

***Norestheria* (Spinicaudata, Crustacea): Morphology and its stratigraphical and geographic significance**

Gerd Geyer and Jürgen Sell

ABSTRACT

A new species of the genus *Norestheria*, *N. franconica* n. sp., is recorded from the Hassberge Formation of the southern part of the Central European Basin. *Norestheria franconica* shows the characteristic morphology of the genus as exemplified by *N. barnaschi*, the type species of *Norestheria*. It predates the type species from the lower Norian, which has suggested as an important index fossil of the lower Norian of the Central European Basin, thus extending the stratigraphical and palaeogeographic range of the genus. It also sheds light on the phylogenetic lineages of mid- to late Triassic spinicaudatans.

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INTRODUCTION

Spinicaudatan “conchostracans” or clam shrimps are among the most valuable index fossils in the non-marine strata of the Triassic in the Central European Basin (earlier termed the “Germanic Basin”). A biostratigraphic framework for the otherwise barely subdividable Keuper beds of this basin has been attempted and established by a number

of publications by Heinz Kozur (e.g., Kozur and Mock, 1993; Kozur and Weems, 2007, 2010; Kozur et al., 2013). Not surprisingly, the pioneering work of Kozur required minor to moderate amendments in terms of adjusted ranges and taxonomic corrections of taxa.

The genus *Norestheria* was established by Kozur and Weems (2010) based on a single spe-

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cies, *N. barnaschi* Kozur and Weems, 2010, known from four specimens from the Morsleben 52A drill-core of eastern Niedersachsen, northern Germany. The specimens were found in strata of the Arnstadt Formation (sample 132 at depth m 162.9–163.0 m; =119.6 m above the base of the Arnstadt Formation), representing a late Alaunian (= middle Norian) age. Additional material of *Norestheria* was recorded by Kozur and Weems (2010) from drill-core Malschenberg 1 of northern Baden-Württemberg, southwestern Germany, at depth m 60.0 and m 60.1–60.2, respectively, which represents the middle part of the Löwenstein Formation (= basal Stubensandstein 3) and thus the late Alaunian as well. This form was dealt with as *Norestheria* n. sp. These Norian occurrences led Kozur and Weems (2010) to name the genus *Norestheria*.

Kozur and Weems (2010) used *Norestheria barnaschi* as an index fossil for the *Norestheria barnaschi*-*Shipingia macdonaldi* Zone, which was not only used as age indicator within the Central European Basin, but also for correlation of the relevant strata into the basins of the Newark Subgroup of eastern North America (e.g., the Sanford Basin, North Carolina, and the Gettysburg Basin, Maryland and Pennsylvania).

In this study, we report another species of the genus *Norestheria* occurring in the Coburg Sandstone Member of the Hassberge Formation of northern Franconia, southern Germany. These strata represent the Tuvallian of the upper/late Carnian and thus predate the Norian occurrences of the genus *Norestheria* (Figure 1).

STUDY AREA, GEOLOGICAL SETTING AND ADDITIONAL FOSSILS

The spinicaudatans described herein were collected from the Coburg Sandstone member of the Hassberge Formation in the classical quarry area in northern Franconia, Bavaria. The situation has been described before in a number of studies (e.g., Geyer and Kelber, 2018) and is only shortly characterised below.

The Coburg Sandstone (German: Coburger Sandstein) forms the upper part of the Hassberge Formation in the siliciclastic marginal belt of the Keuper Basin. The succession features coarse- to fine-grained alluvial siliciclastics which are derived from the Vindelician and Bohemian High in the southeast. They form tongues that interfinger basinward with playa deposits composed of clay- and siltstones with intercalated thin dolostone beds of the central part of the Central European Basin (Figure 2). After an initial channel was formed, its

filling by amalgamating, meandering channels led to sandstone beds of considerable thicknesses, accompanied by occasional slip-off slope and oxbow deposits (Hornung and Aigner, 2004).

Quarries in the Coburg Sandstone located in the Steigerwald and Hassberge regions expose successions of grey fluvial channel and sheet sandstone and intercalated varicoloured (light grey, greenish, yellow, and red) laminated lacustrine sedimentary rocks with small-scale cyclicity (Figure 3).

Freyberg (1965) developed a subdivision of the member into twelve stratal units, which permit a quasi-chronological outline. Each stratal unit can be subdivided into single beds. A dominating more-or-less stratiform succession with intercalated playa-type deposits is punctuated by five major sandstone bodies of channel deposits, which are considerably incised into older strata. For additional data see, e.g., Freyberg (1965), Geyer (2002) and Geyer and Kelber (2018).

Fluvial siliciclastics occasionally yield remains of tetrapods, tetrapod tracks, fishes, and macroplant remains. The spinicaudatan conchostracans (Geyer and Kelber, 2018) are embedded in floodplain and lacustrine silt- and mudstones. These also yield insects (e.g., Kelber and Nitsch, 2005; Prokin et al., 2013; Fedorenko, 2014), notostracans (Trusheim, 1938; Kelber, 1998a, 1998b, 2021; Kelber and Nitsch, 2005), macroplant remains, palynomorphs, and various ichnofossils.

The spinicaudatans are mostly found as quite well-preserved bivalved carapaces which allows recognition of a considerable amount of morphological details.

LOCALITIES

The spinicaudatans from the Coburg Sandstone member described herein have been collected from five quarries of the Ebelsbach-Eltmann quarry area ("Revier"; Freyberg 1965) between Schweinfurt and Bamberg, northern Bavaria, Germany (Figure 4).

1. Roßberg North Quarry/Ankenbrand Quarry (no. 5930-3; Figure 4). Quarry 800 m east of Passmühle in the Ebelsbach valley and ca. 1 km west of Breitbrunn; quarry of the Fränkische Schleifsteinwerke GmbH/Brünner/Bamberger Natursteinwerke Glaser, formerly known as Ankenbrand Quarry. Coordinates: 50° 00' 55" N, 10° 40' 55" E and R 44 05 670 H 55 44 210, respectively. Fossils: Spinicaudatans occur in densely

