Journal of Paleontology, 86(4), 2012, p. 699–719
Copyright © 2012, The Paleontological Society
0022-3360/12/0086-0699$03.00

REASSESSMENT OF THE EARLY CRETACEOUS NON-MARINE OSTRACOD GENERA *HOURCQIA* KRÖMMELBEIN, 1965 AND *PATTERSONCYPRIS* BATE, 1972 WITH THE DESCRIPTION OF A NEW GENUS, *KROEMMELBEINCYPRIS*

STEPHEN F. POROPAT[1,2] AND JEAN-PAUL COLIN[3,4]
[1]Department of Earth Sciences, Uppsala University, Villavägen 16, SE-752 36 Uppsala, Sweden, <stephen.poropat@geo.uu.se>; [2]School of Geosciences, Monash University, Clayton, Victoria, Australia 3800; [3]Universidade de Lisboa, Faculdade de Ciências, Centro de Geologia, Campo Grande C-6, 1749-016, Lisboa, Portugal; and [4]3 Impasse des Biroulayres, F-33610 Cestas, France, <jpcolin33@laposte.net>

ABSTRACT—The Early Cretaceous non-marine ostracod genera *Hourcqia* Krömmelbein and *Pattersoncypris* Bate are reinstated. A previously published referral of *Hourcqia* to *Cypridea* Bosquet is rejected due to the absence of an anteroventral rostrum in the holotype of the type species *Hourcqia africana* Krömmelbein. The genus *Hourcqia* is characterized by an "inverse" valve ratio (right valve larger than left) and the lack of an anteroventral rostrum, and the diagnosis of the genus is broadened to accommodate ornamented forms, resulting in the acceptance of five species: *Hourcqia africana*, *H. confluens* (Krömmelbein and Weber), *H. kouilouensis* (Grosdidier), *H. bateke* (Grosdidier) and *H. sylvesterbradleyi* (Bate). The previously published synonymy of *Pattersoncypris* with the genus *Harbinia* Tsao is also rejected. The diagnosis of *Pattersoncypris* is refined, meaning that three species are recognized: *Pattersoncypris micropapillosa* Bate, *P. salitrensis* (Krömmelbein and Weber), and *P. sinuata* (Krömmelbein and Weber). The new genus *Kroemmelbeincypris* is erected for two species initially assigned to *Hourcqia*, and subsequently to *Pattersoncypris* and *Harbinia* by different authors: *Kroemmelbeincypris symmetrica* (Krömmelbein and Weber) and *K. angulata* (Krömmelbein and Weber). The genus *Hourcqia* is diagnostic of latest Barremian non-marine settings, whilst *Pattersoncypris* and *Kroemmelbeincypris* characterize Aptian saline lacustrine environments. The geographic ranges of all three genera are restricted to northeastern and eastern Brazil and northern and western Africa, though a species of *Pattersoncypris* (*P. dakotaensis* Tibert and Colin) is also present in the United States.

INTRODUCTION

THE EARLY Cretaceous ostracods of eastern Brazil and western Africa provided some of the first paleontological evidence in support of the theory of continental drift (Colin and Lethiers, 1988). The similarities between the paleofauna on both sides of the present day South Atlantic (Tambareau, 1982), combined with the correspondence of the coastlines of the two continents, indicated that they were once connected (Fig. 1). Between 1961 and 1972, Krömmelbein (1961a, 1961b, 1962, 1963, 1964a, 1964b, 1964c, 1965a, 1965b, 1966a, 1966b, 1967, 1968, 1970, 1979) and associates (Krömmelbein and Wenger, 1966; Grekoff and Krömmelbein, 1967; Krömmelbein and Weber, 1971, 1985) published many papers on Late Jurassic to mid-Cretaceous ostracods in eastern Brazil and western Africa.

The description and determination of the stratigraphic range of these ostracods laid the foundations for the ostracod biostratigraphic zonation schemes now used on both sides of the South Atlantic in petroleum exploration. This ostracod zonation, which was first developed in the Recôncavo-Tucano and Sergipe-Alagoas basins, has since been applied in the offshore Brazilian Campos Basin (Moura, 1987, 1988), as well as the Gabon, Congo and Cabinda basins (Grosdidier et al., 1996; Bate, 1999). However, detailed zonations for other offshore southeastern Brazilian basins, such as the Espírito Santo and Santos basins, have not been published.

The ostracods present in the Campos Basin (Moura and Praça, 1985; Moura, 1987, 1988) compare well with those found in the offshore basins of western Africa (Bate, 1999) but are markedly different from those in the basins south of the Walvis Ridge (Dingle, 1999). The ostracods indicate that marine conditions were established in the southernmost South Atlantic much earlier than in the central South Atlantic, suggesting that the united Florianópolis High–Rio Grande Rise–Walvis Ridge system prevented southern oceanic waters from infiltrating the South Atlantic until after the end of the Aptian (Dingle, 1999). Given the vast lateral continuity of many ostracod distributions in the South Atlantic north of the Florianópolis High, it is probable that the ostracods of the Espírito Santo and Santos basins are more closely affiliated with the ostracods from the neighboring Campos Basin than with those from the Pelotas Basin to the south, which is separated from the Santos Basin by the Florianópolis High–Rio Grande Rise system.

Unfortunately, the taxonomy of the uppermost Pre-Salt ostracod taxa has become confused; consequently, their biostratigraphic utility has become compromised to a degree. The taxonomic history of the genera *Hourcqia* Krömmelbein, 1965b and *Pattersoncypris* Bate, 1972 is outlined below.

TAXONOMIC BACKGROUND

Hourcqia africana Krömmelbein, 1965b, the type species of the new genus *Hourcqia* was one of several western African ostracods described by Krömmelbein from the so-called "West African Wealden" beds of the coastal Congo Basin. This genus was evidently widespread in upper Lower Cretaceous non-marine sediments: the holotype was found in the Congo Basin, and other specimens were subsequently reported from Gabon and the basins of north-eastern Brazil (Krömmelbein, 1970). The stratigraphic significance of the genus was emphasized in the original description: since it was not found in the "Middle Cocobeach" or the corresponding Brazilian São Sebastião Formation, it was identified as an indicator of a younger stratigraphic age than had been previously observed, or possibly even preserved, in the Recôncavo-Tucano Basin. Subsequently, Krömmelbein (1970) identified *Hourcqia* as a key genus in

FIGURE 1—Schematic map of the offshore basins surrounding the South Atlantic Ocean, demonstrating the close conjugation of the coastlines of eastern Brazil and western Africa. The oceanward extents of the basins are represented by the 3,000 m bathymetric depth line, which approximately corresponds to the ocean-continent boundary. The positions of three structural features (Florianópolis High, Rio Grande Rise, and Walvis Ridge) which together prevented the influx of oceanic water into the proto-South Atlantic from further south are indicated. Adapted from Coward et al. (1999), with Brazilian basin names and extents modified following the work of Milani et al. (2007).

linking the Brazilian "post-Bahia Series" with the Upper Cocobeach, recording the presence of the genus in a number of localities: the "Muribeca," Maceió, and non-marine Riachuelo formations of the Sergipe Basin; the Santana Formation of the Araripe Basin; the Upper Cocobeach (Gamba and Coniquet) Formation of Gabon; and an uncertain horizon from the Congo Basin. Furthermore, it was determined that two stratigraphically separate species groups were present: the older named "*africana*," the younger "*angulata*" (Krömmelbein, 1970).

The following year, *H. africana* was redesignated as the subspecies *H. africana africana*, and a second subspecies, *H. africana confluens* Krömmelbein and Weber, 1971 was described (Krömmelbein and Weber, 1971). Another species, *H. angulata* Krömmelbein and Weber, 1971, was also described, and four subspecies were assigned to it: *Hourcqia angulata angulata* Krömmelbein and Weber, 1971, *H. angulata sinuata* Krömmelbein and Weber, 1971, *H. angulata symmetrica* Krömmelbein and Weber, 1971 and *H. angulata salitrensis* Krömmelbein and Weber, 1971. These subspecies were all derived from sediments younger than the Bahia Series as defined by Krömmelbein and were particularly important in characterizing them. Due to the fact that the ostracods referred to by Schaller (1969) to distinguish between sedimentary layers cannot be utilized (since names but no images or descriptions were given), these species have become critical in biostratigraphic studies of the upper Lower Cretaceous sediments of both eastern Brazil and western Africa.

In 1972, Bate promoted *H. angulata sinuata* and *H. angulata salitrensis* to species level and assigned them to the new genus *Pattersoncypris*, joining the type species *P. micropapillosa*

Bate, 1972. *Hourcqia angulata angulata* and *H. angulata symmetrica* were not officially referred to *Pattersoncypris* by Bate, though other authors (eventually including Bate) have subsequently referred them to *Pattersoncypris* as well (Grosdidier et al., 1996; Bate, 1999; Coimbra et al., 2002).

Do Carmo et al. (2008) formalized the respective referrals of *Hourcqia* to *Cypridea* Bosquet, 1852, and *Pattersoncypris* to *Harbinia* Tsao, 1959. *Hourcqia africana africana* and *H. africana confluens* were synonymized and transferred to *Cypridea*, resulting in the new combination *Cypridea africana*. Consequently, the stratigraphic separation of these two subspecies, and thus their utility as biostratigraphic markers, was obscured. Additionally, all four subspecies of *P. angulata* were promoted to species level, and along with *P. micropapillosa* were referred to *Harbinia*, forming the new combinations *H. micropapillosa*, *H. angulata*, *H. sinuata*, *H. symmetrica* and *H. salitrensis*. Whilst all five species were retained, and their utility as biostratigraphic markers was not compromised, the synonymization of *Pattersoncypris*, a genus which was, as far as was understood, restricted to the Aptian of Brazil and western Africa, with *Harbinia*, an exclusively Chinese genus, was extremely problematic from a paleobiogeographical perspective.

The publication of Do Carmo et al. (2008) was not the first in which *Pattersoncypris* had been referred to *Harbinia*. Do Carmo has considered the two genera to be synonymous since at least 1998 (Do Carmo, 1998) and referred to species of *Pattersoncypris* as *Harbinia* in several subsequent publications (e.g., Do Carmo et al., 1999, 2004a, 2004b). Interestingly, Do Carmo et al. (1999) claimed to have followed Mello et al. (1993, but cited as 1997) in synonymizing the two genera. However, the paper cited makes no mention of the genus *Harbinia* despite referring to *Pattersoncypris* several times. It is probable, therefore, that it was Do Carmo's idea to synonymize *Pattersoncypris* with *Harbinia*. Other publications have followed Do Carmo et al. (1999) in synonymizing *Pattersoncypris* with *Harbinia* (e.g., Syrio and Rios Netto, 2002a, 2002b).

The overarching problem with the respective referrals of *Hourcqia* and *Pattersoncypris* to *Cypridea* and *Harbinia* is that they were not made on the basis of comparisons of holotype material. The specimens used by Do Carmo et al. (2008) were from background material from Krömmelbein's personal collection held in the Senckenberg Forschungsinstitut und Naturmuseum (SMF), Frankfurt-am-Main, and were exclusively topotypic. The type material, which is also housed at SMF—excluding the specimens described by Krömmelbein and Weber (1971), which are held in the Bundesanstalt für Geowissenschaften und Rohstoffe (formerly Bundesanstalt für Bodenforschung) in Hannover (contra. Do Carmo et al. [2008, p. 790]; their statement concerning the movement of collections from Hannover to Frankfurt is erroneous)—was inspected by (but not loaned to) Do Carmo during a visit in 1997 (A. Lord, personal commun.), though was not used in the formal referral paper (Do Carmo et al., 2008).

The key purpose of this paper, therefore, is to reassess the validity of the genera *Hourcqia* and *Pattersoncypris* based on the holotype material housed at the SMF and BGR, and to assess the validity of all of the species contained therein. This taxonomic revision reinforces the utility of these ostracod species (and genera) as biostratigraphic markers in Lower Cretaceous off shore South Atlantic basin sediments (Fig. 2). Furthermore, the paleoenvironmental settings with which each species has been associated in the literature are reviewed in order to enhance the accuracy of paleoenvironmental interpretations made based on faunas from basins for which no zonation scheme has yet been published.

Institutional abbreviations.—BGR = Bundesanstalt für Geowissenschaften und Rohstoffe (originally the Bundesanstalt für Bodenforschung), Geozentrum, Hannover; NHM = Natural History Museum, London (formerly the British Museum, Natural History); SMF = Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt-am-Main.

SYSTEMATIC PALEONTOLOGY

Class OSTRACODA Latreille, 1802 (nom. correct. Latreille, 1806)
Order PODOCOPIDA Müller, 1894
Suborder PODOCOPINA Sars, 1866
Superfamily CYPRIDOIDEA Baird, 1845
Family CYPRIDEIDAE Martin, 1940
Genus HOURCQIA Krömmelbein, 1965

1965b *Hourcqia* KRÖMMELBEIN, p. 68.

Type species.—*Hourcqia africana* Krömmelbein, 1965 (by original designation).

Included species.—*Hourcqia africana* Krömmelbein, 1965b; *Hourcqia confluens* (Krömmelbein and Weber, 1971); *Hourcqia bateke* (Grosdidier, 1967) ("*Reconcavona*"); *Hourcqia kouilouensis* (Krömmelbein, 1965b) (*Cypridea* [*Sebastianites*?]); *Hourcqia sylvesterbradleyi* (Bate, 1994) (*Cypridea*).

Diagnosis.—Original as translated from Krömmelbein (1965b): A genus presumably belonging to the Cyprididae of unknown subfamily with the following characteristics: Carapace robust or elongate ovate in lateral view, in dorsal view biconvex. Right valve larger than left, overlapping very slightly around the entire margin: overlap is most prominent along the central ventral margin and along the upper anterior margin, where the left valve is weakly concave and the right is convex. Both valves have very weak, poorly-defined pitting in the anterodorsal region; aside from this, no coarse or fine ornamentation has been observed.

Amended diagnosis: A cypridoid ostracod probably belonging to the Cyprideidae, inferred based on the presence of a reduced rostrum in species possibly ancestral to the genus, e.g., *Cypridea* (*Sebastianites*) *minima* Moura, 1972, *Cypridea tchibodaensis* Krömmelbein 1965, or possibly the Candonidae on the basis of the muscle scars identified by De Klasz and Uliczny (1975) in a referred specimen from Gabon, with the following characteristics: Carapace ovate in lateral view, tallest anterior of the mid-point. Both valves markedly convex in dorsal view. Carapace thickest slightly posterior of the mid-point, tapering more to the anterior than to the posterior. Right valve larger than left, overlapping very slightly around the entire margin: most clearly visible along the central ventral margin and along the anterodorsal margin, where the left valve is sometimes weakly concave and the right is convex. Anterior and posterior margins obliquely rounded, hinge margin substraight. Nodes present in stratigraphically lower species of the genus, absent in species found in upper levels; possibly lost in response to environmental change. No recognized sexual dimorphism.

Occurrence.—Pre-Salt series in eastern Brazil and western Africa (Colin and Jacobs, 1990); early to latest Barremian.

Paleoecology.—Non-marine (Krömmelbein, 1965b; Krömmelbein and Weber, 1971), highstand lacustrine (Bate, 1999); associated with coquinas in the Campos Basin (Silva-Telles, 1992; Carvalho et al., 2000; Rangel and Carminatti, 2000), which have been reported to be sporadically interspersed with thin shales containing planktic and benthic foraminifera suggestive of some level of marine influence (Silva-Telles,

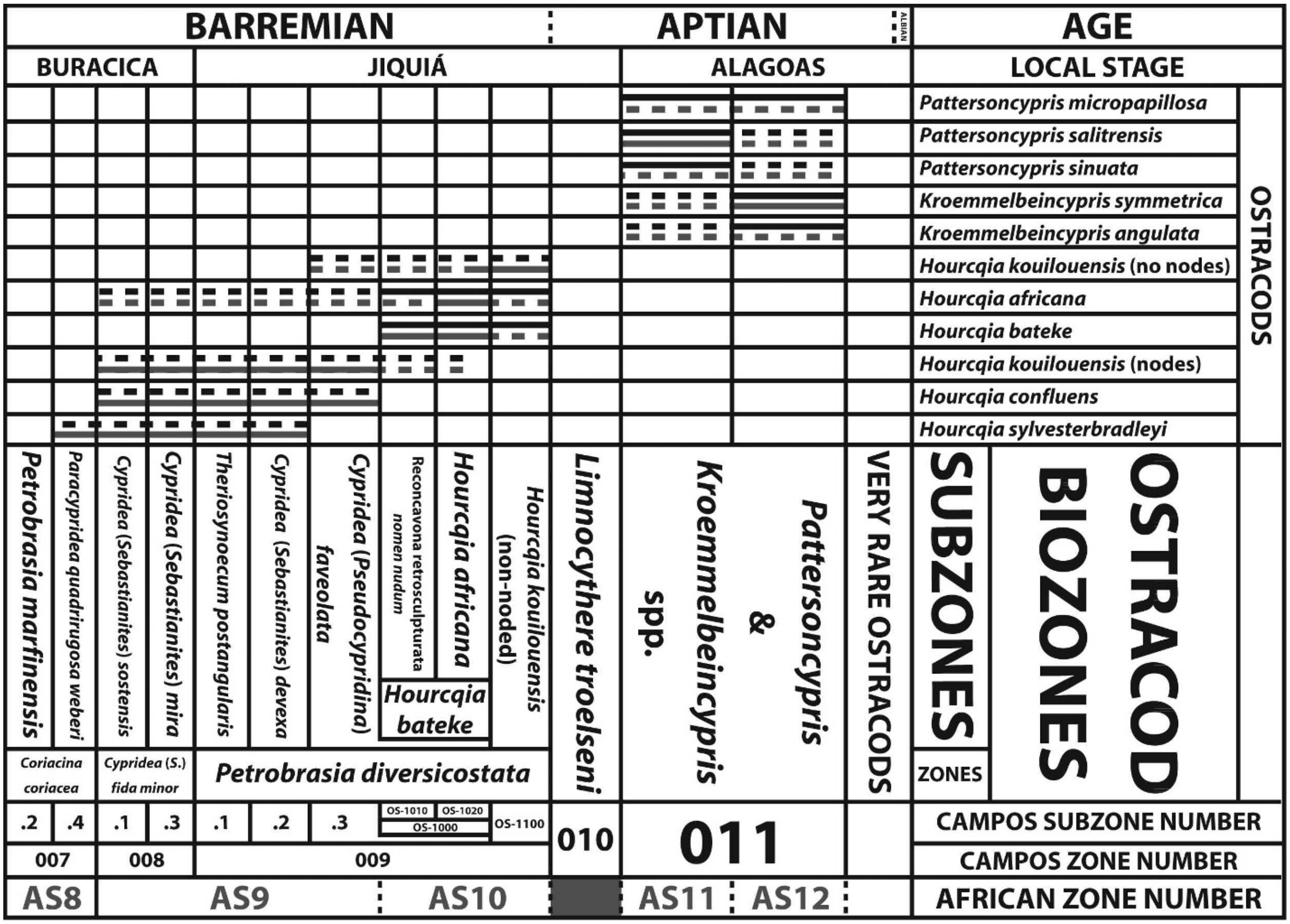

FIGURE 2—Known (solid line) and inferred (dashed line) ranges of the ostracods considered in this paper, based on the Brazilian zonation outlined by Moura (1987) and Silva-Telles (1992) for the Campos Basin and the Western African zonation scheme defined by Grosdidier et al. (1996) and Bate (1999) for the Gabon, Congo and Kwanza basins. The black lines indicate the known and inferred ranges of the ostracod species in the offshore basins of western Brazil, standardized against the zonation of Moura (1987); gray lines indicate the ranges of each taxon in the offshore basins of western Africa. International stage boundaries are approximate relative to Brazilian local stages.

