateau, Deep Sea Drilling Project Site 547, Leg 79 off Morocco. Init. Rep. DSDP, 79: 671–702.

Scott, R.W., 1984. Mesozoic biota and depositional systems of the Gulf of Mexico–Carribean Region. In: G.E.G. Westermann (Editor), Jurassic–Cretaceous Biochronology and Paleogeography of North America. Geol. Assoc. Can. Spec. Pap., 27: 49–64.

Smith, P.L., 1983. The Pliensbachian ammonite *Dayiceras dayiceroides* and early Jurassic palaeogeography. Can. J. Earth Sci., 20 (1): 86–91.

Smith, A.G., Hurley, A.M. and Briden, J.C., 1981. Phanerozoic

Palaeocontinental World Maps. Cambridge Univ. Press, 102 pp.

Smith, P.L. and Tipper, H.W., 1986. Plate tectonics and paleobiogeography: Early Jurassic (Pliensbachian) endemism and diversity. Palaios, 1: 399–412.

Stanley, G.D. and Beauvais, L., 1994. Corals from an Early Jurassic coral reef in British Colombia: refuge on an oceanic island reef. Lethaia, 27: 35–47.

Von Hillebrandt, A., 1981. Kontinentalverschiebung und die Paläozoogeographischen Beziehungen des südamerikanischen Lias. Geol. Rundsch., 70(2): 570–582.

Westermann, G. and Riccardi, A., 1985. Middle Jurassic ammonite evolution in the Andean Province and emigration to Tethys. Lecture Notes Earth Sci., 1: 6–34.

Whatley, R.C. and Ballent, S., in press. Bihemispherical distribution of Jurassic Ostracoda: Palaeogeographical implications. In: Proc. 1994 Pangaea Int. Symp. Can. Soc. Pet. Geol. Mem., 17.

Winterer, E.L. and Hinz, K., 1984. The evolution of the Mazagan continental margin: A synthesis of geophysical and geological data with results of drilling during Deep Sea Drilling Project Leg 79. In: K., Hinz, K. Winterer et al., Init. Rep. DSDP, 79: 893–922.

Woodland, A.W. (Editor), 1971. The Llanbedr (Mochras Farm) Borehole. Inst. Geol. Sci. Rep., 71/18: 1–115.

Ziegler, P.A., 1981. Evolution of sedimentary basins in North-West Europe. In: L.V. Illing and G.D. Hobson (Editors), Petroleum Geology of the Continental Shelf of North-West Europe. Inst. Pet., London, pp. 3–39.