GLOBAL CHRONO-STRAT.			TIME	Spinicaudatan zones (Kozur and Weems 2010)	LITHOSTRATIGRAPHY			
					Regional units southern CEB	Formations marginal/basinal facies	Sub-group	
UPPER TRIASSIC	Rhaetian		201.5	<i>Euestheria brodieana</i>	Anoplophora-Sandstein	Exter Formation	Up. Keuper	
				<i>Gregoriusella polonica</i>				Nassacher Sandst.
			Norian	Sevatian	~ 206	<i>Shipingia olseni</i>	Feuerletten	Trossingen Formation
						Oberer Burgsandstein	Arnstadt Formation	
	Alaunian	<i>Shipingia hebaozhaiensis</i>						
		<i>Norestheria barnaschi-Shipingia mcdonaldii</i>						
	Lacian			Mittlerer Burgsandstein		Löwenstein Formation		
		<i>Euestheria buravasi</i>		Unterer Burgsandstein		Weser Formation		
		<i>Shipingia? weemsi</i>						
	Carnian	Tuvanian	~ 227		<i>Laxitextella freybergi-Shipingia? weemsi</i>			
				<i>Laxitextella freybergi</i>	Coburger Sandstein	Hassberge		
					Blasensandstein	Formation		
				<i>Laxitextella seegisi</i>	Lehrbergsschichten/ Rote Wand	Steigerwald Formation		
		<i>Eosoestheria gallegoi</i>						
		Julian/ Cordevolian	~ 237		Schilfsandstein	Stuttgart-Formation		
				<i>Laxitextella laxitexta</i>	Estheriensschichten	Grabfeld-Formation		
				<i>Laxitextella multireticulata</i>				
MID. TR.	Ladinian			Myophorienschichten Grundgipsschichten	Erfurt-Formation	L. Keup.		
			<i>Euestheria minuta</i>	Lower Keuper				

FIGURE 1. Triassic stratigraphy of the southern Central European Basin, with its lithostratigraphic subdivision of the Keuper beds, and stratigraphic distribution of spinicaudatan index species in the Keuper beds of the basin. Green colour indicates occurrence of *Norestheria franconica* n. sp. in the Coburg Sandstone Member, red colour that of *Norestheria barnaschi* in the Löwenstein Formation.

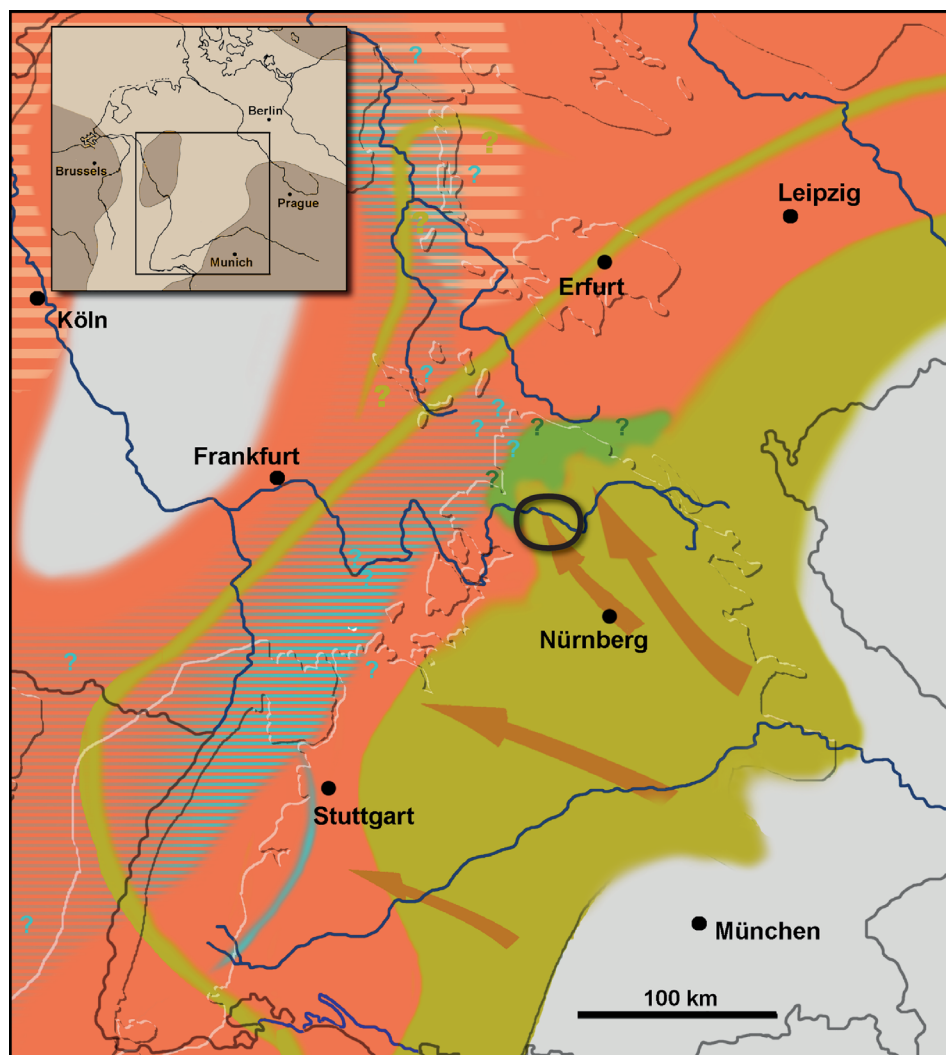


FIGURE 2. Palaeogeographic situation in the southern Germanic Basin (transferred to the present-day geographic situation) during the late Carnian and early Norian. A siliciclastic marginal facies belt (buff) was derived from detritus of the Vindelician High in the Southeast, with the Hassberge Formation characterised as the fluvially dominated mid to distal part of this belt, creating the comparatively well-washed tongues of the Coburg Sandstone member in northern Franconia. Funkenloch strata shown in green, Weser Formation with its typical playa facies in apricot. Study area marked by black ellipse. Modified from Nitsch (2005) and Geyer and Kelber (2018).

2. Roßberg South Quarry/Ankenbrand Quarry (no. 5930-6; Figure 4). Abandoned quarry 200 m ENE of Schönbachsmühle in the Ebelsbach valley and ca. 1 km west of Breitbrunn; quarry of the Fränkische Schleifsteinwerke GmbH, formerly known as Ankenbrand Quarry.
Coordinates: 50° 00' 40" N, 10° 40' 45" E and R 44 05 420 H 55 42 720, respectively.
3. Quarry near Schönbachsmühle (no. 5930-1; Figure 4). Abandoned quarry 300 m west of Schönbachsmühle in the Ebelsbach valley.
Coordinates: 50° 00' 40" N, 10° 40' 15" E and R 44 04 830 H 55 42 540, respectively.
4. Quarry An der Finkenleite near Hermannsberg (no. 5930-4; Figures 3A, 4). Quarry ca. 500 m SSW of Breitbrunn-Hermannsberg. Now abandoned and nearly completely filled.