1996, cited by Dias, 2005) and indicative that this genus was tolerant of at least slightly raised salinity levels (brackish) relative to typical freshwater settings (which generally contain fewer than 0.5 parts per thousand of dissolved salts).

Remarks.—*Hourcqia* was referred to the genus *Cypridea* by Do Carmo and colleagues (2008) based on the observation of a reduced rostrum on a specimen designated as a "homotype" from the Morro do Chaves Member of the Coqueiro Seco Formation in the Sergipe-Alagoas Basin, Brazil. However, the holotype specimen of the type species *Hourcqia africana* (Krömmelbein, 1965b, pl. 3, fig. 10, SMF Xe 5389) does not possess an anteroventral rostrum, and Krömmelbein made no mention of a rostrum in the original description.

Specimens used in the study of Do Carmo et al. (2008) were from background material in the Krömmelbein personal collection (held in the SMF), specimens which were topotypic at best (specimens SMF Xe 18551 and 18553; A. Lord, personal commun.). The "homotype" specimen referred to *Hourcqia africana* from the Sergipe-Alagoas Basin (Do Carmo et al., 2008, fig. 6, nos. 1–4, MCP-1088-PI) more closely resembles an illustrated paratype specimen (Krömmelbein, 1965b, pl. 3, fig. 11, SMF Xe 5392) than the holotype. A possible minuscule rostrum is visible on the anteroventral margin of the left valve of MCP-1088-PI (Do Carmo et al., 2008, fig. 6, nos. 1, 2). However, no rostrum is present on the right valve (Do Carmo et al., 2008, fig. 6, no. 3). Consequently, this specimen cannot be referred to the genus *Cypridea*, since it does not fulfill the criteria proposed by Sylvester-Bradley (1949, p. 130) for *Cypridea*, who typified the genus as having a "(c)arapace bearing on the antero-ventral margin of each valve a projection termed a "beak," often prominent," an assessment modified by Anderson (1967) to include the development of the anteroventral notch (the alveolus) and the posteroventral projection (cyathus), which are also absent in *Hourcqia*. Szczechura (1981) showed that the internal morphology of the rostrum in rostrum-bearing cypridoids varied markedly between specimens often incorporated in the genus *Cypridea*. This was followed by Horne and Colin (2005), who identified *Cypridea* as having a selvage interrupted by the rostrum.

The feature which typifies the genus *Cypridea* is the possession of a rostrum with specific internal characteristics. Thus, the absence of a rostrum in the holotype specimen of the type species *Hourcqia africana* (Fig. 3.1) precludes the referral of the genus to *Cypridea*.

HOURCQIA AFRICANA Krömmelbein, 1965

1965 *Hourcqia africana* KRÖMMELBEIN, p. 69, pl. 3, fig. 10a–10c, non fig. 11a–11c.

1967 *Hourcqia africana* Krömmelbein; GREKOFF AND KRÖMMELBEIN, p. 1329, fig. 14.

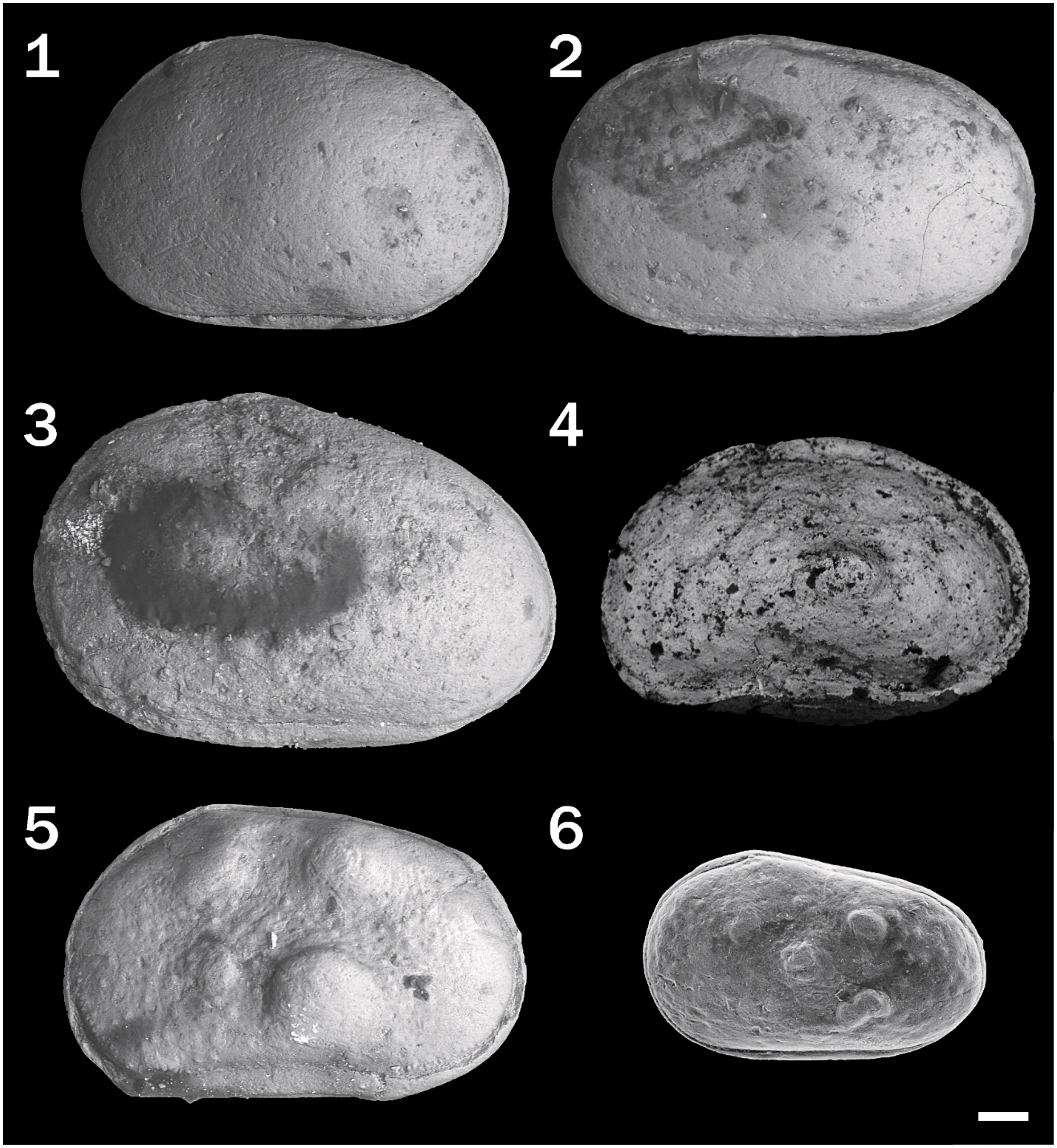

FIGURE *3*—Early Cretaceous non-marine ostracod species from offshore South Atlantic basins: *1*, *Hourcqia africana* Krömmelbein, 1965a, holotype SMF Xe 5389, adult carapace, left lateral view, BK-1-Ter well, ‘‘West-African Wealden,’’ offshore Congo Basin, Congo; *2*, *Hourcqia africana* Krömmelbein, 1965a, referred specimen BfB 7793, adult carapace, left lateral view, Bast-1-Ba well, ‘‘Muribeca? Formation,’’ Sergipe/Alagoas Basin, Brazil; *3*, *Hourcqia confluens* (Krömmelbein and Weber, 1971), holotype BfB Typ.-Nr. 7794, adult carapace, left lateral view, Pta-3-Se well, ‘‘Muribeca Formation,’’ Sergipe Basin, Sergipe State, Brazil; *4*, *Hourcqia bateke* (Grosdidier, 1967), holotype, adult carapace, left lateral view, Tchibota-1 well, ‘‘Congo Basin Wealden,’’ offshore Congo Basin, Congo; *5*, *Hourcqia kouilouensis* (Krömmelbein, 1965b), holotype SMF Xe 5381, adult carapace, left lateral view, BK-1-Ter well, ‘‘West-African Wealden,’’ offshore Congo Basin, Congo; *6*, *Hourcqia sylvesterbradleyi* (Bate, 1994), holotype, adult carapace, left lateral view, Chevron TK-G4 well, Toca B Formation, offshore Congo Basin, Cabinda, Angola. Scale bar=100 µm.

TABLE *1*—Alan Lord's observations of the holotype and paratype specimens of the species *Hourcqia africana*.

Specimen	Specimen No.	Krömmelbein, 1965b	Alan Lord's observations (personal commun., 2011)
Holotype	SMF Xe 5389	pl. 3, fig. 10a, b, c	Well preserved. Anterior margin of left valve with minor marginal rim curving smoothly round to merge with the ventral margin. No anteroventral rostrum.
Paratype	SMF Xe 5390	Not figured	Identical to holotype. No anteroventral rostrum.
Paratype	SMF Xe 5391	Not figured	Angle present on the anteroventral margin of the left valve is present but clearly related to a post mortem fracture.
Paratype	SMF Xe 5392	pl., fig. 11a, b, c	Appears to possess a rostrum in Krömmelbein, 1965b (fig. 11b) but this is a weak feature and may be a result of damage to the anteroventral margin of the left valve. Longer than the other specimens.
Paratype	SMF Xe 5393	Not figured	Not well preserved. May have had a very weak rostrum.

1971 *Hourcqia africana africana* (Krömmelbein); Krömmelbein and Weber, p. 32, pl. 6, fig. 21a–21c.

1975 *Hourcqia africana* Krömmelbein; De Klasz and Uliczny, p. 189, 193, pl. 3, fig. 1.

1984 *Hourcqia africana africana* (Krömmelbein); Grosdidier and Bignoumba, p. 95, pl. 1, fig. 1.

non 1992 *Hourcqia africana* Krömmelbein; Goodall, Coles, and Whitaker, p. 383, pl. 1 (page follows description of pl. 2).

non 2008 *Cypridea africana* (Krömmelbein); Do Carmo, Whatley, Neto, and Coimbra, p. 793, 795, fig. 6, nos. 1–5.

Diagnosis.—Amended: A species of *Hourcqia* characterized by sub-parallel dorsal and ventral margins (Krömmelbein, 1965b) and a lack of ornamentation.

Holotype.—One carapace, SMF Xe 5389, housed in the SMF. Length 0.86 mm; height 0.57 mm; width 0.47 mm.

Type locality and horizon.—BK-1-Ter well drilled near the mouth of the Kouilou River (Bas Kouilou), offshore Congo Basin, "West African Wealden"; approximate co-ordinates S 04°28′40″, E 11°42′45″.

Paratypes.—One carapace, SMF Xe 5390 (PN-1 well, Pointe Noire, Congo); one carapace, SMF Xe 5391 (PI-3 well, Pointe Indienne, Congo); one carapace, SMF Xe 5392 (BK-1 well, Kouilou River mouth, Congo) (elongate morph); one carapace, SMF Xe 5393 (TB-1 well, Tchibota, Congo) (elongate morph); all held in the Senckenberg Museum, Frankfurt. SMF Xe 5392 and SMF Xe 5393 are herein transferred from *H. africana* to *Paracypridea* cf. *P. langdoni* (see below).

Occurrence.—Pre-Salt series in eastern Brazil and western Africa, Barremian-Aptian transition (Colin and Jacobs, 1990). The last appearance of *Hourcqia africana* marks the end of the Barremian (top of the AS10 ostracod Zone in western Africa; Bate, 1999), and the species is present throughout the AS10 Zone (Bate, 1999) and maybe the AS9 Zone in western Africa (Grosdidier et al., 1996), as well as (at least) the OS 1020 Subzone in the Campos Basin (Silva-Telles, 1992).

Description.—Translated and modified from Krömmelbein (1965b): Carapace ovate and robust. Anterior margin obliquely rounded; posterior margin only slightly more acutely rounded than anterior margin. Ventral margin of left valve slightly concave; ventral margin of right valve convex to sub-straight. Dorsal margin roughly straight between well-rounded cardinal angles, descends slightly posteriorly. Greatest carapace height is at the anterior cardinal angle at or slightly behind a third of the carapace length. Carapace in dorsal view stocky, evenly biconvex; greatest carapace thickness posterior of the mid-point. Both carapace ends blunt, anterior end only slightly more acute; contact line of both valves rather straight to slightly curved.

Right valve larger than left, overlapping slightly around the entire margin, most prominently along the ventral margin and the upper anterior margin. Both valves very similar in important characteristics; differences occur in the ventral margin and the anterodorsal margin. In the larger right valve, a small convexity is present along the anterior cardinal angle which displays clear overlap of the corresponding slightly concave section on the smaller left valve.

Both valves show a very faint valve indentation directly below the anterior dorsal angle; this is never clearly defined and often only slightly expressed. Aside from this, no coarse or fine ornamentation is present; carapace surface smooth to very faintly shallowly pitted. No anteroventral rostrum.

Internal features of the holotype unknown, though muscle scars typical of the Candonidae were recognized in a referred specimen from Gabon by De Klasz and Uliczny (1975).

Paleoecology.—Highstand lacustrine settings (Bate, 1999); may have inhabited settings affected by heightened salinity (see below).

Remarks.—In his original description, Krömmelbein (1965b) identified two distinct morphotypes within *Hourcqia africana*: a "stocky" (robust) morph (as typified by the holotype [Fig. 3.1] and a referred specimen) and a more "stretched" (elongate) morph (as in the figured paratype). Only the stocky morph is retained within *Hourcqia africana*: the paratype figured by Krömmelbein (1965b) is now referred to *Paracypridea* cf. *P. langdoni* Krömmelbein, 1961 (sensu Bate, 1999), since identical specimens have been found in sediments from above the first downhole occurrence of *H. africana* in the Congo Basin (J.-P. Colin, personal observation); it is unlikely that this species is actually referable to *Paracypridea*, though the true affinities of *P.* cf. *P. langdoni* will have to be explored elsewhere. The paratype specimen of *H. africana* was extracted from cuttings, unlike the holotype, which was recovered from a core sample; thus, it is possible that it may have caved from younger sediments. Krömmelbein designated three other paratypes, two robust and one elongate; the non-figured elongate specimen is probably also referable to *Paracypridea* cf. *P. langdoni* (A. Lord, personal commun.).

Based on direct observation of all five specimens originally assigned to *Hourcqia africana*, Lord (personal commun., 2011) determined that only one of the elongate paratypes may have an anteroventral rostrum (Table 1); as stated above, this specimen is now considered to represent *Paracypridea* cf. *P. langdoni*. Since similar structures are observed in the specimens figured by Do Carmo et al. (2008), these specimens are also referred to *Paracypridea* cf. *P. langdoni*. With the removal of these specimens from *H. africana*, no referred specimens are recognized as having an anteroventral rostrum.

Krömmelbein (1965b) identified *Hourcqia africana* in the "Westafrikanischer Wealden" sediments of the coastal Gabon and Congo basins, as well as the formations overlying the São Sebastião Formation in northeastern Brazil (presumably the Sergipe-Alagoas basins); however, only specimens from the coastal Congo Basin were illustrated. Subsequently, the distribution of this genus was expanded to the "Muribeca," Maceió and non-marine Riachuelo (now considered to be entirely marine) formations of the Sergipe Basin; the Santana Formation in the Araripe Basin; the Upper Cocobeach (Gamba and Coniquet) of the Gabon Basin; and an uncertain horizon in the Congo Basin (Krömmelbein, 1970). Specimens of the genus were reportedly abundant in all localities, though none were illustrated until Krömmelbein and Weber (1971) illustrated a specimen referred to *H. africana* from the "Muribeca" Formation of the Sergipe Basin (Fig. 3.2). Grosdidier and Bignoumba (1984) illustrated a specimen from the Middle-Upper Cocobeach of Gabon which appears to be intermediate between *H. bateke* and *H. africana* with respect to the degree of valve overlap on the dorsal and ventral margins.

Hourcqia africana is the index species for the AS10 zone in western Africa (Grosdidier et al., 1996; Bate, 1999), and accordingly, the top of the Barremian (Bate, 1999). The range of this species extends to the base of the AS9 Zone (Grosdidier et al., 1996). Bate's (1999) correlation of the western Africa zonation with the eastern Brazilian zonation suggests that *Hourcqia* should be present in sediments representing Schaller's (1969) Zones 009 and 010 in eastern Brazilian basins. The genus has not been identified in the Recôncavo-Tucano Basin, which is not surprising since the only rocks in this area from zones younger than 009 comprise the Marizal Formation, from which no ostracods have been reported (Viana, 1966a, 1966b; Viana et al., 1971; Moura, 1972; Cunha and Moura, 1979). *Hourcqia africana* was not identified in the Campos Basin by Moura and Praça (1985) or Moura (1987, 1988). However, in a published ostracod zonation for the coquina sequence in the Lagoa Feia Formation of the Campos Basin, Silva-Telles (1992) designated *Hourcqia africana africana* as the index taxon for the OS-1020 Zone. These sediments were given an age of Upper Jiquiá, meaning that they straddle the Barremian-Aptian boundary; this fits well with Bate's (1999) correlations.

HOURCQIA CONFLUENS (Krömmelbein and Weber, 1971)

1971 *Hourcqia africana confluens* KRÖMMELBEIN AND WEBER, p. 33, pl. 6, fig. 22a–22c.

Diagnosis.—Amended, similar to *Hourcqia africana*, but with dorsal and ventral margins more strongly convergent towards the posterior, resulting in the anterior margin being significantly more obliquely rounded than the posterior margin.

Holotype.—One carapace, BfB Typ.-Nr. 7794, held in the BGR. Length 1.05 mm; height 0.71 mm; width 0.50 mm.

Type locality and horizon.—"Muribeca" Formation (Post-Bahia Series), coastal Sergipe Basin, Brazil (Krömmelbein and Weber, 1971).

Occurrence.—Sergipe (Krömmelbein and Weber, 1971) and western African coastal basins (Bate, 1999). Early to middle Barremian (always in older strata than *H. africana*); marker species for the AS9 Zone in western Africa (Bate, 1999).

Description.—Translated and modified from Krömmelbein and Weber (1971). Carapace posteriorly-tilted trapezoid in lateral view. Anterior margin rather evenly obliquely rounded, true anterior cardinal angle always absent, since highest point of carapace just anterior of the mid-length. Straight portion of dorsal margin descends quite steeply posteriorly. Posterior dorsal angle obliquely rounded, more acutely rounded further posteriorly resulting in a somewhat pointed posterior margin. Lower section of posterior margin slightly tilted, emphasizing convergence of lateral margins. Ventral margin sub-straight.

