Palaeocopida (Ostracoda) across the Permian–Triassic events: new data from southwestern Taurus (Turkey)

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ABSTRACT – The Palaeocopida have been considered as an entirely Palaeozoic group and their disappearance as a marker for the Palaeozoic–Mesozoic boundary. Despite this, 11 Palaeocopida species have been recorded in the Early Triassic. New data obtained in southwestern Taurus at the Permian–Triassic section of Çürük dağ, permit an assessment of this problem. This paper synthesizes the data on lowermost Triassic ostracodes and revises the youngest Palaeocopida occurrences. A new Early Triassic Palaeocopida species is described (Reviya curakensis n. sp.). J. Micropalaeontol. 23(1): 67–76, May 2004.

INTRODUCTION
For all marine biota, the end-Permian mass extinction is the most dramatic event of the Phanerozoic. At the end of the Permian, 49–57% of marine families, 83% of genera and 96% of species disappear (Sepkoski, 1992; Erwin, 1993; Jablonski, 1994; Benton, 1995; Lethiers 1998; note that the figures vary according to author).

As with other marine organisms, benthic ostracods are subject to the effects of calamitous events (among others, the great end-Permian regression followed by the quick and dysoxic Lower Triassic transgression, the modifications of climates and oceanic circulation, the salinity drop, the volcanism, linked with Pangaea assemblage; synthesis in Lethiers, 1998).

The Early Triassic marine ostracods are poorly known. Some species have been mentioned, in greater or less detail, from the Early Triassic (Induan–Olenekian) of northwestern Australia (Jones, 1970), Pakistan (Sohn, 1970), the Precaspian Depression (Schneider 1948, 1960; Kukhtinov & Crasquin-Soleau, 1999), Nepal (Kozur, 1971), Kashmir (Agarwal, 1979, 1980, 1981), the Germanic Basin (Kozur, 1972), Israel (Hirsch & Gerry, 1974), South China (Wang, 1978; Wei, 1981; Hao, 1992, 1994) and Greece (Crasquin-Soleau & Baud, 1998).

The Çürük dağ section (N36°41'32–E30°27'40) is located in western Taurus, in the Antalya Nappes (Turkey), SW of Antalya (Fig. 1) (Lys & Marcoux, 1978; Crasquin-Soleau et al., 2002). The Pamukçak Formation (Middle–Upper Permian) is overlain by the Kokarkuyu Formation (Lower Triassic) (Lys & Marcoux, 1978; Marcoux & Baud, 1986). In the Çürük dağ section (Fig. 1), the Pamukçak Formation is a thick (400–600 m) succession of inner to outer platform facies (Capitanian to Changhsingian; dating by Foraminifera and calcareous algae; Lys & Marcoux, 1978; Marcoux & Baud, 1986). The lowest Triassic levels are rich in Induan Foraminifera (Ammodiscus, Rectocornaspira, Cyclogira, Earlandia) and rare in conodonts (Isarcicella isarcica staechei (Dai & Zhang) and Hindeodus parvis (Kozur & Ptatakova)) (Crasquin-Soleau et al., 2002). This association is an index of the second conodont Triassic biozone (Lai & Mei, 2000).

In the Upper Permian samples, the ostracod assemblage is similar to other Middle and Upper Permian assemblages observed in the Palaeo-Tethys (see, for example, Crasquin-Soleau & Baud, 1998; Crasquin-Soleau et al., 1999). It is mainly made up of Bairdiaeace (Bairdia, Petasobaeridia, Acratia, Fabalicypris, Luchinilla, Macrocypris, Beschkririna, Microcheilinella), with a minor amount of Quasilitaceae (Graphiodactylus?), Cavellinaceae (Sulcella) and Cypridacea (Basslerella, Argoviella, Callicythere). The Palaeocopida are represented by genera common in the Palaeo-Tethys, such as Hollinella, Knoxiella, Permomyoungiella and Sargentina. The ostracod assemblage is characteristic of a marine platform environment, deposited under a tropical climate.