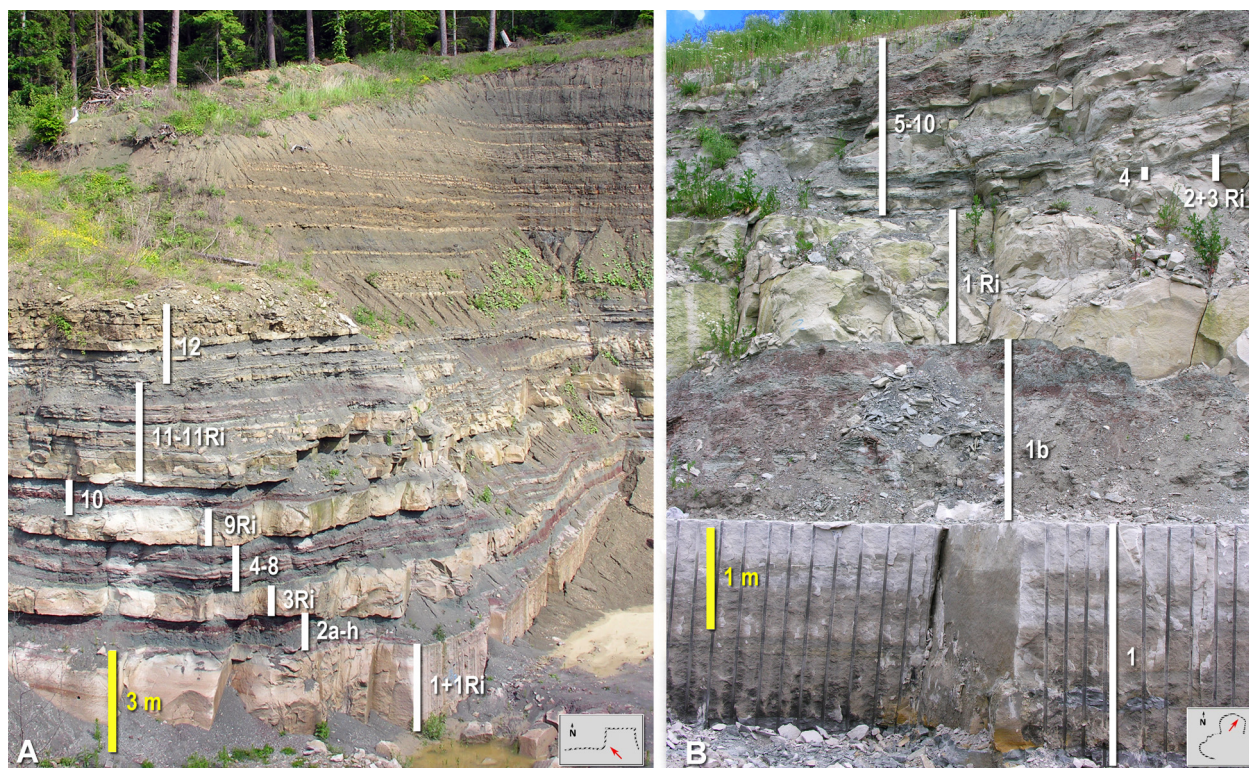


FIGURE 3. Coburg Sandstone member of the Hassberge Formation in the sample localities An der Finkenleite Quarry near Hermannsberg (A) and Hahn Quarry southeast of Eltmann (B). Numbers refer to the stratal units of Freyberg (1965). Inserts sketch plan view of the quarry with situation shown in the photo marked by arrow.

- Coordinates: 50° 00' 25" N, 10° 41' 50" E and R 44 06 720 H 55 41 970, respectively.
5. Hahn Quarry southeast of Eltmann (no. 6030-1; Figures 3B, 4). Quarry to the southeast of Eltmann, known as Hahn Quarry.
Coordinates: 49° 57' 35" N, 10° 40' 20" E and R 44 04 890 H 55 36 840, respectively.
Fossils: Spinicaudatans recovered from the basal 30 cm of blue grey claystone resting directly on the basal lower "Werkstein" level. Specimens occur with remains of macroplants, scattered insects, notostracans, and charcoal particles. For a detailed section of the quarry, see Blankmeister (1989).

SYSTEMATIC PALAEOONTOLOGY

Most of the material used for this study is in a repository of the collection Mainfränkische Trias Euerdorf (acronym SMTE) in the Museum Terra Triassica in Euerdorf. Additional specimens are in the collection of Klaus-Peter Kelber, Würzburg (acronym SKW).

The taxonomy adopted here follows that of Chen and Shen (1985), Martin and Davis (2001), Scholze and Schneider (2015) and Geyer and Kelber (2018), respectively.

Subphylum CRUSTACEA Brönnich, 1772
Class BRANCHIOPODA Latreille, 1817
Order SPINICAUDATA Linder, 1945
Suborder SPINICAUDATA Linder 1945
[nom. transl. Tasch, 1969,
ex "tribe Spinicaudata" Linder, 1945]
Superfamily EOSESTHERIOIDEA Zhang and
Chen in Zhang et al., 1976
[=Lioestherioidea Raymond, 1946 sensu Zhang et al., 1976]

Discussion. See discussion in Geyer and Kelber (2018).

"Family EUESTHERIIDAE Defretin-Lefranc, 1965"

Discussion. The family concepts of the Spinicaudata and particularly those within the Eosestherioidea are generally based on morphological features of the carapace, which are poorly understood in terms of evolutionary trends. Accordingly, no robust data exist that support the presently recognised families and their generic compositions (e.g., Hegna and Astrop, 2020). As an example for