Carapace relatively thin in dorsal view, slightly fusiform, thickest just posterior of the centre. Flanks very slightly indented before the centre.

Right valve larger than the left, overlapping very slightly around the entire periphery, more obviously so along the ventral, anterior dorsal and upper anterior margins. No sculpture observed.

Internal characteristics unknown.

Paleoecology.—Occurs in association with a maximum flooding surface in western African offshore basins (Bate, 1999).

Remarks.—*Hourcqia confluens* was referred by Do Carmo et al. (2008) to *Cypridea africana*. This referral is rejected, since the greater posterior confluence of the dorsal and ventral margins distinguishes *H. confluens* from *H. africana*; furthermore, *H. confluens* occurs in a stratigraphically lower interval than *H. africana*. Its last stratigraphic appearance, (i.e., its first downhole appearance), marks the top of the western African AS9 zone (Bate, 1999). Direct observation of the holotype specimen (Fig. 3.3) originally figured by Krömmelbein and Weber (1971, p. 81, pl. 22a–22c) indicated that this species does not possess an anteroventral rostrum. Consequently, the referral of this species to *Cypridea* is rejected and it is retained within *Hourcqia*.

The type specimen of the species *Brasacypris*? *grosdidieri* De Klasz and Uliczny, 1975 is superficially similar to *Hourcqia confluens*. If these species were found to be synonymous, the biostratigraphic utility of *H. confluens* would be significantly reduced. Following Bate (1999), *H. confluens* is restricted to the AS9 Zone. In contrast, *Brasacypris*? *grosdidieri* was found to occur in the African and AS10 and AS11 zones (N'Toum–lower N'Zeme-Asso Series, Coniquet Formation) by De Klasz and Uliczny (1975) and Grosdidier et al. (1996). Bate (personal commun., 2011) has suggested that *Brasacypris*? *grosdidieri* may represent an interior cast of *Cypridea loango* Grosdidier, 1967; this interpretation is followed herein. Consequently, *Hourcqia confluens* retains biostratigraphic significance. The paratype juvenile specimen of *Brasacypris*? *grosdidieri* figured by De Klasz and Uliczny (1975) appears to be referable to *Cypridea tchibodaensis* Krömmelbein, 1965b. As is the case in all species of *Hourcqia*, *Cypridea tchibodaensis* demonstrates an "inverse" valve-size ratio (right valve larger than left). However, the holotype specimen of this species preserves a minute anteroventral rostrum and rostral notch unaccompanied by a rostral furrow (as mentioned in the original description); if this feature were not present, this species may have been referable to the genus *Hourcqia*. This interpretation is significant because of the implicit evolutionary relationship between *Hourcqia* and *Cypridea*: a close relationship between the two genera would indicate that *Hourcqia* is a member of the family Cyprideidae.

HOURCQIA BATEKE (Grosdidier, 1967)

1967 "*Reconcavona*" *bateke* GROSDIDIER, pl. 3, fig. 7a–7j (mis-labeled 3a–7j)

1985 *Reconcavona* aff. *R. bateke* Grosdidier; MOURA AND PRAÇA, pl. 1, figs. 3, 4.

1988 *Reconcavona* aff. *R. bateke* Grosdidier; MOURA, pl. 1, figs. 3, 4.

Diagnosis.—A species of *Hourcqia* defined by marked dorsal and ventral overlap of the left valve by the right, and (commonly) the presence of a poorly-defined, yet prominent knob on the left valve (causing marked asymmetry of the valves). This species was removed from *Reconcavona* Krömmelbein, 1962 due to the "inverse" valve ratio (right larger than left in *Hourcqia*, left larger than right in *Reconcavona*).

Holotype.—One carapace depicted in Grosdidier, 1967 (pl. 3, fig. a–d); no specimen number designated. Originally housed in the Laboratoire de Micropaléontologie de la Faculté des Sciences de Paris (according to Grosdidier, 1967), now housed (along with the paratypes) in the TOTAL Micropalaeontological Laboratories, Pau, France. Length 0.85–0.90 mm; height 0.55–0.65 mm.

Type locality and horizon.—Top of the "Congo Basin Wealden" (Grosdidier, 1967).

Occurrence.—Congo (Grosdidier, 1967) and Campos (Moura and Praça, 1985; Moura, 1988; Silva-Telles, 1992) basins. Age interpreted as upper Barremian since the holotype was found in the same formation as *Cypridea loango* and *Damonella*? *tinkoussouensis* Grosdidier, 1967, which were identified in Bate's (1999) western African biostratigraphic zonation as occurring in Barremian sediments. Also identified in the uppermost Barremian coquina sequence of the Campos Basin (Silva-Telles, 1992). Top (Grosdidier et al., 1996) of the African AS10 zone (Bate, 1999); OS-1000 Zone in the Campos Basin (Silva-Telles, 1992).

Description.—Translated and modified from Grosdidier (1967).Valves strongly asymmetrical, giving the impression that the specimen has been crushed. Outline asymmetry most strongly pronounced in the dorsal region: larger right valve is tallest just anterior of the mid-point, maximum carapace height equal to three-quarters of its length; smaller left valve tallest further anterior of the mid-length, maximum carapace height equal to three-fifths of its length. Valve overlap greatest on dorsal and ventral margins, more reduced on anterior and posterior margins.

Anteroventral margin rounded, though anterior and anterodorsal margins are more obliquely rounded, merging smoothly with the dorsal margin. Dorsal margin posteroventrally tilted, tends to be straight but never the same length on both valves: longer on the left. Posterior margin forms a flattened arc in the lower two-thirds of its height. Ventral margin slightly concave on left valve, nearly straight on right valve, resulting in marked overlap along this margin. Valve asymmetry is reflected in the greatest thicknesses of the valves: right valve thickest approximately at the mid-length and mid-height, left valve thickest posterior of the mid-length and ventral of the mid-height, raised in a prominent yet poorly-defined cone. Width asymmetry is especially prominent in dorsal and anterior views.

Surface appears rough and finely granular, though this may represent a preservational artifact.

Internal characteristics unknown.

Paleoecology.—Non-marine; contemporaries occur in high-stand lacustrine settings in western African offshore basins (Bate, 1999).

Remarks.—*Hourcqia bateke* (Fig. 3.4) was originally provisionally referred to the genus *Reconcavona* by Grosdidier (1967). However, this genus is characterized by the left valve being larger than the right (Krömmelbein, 1962); accordingly, this species must be excluded from *Reconcavona*, since the right valve is larger than the left. It is probable that *Hourcqia bateke* is closely related to *Hourcqia africana*, based on the morphological similarity exhibited by both species. One specimen figured by Grosdidier and Bignoumba (1984, p. 95, pl. 1, fig. 1) as *Hourcqia africana africana* appears to show intermediate dorsal and ventral margin valve overlap between *H. africana* and *H. bateke*. The two species may have been contemporaries in the Campos Basin, based on the fact that the *Hourcqia africana* Subzone (OS-1020) comprises the upper part of the *Hourcqia bateke* Zone (OS-1000) (Silva-Telles, 1992). Other contemporaries of this species listed by Bate (1999) are *Cypridea loango*, *Paracypridea* cf. *P. langdoni* and *Damonella*? *tinkoussouensis* (which may include *Reconcavona*? *ultima* Krömmelbein and Weber, 1971).

HOURCQIA KOUILOUENSIS (Krömmelbein, 1965b)

1965b *Cypridea* (*Sebastianites*?) *kouilouensis* KRÖMMELBEIN, pl. 1, fig. 5a–5c.
1985 *Limnocypridea subquadrata* Schaller, nomen nudum; MOURA AND PRAÇA, pl. 1, figs. 5–7.
1988 *Limnocypridea subquadrata* Schaller, nomen nudum; MOURA, pl. 1, figs. 5–7.

Diagnosis.—Distinguished from other species of *Hourcqia* by the presence of four nodes on each valve, arranged in an irregular square and forming a cross-shaped (+) depression between them. Some referred specimens lack these nodes, which may represent ecophenotypic variation precipitated by variable environmental conditions.

Holotype.—One carapace, SMF Xe 5381, held in the SMF. Length 0.93 mm; height 0.60 mm; width 0.51 mm.

Type locality and horizon.—BK-1-Ter well drilled near the mouth of the Kouilou River (Bas Kouilou), offshore Congo Basin, "West African Wealden"; approximate co-ordinates S 04°28′40″, E 11°42′45″.

Occurrence.—Congo (Krömmelbein, 1965b) and Campos basins (Moura and Praça, 1985; Moura, 1988; Silva-Telles, 1992). The ranges of *Cypridea kouilouensis* and *Limnocypridea subquadrata* nomen nudum, taken together (following the synonymization of these species and their referral to the genus *Hourcqia*) indicate that this species spanned the mid-latest Barremian, corresponding to (at least) the AS9 Zone in western Africa (Bate, 1999) and the OS-1100 Zone in the Campos Basin (Silva-Telles, 1992).

Description.—Translated and modified from Krömmelbein (1965b). Carapace posteriorly-tilted trapezoidal in lateral view, with evenly obliquely rounded anterior and posterior margins. Greatest carapace height at the anterior cardinal angle (one-third from the anterior of the carapace length). Dorsal margin sub-straight to slightly convex, descends slightly towards the posterior. Posterior cardinal angle similar to anterior cardinal angle. Ventral margin slightly concave on left valve, relatively straight on right valve. Carapace moderately thin and biconvex in dorsal view, with the end of the carapace truncated. Coarse sculpture (when present) comprises well-defined, swollen nodes. Line of valve contact sub-straight.

Right valve larger than left. Both valves are effectively identical, the only difference being that in the anterodorsal region, the left valve is sometimes slightly concave, whilst the right is either less concave or slightly convex. Rostral region underdeveloped; rostrum absent, rostral alveolus absent.

Coarse sculpture comprises four swollen nodes, identical on both valves. Two nodes are dorsal, two are ventral; the anterior nodes are less pronounced than the posterior nodes. The anteroventral node in particular is quite small, and is always smallest. Between the nodes, a slight depression in the shape of an irregular cross (+) is present. Distinct fine sculpture appears to be absent.

Internal characteristics unknown.

Paleoecology.—Non-marine; occurs in conjunction with a maximum flooding surface in western African coastal basins (Bate, 1999).

Remarks.—A species of *Hourcqia* possessing clear coarse sculpture in the shape of four nodes on each valve (Fig. 3.5), *H. kouilouensis* was listed as a contemporary of *H. confluens*, *H. sylvesterbradleyi*, *Theriosynoecum papillaris* (Krömmelbein, 1965b) and several species of *Petrobrasia* Krömmelbein, 1965a by Bate (1999).

The specimens depicted by Moura and Praça (1985) and Moura (1988) as *Limnocypridea subquadrata* nomen nudum, a name first published in Schaller's (1969) revision of the stratigraphy of the Sergipe-Alagoas Basin without an accompanying description or illustration, almost certainly represent a non-noded morph of *H. kouilouensis*. The outlines of the three specimens are virtually identical to that of the *H. kouilouensis* holotype, aside from the sharper angle of the posteroventral margin and the greater inflation of the carapace. Given that Silva-Telles (1992) mentions the presence of noded and smooth morphs of *Limnocypridea subquadrata* nomen nudum in the sediments of the coquina sequence of the Campos Basin (OS-1100 Zone), it seems likely that these two morphs represent the same species. It is possible that the expression of nodes was dependent on paleoenvironmental conditions, an inference supported by the observation of ecophenotypic variation in *H. sylvesterbradleyi* (Bate, 1994, 1999) and modern taxa such as *Cyprideis torosa* Jones, 1850 (Van Harten, 2000).

HOURCQIA SYLVESTERBRADLEYI (Bate, 1994)

1994 *Cypridea sylvesterbradleyi* BATE, p. 103, pl. 21, figs. 1–5; pl. 21, figs. 1–4.

1992 *Cypridea* (*Sebastianites*) cf. *eminens* Grekoff and Krömmelbein; GOODALL, COLES, AND WHITAKER, p. 368.

1992 *Sebastianites* cf. *eminens* (Grekoff and Krömmelbein); GOODALL, COLES, AND WHITAKER, pl. 1 (after pl. 2 caption).

Diagnosis.—Distinguished from other species of *Hourcqia* by the presence of five nodes on each valve, arranged in a cross (×); these are often under-developed or completely undeveloped, seemingly in response to unfavorable environmental conditions.

Holotype.—Adult carapace, OS 14669, held in the NHM. Length 0.69 mm; height 0.42 mm; width 0.22 mm.

Type locality and horizon.—Chevron TK-G4 well, 18.5 km southwest of Landana, offshore Cabinda, Angola; Toca B Formation (Bate, 1994); approximate coordinates S 05°19′15″, E 12°00′09″.

Paratypes.—Carapace, OS 14670; right valve, OS 14671; left valve, OS 14672; carapace, OS 14673; right valve, OS 14674; all held in the NHM.

Occurrence.—Offshore Congo and Gabon basins (including Cabinda (Goodall et al., 1992)) (Bate, 1994, 1999). Upper Barremian (Bate, 1994), African AS8b-AS9 zones (Bate, 1994, 1999).

Description.—Carapace posteriorly-tilted ovate in lateral view. Greatest carapace height at anterior cardinal angle, one-third of the carapace length. Anterior margin obliquely rounded, anterior cardinal angle present at connection to dorsal margin. Hinge margin straight or slightly concave, tilting towards the posterior. Posterior margin more acutely rounded than anterior, with lower apex than anterior margin. Carapace thin biconvex in dorsal view, nodal projections obvious. Line of contact between valves sub-straight.

Coarse sculpture comprises five nodes arranged in a cross (×); two nodes occur mid-dorsally, two mid-ventrally, and one is median; anterior nodes less pronounced than posterior nodes, median node intermediate.

Right valve larger than left. Valves identical apart from the presence of a slight concavity at the anterior cardinal angle in the left valve (absent in right valve) and the slightly concave ventral margin of the left valve (sub-straight in right valve).

Rostrum absent, rostral alveolus absent.

Internal characteristics unknown.

Paleoecology.—Occurs in transgressive lacustrine settings in western African offshore basins (as listed above) (Bate, 1999).

Remarks.—*Hourcqia sylvesterbradleyi* (Fig. 3.6) is quite similar to *H. kouilouensis*, though is distinguished from this species by the presence of a central node between the two anterior and posterior nodes, as well as the more oblique rounding of the cardinal angles. *Hourcqia sylvesterbradleyi* is also somewhat smaller than *H. kouilouensis*: the former reaches a maximum length of 0.79 mm (Bate, 1994), whilst the holotype of the latter is 0.93 mm long (Krömmelbein, 1965b). Both species demonstrate variable node expression, possibly a result of ecophenotypic variation in response to changing environmental conditions.

Family CYPRIDIDAE Baird, 1845
Subfamily CYPRINOTINAE Bronstein, 1947
Genus PATTERSONCYPRIS Bate, 1972

1972 *Pattersoncypris* BATE, p. 380.

Type species.—*Pattersoncypris micropapillosa* Bate, 1972 (by original designation).

Included species.—*Pattersoncypris micropapillosa* Bate, 1972; *Pattersoncypris sinuata* (Krömmelbein and Weber, 1971) (*Hourcqia angulata*); *Pattersoncypris salitrensis* (Krömmelbein and Weber, 1971) (*Hourcqia angulata*), *Pattersoncypris dakotaensis* (Tibert and Colin, 2009, in Tibert et al., 2009) (*Hourcqia*).

Diagnosis.—Amended: Carapace ovate in lateral view. Greatest carapace height approximately at mid-length, forming a pronounced hump. Both valves strongly convex in dorsal view, carapace thickest at or slightly posterior of mid-length. Carapace surface lacks coarse ornamentation. Left valve slightly larger than right, with at least slight overlap on all margins.

Anterior and posterior margins obliquely rounded, anterior margin more-so than the posterior, with higher apex. Anterodorsal margin of right valve slightly concave; convex to concave on left valve (though always less concave than right), accentuating dorsal hump of carapace and anterodorsal angle. Hinge margin slightly convex, angled posteroventrally. Ventral margin ranges from slightly concave to slightly convex.

Carapace surface smooth to papillate. No coarse ornamentation.

No recognized sexual dimorphism of the carapace.

Hinge adont; right valve was described by Bate (1972) as having a groove for accommodation of the dorsal margin of the left valve, though this does not appear to accurately describe the nature of the hinge of the holotype specimen (Fig. 4.1) unless the valves of the carapace have been detached.

Muscle scars typical of Cyprididae.

Internal characteristics as per Bate (1972) and Smith (2000a).