In the basal beds of the Kokarkuyu Formation (Lower Triassic), the ostracods are represented by Bairdiaeace (mainly the genera Bairdia, Bairdiacypris, Luchinilla), Cavellinaceae (Sulcella?) and by Palaeocopida (Kirkbyaceae, Reviya curakensis n. sp., and an undetermined Paraparchitacea). This assemblage, which has a lower specific and generic diversity than the assemblages observed in the Upper Permian beds, seems to indicate a shallower environment and/or with salinity variations, always under a tropical climate.

It has long been thought that the Palaeocopida (ostracods with a straight dorsal border) became extinct during the Permian and their presence was considered as an index of Palaeozoic age. However, Palaeocopida have been reported from the Early Triassic of Pakistan (Olenekian), Australia (Induan), South China (Induan and Olenekian) and Hungary (Late Early Induan) (Table 1, with references).

Ostracods of the lower part of the Kokarkuyu Formation in the Çürük dağ section are the oldest Triassic forms figured and described to date, coming from the parvis and staechei Biozones. The Palaeocopida, Kirkbyaceae, here discovered, are the youngest observed outside of South China and Pakistan. Ostracodes were mentioned in the lowermost Triassic of Dolomites (Werfen Formation, Italy) by Brogli Loriga (1986), but they have never been studied.

Furthermore, these findings are very important in the understanding of a critical aspect of the end-Permian mass extinction – the anomalous pattern of the post-extinction recovery, which seems to be significantly delayed for most clades (Erwin, 1998; Twitchett, 1999; Rong & Shen, 2002). Even if the ostracod assemblage at the base of the Kokarkuyu Formation shows a low specific and generic diversity, it increases the
number of Lower Triassic ostracods known, with the occurrence of 12 species, one of which – at least – is new. This could suggest that there are places – free from low oxygen restriction – where the recovery of benthic groups was more rapid.

PALAEOCOPIDA ACROSS THE PERMIAN–TRIASSIC BOUNDARY

In 1961, in the ‘Treatise of Invertebrate Paleontology – Part Q: Ostracoda’ (Moore, 1961), the order Palaeocopida Henningsmoen, 1953 was reported to range from the Early Ordovician to the Middle Permian. Scott (in Moore, 1961) defined the Palaeocopida as follows: ‘dorsal margin long and straight; surface smooth or ornamented; lobes, sulci, ventral and adventral structures common; calcareous inner lamella absent; dimorphic or non-dimorphic; soft parts unknown’. They are marine.

In the Treatise, the stratigraphic range was questionably extended up to Recent because the superfamily Punciacea is referred, with doubt, to this order. Kozur (1998) published new Upper Triassic Punciacea genera and species which are, in his opinion, the missing link between the Punciacea and Kirkbyacea. Horne et al. (2002) confirmed that the Punciacea belong to the Palaeocopida with a few genera such as Manawa and Promanawa. In both cases, this is a Palaeozoic order with isolated Recent representatives, with a great gap during almost all of the Mesozoic, due to the lack of data during this time interval.

Middle and Late Permian Palaeocopida

Since 1961, numerous papers have been published with reference to Middle and Late (International scale – decision of IUGS (Beijing, 1996) and taken up by Waterhouse (1997)) Permian ostracods. Table 2 lists some of the papers where Palaeocopida were described and/or reported (not an exhaustive list).
### Table 1. Early Triassic palaeocopid species in literature.

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<td><em>C. discarinita</em></td>
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<td><em>C. neutrum</em></td>
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<td><em>C. zhengfengensis</em></td>
<td>Early Induan W Guizhou and NE Yunnan (South China)</td>
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<td><em>H. cf. piana</em></td>
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<td><em>Roundyella? papilliformis</em></td>
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<td><em>Reviya curukensis</em> n.sp.</td>
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Grey boxes, papers where the species is described and/or figured and/or mentioned; crossed boxes, papers where the species is regarded as crossing the Permian–Triassic boundary.

### Table 2. Sources describing Palaeocopida from the Middle and Late Permian.

<table>
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<td>Gramm (1997)</td>
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<td>Crasquin-Soleau &amp; Baud (1998)</td>
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*Papers published before the Treatise but not taken into account in it.*
**Early Triassic Palaeocopida**

Belousova (1965) described the ostracod fauna of the Late Permian (Dzulifian=Wuchiapingian)–Early Triassic (Induan) from Dzhulfia section (Armenia). She figured 26 species, among which, 19 are new. In this paper, eight species cross the Permian–Triassic boundary. She reported two species of Palaeocopida in the Early Triassic: *Amphissites notabilis* Belousova, 1965 and *Hollinella cushmani* Kellett, 1933; this last species is a junior synonym of *Hollinella bassleri* (Kellett, 1928) (Bess & Jordan, 1972). Chao (1965) and Tozer (1967) considered this part of the section to be latest Permian.