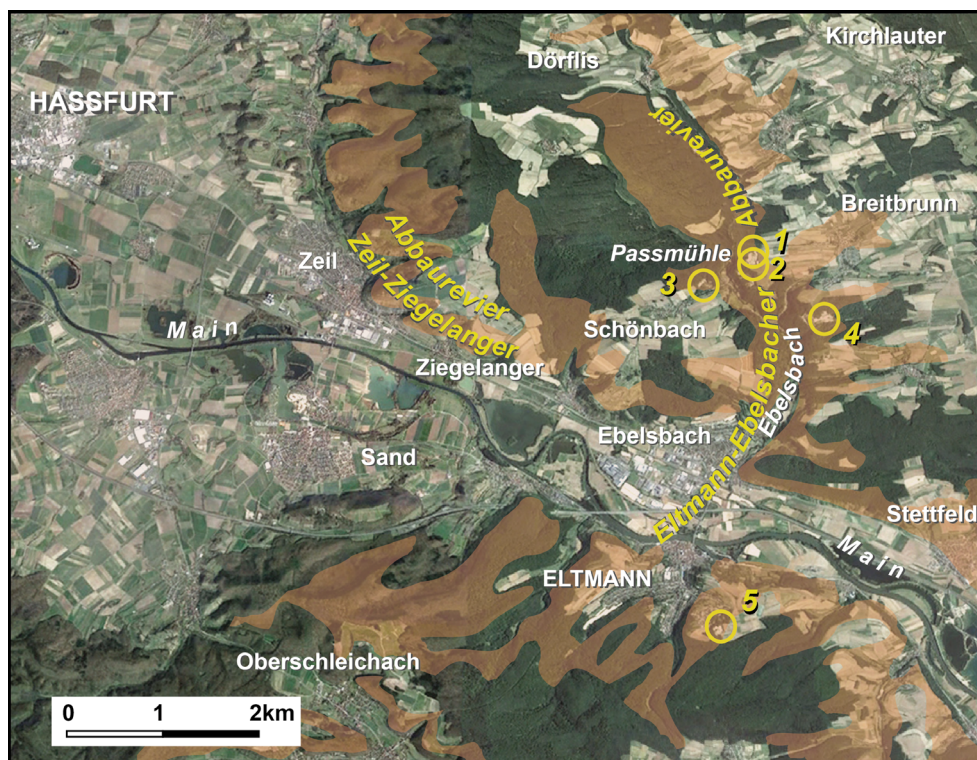


FIGURE 4. Sketch map showing the northwestern Steigerwald and southwestern Hassberge ranges with the major quarry areas of the Coburg Sandstone member of Zeil–Ziegelanger and Eltmann–Ebelsbach. Localities of the spinicaudatans described in this study: 1 Roßberg North Quarry/Ankenbrand Quarry; 2 Roßberg South Quarry/Ankenbrand Quarry; 3 Quarry near Schönbachsmühle; 4 Quarry An der Finkenleite near Hermannsberg; 5 Hahn Quarry southeast of Eltmann. Detailed information in the text.

the resulting confusion, the genus *Pseudestheria* has been alternately assigned to four families in the past 20 years: Euestheriidae, Lioestheriidae, Pseudestheriidae, and Orthothemosiidae. The first three families are poorly defined and tied to type genera which are dependant on type species that have never been adequately figured (e.g., Poschmann et al., 2024). In particular, the family Euestheriidae is presently ill-defined (see, e.g., Fang and Liao, 2024; Poschmann et al., 2024). Part of the confusion arises from quite obvious differences in the specimens identified as *Euestheria minuta* (Alberti in Zieten, 1833), the type species of *Euestheria* Depéret and Mazeran (1912) exemplified their generic concept based on material identified as *E. minuta* from the Permian of Autun, France, which differs considerably from the specimens from the Lower Keuper beds of southern Germany, on which the species has been based. This brought Defretin-Lefranc (1965) to distinguish three groups with different surface ornaments (termed “structure lisse ou ponctuée”, “structure réticulée”, and “réticule-radiée et structure radiée”). Consequently, the species from the Permian of

Autun represents a different genus than the species from the Lower Keuper beds of southern Germany. They could perhaps be assigned to *Lioestheria* Depéret and Mazeran, 1912 or may represent a different, not yet established genus (see also Sell, 2018).

Here, we assume that most of the spinicaudatans known from the Carnian through Norian beds of the Central European Basin and also of the Newark Subbasin reflect intricate morphological developments of a single clade, although this, in turn, does not suggest a geographical argument for the evolution of the group. We refer this clade provisionally to the family “Euestheriidae” although more data of analyses of morphological characters of the carapace as well as knowledge on soft-part anatomy would be needed to establish robust taxonomic units.

The genus *Norestheria* Kozur and Weems, 2010 has been placed under the family Shipingiiidae Kozur and Weems, 2005 by Kozur and Weems (2010), but lacks the typical oval to elliptic, cycladiform shape of the carapace with a nearly

straight dorsal margin, and an umbo in anterior, marginal or nearly marginal position.

Genus *Norestheria* Kozur and Weems, 2010

Type species. *Norestheria barnaschi* Kozur and Weems, 2010, by original designation; from the Arnstadt and Löwenstein formations, Alaunian, middle Norian, of the Central European Basin.

Diagnosis (emended herein). Genus of the Euestheriidae with dorsal margin straight to slightly convex, fairly short, grading into the anterior margin and a mostly indistinct posterodorsal corner; anterior margin more extended than posterior margin, in lower part with a long oblique region that changes its curvatures from barely curved in the lower and a slight curvature in its upper part; ventral margin poorly bent along its anterior and middle course, slightly convex in its posterior part, with an abrupt change in curvature creating a nearly angular course from the ventral to the anterior margin; transition from the ventral to the posterior margin along a gradual curvature. Growth bands variable, straight to nearly straight in the ventral and anteroventral sectors, but often more tilted and obliquely oriented in the lower part of the anterior quarter; microsculpture a dense reticulate pattern, partly accompanied by radial fringes and lirae.

Discussion. Kozur and Weems (2010, p. 403) presented a comprehensive diagnosis for the genus, which has the character of a description and does not pinpoint the quasi-apomorphic characters. The main feature that allows to recognize *Norestheria barnaschi* is the presence of a nearly arcuate course of the margin from the ventral to the anterior sector. The same feature can be seen in *Norestheria franconica* n. sp. as well as in the informal species *Norestheria* n. sp. suggested by Kozur and Weems (2010).

Another significant character claimed for *Norestheria barnaschi* is the rapid change in the direction of the growth bands from the anterior quarter to the rest of the shell exterior. The authors emphasize that this change of the tilting is seen in *Norestheria* n. sp. as well. However, Kozur and Weems (2010) admitted that this feature may be enhanced by deformation. Indeed, some of the specimens of *N. franconica* partly present this change in inclination of the growth ridges (e.g., SMTE 5930-4-576), whereas it seems not to be developed in others (e.g., SMTE 5930-1-198) so that we tend to assume that the major expression of this feature must be ascribed to a (resulting) dorsoventral compaction (or rather compression) of the valves which happens to occur in the Keuper beds during early

diagenetic effects oblique to the general bedding planes.

Among the similar and certainly closely related genera is *Laxitextella* Kozur, 1982, which has a similar microsculpture, but this ornamentation does not become larger in the anterior sector of the valves. Furthermore, *Laxitextella* is distinguished by its “normal” ovoidal outline of the valves and has a stronger curvature in the umbonal area.

Euestheria Depéret and Mazeran, 1912 had developed into a waste bin for Triassic clam shrimps but underwent a number of considerable shifts in taxonomy and nomenclature during the last decades (see discussion above and also in Geyer and Kelber, 1998). Nonetheless, generic concepts still differ, and imperfect preservation of several critical species led to persisting confusion. Species such as “*Euestheria*” *kozuri* Geyer and Kelber, 1998 (from the Coburg Sandstone member of the Hassberge Formation) and two unnamed forms from the same stratigraphic interval appear to represent transitional forms that bracket the gap between the early representatives of “*Euestheria*” (such as *E. minuta* Alberti in Zieten, 1833; but see discussion above) and *Laxitextella*. In developing a small-scale reticulate ornament between the growth lines but retain a more protruding umbo and lack the angulation seen at the valve margin of *Norestheria*.