Occurrence.—Throughout north-eastern Brazil and both sides of the proto-South Atlantic: reported from the Potiguar (Do Carmo et al., 1999), Grajaú (Ramos et al., 2006), Araripe (Bate, 1972; Smith, 2000a; Do Carmo et al., 2008; and surrounds see Hessel et al., 2006), Sergipe (Schaller, 1969; Bate, 1972) and Campos (Moura, 1987, 1988) basins on the Brazilian side; also present in Liberia (Bate, 1972) and the coastal Congo Basin (Bate, 1999). Late Early Cretaceous (Krömmelbein and Weber, 1971; Bate, 1972), Aptian (Bate, 1999); African Zones AS11-AS12 (Bate, 1999); Brazilian Zone 011 (Moura, 1987, 1988). Based on its absence in sediments above the Santana Formation, *Pattersoncypris* was probably extinct by the Albian–Cenomanian transition. This genus was used to determine the age (Aptian) and provenance (Romualdo Member of the Santana Formation) of the spinosaurid dinosaur *Irritator challengeri* Martill et al., 1996, due to the fact that this specimen was purchased without these data (Sues et al., 2002). Grosdidier (1979) figured a specimen

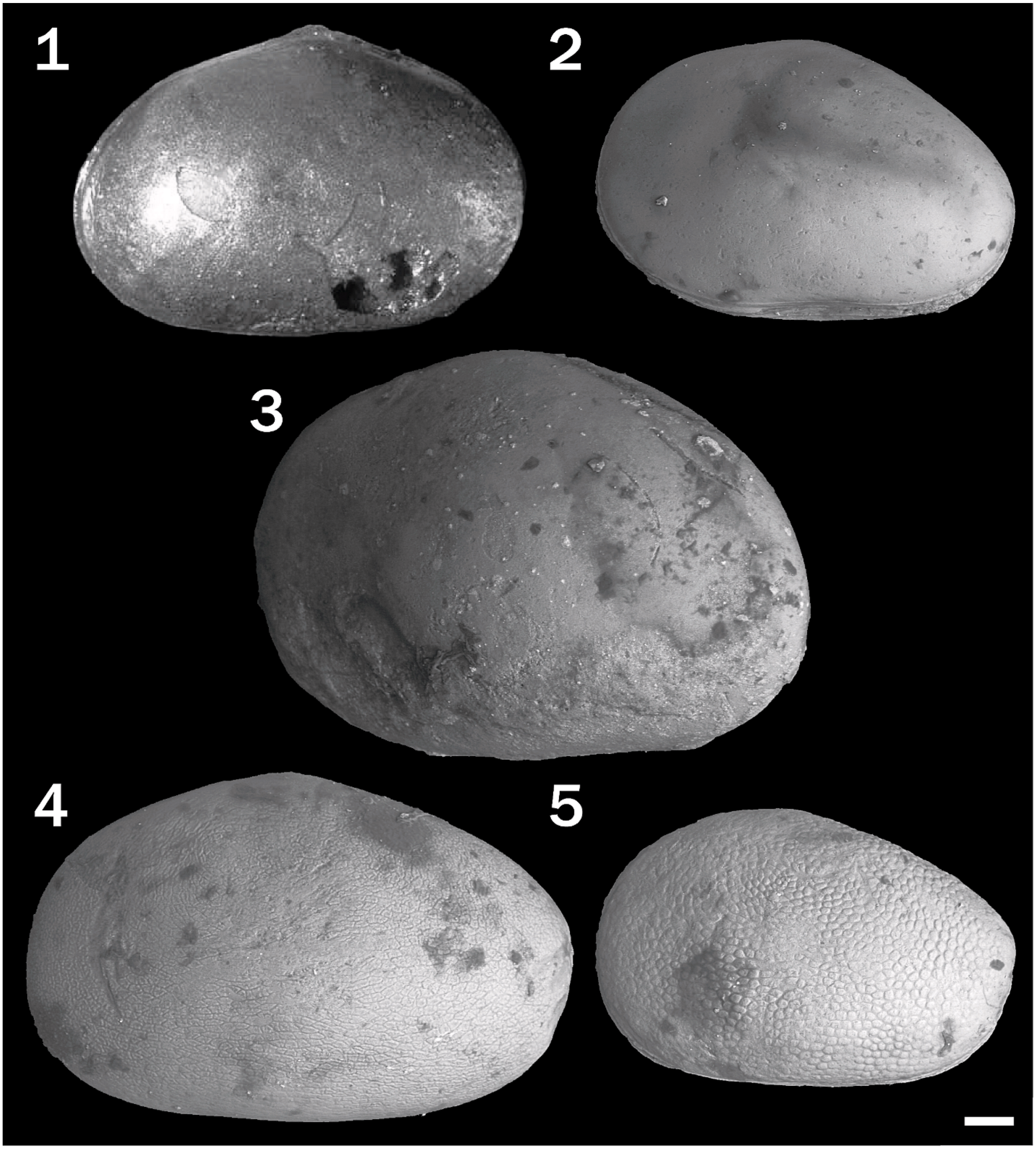

FIGURE 4—Early Cretaceous non-marine ostracod species from offshore South Atlantic basins: *1*, *Pattersoncypris micropapillosa* Bate, 1972, holotype Io. 4680, adult female carapace, right lateral view, Santana Formation (fish beds), Araripe Basin, Ceará State, Brazil; *2*, *Pattersoncypris sinuata* (Krömmelbein and Weber, 1971), holotype BfB Typ.-Nr. 7796, adult carapace, left lateral view, Pia-4-Al well, Maceio Formation, Alagoas Basin, Alagoas State, Brazil; *3*, *Pattersoncypris salitrensis* (Krömmelbein and Weber, 1971), holotype BfB Typ.-Nr. 7798, adult carapace, left lateral view, Santana Formation (above the fish beds), Araripe Basin, Pernambuco State, Brazil; *4*, *Kroemmelbeincypris symmetrica* (Krömmelbein and Weber, 1971), holotype BfB Typ.-Nr. 7797, adult carapace, left lateral view, Vgst-1-Ma well, Codó Formation, Paraná Basin, Maranhão State, Brazil; *5*, *Kroemmelbeincypris angulata* (Krömmelbein and Weber, 1971), holotype BfB Typ.-Nr. 7795, ?adult carapace, left lateral view, Pia-3-Al well, Maceio Formation, Alagoas Basin, Alagoas State, Brazil. Scale bar=100 µm.

TABLE 2—Comparison between the species *Harbinia hapla* and *Pattersoncypris micropapillosa*, demonstrating the numerous differences between the two species. The non-overlapping age and geographical range, as well as a number of morphological characteristics (e.g., degree of valve overlap; right valve anterodorsal margin; height of posterior margin apex) separate these genera.

Characteristic	*Harbinia hapla*	*Pattersoncypris micropapillosa*
Carapace shape	Sub-triangular; rounded wedge-shaped	Ovate
Anterior margin	Obliquely rounded	Obliquely rounded
Anterior margin apex	~Half the height	~Half the height
Anterior cardinal angle	Well-defined	Well-defined
Anterodorsal margin (left)	Convex	Convex
Anterodorsal margin (right)	Convex	Concave
Anterodorsal hump	Prominent	Prominent
Anterodorsal/posterodorsal margin	Anterodorsal longer	Posterodorsal longer
Hinge margin	Sub-straight	Slightly convex
Hinge groove	On left valve; overlaps right valve even along hinge line	On right valve; overlaps left valve only along hinge line
Posterior cardinal angle	Slightly expressed	Extremely slightly expressed
Posterior margin	Acutely rounded	Less obliquely rounded
Posterior margin apex	~One-fifth of the height	~One-third of the height
Ventral margin	Sub-straight to slightly concave	Slightly convex to slightly concave
Valve asymmetry	Left larger than right	Left larger than right
Degree of valve asymmetry	Marked discrepancy	Sub-equivalve
Valve overlap	Left overlaps right except at hinge line	Left overlaps right except at hinge line
Anterodorsal margin overlap	Massive despite convex right valve	Reduced despite concave right valve
Ornamentation	Striate/reticulate	Smooth/papillate
Hinge	Adont	Adont
Muscle scars	Typical for Cyprididae	Typical for Cyprididae
Marine/Non-marine	Non-marine	Non-marine
Palaeoenvironmental tolerance	Fresh- to brackish-water settings	Brackish- to saline-water settings
Age	Santonian–Campanian	Aptian–Albian; possibly Cenomanian
Geographic range	China	Eastern Brazil, Angola, Congo, Gabon, Liberia, Morocco, Chad; possibly U.S.A.
Assemblage characteristics	Never occurs in mixed or monospecific assemblages	Frequently occurs in mixed or monospecific assemblages

labeled as *Hourcqia*? GA G14 from the Aptian–Albian transition, the lowest part of the marine sequence in Gabon. This specimen may be referable to *Pattersoncypris*: the left valve is larger than the right, the anterodorsal margin is slightly concave, and no coarse ornamentation is preserved. The slope of the posterodorsal margin suggests that it may represent *Pattersoncypris sinuata*. However, if this specimen truly belongs to *Pattersoncypris*, a broader environmental tolerance for this genus must be inferred since the undoubtedly marine *Aracajuia benderi* Krömmelbein, 1967 and *Sergipella transatlantica* Krömmelbein, 1967 occur in the same beds.

Paleoecology.—Lowstand saline lacustrine settings (Bate, 1999); characterizes paucispecific assemblages in the Campos Basin of Brazil (Moura, 1987, 1988). Contemporaries in the Araripe Basin include species of *Cypridea*, *Darwinula* Brady and Robertson, 1885 and *Theriosynoecum* Branson, 1936 (Coimbra et al., 2002).

Remarks.—The genus *Pattersoncypris* was based on specimens from the Santana Formation in the Araripe Basin (Bate, 1972). The carapaces of many of these specimens were not well-preserved, though they were extraordinary in that they preserved phosphatized soft parts (Bate, 1972). Three species were initially assigned to the genus: *Pattersoncypris micropapillosa*, *Hourcqia angulata sinuata* and *Hourcqia angulata salitrensis*. However, two other subspecies of *Hourcqia angulata*, *H. angulata angulata* and *H. angulata symmetrica*, were never officially assigned to *Pattersoncypris* by Bate, despite the fact that numerous papers refer to one or both of these species using this genus name (Grosdidier et al., 1996; Bate, 1999; Coimbra et al., 2002). The assignment of these subspecies of *Hourcqia* to *Pattersoncypris* appears to have been assumed because of the referral of the other subspecies to the genus by Bate (1972), who followed suit in later publications (Bate, 1999).

Based on shared morphological characteristics, *P. symmetrica* and *P. angulata* are herein considered to comprise a separate radiation from *P. micropapillosa*, *P. salitrensis* and *P. sinuata* (and *P. dakotaensis*); indeed, the degree of difference is considered sufficient to warrant generic separation. These species are transferred to a new genus, *Kroemmelbeincypris*, which will be discussed below.

Pattersoncypris was referred to the Chinese genus *Harbinia* by Do Carmo and colleagues (2008) based on the overall similar morphology of the two taxa. However, Do Carmo had considered *Pattersoncypris* as a junior synonym of *Harbinia* since at least 1998. In his thesis (Do Carmo, 1998) he also described three new species of *Harbinia* (which remain nomina nuda): *Harbinia alta*, *Harbinia crepata* and *Harbinia triangulata*. These species have since been referred to in several published abstracts (Antonietto et al., 2009; Do Carmo et al., 2009; Gobbo et al., 2009) but have not been formally described.

Characters which *Pattersoncypris* and *Harbinia* share include: an adont hinge; the presence of an anterodorsal hump; left valve larger than right; and muscle scars typical of Cyprididae (Hou, 1984; Do Carmo et al., 2008). However, comparison of the holotype specimen of *P. micropapillosa*, the type species of the genus *Pattersoncypris*, with that of the type species of *Harbinia*, *H. hapla*, illustrates that these genera differ in a number of morphological characteristics (Table 2). First and foremost, the degree of valve asymmetry is far greater in *H. hapla* than in any species of *Pattersoncypris*, which results in a large disparity in the degree of anterodorsal valve overlap: in *P. micropapillosa*, the anterodorsal margin on the right valve is slightly concave, being slightly overlapped by the straighter, slightly-larger left valve. In contrast, *H. hapla* shows significant overlap of the right valve by the left in this region, due to the fact that the anterodorsal margin of the left valve is distinctly convex and, as can be best observed in dorsal view, significantly extends across the right valve. Furthermore, as originally defined by Tsao (1959) (though not as redefined by Hou, 1984), *H. hapla* was characterized as having a posteroventrally oriented diagonal depression on each valve, a feature which has never been recorded in any species of *Pattersoncypris*. The ventral margin of the right valve of *P. micropapillosa* is slightly concave to slightly convex, rather than always being slightly concave as in *Harbinia*; the ventral margins of *P. salitrensis* and *P. sinuata* are likewise always concave, though these species deviate from *H. hapla* in other ways. The species transferred in this paper to the new genus *Kroemmelbeincypris* (*K. symmetrica* and *K. angulata*) generally have convex ventral margins. The apex of the posterior margin of *Pattersoncypris*, which occurs at one-third of the total carapace height above the ventral margin, is markedly higher than that of *Harbinia*, which occurs at one-fifth the height of the carapace.

The hinge zones of *H. hapla* and *P. micropapillosa*, as originally described, could be taken to be quite different: Tsao (1959) states that the hinge groove of *Harbinia* is in the left valve, whilst Bate (1972) writes that in *Pattersoncypris* the groove on the right valve would have accommodated the left. This is problematic, since this would suggest that overlap of the right valve by the left would not be possible; however, the holotype of *P. micropapillosa* shows overlap of the left valve over the right along this margin (Fig. 4.1), meaning that it does not fit the original description of the species. In contrast, at least one paratype specimen (Bate, 1972, pl. 66, fig. 3) demonstrates overlap of the left valve by the right along the hinge margin. It is probable that, as is the case in *Hourcqia*, populations of *Pattersoncypris* demonstrate considerable carapace variation; however, further examination of the holotype and paratype material of *P. micropapillosa* will be necessary to further clarify the degree of variation in this species. The hinge margin of the holotype should be taken as typical for the species (as is reflected in the amended diagnosis above), thus some paratypes may have to be reassigned.

The disparity between the stratigraphic and temporal ranges of *Harbinia* and *Pattersoncypris* lends further support to the separation of the two genera. As originally defined, *Pattersoncypris* was restricted to the Aptian–Albian of eastern South America and western Africa. If *Pattersoncypris dakotaensis* truly belongs to *Pattersoncypris*, then the stratigraphic range of the genus extends to the upper Cenomanian of North America (Tibert et al., 2009). *Pattersoncypris* (specifically *P. sinuata*) has also been identified in Albian strata in Morocco (Andreu-Boussut, 1991), though the ?Hauterivian–lower Barremian species *Harbinia atlasica* Mojon et al., 2009 is not transferred to *Pattersoncypris* because of the absence of the characteristic anterodorsal concavity and the low apices of the anterior and posterior margins. In contrast, *Harbinia* (type species *H. hapla*) was first described from the Nenjiang Formation of the Songliao Basin, China, in strata interpreted as being Lower Cretaceous in age (Tsao, 1959). However, these strata are now thought to have been deposited during the Campanian (Wan et al., 2007; Wang et al., 2007; Zhang et al., 2007; Wang et al., 2009; Li et al., 2011), and *Harbinia hapla* is now thought to be restricted to the Upper Cretaceous of China (Ye, 1988, 1990). The stratigraphically lower Qingshankou Formation, which is separated above from the Nenjiang Formation by the Yaojia Formation, has been dated as being 119.0–89.0 Ma (Wang et al., 1996), providing an upper age limit for the Nenjiang Formation. Planktic foraminifera from the lower member of the Nenjiang Formation indicate a Coniacian to Santonian age, corroborating this result (Xi et al., 2011). However, the dinocysts of the Nenjiang Formation, identified by Gao et al. (1992, cited by Sha, 2007), appear to suggest a Cenomanian age. Nonetheless, this has been considered irreconcilable with the Turonian–Coniacian (Sha, 2007) or Santonian (Li et al., 2011) age determined for the underlying Yaojia Formation obtained from palynomorph analyses, and is at odds with the other evidence outlined above.

Further evidence against the synonymy of *Pattersoncypris* with *Harbinia* is the marked discrepancy between the paleoenvironmental settings with which they are associated. *Pattersoncypris* is thought to have inhabited saline water bodies, since it is often present in formations associated with or underlying evaporite layers (Coimbra et al., 2002) and forms mono- or paucispecific assemblages (Arai and Coimbra, 1990) typical of unfavorable environmental conditions (Bate, 1999). In contrast, *Harbinia* is never associated with evaporitic successions, despite the fact that the Nenjiang Formation from which the holotype was derived is thought to have been a brackish water setting affected by infrequent marine transgressions (Sha, 2007; Wang et al., 2007). The presence of typically marine bivalves alongside a greater variety of non-marine species (Sha, 2007), brackish to freshwater dinocysts (Gao et al., 1992, cited by Sha, 2007), and relatively diverse ostracod assemblages often displaying nodes or other coarse ornamentation (Ye, 1988), are all suggestive of favorable environmental conditions.

In summary, *Pattersoncypris* is restricted to Aptian–Albian marine-influenced lacustrine settings in Brazil, western Africa and Morocco, and potentially the Cenomanian of the U.S.A., whilst *Harbinia* is confined to Santonian–Campanian lacustrine deposits of China. If these two genera are synonymous, their dispersal route to China from Brazil has to be identified. Since neither *Harbinia* nor *Pattersoncypris* is thought to have inhabited marine settings, aerial or terrestrial transportation would have to be inferred. It is possible that dispersal took place through North America, with individuals or desiccation-resistant eggs transported from Brazil to China on mud attached to the feet of pterosaurs or birds, as has been inferred to explain the modern-day disjunct distribution of *Potamocypris humilis* (Sars, 1924) by Horne and Smith (2004). However, the near-absence of any species referable to either *Harbinia* or *Pattersoncypris* in localities between Brazil and China lends little support to this interpretation. The lack of paleogeographic and stratigraphic overlap between the two genera, in tandem with the morphological differences outlined above, suggest that *Pattersoncypris* is not synonymous with *Harbinia*, and that the similarities between the two genera are a result of homeomorphy.

PATTERSONCYPRIS MICROPAPILLOSA Bate, 1972

1971 Phosphatized Brazilian Cretaceous ostracods BATE, p. 398, fig. 1.
1972 *Pattersoncypris micropapillosa* BATE; p. 379, figs. 1–12; pls. 66–71.
1973 *Pattersoncypris micropapillosa* Bate; BATE, p. 101, pl. 1, no. 19.
?non 1990 *Pattersoncypris micropapillosa* Bate; ARAI AND COIMBRA, p. 238, pl. 1, fig. 2.
non 1990 *Pattersoncypris micropapillosa* Bate; DÉPÊCHE, BERTHOU, AND CAMPOS, p. 303, pl. 1, figs. 9–11; p. 305, pl. 2, figs. 9–13; p. 307, pl. 3, figs. 6, 7, 13, 15, 16.
2000a *Pattersoncypris micropapillosa* Bate; SMITH, p. 63, figs. 2–9 (excluding *Eucypris virens* [Jurine, 1820] diagrams); pls. 1–9.
?non 2002a *Harbinia micropapilosa* [*sic*] (Bate); SYRIO AND RIOS-NETTO, p. 69, fig. 1, no. 5.
non 2006 *Harbinia micropapillosa* (Bate); RAMOS, ROSSETTI, AND PAZ, p. 344, fig. 4A–4D.
?non 2008 *Harbinia micropapillosa* (Bate); DO CARMO, WHATLEY, NETO, AND COIMBRA, p. 795, fig. 6, no. 6.
2009 *Harbinia micropapillosa* (Bate); MATZKE-KARASZ, SMITH, SYMONOVÁ, MILLER, AND TAFFOREAU, p. 1535, fig. 1B–1D, 1F.

Diagnosis.—A species of *Pattersoncypris* characterized by a pronounced dorsomedian hump, the presence of tiny papillae across the surface of the shell, the posterodorsal cardinal angle being higher than the anterodorsal cardinal angle, posterior margin with higher apex (one third carapace height from the ventral) than anterior, and slightly concave to slightly convex ventral margin.

Holotype.—Adult female carapace, Io. 4680, held in the NHM. Length 0.93 mm; height 0.67 mm; width 0.61 mm (Bate, 1972).

Type locality and horizon.—Santana Formation, Serra do Araripe, Ceará (Araripe Basin), northeastern Brazil (Bate, 1972).

Paratypes.—From Bate (1972): Adult carapace, Io. 4681 (♀); adult carapace, Io. 4682 (♂); adult left valve, Io. 4684; adult right valve, Io. 4685; adult carapace, Io. 4692 (♀); adult carapace, Io. 4693 (♀); adult carapace, Io. 4696 (♂); adult carapace Io. 4698 (♀); adult carapace, Io. 4700 (♀); juvenile right valve, Io. 4702; adult carapace, Io. 4704 (♀); juvenile carapace, Io. 4705; juvenile carapace, Io. 4706; broken adult right valve, Io. 4707; Io. 4708; Io. 4709 (♀); adult carapace Io. 4710 (♂); adult carapace Io. 4711; adult carapace Io. 4712; Io. 4713 (♀); Io. 4714; Io. 4715 (♀); Io. 4719 (♂?); Io. 4720 (♀); and Io. 4721 (♀); all held in the NHM. Of these, Smith (2000a) lists only Io. 4681, Io. 4682, Io. 4692, Io. 4696, Io. 4700, Io. 4702, Io. 4705, Io. 4706, and Io. 4710 as paratypes. Smith referred a number of other specimens to the species (OS 15517-19, OS 15521, OS 15523-7, OS 15529-33, OS 15535-56). These specimens are also held in the NHM.