In 1970, Jones presented the Early Triassic ostracods from the Perth Basin (Western Australia). He recognized a new species, *Pracagnium neutralum* Jones, 1970, which belongs to the genus *Carinaknightina* erected the same year by Sohn (1970). This species and *Hollinella* sp. are the two palaeocopids occurring in the Early Triassic of the Perth Basin.


Kozur (1985a) defined ostracod assemblage zones with biostratigraphic value in the Late Palaeozoic–Early Triassic of the Bükk Mountains (Hungary). According to that author, *Hollinella tingi* s.s. (this sensu stricto is not explained) occurs in Europe, associated with *Isarccilae isarica* (conodont index of the second biozone of Triassic/Induan/Griesbachian) and in China in *Ophiceras*-bearing beds (Griesbachian). He considered the base of the *Hollinella tingi* assemblage zone as ‘a good marker for the Permo-Triassic boundary’. He defined the lower and the upper boundaries of the assemblage zone by the appearance and the disappearance of *Hollinella tingi* (Kozur, 1985a: 239).

In 1992, Hao presented 11 species from the Early Triassic from Guizhou (South China); he described three new species, two Palaeocopida among them: *Hollinella unispinata* Hao, 1982 and *C. zhenfengensis* Hao, 1982 (synonym of *C. aff. carinata* Sohn, 1970) associated with the following Palaeocopida: *C. carinata*, *Hollinella tingi*, *Hollinella cf. plana* Jiang, 1983, *Hollinella cf. tingi* and *Langdaia suboblonga*.

In conclusion, in the literature 11 Palaeocopida species belonging to five genera are considered to occur in the Early Triassic (Table 1).

In the Çürük dağ section, the authors have recognized two new Palaeocopida in the earliest Triassic. One species is described below (*Revivia curukensis* n. sp. Crasquin-Soileau). The other one is more problematic and the attribution should be taken with caution (Paraparchitidae sp. indet.) due to poor preservation of the material (Pl. 1, fig. 10).

**Palaeocopida across the Permian–Triassic boundary**

In the literature, three Palaeocopida species were reported to cross the Permian–Triassic boundary: *Hollinella tingi*, *Hollinella unispinata* and *Roundyella? papilliformis* Wang, 1978 (Table 3). Podocopid species – *Fabalicypris reniformis* (Chen, 1958) (Bairdiacea) and *Basslerella obesa* Kellett, 1935 (Cytheracea) – are recognized by Hao (1992, 1994) to survive to the mass extinction. These two species were not found in the Çürük dağ section and are not discussed further. On the other hand, *Bairdia subsymmetrica* (Shi, 1987), described in the Changsingian of Meishan (South China) (Shi & Chen, 1987), is present in the earliest Triassic of the Kemer area (Pl. 1, figs 13–14), thus, crossing the Permian–Triassic boundary.

*Hollinella tingi* was described by *Beyrichia tingi* by Patte (1935), from the Early Permian T’unγstzu and Takulesinch’ang Districts of South China. The preservation is poor and it was described based on external moulds on sample surfaces. According to Bless & Jordan (1972), this species is very poorly known.

In 1954, Hou recognized this species in the Upper Permian black shales of the Chihsa Formation (Western Hupei, South China). Hou described cardinal spines, missing in the original description. This author rightly attributed the species to the genus *Hollinella*.

In 1964, Ishizaki assigned specimens discovered in the Early Pennsylvanian (Late Carboniferous) of Japan to *Hollinella tingi*. The preservation of the figured specimen (Ishizaki, 1964: pl. 1, fig. 1) is so bad that it is quite impossible to confirm the assignment.