The relatively conspicuous change in curvature of the margin and the corresponding growth ridges creating a nearly angular course from the ventral to the anterior margin is quite unique in Triassic spinicaudatans from the northern hemisphere. However, the family Ulugkemiidae includes other clam-shrimps from the Devonian through Permian of the Pre-Baltic and Pre-Uralian region of Russia and the Triassic of Argentina with abrupt changes in the curvature of growth-bands, such as *Beligum* Novozhilov, 1958, *Ulugkemia* Novozhilov, 1958, and *Triasulugkemia* Gallego and Melchor, 2000. However, those genera show only anteroventral and posteroventral indentations or solely an anteroventral indentation depicted by the growth ridges in nearly regularly ovate carapaces – quite different in character from the course of the carapace margin in *Norestheria*.

Norestheria franconica n. sp.

Figures 5–7

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v. *Euestheria*? sp. nov. A; Geyer and Kelber, 2018, p. 13–15, fig. 8A, C.

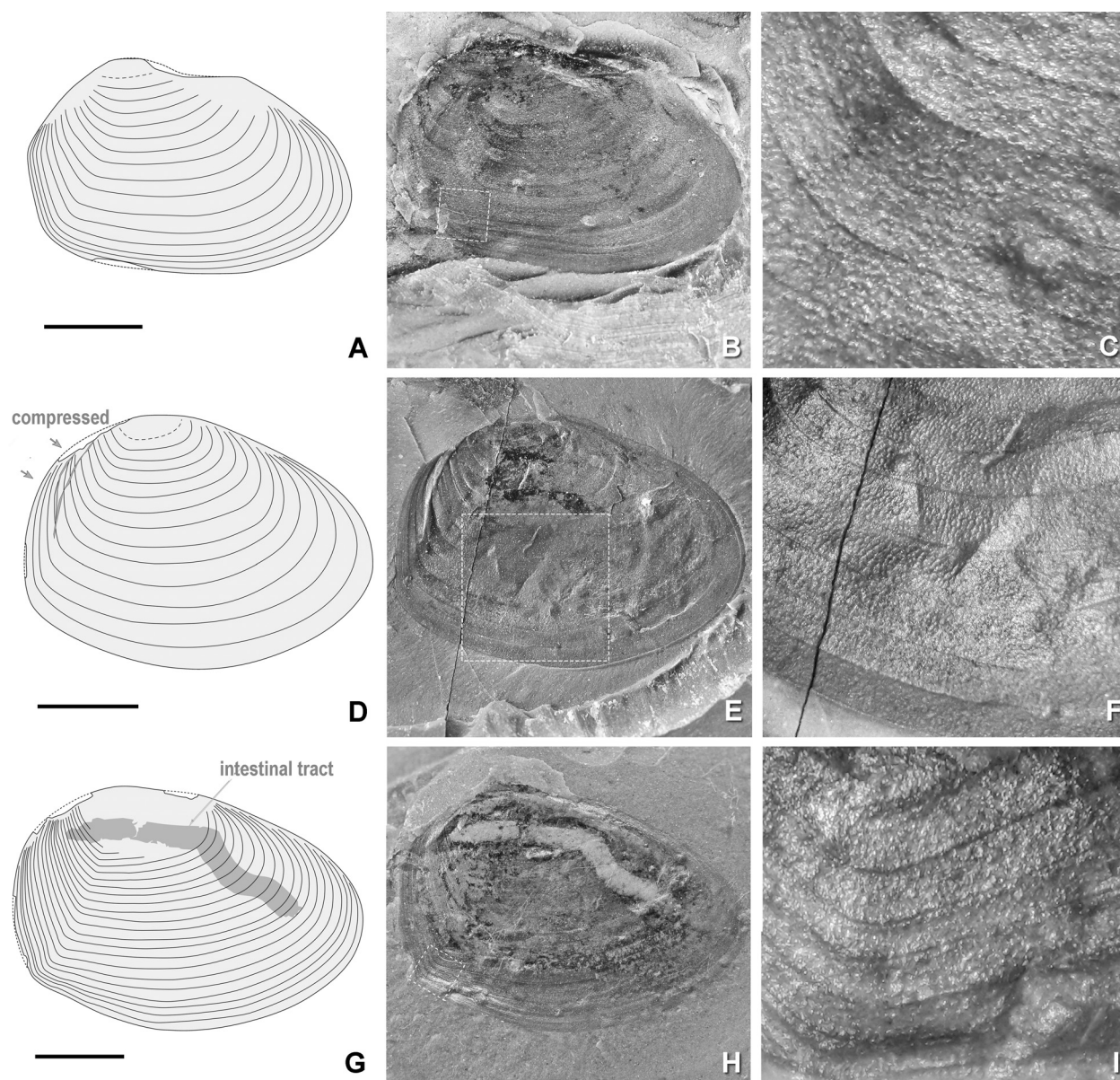


FIGURE 5. *Norestheria franconica* n. sp. **A–C** SMTE 6030-1-254, paratype, sketch (A), view of entire specimen (B) and magnified view illustrating morphology of growth lines and surface ornament of growth bands (C); **D–F** SMTE 6030-1-390, paratype, sketch (D), view of entire specimen (E) and magnified view illustrating morphology of growth lines and surface ornament of growth bands (F); **G–I** SMTE 6030-1-626, paratype, sketch (G), view of entire specimen (H) and magnified view illustrating morphology of growth lines and surface ornament of growth bands (I). All specimens from Hahn quarry near Eltmann, stratal unit 5 of the Coburg Sandstone member, Hassberge Formation (see Figure 2B). All scale bars (in A, D, G) 1 mm.

Etymology. A reference to the geographic occurrence of the species in the Franconian region, southern Germany.

Holotype. Specimen SKW ELT-C-12a, carapace composed of two slightly rotated valves, described and figured as *Euestheria*? sp. nov. A in Geyer and Kelber (2018, fig. 8A, 8C).

Type locality. Hahn Quarry, SE of Eltmann, Franconia.

Type stratum. Coburg Sandstone member, Hassberge Formation; *Laxitextella freybergi* Zone, late Tuvalian, upper/late Carnian.