Occurrence.—Specimens from the Riachuelo Formation in the Sergipe-Alagoas Basin as well as Liberia were alluded to in the original description (Bate, 1972), though these were not illustrated or described. The stratigraphic range of the species in the Araripe Basin (Coimbra et al., 2002) and the surrounding basins (Hessel et al., 2006) is well-established: *Pattersoncypris micropapillosa* is present in the Rio da Batateira Formation (Barbalha) (Syrio and Rios-Netto, 2002a), as well as all three members of the Santana Formation: the Crato (Arai and Coimbra, 1990; Dépêche et al., 1990; Silva-Telles and Viana, 1990; Viana, 1990; Berthou et al., 1994; Coimbra et al., 2002), Ipubi (Coimbra et al., 2002) and Romualdo (Lima, 1979; Dépêche et al., 1990; Coimbra et al., 2002). This means that *P. micropapillosa* is present throughout the Aptian–Albian (Bate, 1972) Brazilian Zone 011 (Schaller, 1969; Coimbra et al., 2002; Do Carmo et al., 2008).

Description.—Modified from Bate (1972): Carapace ovate in lateral view. Greatest carapace height at mid-length, forming a pronounced dorsal hump. Anterior margin obliquely rounded. Posterior margin more acutely rounded with lower apex. Anterodorsal margin concave, accentuating dorsal hump of carapace and forming anterior cardinal angle, especially acute on right valve. Hinge margin sub-straight, sloping posteroventrally. Ventral margin slightly concave to slightly convex.

Both valves strongly convex in dorsal view, carapace thickest slightly anterior of mid-length. Carapace covered in small papillae.

Virtually equivalve, though left valve always larger than right. Slight overlap around all margins, most prominent anterodorsally where the right valve displays a deeper concavity than the left.

Hinge simple, adont; appears to show some variation between specimens assigned to this species. Bate (1972) initially described the hinge as a groove on the right valve into which the dorsal margin of the left valve was inserted, though this would preclude overlap of the right valve by the left at this point, a feature clearly seen in the holotype and several referred paratypes but not in others.

Muscle scars typical for Cyprididae: following the description of Smith (2000a), five to seven muscle scars are present medially. Most posterior scar elongate with long axis anterodorsally inclined. Four similarly oriented scars arranged in two rows occur anterior of this scar. Slightly ventral of these are two slightly larger scars, again with the long axis anterodorsally inclined.

Internal characteristics as per Bate (1972) and Smith (2000a).

Maximum dimensions reported by Smith (2000a): length 1.122–1.244 mm; height 0.756–0.842 mm.

Paleoecology.—*Pattersoncypris micropapillosa* is present throughout the Rio da Batateira and Santana formations in the Araripe Basin. The Rio da Batateira Formation has been interpreted to represent a mixohaline water body (0–10‰ salt) (Syrio and Rios-Netto, 2002a), possibly a fluvio-lacustrine carbonate system (Coimbra et al., 2002). The Santana Formation, which comprises the Crato, Ipubi, and Romualdo members, is thought to represent the same carbonate system at the base (Crato), followed by a transitional evaporitic/littoral marine system (Ipubi and Romualdo) (Coimbra et al., 2002). Thus, the Santana Formation represents a lake system under pulsative marine influence, which resulted in a mixohaline environment and prevented the development of a high diversity ostracod fauna (Arai and Coimbra, 1990).

According to Coimbra et al. (2002), the presence of *Pattersoncypris micropapillosa* in the Santana Formation is associated with moderate quantities of dinoflagellates. In contrast, when dinoflagellates comprise more than 50% of total recovered palynomorphs, a more diverse ostracod assemblage is observed. This suggests that *P. micropapillosa* was able to persist in conditions that selected against dinoflagellates and other ostracod species; it is probable that changes in salinity precipitated these faunal shifts. The persistence of this species through the Ipubi Formation, which is dominantly gypsum, suggests that *P. micropapillosa* was able to tolerate settings characterized by increased salinity (Coimbra et al., 2002).

Abundant *Pattersoncypris micropapillosa* specimens are associated with nodules bearing fish fossils (Bate, 1971). Thus, it is possible that these ostracods took advantage of mass-mortality events, which have been linked to possible oxygen-level drops (Martill et al., 2008). However, the fish nodule-bearing layer of the Romualdo Member in the Santana Formation has been interpreted to represent better oxygenated conditions (Dépêche et al., 1990), suggesting that another environmental factor may have been responsible. Several other possible causes have been posited (Martill et al., 2008), though many have been discounted due to a lack of supporting evidence.

Further light may be shed on the paleoenvironmental setting of the Araripe Basin from the fish fauna. Leal and Brito (2004) suggested that the marine fish species *Cladocyclus gardneri* Agassiz, 1841, with which the specimens first reported by Bate (1971) were associated, used the Araripe Basin paleo lake as a nursery. The absence of other typical marine taxa, especially benthic forms, may indicate that the lake was stratified, with anoxic or hypersaline conditions in the bottom waters (Martill, 1988; Smith, 2000a). An increase in salinity, possibly caused by a lowering of lake level, would select against marine species: *Cladocyclus gardneri* specimens are present in both the Crato and Romualdo members but are absent from the Ipubi evaporites, whilst several other fish species are restricted to either the Crato or Romualdo members (Leal and Brito, 2004). Conversely, the same changes would select for salt-tolerant taxa, like *P. micropapillosa*.

Remarks.—*Pattersoncypris micropapillosa* (Fig. 4.1) was founded upon remarkably-preserved specimens from the Araripe Basin which have been studied in great detail (Bate, 1971, 1972, 1973; Smith, 2000a; Matzke-Karasz et al., 2009). Features of the upper lip (Smith, 2000b) and the positioning of the muscle scars prompt referral to the Cyprinotinae, as they are typical for the family (Smith, 2000a), whilst the internal features indicate that the species reproduced sexually using giant sperm, as in modern cypridids (Matzke-Karasz et al., 2009).

PATTERSONCYPRIS SINUATA (Krömmelbein and Weber, 1971)

1971 *Hourcqia angulata sinuata* Krömmelbein and Weber, pl. 6, fig. 24a–24c.
1985 "*Cytheridea*"? sp. sp. gr. 201/218 Moura and Praça, p. 407, pl. 2, figs. 19, 22.
1988 "*Cypridea*" spp. ex. gr. 201/218 Moura, p. 1212, pl. 2, figs. 7, 10.
1991 *Hourcqia angulata sinuata* Krömmelbein and Weber; Andreu-Boussut, p. 480, pl. 1, figs. 4–9.
1997 *Hourcqia* gr. *angulata* Krömmelbein and Weber; Colin and Dépêche, p. 434, fig. 2, no. 19.
2006 *Harbinia sinuata* (Krömmelbein and Weber); Ramos, Rossetti, and Paz, p. 344, figs. 4I–4L.
2008 *Harbinia sinuata* (Krömmelbein and Weber); Do Carmo, Whatley, Neto, and Coimbra, 2008, pl. 6, fig. 10.

Diagnosis.—A species of *Pattersoncypris* differentiated from others by the presence of a distinct anterodorsal concavity, and the steep, posteroventrally angled slope of the dorsal margin, (which causes acute-rounding of the posterior margin), the presence of a clear ventral concavity, and the lack of fine ornamentation.

Holotype.—One carapace, BfB, Typ.-Nr. 7796, held in the BGR. Length 0.86 mm; height 0.58 mm; width 0.42 mm.

Type locality and horizon.—Pia-4-Al well, 930–960 m rinse sample, Alagoas, Brazil. Originally cited as having been derived from the non-marine Riachuelo Formation (Krömmelbein and Weber, 1971), Do Carmo et al. (2008) noted that this formation is now restricted to Albian marine sediments in the Sergipe-Alagoas Basin. Thus, Do Carmo et al. (2008) suggested that the holotype was actually from the Maceió Formation as defined by Feijo (1994). According to Campos Neto et al. (2007), the Muribeca Formation is present between the Maceió and Riachuelo formations; it is probable that this was not considered by Do Carmo et al. (2008) as a potential candidate for the provenance of the holotype specimen due to the fact that species of *Hourcqia* occur within the Muribeca Formation. With the referral of *Hourcqia* gr. *angulata* (Colin and Dépêche, 1997, fig. 6, no. 17), the range of these species is expanded into Chad; it may also be present in the Morocco (Andreu-Boussut, 1991).

Occurrence.—Aptian sediments corresponding to Brazilian Zone 011 (Do Carmo et al., 2008) in the Alagoas (Krömmelbein and Weber, 1971), Campos (Moura and Praça, 1985; Moura, 1988), Potiguar (Do Carmo et al., 2008) and Grajaú (Ramos et al., 2006) basins, Brazil; Chad (Colin and Dépêche, 1997); possibly present in the Albian of Morocco (Andreu-Boussut, 1991).

Description.—Translated and modified from Krömmelbein and Weber (1971): Carapace skewed-trapezoidal but strongly-rounded in lateral view, tall relative to carapace length. Maximum height of carapace at mid-length. Posterodorsal margin (hinge margin) effectively straight, steeply inclined posteroventrally. Posterior cardinal angle completely rounded. Posterior margin acutely rounded. Anterodorsal margin shows a shallow concavity immediately anterior of the dorsal hump; further anterior still, the margin curves obliquely to the anteroventral margin. Ventral margin obliquely rounded with a clear concavity in the middle section. Carapace in dorsal view evenly biconvex; carapace thickest posterior of mid-length; posterior more obtuse than anterior.

Left valve slightly larger than right, insignificant overlap around the entire carapace.

Valve surfaces lack ornamentation, usually extremely smooth to porcelanous.

Internal characteristics unknown.

Paleoecology.—Specimens of *Pattersoncypris sinuata* from the Alagamar Formation, Potiguar Basin, have been interpreted to have been deposited in a hypohaline lacustrine environment, suggesting that this species was capable of tolerating higher salinities than *Darwinula*, *Cypridea*, and *Theriosynoecum* (Do Carmo et al., 1999).

Remarks.—The holotype specimen of *Pattersoncypris sinuata* (Fig. 4.2) is quite small, suggesting to some authors (e.g., Do Carmo et al., 2008) that it represents a subadult instar. This cannot be assessed at the present time due to the lack of comparative material available to the authors. Nonetheless, this species is easily distinguished from *P. micropapillosa* by the reduced strength of the dorsomedian hump and the presence of a ventral concavity, and from *P. salitrensis* and *P. micropapillosa* by the sharp posteroventral slope of the posterodorsal margin.

PATTERSONCYPRIS SALITRENSIS (Krömmelbein and Weber, 1971)

1971 *Hourcqia angulata salitrensis* Krömmelbein and Weber, p. 37, pl. 6, fig. 26a–26c.
?1967 *Hourcqia*? sp. Grekoff and Krömmelbein, p. 1350, pl. 8, fig. 50a, 50b.
1972 *Pattersoncypris angulata salitrensis* (Krömmelbein and Weber); Bate, p. 389, text-fig. 11c, 11d, 11f.
?1985 "*Cytheridea*"? sp. sp. gr. 201/218 Moura and Praça, p. 1212, pl. 2, fig. 24.
?1988 "*Cypridea*" spp. ex. gr. 201/218 Moura, p. 407, pl. 2, fig. 12.
non 1990 *Hourcqia angulata salitrensis* Krömmelbein and Weber; Dépêche, Berthou, and Campos, pl. 3, fig. 14.
non 1990 *Hourcqia* cf. *angulata salitrensis* Krömmelbein and Weber; Silva-Telles and Viana, pl. 2, fig. 8.
1997 *Hourcqia* gr. *angulata* Krömmelbein and Weber; Colin and Dépêche, p. 442, fig. 6, no. 17.
2002a *Harbinia salytrensis* [*sic*] (Krömmelbein and Weber); Syrio and Rios-Netto, p. 69, fig. 1, no. 3.
2006 *Harbinia salitrensis* (Krömmelbein and Weber); Ramos, Rossetti, and Paz, p. 344, fig. 4Q, 4S, 4T, non 4R.
2008 *Harbinia salitrensis* (Krömmelbein and Weber); Do Carmo, Whatley, Neto, and Coimbra, p. 795, fig. 6, no. 8.

Diagnosis.—A large *Pattersoncypris* species very similar to *Pattersoncypris micropapillosa*. Differentiated from this species on the basis of its slightly concave ventral margin, the greater overlap of the right valve by the left at the anterodorsal margin, and the less accentuated nature of the dorsomedian hump. Distinguished from *Pattersoncypris sinuata* by the more gradual slope of the posterodorsal margin.

Holotype.—One carapace, BfB, Typ.-Nr. 7798, held in the BGR. Length 1.14 mm; height 0.77 mm; width 0.64 mm.

Type locality and horizon.—Santana Formation (above the fish beds), Araripe Basin, Pernambuco State, Brazil (Krömmelbein and Weber, 1971).

Occurrence.—Aptian (Krömmelbein and Weber, 1971; Bate, 1999) sediments pertaining to the Brazilian ostracod Zone 011 (Do Carmo et al., 2008) of the Araripe (Krömmelbein and Weber, 1971; Syrio and Rios-Netto, 2002a; Do Carmo et al., 2008), Grajaú (Ramos et al., 2006) and ?Campos (Moura and Praça, 1985; Moura, 1988) basins, Brazil; possibly also present in Chad (Colin and Dépêche, 1997).

Description.—Translated and modified from Krömmelbein and Weber (1971). Carapace ovate in lateral view. Dorsal margin with clear dorsomedian hump; accordingly, maximum carapace height approximately at mid-length. Anterior margin obliquely rounded, transitioning into the slightly concave anterodorsal margin before merging with dorsomedian hump. Posterodorsal (hinge) margin slopes relatively steeply to the posterior, with a rounded but noticeable posterodorsal angle leading into in the more acutely-rounded posterior margin. Ventral margin slightly concave.

Carapace thickly fusiform in dorsal view. Greatest carapace thickness posterior of the mid-length. Carapace tapered anteriorly, moderately obtuse posteriorly. Left valve larger than right, overlapping only slightly along the free margins, clearest along the anterodorsal margin where the right valve is more concave than the left.

Valve surfaces quite smooth without clear fine sculpture.

Internal characteristics unknown.

Paleoecology.—Saline lacustrine (Bate, 1999).

Remarks.—*Pattersoncypris salitrensis* (Fig. 4.3) was first reported from sediments of the Santana Formation above those containing fish nodules. Perhaps unsurprisingly, *Pattersoncypris micropapillosa*, which was first found within the fish nodule layer, is quite similar to *Pattersoncypris salitrensis*. The major differences between the two are the anterodorsal overlap of the right valve by the left, which is greater in *Pattersoncypris salitrensis* than in *Pattersoncypris micropapillosa*; the expression of the posterior cardinal angle, which is greater in *Pattersoncypris salitrensis* than in *Pattersoncypris micropapillosa*; and the ventral margin, which in *Pattersoncypris salitrensis* is always slightly concave but is straight or slightly convex in *Pattersoncypris micropapillosa*.

Subfamily ?CYPRINOTINAE Bronstein, 1947
Genus KROEMMELBEINCYPRIS new genus

Type species.—*Kroemmelbeincypris symmetrica* (Krömmelbein and Weber, 1971).

Included species.—*Kroemmelbeincypris symmetrica* (Krömmelbein and Weber, 1971) (*Hourcqia*), *Kroemmelbeincypris angulata* (Krömmelbein and Weber, 1971) (*Hourcqia*).

Etymology.—In honor of Karl Krömmelbein, whose pioneering studies of Lower Cretaceous deposits in northeastern Brazil and western Africa provided the foundation for the ostracod zonation scheme which remains critical for biostratigraphic control in the offshore basins surrounding the South Atlantic Ocean.

Diagnosis.—Carapace pentagonal-ovoid in lateral view. Greatest carapace height anterior of mid-point. Anterior margin obliquely rounded, anterodorsal margin convex. Dorsal margin roof-shaped, sloping anteriorly and ventrally. Posterodorsal margin slightly convex or straight, posterior margin slightly anteroventrally inclined. Ventral margin convex. Left valve larger than right, slight overlap on all free margins. Fine ornamentation expressed as tessellation: strong in some specimens, absent in others. Absence of this patterning may be a preservational artifact (e.g., internal casts) or an indicator of ecophenotypic variation within this species. No recognized sexual dimorphism.

Occurrence.—Aptian (Bate, 1999) of the eastern Brazilian Paraná (Krömmelbein and Weber, 1971) and Araripe (Dépêche et al., 1990; Coimbra et al., 2002) basins, as well as western Africa (Bate, 1999).

Paleoecology.—Saline lacustrine (Bate, 1999).

Remarks.—The species *Kroemmelbeincypris symmetrica* and *Kroemmelbeincypris angulata* are removed from *Pattersoncypris* on the basis of a number of morphological differences: the anterodorsal margin of the right valve is straight (not concave as in *Pattersoncypris*), the posterior margin slopes anteroventrally (not being rounded), the ventral margin is weakly convex (not straight or concave), and a tessellated pattern covers the entire carapace (not papillate or smooth). In fact, neither *Kroemmelbeincypris symmetrica* or *Kroemmelbeincypris angulata*, which were originally described as subspecies of *Hourcqia angulata*, *Hourcqia angulata symmetrica* and *Hourcqia angulata angulata*, were officially assigned to *Pattersoncypris*, despite the fact that numerous papers refer to these species by this genus name (Grosdidier et al., 1996; Bate, 1999; Coimbra et al., 2002). This referral was probably presumed (or assumed) because two other subspecies of *H. angulata* (*sinuata* and *salitrensis*) were referred to *Pattersoncypris* by Bate (1972).

Since no muscle scars or internal characteristics are known for either species of *Kroemmelbeincypris*, its precise relationships to other ostracods are based only on external features. It is probable that this genus is closely related to *Pattersoncypris*, though *K. symmetrica* and *K. angulata* clearly comprise a separate radiation from *P. micropapillosa*, *P. salitrensis* and *P. sinuata*.

KROEMMELBEINCYPRIS SYMMETRICA (Krömmelbein and Weber, 1971)

1971 *Hourcqia angulata symmetrica* KRÖMMELBEIN AND WEBER, pl. 6, fig. 25a–25c.
1990 *Cultella* sp. 1 DÉPÊCHE, BERTHOU, AND CAMPOS, pl. 2, fig. 2.
1990 *Pattersoncypris micropapillosa* (Krömmelbein and Weber); DÉPÊCHE, BERTHOU, AND CAMPOS, pl. 3, fig. 6.
1990 *Pattersoncypris* cf. *angulata angulata* (Krömmelbein and Weber). MUSACCHIO, p. 564, pl. 1, fig. 4.
1990 *Hourcqia angulata symmetrica* Krömmelbein and Weber; SILVA-TELLES AND VIANA, pl. 1; pl. 3, fig. 8.
1999 *Pattersoncypris angulata symmetrica* (Krömmelbein and Weber); BATE, p. 289, fig. 3.
2002 *Pattersoncypris angulata symmetrica* (Krömmelbein and Weber); COIMBRA, ARAI, AND CARREÑO, fig. 4, no. 30.
non 2004 *Harbinia symmetrica*? (Krömmelbein and Weber); DO CARMO, TOMASSI, AND OLIVEIRA, fig. 4, no. 1.
2004 *Harbinia* sp. 1 DO CARMO, TOMASSI, AND OLIVEIRA, fig. 4, no. 2.
non 2006 *Harbinia* aff. *H. symmetrica* (Krömmelbein and Weber); RAMOS, ROSSETTI, AND PAZ, p. 344, fig. 4M–4P.
2008 *Harbinia symmetrica* (Krömmelbein and Weber); DO CARMO, WHATLEY, NETO, AND COIMBRA, fig. 6, no. 9.