In 1978, Wang wrote that *Hollinella tingi* occurs in the Late Changhsingian and Early Induan of Western Guizhou and

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**Explanation of Plate 1.**

Figs 1–9. *Revivia curukensis* Crasquin-Soileau n. sp. (All specimens from Kokarkuyu Formation, Induan, Early Triassic): 1, holotype, left lateral view, collection number P6M1467, sample 02TK56; 2, dorsal view, collection number P6M1468, sample 02TK56; 4, paratype, left lateral view, collection number P6M1469, sample 02TK57; 5, right lateral view, collection number P6M1470, sample 02TK56; 3, paratype, right lateral view, collection number P6M1471, sample 02TK56; 6, left lateral view, collection number P6M1472, sample 02TK56; 7, left lateral view, collection number P6M1473, sample 02TK56; 8, left lateral view, collection number P6M1474, sample 02TK118; 9, right lateral view, collection number P6M1475, sample 02TK58; 10, Paraparachitacea gen. and sp. indet, left lateral view, collection number P6M1476, sample 02TK118, Kokarkuyu Formation, Induan, Early Triassic. 11, *Callicythere* sp., right lateral view, collection number P6M1477, sample 02TK47, Pamucak Formation, Capitanian–Changhsingian, Middle–Late Permian. 12, *Liuchinia cf. parva* Wei 1981, right lateral view, collection number P6M1478, sample 02TK46, Pamucak Formation, Capitanian–Changhsingian, Middle–Late Permian. Figs 13–14. *Bairdia subsymmetrica* (Shi 1987) (specimens from Kokarkuyu Formation, Induan, Early Triassic, sample 02TK57): 13, right lateral view, collection number P6M1479; 14, right lateral view, collection number P6M1480. Scale bar for all figures is 100 µm. All specimens come from the Çürük dağ section, Antalya Nappes, Taurus, Turkey, N36°41’32–E30°27’40. Specimens are stored in the Pierre et Marie Curie University Collection, Paris, France.

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Northeastern Yunnan. The figured specimens (Wang, 1978: pl. 1, figs 5–7) are relatively close to Hou’s specimens. However, the specimen figured (pl. 1, fig. 6) has a higher ratio height/length and a small node on L3; the specimens figured in Wang’s pl. 1 (figs 5 and 7) show more arched L1 and the lobes are more rounded.

In 1981, Wei figured (pl. 1, figs 1–3) three specimens from the Induan–Olenekian of Sichuan, assigned to *Hollinella tingi*. The first two (Wei, 1981: pl. 1, figs 1 and 2) are very badly preserved and the assignment must be considered dubious. The specimen figured in Wei (1981: pl. 1, fig. 3) shows an anterior border very different (on this specimen the curvature radius is definitely shorter) than the Patte (1935) & Hou (1954) specimens.

In 1985a (pl 13, fig. 3), Kozur figured a corroded and abraded specimen from the Werfenian (Induan) of the Bükk Mountains (Hungary). It is impossible to give this specimen an assignment at the species level. Furthermore, it is not reasonable to use this species as a stratigraphic index for the Permian–Triassic boundary as suggested by that author.

In 1987, Shi & Chen figured specimens of *Hollinella tingi* from the Early and Middle Changhsingian of Meishan section. The specimen figured (pl. 16, fig. 2) is close to the type species and seems to have a ventral ridge. In 1994, Hao figured ostracods from the Permian–Triassic interval. *Hollinella tingi* from the Triassic (Hao, 1994: pl. 1, fig. 2) is the same picture as in the 1992 paper; the Permian specimen (pl. 1, fig. 6) is close to the type species but it shows a strong punctuation and the cardinal spines are not visible.

In conclusion, *Hollinella tingi* occurs in the Early Permian (Patte, 1935; Hou, 1954). It could occur in the Late Permian (Shi & Chen, 1987). Its presence in the Late Carboniferous is very doubtful (Ishizaki, 1964). The species is not present in the Triassic.

In 1992, Hao described *Hollinella unispinata* from the Induan of Guizhou (South China). In 1994, Hao displayed the occurrence of *Hollinella unispinata* in the Late Permian but without explanation or figures. He repeated this for *Roundyella papilliformis* described by Wang in 1978 in the Late Permian from Western Guizhou and Northeastern Yunnan, i.e. he put an occurrence in the Early Triassic without explanation. So the range of the two species across the Permian–Triassic boundary has not yet been proven.