Paratypes. 48 specimens, all from Coburg Sandstone member of the Hassberge Formation; 5 specimens from Roßberg North Quarry (SMTE

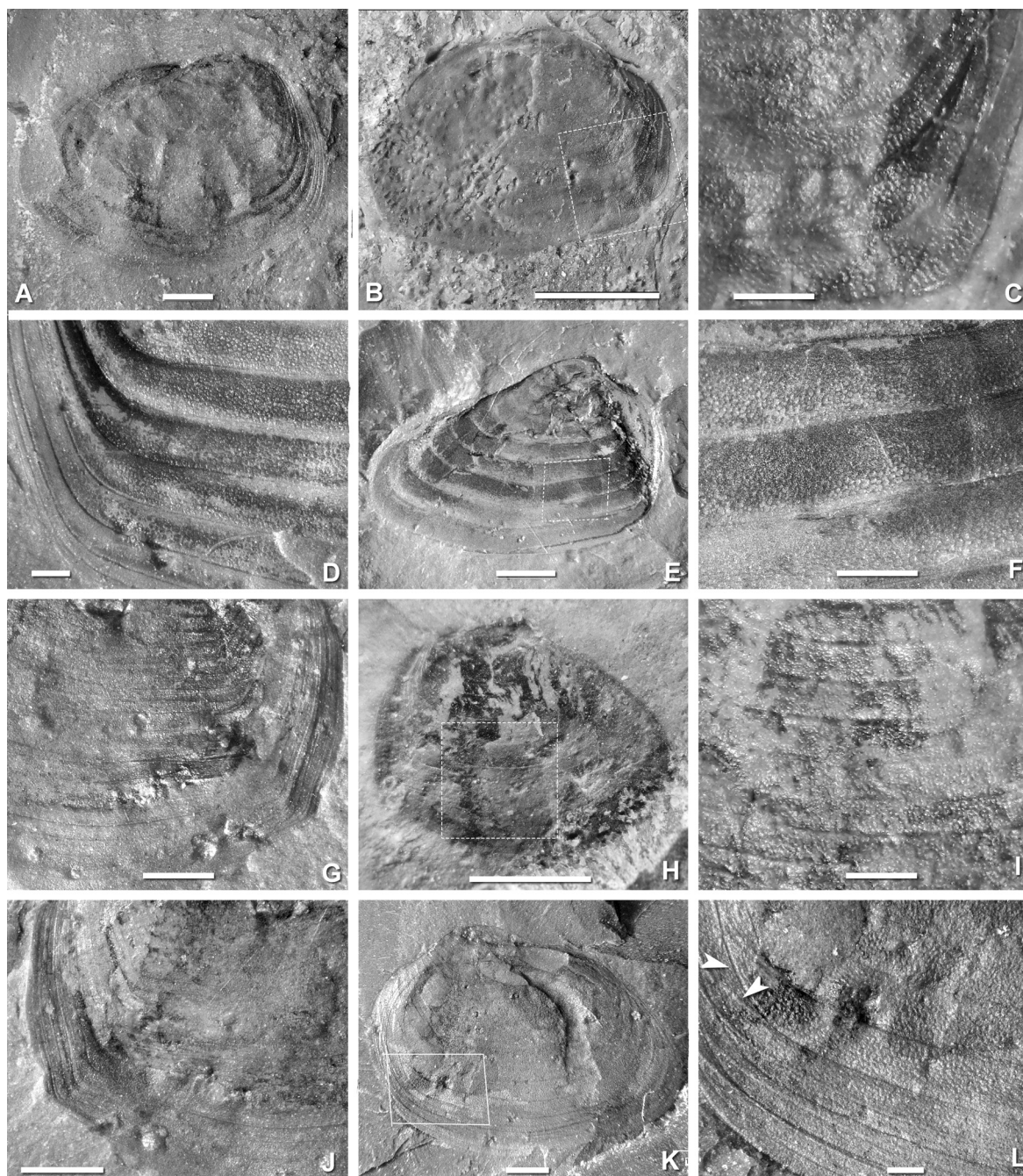


FIGURE 6. *Norestheria franconica* n. sp. **A** SMTE 5930-1-198, paratype, carapace with differential plastic deformation caused by compaction. **B, C** SMTE 5930-4-577a, paratype, entire specimen, partly exfoliated and with impressions of quartz grains (**B**) and magnified view of anteroventral corner illustrating rapid bend of margin and reticulate ornament of growth bands (**C**); **D** SMTE 5930-4-576, paratype, detail of anteroventral margin and ornament of growth bands; **E, F** SMTE 5930-4-673, paratype, slightly compressed carapace, view of entire specimen (**E**) and magnified view of growth bands with reticulate ornament (**F**); **G** SMTE 6030-1-626a, paratype, detail of anteroventral margin; **H, I** SMTE 6030-1-500, paratype, entire specimen (**H**) and magnified view of growth bands (**I**); **J** SMTE 6030-1-626a, paratype, detail of anteroventral margin; **K, L** SMTE 6030-1-4961a, paratype, bivalved specimen, view of entire specimen (**K**) and detail of anterolateral parts with growth lines of left and right valves impressed onto the visible surface (arrows; **L**). Specimens with prefix 6030-1- from Hahn quarry near Eltmann, stratal unit 5 of the Coburg Sandstone member, Hassberge Formation, specimens with prefix 5930-1- from quarry near Schönbachsmühle, stratal unit 10, specimens with prefix 5930-4 from Finkenleite quarry near Breitbrunn-Hermannsberg, stratal unit 2. Scale bars equal 1 mm in **A, B, E, F, H, J** and **L**, 500 μ m in **C, G, I**, and **L**, 250 μ m in **D**.

5930-3-8, -39, -45, -64a, -121), all from stratal unit 2; 6 specimens from quarry near Schönbachsmühle (SMTE 5930-1-197, -198a, -199Ia/-199IIa, -199Ib, -200, -201), all from stratal unit 10; single specimen from Roßberg South Quarry (SMTE 5930-6-40); 14 specimens from Finkenleite quarry near Hermannsberg (SMTE 5930-4-576a, -576b, -577a, -577b, -582a, -582b, -582c, -585, -588I, -589a, -599a, -599b, -673a, -673b), all from stratal unit 2; 41 specimens from Hahn quarry near Eltmann (SMTE 6030-1-120Ia/-120IIa, -120Ib/-120IIb, -120Ic/-120IIc, -210Ia/-210IIa, -218I/-218II, -254a, -254b, -255a, -255b, -255c, -283, -390a, -390b, -496Ia/-496IIa, -496Ib, -496Ic, -496Id, -500a, -500b, -512a, -517a, -517b, -517c, -517d, -528, -531, -544, -547, -623, -625, -626a, -626b, -626*, -628, -638a, -638b, -640I/-640II, -641, -657, -659a, -659b), all from stratal unit 5. Tentatively assigned to *N. franconica*: SKW ELT-C-12b (from the same slab as the holotype).

Diagnosis. Species of *Norestheria* with moderately large carapace (ca. 2 to 3 mm long in adult individuals); umbonal area small; dorsal margin with subangular posterodorsal edge; anterior margin with slightly curved upper section, lower section almost straight, obliquely directed; growth bands up to ca. 25, directed steeply oblique to axis in the anterior sector.