Diagnosis.—A species of *Kroemmelbeincypris* distinguished from *Kroemmelbeincypris angulata* by the greatest carapace height being only slightly anterior of the mid-point, which gives the carapace a symmetrical appearance. Distinguished from species of *Pattersoncypris* by the reduced development of the anterodorsal concavity associated with the nearly symmetrical inclination of the anterodorsal and posterodorsal margins, and the slightly anteroventrally inclined posterior margin.

Holotype.—One carapace, BfB, Typ.-Nr. 7797, held in the BGR. Length 1.12 mm; height 0.72 mm; width 0.58 mm.

Type locality and horizon.—Vgst-1-Ma well, 384 m rinse sample, Codó Formation, Paraná Basin, Maranhão State, Brazil.

Occurrence.—Aptian (Krömmelbein and Weber, 1971); found throughout the Rio da Batateira Formation and the Crato, Ipubi and Romualdo members, which comprise the Santana Formation in the Araripe Basin (Coimbra et al., 2002) and are referable to Brazilian Zone 011 (Moura, 1987, 1988; Do Carmo et al., 2008); also present in the Gamba Formation in the Gabon Basin, and the Chela Formation in the Congo and Cabinda basins (Bate, 1999), referable to African Zones AS11–AS12 (Grosdidier et al., 1996; Bate, 1999).

Description.—Translated and modified from Krömmelbein and Weber (1971). Stretched ovate-pentagonal in lateral view. Anterior margin obliquely rounded, anterodorsal margin less steeply-sloping than posterodorsal margin, slightly convex. Dorsal margin broadly roof-shaped (^); maximum height of carapace slightly anterior of mid-length. Hinge margin slopes gently to posterodorsal cardinal angle, where the margin curves sharply into the anteroventrally oriented posterior margin. Posteroventral margin slightly less sharply curved, merging relatively smoothly with ventral margin. Ventral margin weakly convex.

Carapace evenly biconvex in dorsal view, tapering slightly more towards the anterior. Greatest carapace thickness posterior of the mid-length.

Left valve larger than right, slightly overlapping at the free margins.

Valve surfaces with fine tessellated ornamentation, gives the carapace a leathery appearance. Some referred specimens demonstrate reduced or no ornamentation.

Internal characteristics unknown.

Paleoecology.—Saline lacustrine (Bate, 1999).

Remarks.—*Kroemmelbeincypris symmetrica* (Fig. 4.4) is an extremely important taxon in the South Atlantic Pre-Salt, as it is the zone marker for the AS12 Zone (Grosdidier et al., 1996; Bate, 1999) on the western African side and Zone 011 on the Brazilian side (Do Carmo et al., 2008). Krömmelbein and Weber considered *Pattersoncypris salitrensis* to be the closest relative of *Kroemmelbeincypris symmetrica*. However, the holotypes of *Kroemmelbeincypris symmetrica* and *Kroemmelbeincypris angulata* show numerous shared characteristics of the anterodorsal, posterior and ventral margins as well as similar ornamentation, suggesting that the relationship between these two species is closer. Some referred specimens show more similarity to *Pattersoncypris salitrensis*, in particular the specimen illustrated by Do Carmo and colleagues (2008, fig. 6, no. 9).

An ontogenetic series of *Kroemmelbeincypris symmetrica* was published by Silva-Telles and Viana (1990) based on specimens from the uppermost Romualdo Member of the Santana Formation. However, the largest specimens recorded were only 0.95 mm long, whilst the holotype of *K. symmetrica* is 1.12 mm; this suggests that the true adult and A-1 instar may not have been observed.

KROEMMELBEINCYPRIS ANGULATA (Krömmelbein and Weber, 1971)

1971 *Hourcqia angulata angulata* KRÖMMELBEIN AND WEBER, pl. 6, fig. 23a–23c.
1989 *Hourcqia angulata angulata* Krömmelbein and Weber; VIANA, BRITO, AND SILVA-TELLES, p. 216, fig. 2a–2c.
?non 1990 *Hourcqia angulata angulata* Krömmelbein and Weber; DÉPÊCHE, BERTHOU, AND CAMPOS, p. 303, pl. 1, figs. 1, 2.
non 1990 *Hourcqia angulata* Krömmelbein and Weber; DÉPÊCHE, BERTHOU, AND CAMPOS, p. 305, pl. 2, figs. 4–6; p. 307, pl. 3, figs. 10, 11.
non 1990 *Hourcqia angulata angulata* Krömmelbein and Weber; DÉPÊCHE, BERTHOU, AND CAMPOS, p. 307, pl. 3, figs. 8, 17, 18.
non 1990 *Pattersoncypris* cf. *angulata angulata* (Krömmelbein and Weber); MUSACCHIO, p. 564, pl. 1, fig. 4.
?non 1990 *Hourcqia angulata angulata* Krömmelbein and Weber; SILVA-TELLES AND VIANA, p. 327, pl. 3, fig. 3.
?1990 *Hourcqia angulata* ssp. Krömmelbein and Weber; SILVA-TELLES AND VIANA, p. 327, pl. 3, fig. 4.
non 1997 *Hourcqia* gr. *angulata* Krömmelbein and Weber; COLIN AND DÉPÊCHE, p. 442, fig. 2, no. 19; fig. 6, no. 17.
2002 *Pattersoncypris angulata angulata* (Krömmelbein and Weber); COIMBRA, ARAI, AND CARREÑO, fig. 4, no. 29.
?non 2006 *Harbinia angulata* (Krömmelbein and Weber); RAMOS, ROSSETTI, AND PAZ, p. 344, fig. 4E–4H.
2008 *Harbinia angulata* (Krömmelbein and Weber); DO CARMO, WHATLEY, NETO, AND COIMBRA, p. 795, fig. 6, no. 11.

Diagnosis.—Differentiated from *K. symmetrica* by the strongly anteroventral angle of the posterior margin, the anterior shift of the greatest carapace height, and stronger tessellation. Distinguished from species of *Pattersoncypris* by the angular outline of the carapace and the presence of tessellation on the entire surface of both valves.

Holotype.—One carapace, BfB, Typ.-Nr. 7795, held in the BGR. Length 0.86 mm; height 0.58 mm; thickness 0.42 mm.

Type locality and horizon.—Pia-3-Al well, 1,140–1,170 m core sample, Alagoas, Brazil. Originally cited as deriving from the non-marine Riachuelo Formation (Krömmelbein and Weber, 1971), this formation was redefined by Feijo (1994) to include only marine sediments, as noted by Do Carmo et al. (2008) who identified the Maceió Formation as a possible type locality for this species. Campos Neto et al. (2007) identified the Muribeca Formation between the Maceió and Riachuelo formations; this formation may also be a potential candidate for the provenance of the holotype of this species.

Occurrence.—Aptian (Krömmelbein and Weber, 1971), Brazilian Zone 011 (Coimbra et al., 2002; Do Carmo et al., 2008); present in the uppermost Pre-Salt strata in the Alagoas Basin (Krömmelbein and Weber, 1971); also identified throughout the Rio da Batateira Formation and the Crato, Ipubi and Romualdo members which comprise the Santana Formation (Coimbra et al., 2002).

Description.—Translated and modified from Krömmelbein and Weber (1971). Carapace in lateral view inclined-trapezoidal. Dorsal margin angled in an angular roof-like (^) fashion typical for the genus. Maximum height of carapace anterior of the mid-length; hinge region relatively straight, terminating and curving acutely at the posterior margin, forming a distinct cardinal angle. Posterior margin sub-straight. Anterior margin obliquely rounded from the dorsal (the point of greatest carapace height) to the ventral margin. Ventral margin more-or-less straight, can be slightly convex.

Carapace in dorsal view evenly biconvex; greatest thickness approximately in the middle, valve margin practically straight.

Left valve larger than right, greatest degree of overlap in the anterodorsal margin (immediately anterior of the maximum carapace height) and, to a lesser degree, in the posterodorsal margin (near the cardinal angle).

Primary ornamentation is not present, though the curvature of the anterodorsal, anterior and anteroventral regions is sometimes characterized by a very shallow depression. Secondary ornamentation is present in the form of raised oblong peaks, which give the valves a tessellated or scaly appearance.

Internal characteristics unknown.

Paleoecology.—Saline lacustrine (Viana et al., 1989).

Remarks.—*Kroemmelbeincypris angulata* (Fig. 4.5) appears to be most closely related to *Kroemmelbeincypris symmetrica*,

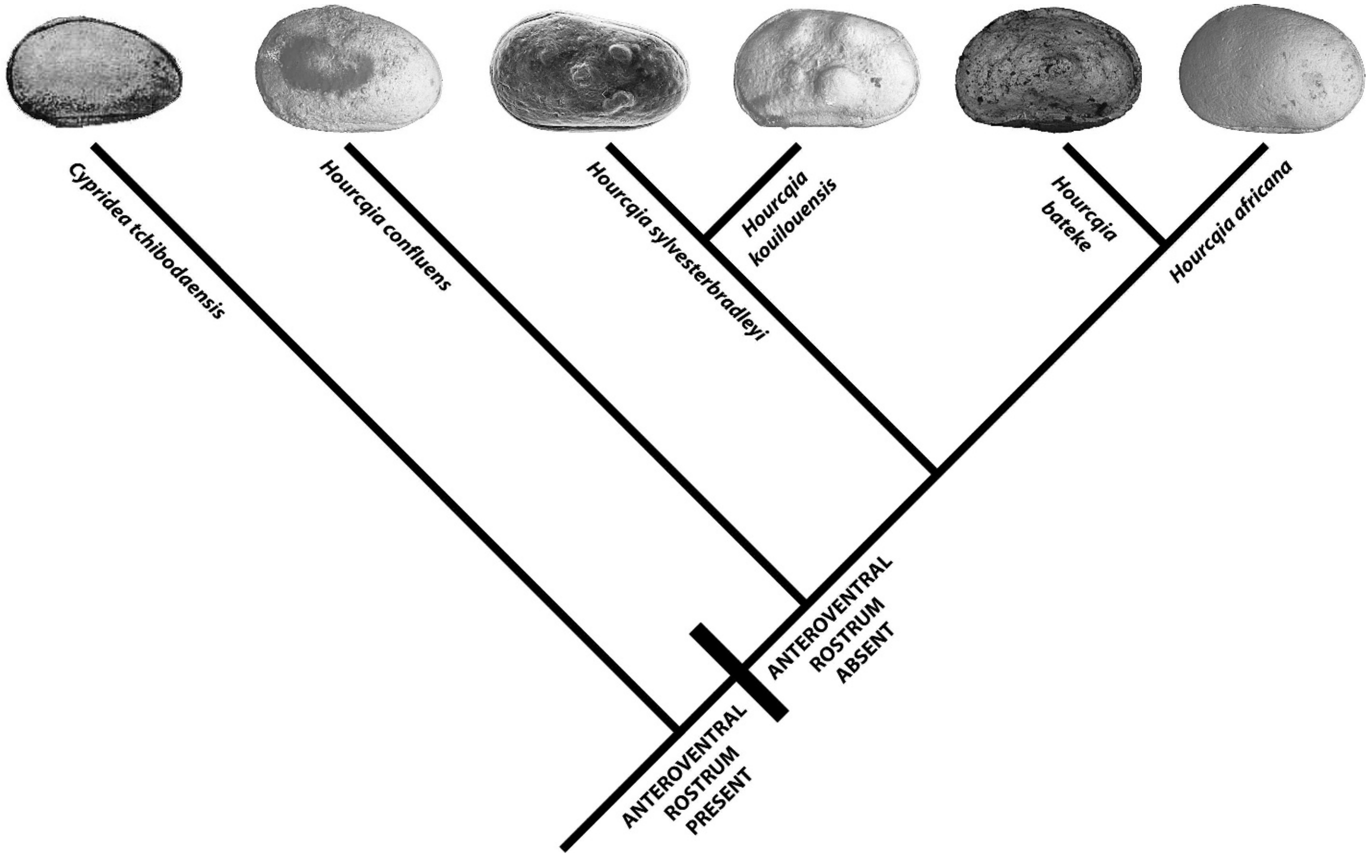

FIGURE 5—Inferred relationships of the various species herein assigned to the genus *Hourcqia*. *Hourcqia bateke* and *H. africana* are inferred to be closely related on the basis of a specimen referred to *H. africana* by Grosdidier and Bignoumba (1984). *Hourcqia sylvesterbradleyi* and *H. kouilouensis* are linked because both display ecophenotypic variation in node development. *Hourcqia* is inferred to be related to the genus *Cypridea* due to perceived similarities between *H. confluens* and *C. tchibodaensis*, which has an "inverse" valve-size ratio (as does *Hourcqia*) yet possesses a rostrum.

with which it shares several characteristics pertaining to the anterodorsal, posterior and ventral margins, as well as distinctive tessellated ornamentation. It has been shown to be a contemporary of this species in the Araripe Basin (Coimbra et al., 2002), and the fact that *K. symmetrica* is the index taxon of the African AS12 Zone (Grosdidier et al., 1996; Bate, 1999) suggests that *K. angulata* may also be present in sediments of this age. Furthermore, given that the holotypes of *K. angulata* and *P. sinuata* were found in the same formation (Riachuelo) in the same basin (Alagoas) by Krömmelbein and Weber (1971), it is likely that their stratigraphic ranges overlap. This supports the interpretation made by Do Carmo et al. (2008) that both species of *Kroemmelbeincypris* (*K. symmetrica*, *K. angulata*) and all three species of *Pattersoncypris* (*P. micropapillosa*, *P. sinuata*, *P. salitrensis*) are able to be used as indicators of the Brazilian Zone 011.

DISCUSSION

The genus *Hourcqia* is distinct from the genus *Cypridea*, and *Pattersoncypris* is not synonymous with *Harbinia*. The description of *Hourcqia* has been modified to include species demonstrating ecophenotypic variation (*H. kouilouensis*, *H. sylvesterbradleyi*), with a crucial characteristic of the genus being that the right valve is larger than the left (*H. africana*, *H. confluens*, *H. bateke*). The definition of *Pattersoncypris* has been restricted to include only three species based on the presence of an anterodorsal concavity on the right valve which facilitates overlap of the right by the left (*P. micropapillosa*, *P. angulata*, *P. salitrensis*). Finally, two species formerly assigned to *Hourcqia*, and subsequently (unofficially) transferred to *Pattersoncypris*, are shown to be sufficiently different to warrant the erection of the new genus *Kroemmelbeincypris* (*K. symmetrica* and *K. angulata*). All three of these genera are members of the Cypridoidea and are key markers of the uppermost Pre-Salt sequence in eastern Brazil and western Africa.

The similarities between *Cypridea tchibodaensis* and *Hourcqia confluens* may suggest a close relationship between these two species. As noted above, if the rostrum of *C. tchibodaensis* was further reduced to the point of being non-existent, retention of the species within the genus *Cypridea* would be indefensible. It is possible that *Hourcqia* is a cyprideid ostracod which evolved in response to increasingly saline lacustrine conditions in the paleo-South Atlantic. The presence or absence of nodes in the species *H. kouilouensis* and *H. sylvesterbradleyi* has been attributed to ecophenotypic variation. Indeed, Moura (1987) only identified the smooth Limnocypridea? subquadrata nomen nudum (here referred to *H. kouilouensis*) in the uppermost Zone 009.3, whilst ornamented *H. kouilouensis* specimens were present from the base of the zone.

A close relationship between *Hourcqia africana* and *H. bateke* is proposed (Fig. 5) based on the overall morphological similarities between the two species and their close stratigraphic association. The main difference between the two species (aside from the conical protrusion sometimes present in *H. bateke*) is the degree of valve overlap (less pronounced in *H. africana* than in *H. bateke*). However, a specimen referred to *H. africana* by Grosdidier and Bignoumba (1984), demonstrates a greater degree of valve overlap than in any other *H. africana* specimen

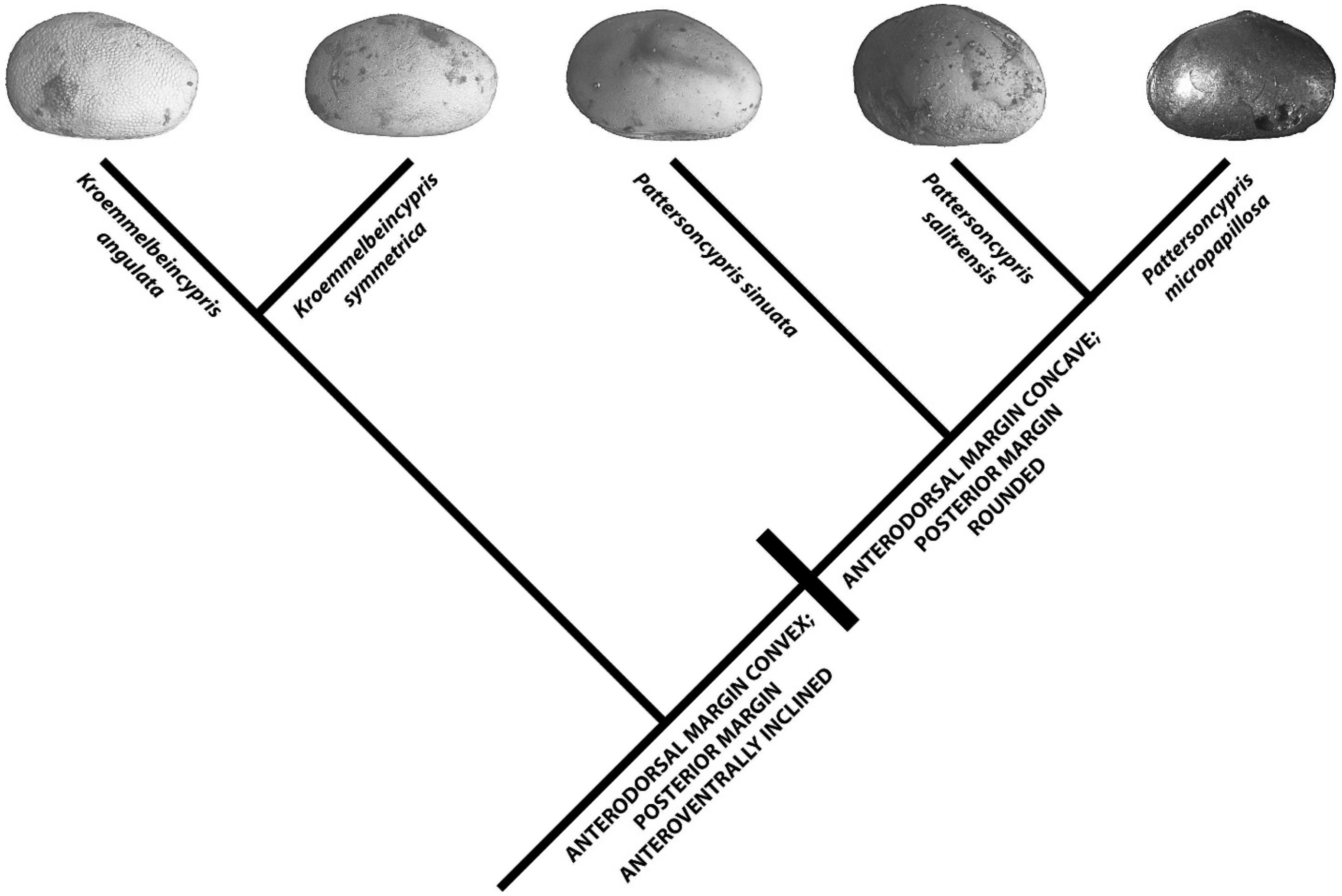

FIGURE 6—Inferred relationships of the species assigned to the genera *Pattersoncypris* and *Kroemmelbeincypris*. The two genera are differentiated on the basis of the anterodorsal margin which is concave on one or both of the valve is *Pattersoncypris* but sub-straight to convex on both valves in *Kroemmelbeincypris* and the posterior margin which is obtusely rounded in *Pattersoncypris* but anteroventrally inclined and sub-straight in *Kroemmelbeincypris*. *Pattersoncypris salitrensis* and *P. micropapillosa* are closely related; it is possible that *P. sinuata* represents a juvenile of one of these species. *Kroemmelbeincypris angulata* and *K. symmetrica* differ in the position of the greatest carapace height (slightly more anterior in *K. angulata*) and the degree of anteroventral inclination of the posterior margin (greater in *K. angulata*).

but less than is observed in *H. bateke*. Indeed, rich populations of *H. africana* recently observed by one of the authors (JPC) from the Congo demonstrate great variability in the degree of valve overlap. Given that they have been shown to co-occur in the Campos Basin (Silva-Telles, 1992), and based on their overall morphological similarity, a close relationship between these two species seems reasonable.