The ostracod fauna discovered in the Çürük dağ section provides new data, with 28 species occurring in the Late Permian and 12 in the earliest Triassic (Table 4). Concerning the Palaeocopida, the occurrence of the new species *Reviya curukensis* proves the survival of this genus into the Triassic. One specimen, badly preserved, seems to belong to *Paraparchitacea* (Pl. 1, fig. 10), which be confirmed by further study.

Two Triassic genera, *Callicythere* (Cytheracea) and *Liu zhinia* (Bairdiacea) (Pl. 1, figs 11–12), are recognized for the first time.
CONCLUSIONS

As yet there is no conclusive evidence to show that individual species of Palaeocopida range across the Permian–Triassic boundary, although it is known that some genera do so (e.g. Hollinella, Carinoknightina and Reviya). To date, 12 species of Palaeocopida are known from lowermost Triassic sediments. It is also possible that members of the Paraparchitacea may survive into the earliest Triassic but this has yet to be proven with certainty.

Three non-palaeocopid Permian species are known to occur in the Early Mesozoic – Fabalicypris parva Wang, 1978, Graphiadactyllis? sp., and Hollinella (H.) cf. mertensi Crasquin-Soleau, 1999. This study revises upwards the ostracod species extinction rate evaluated by Lethiers (1998) for the Permian–Triassic boundary, from 93% to 98%.

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APPENDIX A: TAXONOMY

Order Palaeocopida Henningsmoen, 1953
Suborder Kirkbyocopina Gründel, 1969
Superfamily Kirkbyacea Ulrich & Bassler, 1906
Family Kirkbyidae Ulrich & Bassler, 1906
Genus Reviya Sohn, 1961

Reviya curukensis Crasquin-Soleau n. sp.

(Pl. 1, fgs. 1–9)


Derivation. From the type locality, Çürük dağ section.

Diagnosis. Species of Reviya with posterior border showing smaller curvature radius than anterior border; and reticulation free of anastomosing ridges.

Holotype. One complete carapace (Pl. 1, fig. 1), collection number P6M1467.

Paratypes. Two complete carapaces (Pl. 1, fgs. 3–4), collection numbers P6M1468 and P6M1469.
Material. Nineteen carapaces, 15 valves and numerous fragments.

Type level. Sample 01TK56, Hindeodus parvus–Isarica Zone, Early Induan.

Type locality. N36°41'32–E30°27'40, Çürükdag section, Antalya Nappes, Taurus, Turkey.

Description. Species of Reviya (Kirkbyidae with straight-backed sub-elliptical tumid reticulated carapace without nodes or carinae and with elongate sub-central pit; Sohn, 1961: 141; rewritten by Becker, 1997: 161); right valve larger than left; overlapping along all free margins; anterior border regularly arched with radius of curvature larger than posterior; ventral border slightly concave in median part, stronger on left valve; carapace slightly compressed in antero-ventral part; presence of a smooth and narrow marginal ridge.

Dorsal view biconvex, right valve larger than left; slight depression at pit; maximum width near mid-length; hinge line straight; more compressed than the other species of the genus.

Surface punctuated; sub-central elongated kirkbyian pit, located at the lower third of height.

Comparisons. Reviya curukensis n. sp. seems to be closely comparable to Reviya mimicus (Geis, 1932) from the Late Mississippian of Indiana from which it differs by it smaller width and its posterior border being less high than the anterior one. It differs from the type species Reviya obesa (Croneis & Gale, 1932) by the absence of the reticulation formed by anastomosing ridges sub-parallel to free margins.

Dimensions. Adults: L=0.55–0.97 mm; H=0.29–0.46 mm; W=0.30–0.49 mm (see Fig. A1).

Occurrence. Induan of the Çürükdag section, Antalya Nappes, Taurus, Turkey; Kokarkuyu Formation, Induan, Early Triassic. Marine.

Stratigraphic remarks. The genus Reviya Sohn, 1961 is known in the Late Mississippian (Early Carboniferous). The Early Triassic occurrence of Reviya curukensis n. sp. extends the stratigraphic range of the genus from the Late Mississippian up to the Early Triassic. Another Reviya species is present in the Late Permian of the Çırükdağ section (Crasquin-Soleau et al., in press).

Fig. A1. Height–length diagram of Reviya curukensis Crasquin-Soleau n. sp.

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