Description. Carapace moderately large, length up to 8 mm and height up to 5.5 mm, slightly convex. Umbonal area distinct, relatively small, marginal to slightly supramarginal, located submedially. Dorsal margin very short to short, straight to faintly, length 45 to 55% maximum length of carapace; posterodorsal corner blunt and indistinct. Posterior margin clearly less high than anterior margin, its middle section strongly curved, posterodorsal section straight to slightly curved, lower part gently bent (e.g., Figure 5B, E, H). Anterior margin consists of distinctly curved upper section, anteroventral section poorly curved and directed distinctly oblique, with steeply inclined ventralward; anterior and ventral margins connected at a blunt corner, which becomes increasingly more strongly curved during ontogeny and thus develops into a distinct semi-angular transition from the ventral to the anterior margin (e.g., Figure 6C, D, G, J). Ventral margin with moderate curvature; its anterior and middle section slightly curved, posterior sector more strongly curvilinear. Growth bands distinct, variable in number (from ca. 10 to 25); with sharp face towards margin of the carapace, subevenly developed throughout most of the valve, but growth bands more steeply inclined in

the anterior quarter of the valve; growth lines thin, moderately prominent, smooth strips, confined on both sides by a sharp, shallow groove (Figure 6D). Microsculpture consists of reticulate pattern (e.g., Figure 6C, F, L), with meshes of ca. 5 µm on the growth bands of the juvenile part of the valves, maximum size ca. 25 to 30 or 35 µm on growth bands of the adult part of the valves (depending on their relative position on the valves).

The growth lines are thin smooth strips, which can be seen in well preserved specimens to be confined on both sides by a sharp, shallow groove. The microsculpture between the growth lines consists of a dense reticulate network that is often quite irregularly developed and accompanied by radial fringes and lirae in some areas of the valves and in a considerable number of specimens. Dorsoventral compression (see under genus) certainly intensified these lirae.

Remarks. *Norestheria barnaschi* Kozur and Weems, 2010 has a microsculpture that consists of a dense and delicate network of radial lirae. The size of the meshes changes rapidly at approximately one-quarter of the valve length into larger elements. Kozur and Weems (2010, fig. A5,5 and A5,6) figured a second, informal new species of *Norestheria* from the Löwenstein Formation, which has a microsculpture that consists only of dense and fine meshes which also changes abruptly into a coarse reticulate pattern at the turning line of curvature of the growth lines. The microsculpture in *N. franconica* consists of a reticulate pattern that does not change the widths of the meshes into anterior direction.

Modern spinicaudatans have been reported to show three reproductive strategies, i.e. dioecy, hermaphroditism and parthenogenesis (e.g., Weeks et al., 2007, 2008; Brantner et al., 2013). Female spinicaudatan individuals may carry up to several hundreds of resting eggs, or cysts, in a subumbilical area between the back and the carapace. These cysts are quite resistant against drought and other factors as in all branchiopods, and the embryos remain able to hatch after many years even under extreme conditions (such as long dry periods, extreme heat or strong frost). Some specimens from the Hahn quarry and also from the quarry near Schönbachsmühle were preserved with clusters of densely packed cysts located in the dorsal part of the carapace (Figure 7).

All cysts were found inside the carapace (Figure 7). This suggests that they were still attached to the body during the moment of embedding. The cysts are now mostly flattened and preserved quite