The relationships of the species *Pattersoncypris micropapillosa* have been well-established on the basis of studies of the appendages (Bate, 1971, 1972, 1973; Smith, 2000a), internal features of the carapace (Smith, 2000a) and the internal organs (Matzke-Karasz et al., 2009). This form is clearly referable to the Cyprididae (Smith, 2000b), and can be further assigned to the Cyprinotinae (Smith, 2000a; Do Carmo et al., 2008). *Pattersoncypris salitrensis* and *P. sinuata* are clearly related to *P. micropapillosa*, hence they are referred to the same family (Fig. 6). The transfer of *K. symmetrica* and *K. angulata* from *Pattersoncypris* to *Kroemmelbeincypris* means that their exact relationships remain uncertain, due to the fact that muscle scars, appendages and internal organs are not known for either species. Based on the overall morphological similarities shared by the two genera, it is possible that *Kroemmelbeincypris* is closely related to *Pattersoncypris*, although herein it is only tentatively referred to the Cyprinotinae.

CONCLUSIONS

The primary aim of this paper was to reassess the taxonomic status of the genera *Hourcqia* and *Pattersoncypris*, which were synonymized with *Cypridea* and *Harbinia* respectively by Do Carmo et al. (2008). *Hourcqia* was removed from the genus *Cypridea* on the grounds that no anteroventral rostrum was observable on the holotype specimen of the type species *H. africana*. *Pattersoncypris* was removed from the genus *Harbinia* based on a number of morphological characteristics and due to the fact that the two genera demonstrate no geographic or temporal overlap. In order to more precisely define the genus *Pattersoncypris*, two species were transferred to the new genus *Kroemmelbeincypris*, since they lack the dorsomedian hump-accentuating anterodorsal concavity which characterizes the former genus.

This paper also aimed to reassess the stratigraphic utility of the ostracod species discussed in the Lower Cretaceous sediments of South Atlantic offshore basins. The renewed separation of *Hourcqia africana* and *H. confluens* resulted in the former being diagnostic of the African AS10 Zone (Grosdidier et al., 1996), whilst the latter regained its identity as an indicator of the African AS9 Zone (Bate, 1999). *Hourcqia africana* is also characteristic of the OS-1020 Subzone in the Campos Basin (Silva-Telles, 1992). The other three species referred to *Hourcqia* can also be used to distinguish the AS9 and AS10 zones, since *H. kouilouensis* and *H. sylvesterbradleyi* are listed as contemporaries of *H. confluens* (Bate, 1999), whilst *H. bateke* characterizes the OS-1000 Zone (of which the OS-1020 Subzone is a subdivision) (Silva-Telles, 1992). All three species of *Pattersoncypris* and both species of *Kroemmelbeincypris* were identified as index taxa for the Brazilian Zone 011 by Do Carmo et al. (2008). Only two of these species were identified as markers for the African Pre-Salt zones: *Pattersoncypris salitrensis* for the AS11 Zone, *Kroemmelbeincypris symmetrica* for the AS12 Zone (Bate, 1999). However, given that *P. micropapillosa* and *K. angulata* have been identified as contemporaries of *K. symmetrica* in the Araripe Basin (Coimbra et al., 2002), and the fact that the type specimen of *P. sinuata* was derived from the same formation as that of *K. angulata*, the assessment of Do Carmo et al. (2008) that all of these species can be used to typify the Brazilian Zone 011 appears to be correct (Fig. 2).

ACKNOWLEDGMENTS

The authors would like to sincerely acknowledge M. T. Warne (Deakin University) for suggestions for improvements to the manuscript; R. H. Bate (Global Exploration Services Limited) and D. J. Horne (Queen Mary, University of London) for providing excellent reviews of the paper; A. Lord (Senckenberg Research Institute and Natural History Museum) for insights and provision of images used in this publication; J.-L. Volat (TOTAL) for providing access to Grosdidier's type material and images used in this publication; G. Miller and L. Stevens (Natural History Museum, London) for providing images of NHM specimens used in this publication; and Xi D.-P. (Beijing University, Beijing, China) for providing recent literature concerning the age of the Nenjiang Formation in the Songliao Basin, China. The primary author would like to warmly thank D. Seegets-Villiers and P. Komarower (both of Monash University) for providing translations of some of Grosdidier and Krömmelbein's descriptions, and D. L. Thompson, P. Vickers-Rich, M. Anderson, W. M. Hall, and J. D. Stilwell (all of Monash University) for reviewing an early version of this manuscript. The primary author would like to thank the Australian Government for the Australian Postgraduate Award which funded his Ph.D. and acknowledges the Australian Research Council (for a linkage grant awarded to J. D. Stilwell).

REFERENCES

Agassiz, J. L. R. 1841. On the fossil fishes found by Mr. Gardner in the Province of Ceará, in the North of Brazil. Edinburgh New Philosophical Journal, 30:82–84.

Anderson, F. W. 1967. Ostracods from the Weald Clay of England. Bulletin of the Geological Survey of Great Britain, 34:237–269.

Andreu-Boussut, B. 1991. Les ostracodes du Crétacé Moyen (Barrémien à Turonien), le long d'une transversale Agadir-Nador (Maroc). Université de Toulouse, Toulouse, 823 p.

Antonietto, L. S., S. R. Gobbo, D. A. Do Carmo, M. L. Assine, M. L, and M. A. M. C. C. Fernandes. 2009. Ontogeny of some species of *Harbinia* Tsao, 1959 (Crustacea, Ostracoda) from Santana Formation, NE-Brazil: taxonomy and paleoecology. *In* J. C. Coimbra (ed.), Program and Abstracts, 16th International Symposium on Ostracoda.

Arai, M. and J. C. Coimbra. 1990. Análise paleoecológica do registro das primeiras ingressões marinhas na Formação Santana (Cretáceo Inferior da Chapada do Araripe). Atas do I Simpósio sobre a Bacia do Araripe e Bacias Interiores do Nordeste, 14 a 16 de junho de 1990; Anais, Crato, DNPM:225–239.

Baird, W. 1845. Arrangement of the British Entomostraca, with a list of species, particularly noticing those which have as yet been discovered within the bounds of the club. Transactions of the Berwickshire Naturalists' Club, 2(13):145–158.

Bate, R. H. 1971. Phosphatized ostracods from the Cretaceous of Brazil. Nature, 230:397–398.

Bate, R. H. 1972. Phosphatized ostracods with appendages from the Lower Cretaceous of Brazil. Palaeontology, 15:379–393.

Bate, R. H. 1973. On *Pattersoncypris micropapillosa* Bate. Stereo-Atlas of Ostracod Shells, 1:101–108.

Bate, R. H. 1994. On *Cypridea sylvesterbradleyi* Bate sp. nov. Stereo-Atlas of Ostracod Shells, 21:103–106.

Bate, R. H. 1999. Non-marine ostracod assemblages of the Pre-Salt rift basins of West Africa and their role in sequence stratigraphy, p. 283–292. *In* N. R. Cameron, R. H. Bate, and V. S. Clure (eds.), The Oil and Gas Habitats of the South Atlantic: Geological Society Special Publication 153. Geological Society, London.

Berthou, P. Y., F. Dépêche, J.-P. Colin, J. B. d. M. Figueira, and M. d. S. L. Teles. 1994. New data on the ostracodes from the Crato lithogic units (lower member of the Santana Formation, latest Aptian–Lower Albian) of the Araripe Basin (northeastern Brazil). Acta Geológica Leopoldensia, 17:539–554.

Bosquet, J. 1852. Description des Entomostracés fossiles des terrains Tertiares de la France et de la Belgique. Mémoires couronnés et Mémoires des Savants Étrangers, 24:1–142.

Brady, G. S. and A. H. F. Robertson. 1885. Genus *Darwinula*. *In* T. R. Jones, 1885, On the Ostracoda of the Purbeck Formation; with notes on Wealden species. Quarterly Journal of the Geological Society of London, 41(1–4):346.

Branson, C. C. 1936. New name for a Morrison ostracode genus. Journal of Paleontology, 10:323.

Bronstein, Z. S. 1947. Ostracodes des eaux douces, p. 1–339. *In* E. N. Pavlovsky and A. A. Stackelberg (eds.), Faune de l'URSS, Vol. 31. Crustacés, Vol. 2, No. 1. Zoologicheskiy Institut Akademii Nauk SSSR, Moscou-Leningrad.

Campos Neto, O. P. d. A., W. S. Lima, and F. E. G. Cruz. 2007. Bacia de Sergipe-Alagoas. Boletim de Geociências da Petrobrás, 15:405–415.

Carvalho, M. D., U. M. Praça, A. C. Silva-Telles, Jr. R. J. Jahnert, and J. L. Dias. 2000. Bioclastic carbonate lacustrine facies models in the Campos Basin (Lower Cretaceous), Brazil, p. 245–256. *In* E. H. Gierlowski-Kordesch and K. R. Kelts (eds.), Lake Basins through Space and Time: AAPG Studies in Geology 46. AAPG, Tulsa, Oklahoma.

Coimbra, J. C., M. Arai, and A. L. Carreño. 2002. Biostratigraphy of Lower Cretaceous microfossils from the Araripe basin, northeastern Brazil. Geobios, 35:687–698.

Colin, J.-P. and F. Dépêche. 1997. Faunes d'ostracodes lacustres des bassins intra-cratoniques d'âge Albo-Aptien en Afrique de l'Ouest (Cameroun, Tchad) et au Brésil: Considérations d'ordre paléoécologiques et paléobiogéographiques. African Geosciences Review, 4:431–450.

Colin, J.-P. and L. Jacobs. 1990. L'âge des couches à dinosaures du Malawi: apport des ostracodes [On the age of the Malawi Dinosaur Beds: evidence from ostracodes]. Comptes Rendus de l'Académie des Sciences (Paris), 311(2):1025–1029.

Colin, J.-P. and F. Lethiers. 1988. The importance of ostracods in biostratigraphic analysis, p. 27–45. *In* P. De Deckker, J.-P. Colin, and J.-P. Peypouquet (eds.), Ostracoda in the Earth Sciences. Elsevier, Amsterdam.

Coward, M. P., E. G. Purdy, A. C. Ries, and D. G. Smith. 1999. The distribution of petroleum reserves in basins of the South Atlantic margins, p. 101–131. *In* N. R. Cameron, R. H. Bate, and V. S. Clure (eds.), The Oil and Gas Habitats of the South Atlantic: Geological Society Special Publication No. 153. The Geological Society, London.

Cunha, M. C. C. and J. A. Moura. 1979. Espécies novas de ostracodes não-marinhos da Série do Recôncavo: paleontologia e bioestratigrafia. Boletim tecnico da Petrobrás, 22:87–100.

De Klasz, I. and F. Uliczny. 1975. Précisions sur certains genres d'ostracodes non-marins du crétacé inférieur ("cocobeach") du Gabon et description de quelques nouvelles espèces. Revue de L'Institut Français du Pétrole, 30:187–196.

Dépêche, F., P.-Y. Berthou, and D. d. A. Campos. 1990. Quelques observations sur les faunes d'ostracodes du Crétacé du Bassin d'Araripe (NE du Brésil). Atas do I Simpósio sobre a Bacia do Araripe e Bacias Interiores do Nordeste, 14 a 16 de junho de 1990. Anais, Crato, DNPM:293–308.

Dias, J. L. 2005. Tectônica, estratigrafia e sedimentação no Andar Aptiano da margem leste brasileira. Boletim de Geociências da Petrobrás, 13:7–25.

Dingle, R. V. 1999. Walvis Ridge Barrier: its influence on palaeoenvironments and source rock generation deduced from ostracod distributions in the early South Atlantic Ocean, p. 293–302. *In* N. R. Cameron, R. H. Bate, and V. S. Clure (eds.), The Oil and Gas Habitats of the South Atlantic: Geological Society Special Publicaton No. 153. Geological Society, London.

Do Carmo, D. A. 1998. Taxonomia, paleoecologia e distribução estratigráfica dos ostracodes da Formação Alagamar (Cretáceo

Inferior), Bacia Potiguar, Brasil. Unpublished Ph.D. dissertation, Universidade Federal do Rio Grande do Sul, 155 p.

DO CARMO, D. A., Y. T. SANGUINETTI, J. C. COIMBRA, AND E. M. GUIMARÃES. 1999. Paleoecologia dos ostracodes não-marinhos do Cretáceo Inferior da bacia Potiguar, RN, Brasil. Boletim do 5° Simpósio sobre o Cretáceo do Brasil e 1er Simpósio sobre el Cretácico de América del Sur, 1999; Serra Negra, UNESP:383–391.

DO CARMO, D. A., H. Z. TOMASSI, AND S.B.S.G. DE OLIVEIRA. 2004a. Taxonomia e distribuição estratigráfica dos ostracodes da Formação Quiricó, Grupo Areado (Cretáceo Inferior), Bacia Sanfranciscana, Brasil. Revista Brasileira de Paleontologia, 7:139–149.

DO CARMO, D. A., D. M. L. RAFAEL, R. M. VILHENA, AND H. Z. TOMASSI. 2004b. Redescrição de *Theriosynoecum silvai* e *Darwinula martinsi*, Membro Crato (Formação Santana), Cretáceo Inferior, Bacia do Araripe, NE Brasil. Revista Brasileira de Paleontologia, 7:151–158.

DO CARMO, D. A., R. WHATLEY, J. V. D. Q. NETO, AND J. C. COIMBRA. 2008. On the validity of two Lower Cretaceous non-marine Ostracode genera: biostratigraphic and paleogeographic implications. Journal of Paleontology, 82:790–799.

DO CARMO, D. A., J. C. COIMBRA, AND R. WHATLEY. 2009. Taxonomy of limnic ostracodes from Alagamar Formation, mid-late Aptian, Potiguar Basin, NE-Brazil. *In* J. C. Coimbra (ed.), Program and Abstracts, 16th International Symposium on Ostracoda.

FEIJO, F. J. 1994. Bacia de Sergipe e Alagoas. Boletim de Geociências da Petrobrás, 8:149–161.

GAO, R. Q., C. Q. HE, AND X. Y. QIAO. 1992. Cretaceous Non-marine Dinoflagellates, Chlorophytes and Acritarchs from the Songliao Basin. Nanjing University Press, Nanjing, 68 p. (In Chinese).

GOBBO, S. R., D. A. DO CARMO, R. L. PINTO, L. S. ANTONIETTO, AND S. C. SOUSA-E-SILVA. 2009. A proposal of identification key for especies of *Harbinia* Tsao, 1959 (Crustacea, Ostracoda). *In* J. C. Coimbra (ed.), Program and Abstracts, 16th International Symposium on Ostracoda.

GOODALL, J. G. S., G. P. COLES, AND M. F. WHITAKER. 1992. An integrated palynological, palynofacies and micropalaeontological study of the Pre-Salt formations of the South Gabon subbasin and the Congo Basin, p. 365–399. *In* R. Curnelle (ed.), Géologie de l'Afrique et de l'Atlantique Sud: Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine, Mémoire 13. Elf-Aquitaine, Pau.

GREKOFF, N. AND K. KRÖMMELBEIN. 1967. Étude comparée des ostracodes mésozoïques continentaux des bassins atlantiques: série de Cocobeach, Gabon et série de Bahia, Brésil. Revue de L'Institut Français du Pétrole, 22:1307–1353.

GROSDIDIER, E. 1967. Quelques ostracodes nouveaux de la Série anté–salifère ("Wealdienne") des bassins côtiers du Gabon et du Congo. Revue de Micropaléontologie, 10:107–118.

GROSDIDIER, E. 1979. Principaux ostracodes marins de l'intervalle Aptien-Turonien du Gabon (Afrique Occidentale). Bulletin du Centre de Recherches Exploration-Production Elf-Aquitaine, 3:1–35.

GROSDIDIER, E. AND J. BIGNOUMBA. 1984. Exemple de coupures écostratigraphiques basées sur un renouvellement des faunes d'ostracodes lacustres dans le Crétacé inférieur du rift atlantique au droit du Sud Gabon. Géologie Méditeranéenne, 11:87–95.

GROSDIDIER, E., E. BRACCINI, G. DUPONT, AND J.-M. MORON. 1996. Biozonation du Crétacé Inférieur non marin des bassins du Gabon et du Congo, p. 67–82. *In* S. Jardiné, I. De Klasz, and J.-P. Debenay (eds.), Géologie de l'Afrique et de l'Atlantique Sud: Bulletin des Centres Recherches Exploration-Production Elf Aquitaine, Mémoire 16. Elf Aquitaine. Pau.

HESSEL, M. H., M. E. TOME, AND C. R. MOURA. 2006. Ostracodes mesozoicos das bacias do interior do Nordeste brasiliero: o estado da arte. Revista de Geologia, 19:187–206.

HORNE, D. J. AND J.-P. COLIN. 2005. The affinities of the genus *Cypridea* Bosquet, 1852, and its allies, with consideration of implications for the phylogeny of nonmarine cypridoidean ostracods. Revue de Micropaleontologie, 48:25–35.

HORNE, D. J. AND R. J. SMITH. 2004. First British record of *Potamocypris humilis* (Sars, 1924), a freshwater ostracod with a disjunct distribution in Europe and southern Africa. Bollettino della Societa Palaeontologica Italiana, 43:297–306.

HOU, Y.-T. 1984. Problems concerning the classification of the genera *Harbinia*, *Sinocypris*, *Quadracypris* and *Nanxiongium* (Ostracoda). Acta Micropaleontologica Sinica, 9:17–34.

JONES, T. R. 1850. Description of the Entomostraca of the Pleistocene beds of Newbury, Copford, Clacton, and Grays. Annals and Magazine of Natural History, 6, ser. 2, 31:25–28.

JURINE, L. 1820. Histoire des Monocles qui se trouvent aux environs de Genève. J. J. Paschoud, Genève, 258 p.

KRÖMMELBEIN, K. 1961a. Stratigraphische Probleme in den wichtigsten Erdöl-Aufschlußgebieten Brasiliens. Erdöl u. Kohle, 14:893–900.

KRÖMMELBEIN, K. 1961b. Uber Dimorphismus bei Arten der Ostracoden-Gattung *Paracypridea* Swain (Cyprideinae) aus dem NE-brasilianischen "Wealden." Senckenbergiana lethaea, 42:353–375.

KRÖMMELBEIN, K. 1962. Zur Taxonomie und Biochronologie stratigraphisch wichtiger Ostracoden-Arten aus der oberjurassich?-unterkretazischen Bahia-Serie Wealden-Fazies) N-E Braziliens. Senckenbergiana lethaea, 43:437–528.

KRÖMMELBEIN, K. 1963. *Ilhasina* n. g. und *Salvadoriella* n. g. zwei neue Ostracoden-Gattungen aus der Bahia-Serie (nicht-mariner Oberjura?-Unterkreide) NE-Brasilien. Zoologischer Anzeiger, 171:376–390.

KRÖMMELBEIN, K. 1964a. Über einige neue Arten der Ostracoden-Gattung *Reconcavona* Krömmelbein 1962 aus der NE-brasilianischen Bahia-Serie (nicht-mariner Oberjura?-Unterkreide). Senckenbergiana lethaea, 45(1–4):29–41.

KRÖMMELBEIN, K. 1964b. Neue Arten der Ostracoden-Gattung *Paracypridea* Swain, aus der Bahia, Serie des Reconcavo Bahiano (Oberjura? Unterkreide, Wealden-Fazies, NE-Brasilien). Boletim Paranaense de Geografia, 10–15:139–160.

KRÖMMELBEIN, K. 1964c. Ostracoden aus der marinen "Küsten-Kreide" Brasiliens 1: *Brachycythere* (*Brachycythere*) *sapucariensis* n. sp. aus dem Turonium. Senckenbergiana lethaea, 45:489–495.

KRÖMMELBEIN, K. 1965a. Neue, für Vergleiche mit West-Afrika wichtige Ostracoden-Arten der brasilianischen Bahia-Serie (Ober-Jura?/Unter-Kreide in Wealden-Fazies). Senckenbergiana lethaea, 46a:177–213.

KRÖMMELBEIN, K. 1965b. Ostracoden aus der nicht-marinen Unter-Kreide ("Westafrikanischer Wealden") des Congo-Küstenbeckens. Meyniana, 15:59–74.

KRÖMMELBEIN, K. 1966a. On "Gondwana Wealden" Ostracoda from NE Brazil and West Africa, p. 113–119. *In* J. E. Van Hinte (ed.), Proceedings of the 2nd West African Micropaleontological Colloquium. E. J. Brill, Leiden.

KRÖMMELBEIN, K. 1966b. Preliminary Remarks on Some Marine Cretaceous Ostracodes from Northeastern Brazil and West Africa, p. 119–123. *In* J. E. Van Hinte (ed.), Proceedings of the 2nd West African Micropaleontological Colloquium. E. J. Brill, Leiden.

KRÖMMELBEIN, K. 1967. Ostracoden aus der marinen "Küsten-Kreide" Brasiliens 2: *Sergipella transatlantica* n. g. n. sp. und *Aracajuia benderi* n. g. n. sp. aus dem Ober-Aptium/Albium. Senckenbergiana lethaea, 48:525–533.

KRÖMMELBEIN, K. 1968. The first non-marine Lower Cretaceous ostracods from Ghana, west Africa. Palaeontology, 11:259–263.

KRÖMMELBEIN, K. 1970. Non-marine Cretaceous ostracods and their importance for the hypothesis of "Gondwanaland." Proceedings of the Second Gondwana Symposium, South Africa, 7:617–619.

KRÖMMELBEIN, K. 1979. African Cretaceous ostracods and their relations to surrounding continents, p. 305–310. *In* J. Gray and A. J. Boucot (eds.), Historical Biogeography, Plate Tectonics and the Changing Environment. Oregon State University Press.

KRÖMMELBEIN, K. AND R. WEBER. 1971. Ostracoden des "Nordost-Brasilianischen Wealden." Beihefte zum Geologischen Jahrbuch, 115:1–93.

KRÖMMELBEIN, K. AND R. WEBER. 1985. Ostracodes do "Wealden" do nordeste brasileiro. Ciência-Técnica-Petróleo (Seção: Exploração de Petróleo), 16:9–39.

KRÖMMELBEIN, K. AND R. WENGER. 1966. Sur quelques analogies remarquables dans les microfaunes Crétacées du Gabon et du Bresil oriental (Bahia et Sergipe). I.U.G.S. Symposium on 'Sedimentary basins of the African coasts' 1, Atlantic Coast, 193–196.

LATREILLE, P. A. 1802. Histoire naturelle des crustacés et des insectes. F. Dufart, Paris, 2, 382 p.

LATREILLE, P. A. 1806. Genera Crustaceorum et Insectorum Secundum Ordinem Naturalem in Familias Disposita, Iconibus Exemplisque Plurimis Explicata. A. Koenig, Paris and Argentorati, 1, 280 p.

LEAL, M. E. D. C. AND P. M. BRITO. 2004. The ichthyodectiform *Cladocyclus gardneri* (Actinopterygii: Teleostei) from the Crato and Santana Formations, Lower Cretaceous of Araripe Basin, North-Eastern Brazil (*Cladocyclus gardneri* (Actinoptérygiens : Téléostéens, Ichthyodectiformes) des Formations Crato et Santana, Crétacé inférieur, Bassin d'Araripe, NE Brésil). Annales de Paleontologie, 90:103–113.

LI, J., D. J. BATTEN, AND Y. ZHANG. 2011. Palynological record from a composite core through Late Cretaceous–early Paleocene deposits in the Songliao Basin, Northeast China and its biostratigraphic implications. Cretaceous Research, 32:1–12.

LIMA, M. R., 1979, Paleontologia da Formação Santana (Cretáceo do nordeste do Brasil): estágio atual do conhecimento. Anais da Academia Brasileira de Ciências, 51: 545–556.

MARTILL, D. M. 1988. Preservation of fish in the Cretaceous Santana Formation of Brazil. Palaeontology, 31:1–18.

MARTILL, D. M., P. M. BRITO, AND J. WASHINGTON-EVANS. 2008. Mass mortality of fishes in the Santana Formation (Lower Cretaceous, ?Albian) of northeast Brazil. Cretaceous Research, 29:649–658.

MARTILL, D. M., A. R. I. CRUICKSHANK, E. FREY, P. G. SMALL, AND M. CLARKE. 1996. A new crested maniraptoran dinosaur from the Santana Formation (Lower Cretaceous) of Brazil. Journal of the Geological Society, 153:5–8.

MARTIN, G. P. R. 1940. Ostracoden des norddeutschen Purbeck und Wealden. Senckenbergiana lethaea, 22:275–361.

MATZKE-KARASZ, R., R. J. SMITH, R. SYMONOVÁ, C. G. MILLER, AND P. TAFFOREAU. 2009. Sexual intercourse involving giant sperm in Cretaceous ostracode. Science, 324:1535.

MELLO, M. R., E. A. M. KOUTSOUKOS, E. V. DOS SANTOS NETO, AND A. C. SILVA-TELLES JR. 1993. Geochemical and micropaleontological characterization of lacustrine and marine hypersaline environments from Brazilian sedimentary basins. In: Source Rocks in a Sequence Stratigraphic Framework: AAPG Studies in Geology, p. 17–34.

MILANI, E. J., H. D. RANGEL, G. V. BUENO, J. M. STICA, W. R. WINTER, J. M. CAIXETA, AND O. C. P. NETO. 2007. Bacias Sedimentares Brasileiras: Cartas Estratigráficas. Anexo ao Boletim de Geociências da Petrobrás, 15:1.

MOJON, P.-O., H. HADDOUMI, AND A. CHARRIÈRE. 2009. Nouvelles données sur les Charophytes et Ostracodes du Jurassique moyen-supérieur-Crétacé inférieur de l'Atlas marocain. Carnets de Géologie/Notebooks on Geology-Mémoire, 2009/03:1–39.

MOURA, J. A. 1972. Algumas espécies e subspécies novas de ostracodes da Bacia Reconcavo/Tucano. Boletim tecnico da Petrobrás, 15:245–263.

MOURA, J. A. 1987. Biocronoestratigrafia da seqüência não marinha do Cretáceo Inferior da Bacia de Campos, Brasil: Ostracodes. Anais Do X Congresso Brasil de Paleontologia, Rio De Janeiro, 19–25 Julho, 1987:716–731.

MOURA, J. A. 1988. Ostracods from non-marine Early Cretaceous sediments of the Campos Basin, Brazil, p. 1207–1216. *In* T. Hanai, N. Ikeya, and K. Ishizaki (eds.), Evolutionary Biology of Ostracoda: Its Fundamentals and Applications-Proceedings of the 9th International Symposium on Ostracoda, Shizuoka, Japan 1985. Elsevier, Tokyo.

MOURA, J. A. AND U. M. PRAÇA. 1985. Ostracodes das seqüências não marinhas e transicionais Mesozóicas (Andares Jiquiá e Alagoas), Bacia de Campos, p. 401–408. *In* D. A. Campos, C. S. Ferreira, I. M. Brito, and C. F. Viana (eds.), Coletânea de Trabalhos Paleontológicos: Série Geologia, 27 (2). Departmanento Nacional da Produção Mineral/Ministério das Minas e Energia, Brasília.

MÜLLER, G. W. 1894. Die Ostracoden des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Fauna und Flora des Golfes von Neapel und der Angrenzenden Meeres-Abschnitte, 21:1–404.

MUSACCHIO, E. A. 1990. Non-marine Cretaceous ostracods from Argentina and their palaeobiogeographical relationships, p. 557–569. *In* R. Whatley and C. Maybury (eds.), Ostracoda and Global Events. Chapman and Hall, London.

RAMOS, M. I. F., D. F. ROSSETTI, AND J. D. S. PAZ. 2006. Caracterização e significado paleoambiental da fauna de ostracods da Formação Codó (Neoaptiano), Leste da Bacia de Grajaú, MA, Brasil. Revista Brasileira de Paleontologia, 9:339–348.

RANGEL, H. D. AND M. CARMINATTI. 2000. Rift lake stratigraphy of the Lagoa Feia Formation, Campos Basin, Brazil, p. 225–244. *In* E. H. Gierlowski-Kordesch and K. R. Kelts (eds.), Lake Basins through Space and Time: AAPG Studies in Geology, 46.

SARS, G. O. 1866. Oversigt af Norges marine Ostracoder. Forhandlinger i Videnskabs-Selskabet i Christiania, Christiania (Oslo), Norway, p. 1–130

SCHALLER, H. 1969. Revisão estratigráfica da Bacia de Sergipe/Alagoas. Boletim tecnico da Petrobrás, 12:21–86.

SHA, J. 2007. Cretaceous stratigraphy of northeast China: non-marine and marine correlation. Cretaceous Research, 28:146–170.

SILVA-TELLES, A. C., JR. 1992. Novo zoneamento da sequência das coquinas da Formação Lagoa Feia (Neojiquia da Bacia de Campos) com base em ostracodes-aspectos evolutivos. Anais 37° Congresso Brasileiro de Geologia, 1992 (São Paulo), 2:489–490.

SILVA-TELLES, A. C., JR. 1996. Estratigrafia de seqüências de alta resolução do Membro Coqueiros da Formação Lagoa Feia (Barremiano?/Aptiano da Bacia de Campos-Brasil), Universidade Federal do Rio Grande do Sul, Rio Grande do Sul, 268 p.

SILVA-TELLES, A. C., JR. AND M. S. S. VIANA. 1990. Paleoecologia dos ostracodes da Formação Santana (Bacia do Araripe): um estudo ontogenético de populações. Atas do I Simpósio sobre a Bacia do Araripe e Bacias Interiores do Nordeste, 14 a 16 de junho de 1990; Anais, Crato, DNPM, p. 309–327.

SMITH, R. J. 2000a. Morphology and ontogeny of Cretaceous ostracods with preserved appendages from Brazil. Palaeontology, 43:63–98.

SMITH, R. J. 2000b. The morphology of the upper lip of Cypridoidea ostracods: taxonomic and phylogenetic significance. Hydrobiologia, 418:169–184.

SUES, H.-D., E. FREY, D. M. MARTILL, AND D. M. SCOTT. 2002. *Irritator challengeri*, a new spinosaurid (Dinosauria, Theropoda) from the Lower Cretaceous of Brazil. Journal of Vertebrate Paleontology, 22:535–547.

SYLVESTER-BRADLEY, P. C. 1949. The ostracod genus *Cypridea* and the zones of the Upper and Middle Purbeckian. Proceedings of the Geologists' Association, 60:125–153.

SYRIO, V. N. AND A. M. RIOS-NETTO. 2002a. Estudo bioestratigráfico e paleoambiental preliminar de ostracodes da Formação Rio da Batateira, Bacia Sedimentar do Araripe-Brazil. Boletim do 6° Simpósio sobre o Cretáceo do Brasil, 67–70.

SYRIO, V. N. AND A. M. RIOS-NETTO. 2002b. Ostracodes from the Rio da Batateira Formation (Lower Cretaceous, Araripe Basin): preliminary results on systematics, biostratigraphy and paleoecology. Anais da Academia Brasileira de Ciencias, 74:369.

SZCZECHURA, J. 1981. The taxonomy of *Cypridea* Bosquet, 1852 and similar ostracodes. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 162:254–269.

TAMBAREAU, Y. 1982. Les ostracodes et l'histoire géologique de l'Atlantique Sud au Crétacé. Bulletin du Centre de Recherches Exploration-Production Elf-Aquitaine, 6:1–37.

TIBERT, N. E., J.-P. COLIN, AND R. M. LECKIE. 2009. Taxonomy, biostratigraphy and paleoecology of Cenomanian and Turonian ostracodes from the Western Interior Basin, Southwest Utah, U.S.A. Revue de Micropaléontologie, 52:85–105.

TSAO, L.-P. 1959. *Harbinia* Tsao, 1959, inOstracodes from the Lower Cretaceous deposits of the Songliao Basin, p. 48–49. *In* M. A. Nechayeva, T.-J. Liu, T.-I. Sous, T.-S. Sou, F.-Z. Teh, and L.-P. Tsao (eds.), Monographs of the Institute of Geology, Ministry of Geology, People's Republic of China, Series B. Geology Press, Peking.

VAN HARTEN, D. 2000. Variable noding in *Cyrpideis torosa* (Ostracoda, Crustacea): an overview, experimental results and a model from Catastrophe Theory. Hydrobiologia, 419:131–139.

VIANA, C. F. 1966a. Stratigraphic distribution of Ostracoda in the Bahia Supergroup (Brazil), p. 240–257. *In* J. E. Van Hinte (ed.), Proceedings of the 2nd West African Micropaleontological Colloquium. E. J. Brill, Leiden.

VIANA, C. F. 1966b. Correspondência entre os ostracodes das séries Cocobeach (Gabão) e Bahia (Brasil). Boletim tecnico da Petrobrás, 9:367–382.

VIANA, C. F., E. G. DA GAMA JUNIOR, I. D. A. SIMOES, J. A. MOURA, J. D. R. FONSECA, AND R. J. ALVES. 1971. Revisao estratigrafica da Bacia Reconcavo/Tucano. Boletim tecnico da Petrobrás, 14:157–192.

VIANA, M. S. S., P. M. BRITO, AND A. C. SILVA-TELLES, JR. 1989. Paleontologia de uma camada de folhelhos pirobetuminosos do Membro Romualdo, Formação Santana, na Mina Pedra Branca, Município de Nova Olinda, Ceará. Anais do XI Congresso Brasileiro de Paleontologia, 1989. Anais, Curitiba, SBP:207–217.

WAN, X., P. CHEN, AND M. WEI. 2007, The Cretaceous system in China. Acta Geologica Sinica, 81:957–983.

WANG, P., X. DU, J. WANG, AND D. WANG. 1996. Chronostratigraphy and stratigraphic classification of the Cretaceous of the Songliao Basin. Acta Geologica Sinica, 9:207–218.

WANG, P., X. A. XIE, F. MATTERN, Y. REN, D. ZHU, AND X. SUN. 2007. The Cretaceous Songliao Basin: volcanogenic succession, sedimentary sequence and tectonic evolution, NE China. Acta Geologica Sinica, 81:1002–1011.

WANG, C., Y. HUANG, AND X. ZHAO. 2009. Unlocking a Cretaceous geologic and geophysical puzzle: Scientific drilling of Songliao Basin in northeast China. The Leading Edge, 28:340–344.

XI, D., X. WAN, Z. FENG, S. LI, Z. FENG, J. JIA, X. JING, AND W. SI. 2011. Discovery of Late Cretaceous Foraminifera in the Songliao Basin: evidence from SK-1 and implications for identifying seawater incursions. Chinese Science Bulletin, 56:253–256.

YE, D.-Q. 1988. Ostracod evolution and depositional characteristics of the Cretaceous Nenjiang Formation in the Songliao Basin, China, p. 1217–1227. *In* T. Hanai, N. Ikeya, and K. Ishizaki (eds.), Evolutionary Biology of Ostracoda: Its Fundamentals and Applications–Proceedings of the 9th International Symposium on Ostracoda, Shizuoka, Japan 1985. Elsevier, Tokyo.

YE, D. 1990. The geological and exploration significance of Cretaceous non-marine Ostracoda from the Hailaer Basin, northwestern China, p. 251–261. *In* R. Whatley and C. Maybury (eds.), Ostracoda and Global Events. Chapman and Hall, London.

ZHANG, Z., Z. LIU, W. BAICHANG, Y. ZHANG, AND D. YE. 2007. Ostracod biostratigraphy of the Late Cretaceous Qingshankou Formation in the Songliao Basin. Acta Geologica Sinica, 81:727–738.

ACCEPTED 5 FEBRUARY 2012