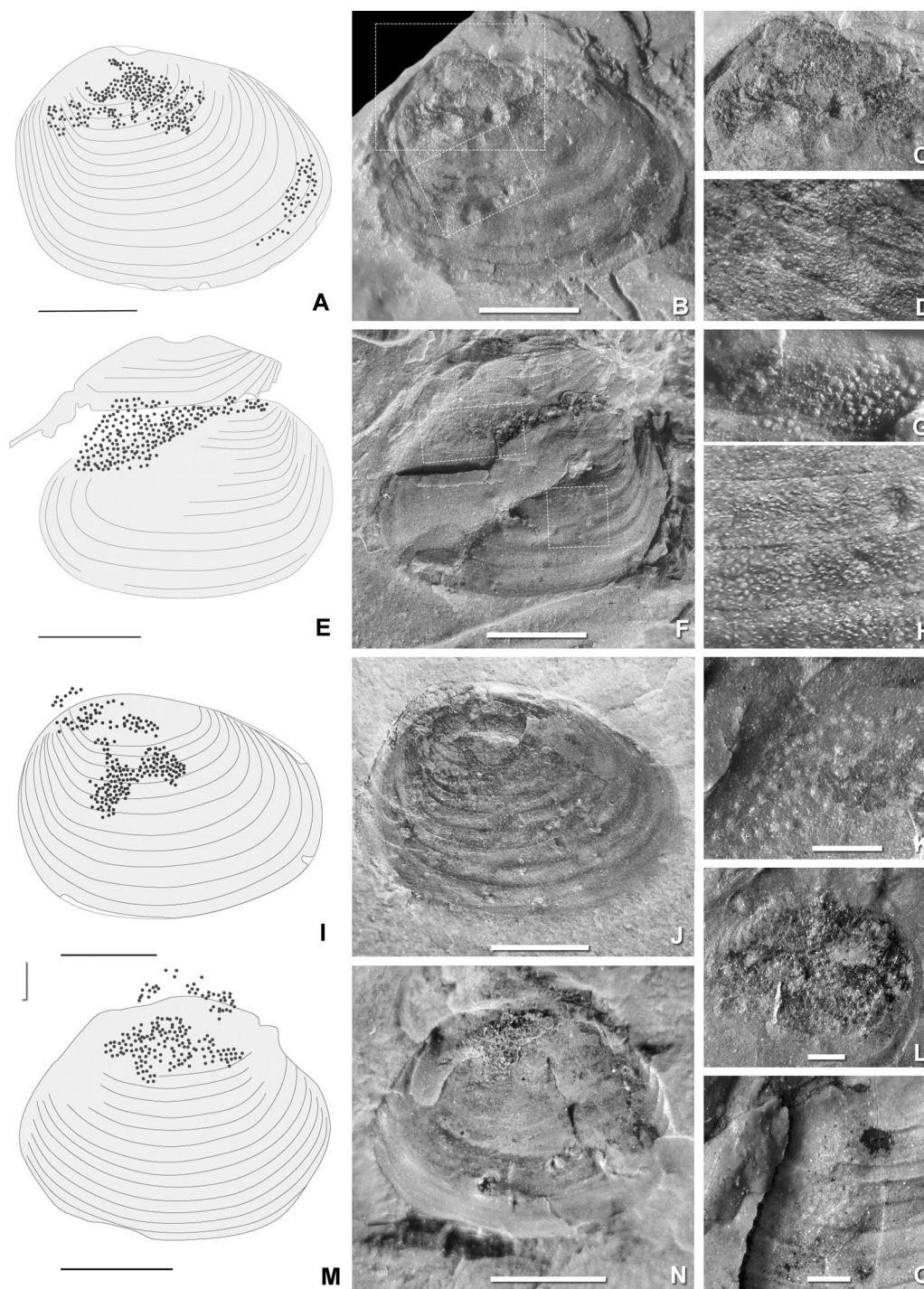


FIGURE 7. *Norestheria franconica* n. sp., specimens with clusters of resting eggs. **A–D** SMTE 6030-1-623, paratype, sketch with indication of cyst cluster positions (A), view of entire specimen (B) and magnified views of umbonal region with cysts (C) and growth bands (D); **E–H** SMTE 6030-1-255, paratype, sketch with indication of cyst cluster (E), view of entire specimen (F) and magnified views of cyst accumulation (G) and growth bands with reticulate ornament (H); **I, J** SMTE 6030-1-218, paratype, sketch with indication of cyst cluster (I), view of entire specimen (J); **K** SMTE 6030-1-255, paratype, detail showing cysts; **L** SMTE 6030-1-625, paratype, cyst cluster below umbonal region; **M, N** SMTE 6030-1-210, paratype, sketch with indication of cyst positions (M), view of entire specimen (N); **O** SMTE 5930-1-199IIb, paratype, detail of exfoliate carapace showing accumulation of resting eggs. All specimens with prefix 6030-1- from Hahn quarry near Eltmann, stratal unit 5 of the Coburg Sandstone member, Hassberge Formation, specimens in O from quarry near Schönbachsmühle. Scale bars equal 1 mm in A, B, E, F, I, J, M and N, 500 µm in K, L, O.

dimly. Their surfaces were affected by structures of the carapace and are thus further deformed. However, they appear relatively globular and with a smooth surface and carbon staining. Some of the cysts with a preservation that appear to reliably reflect the original size and morphology have been measured and are approximately 100 µm in diameter (thus of similar size as documented for other clam shrimps by Poschmann et al., 2024). The number of cysts on the samples varies between 190 und 290.

A superficially similar phenomenon can be seen in specimen SMTE 5930-4-577a (Figure 6B). However, the apparent egg-bearing area in this specimen results from the insertion of quartz grains. These have diameters in the range of approximately 150 to 200 µm.

Norestheria franconica is found in two different forms, which clearly suggests the presence, or absence of a brood chamber. This dimorphism led to a size of the carapace which is distinctly higher at the female specimens (height/length ratio 0.72 to 0.77) than at male specimens (height/length ratio 0.64 to 0.68) (Table 1).

STRATIGRAPHIC SIGNIFICANCE AND CONCLUSIONS

As mentioned above, Kozur and Weems (2010) used *Norestheria barnaschi* as an index

fossil for their *Norestheria barnaschi*-*Shipingia mcdonaldi* Zone, introduced as a distinct biozone for the Alaunian, middle Norian, replacing the lower part of the *Shipingia hebaozaiensis* Zone of Kozur and Weems (2007). That zone is based on the (locally!) common occurrence of *Norestheria barnaschi* and *Shipingia mcdonaldi*, with *Euestheria* sp. being the only other spinicaudatan known from that zone. Kozur and Weems (2010) referred to the Malschenberg 1 borehole (Etzold and Franz, 2005) as the “type locality” for the zone.

The occurrences of *Norestheria barnaschi* in the Morsleben 52A and in the Malschenberg 1 drill-cores ties the basinal playa facies of the Central European Basin (= Arnstadt Formation) with its marginal arenitic facies (Löwenstein Formation). *Shipingia mcdonaldi* was identified from occurrences without *Norestheria* in an intermediate facies belt (“Steinmergelkeuper”) of Thuringia, central Germany, from the Wachsenburg Sandstone (= middle Arnstadt Formation).

Shipingia mcdonaldi Kozur and Weems, 2010 was originally determined as being early representatives of *Shipingia hebaozaiensis* Shen, 1976. Kozur and Weems (2010) reinterpreted these specimens as representing a different species. The type material comes from the Heidlersberg Member of the Gettysburg Formation of the Newark Subgroup, but the species was also identified from

TABLE 1. Dimensions shown in measurement of specimens of *Norestheria franconica* n. sp. Collection numbers in the left column refer to the collection of the Museum Terra Triassica (SMTE). Abbreviations: L, total valve length in millimetres; H, total height of valve in millimetres; H/L, ratio height/length; I, length of dorsal margin; I/L, ratio length of dorsal margin vs. total length; GL, number of growth lines; AMmax/H, ratio of anterior margin height vs. total height of valve; PMmax/H, ratio of posterior margin height vs. total height of valve; VMmax/L, ratio of ventral ventral margin vs. maximum valve length.

	L	H	H/L	I	I/L	GL	AMmax/H	PMmax/H	VMmax/L
5930-1-198a	6.72	4.92	0.73	3.11	0.46	>18	0.48	0.51	0.50
5930-4-673a	5.17	3.3	0.64	—	—	>11	0.45	0.57	0.48
6030-1-218l	6.26	4.58	0.73	3.14	0.50	>12	0.47	0.55	0.50
6030-1-254a	6.65	4.4	0.66	3.0	0.45	>17	0.43	0.63	0.53
6030-1-255a	5.3								
6030-1-390a	6.9	5.0	0.72	3.25	0.47	>15	0.47	0.59	0.50
6030-1-500a	5.0	3.75	0.75			>25			
6030-1-512a	6.25	—	—	—	—				
6030-1-517a	4.,6	3.1	0.68			>10			
6030-1-547	8.0	5.25	0.66			>23			
6030-1-623	6.29	4.86	0.77	3.35	0.53	>15	0.42	0.56	0.50
6030-1-625	6.5	4.0	0.73			>11			
6030-1-626	8.0	5.4	0.68	3.98	0.49	>24	0.46	0.56	0.49

the Wachsenburg Sandstone (Arnstadt Formation) and the Stubensandstein 3 (Löwenstein Formation) of the southern Central European Basin. This enabled Kozur and Weems (2010) to identify the *Norestheria barnaschi-Shippingia mcdonaldi* Zone not within the Central European Basin but also in the Newark Subgroup of eastern the United States, i.e. from the Heidlersburg Member of the Gettysburg Formation of the Gettysburg Basin, Pennsylvania, and from the Sanford Formation of the Sanford Subbasin, Deep River Basin, North Carolina.

This study features another, closely related species of *Norestheria*, *N. franconica* n. sp., from the Tualian of the upper/late Carnian of the southern part of the Central European Basin. These strata clearly belong to the *Laxitextella freybergi* Zone as described and discussed in some in detail

by Geyer and Kelber (2018). These separated occurrences again undermine a more or less tacit supposition that most of the Carnian through Rhaetian “conchostracan” zones reflect phylogenetic developments within the spinicaudatans. As in the case of the genera *Laxitextella* and *Shippingia*, stratigraphic occurrences do not fit with the assumed ancestor-descendant relationships. More material will be needed to settle the momentarily largely accepted, but possibly overaccurate biozonation for the Central European Basin.

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