

Badenian (middle Miocene) decapod crustaceans from western Ukraine, with remarks on eco-taphonomy, palaeoecology and biogeography

MARCIN GÓRKA

*Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, PL-02-089 Warszawa, Poland.
E-mail: magurka@uw.edu.pl*

ABSTRACT:

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The decapod fauna from the Badenian (middle Miocene) deposits of western Ukraine comprises in total 31 taxa: 20 species, 9 taxa left in open nomenclature, and 2 determined at family level. Thirteen of these taxa are reported for the first time from the territory of Ukraine. Among them are the first records of *Trapezia glaessneri* Müller, 1976 in the Fore-Carpathian Basin and *Pachycheles* sp. in Paratethys. One taxon (*Petrolisthes* sp. A) probably represents a new species. The occurrence of this significant decapod fauna is restricted almost exclusively to the Upper Badenian (i.e., early Serravallian) coralgall reefs of the Ternopil Beds. The taxonomic composition of the decapods indicates that the Late Badenian depositional environment was a shallow marine basin dominated by reefs that developed in warm-to-tropical waters of oceanic salinity. The decapod assemblage from the Ternopil Beds is similar in its taxonomic composition to numerous decapod faunules from fossil reefs of Eocene to Miocene age from the Mediterranean realm and of Miocene age from Paratethys. In contrast, decapod remains are very scarce in Badenian siliciclastic deposits (Mikolaiv Beds) and are represented by the most resistant skeletal elements, i.e., dactyli and fixed fingers. This scarcity was caused by the high-energy environment, with frequent episodes of redeposition, which disintegrated and abraded the decapod remains.

Key words: Crustaceans; Decapods; Taxonomy; Paleoenvironment; Eco-taphonomy; Badenian (middle Miocene); Ukraine.

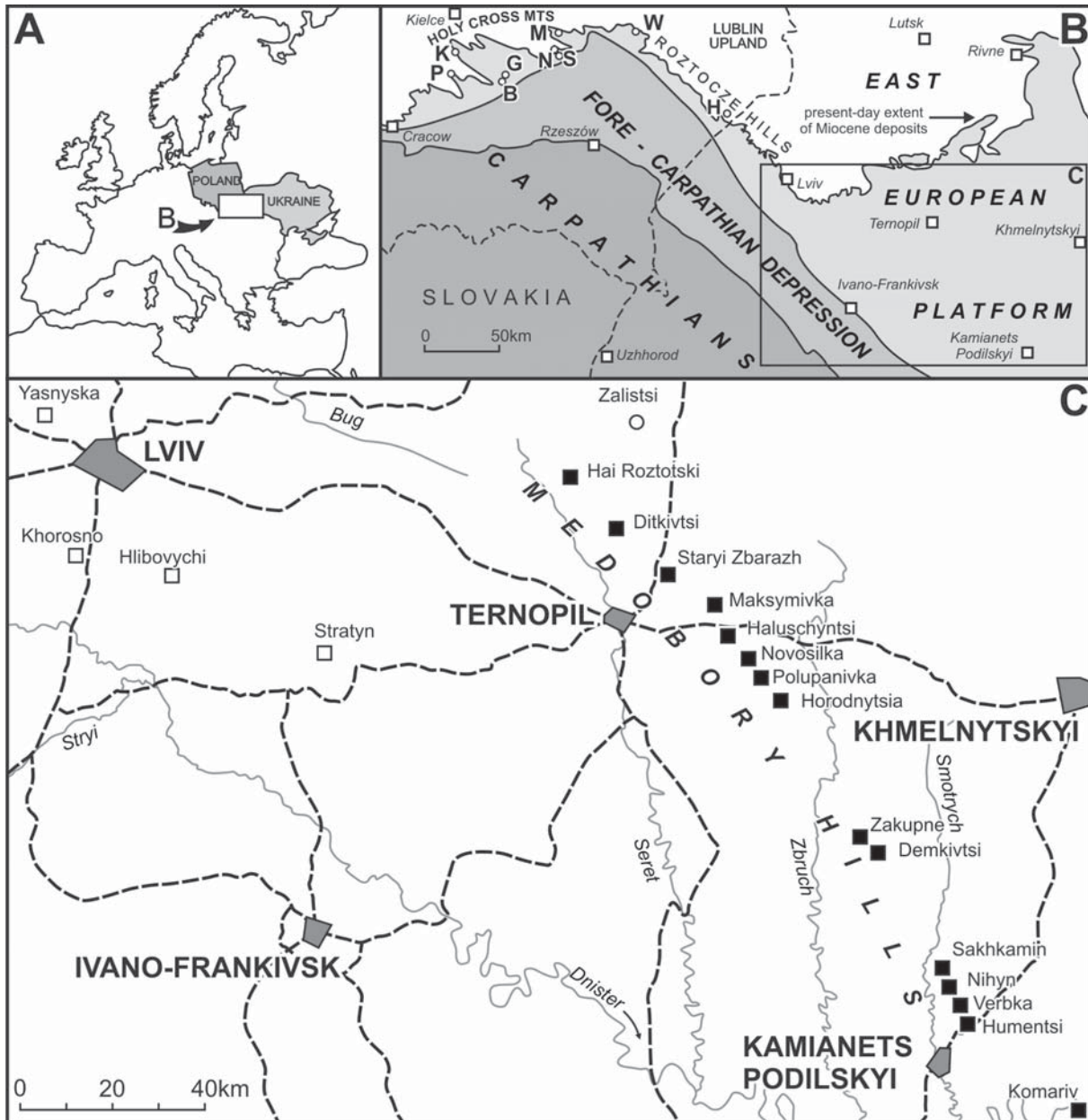
PREFACE

During the years, my interest in the Miocene of the Fore-Carpathian Basin was supported by the most valuable attentiveness of the late Professor Andrzej Radwański. Our long-lasting discussions on various subjects were permanent elements of my geological education. That was during my M.Sc. and Ph.D. studies when Professor Radwański was my scientific supervisor but also after that time when we spent plenty of time engaged in collaborative fieldwork in western Ukraine. The material presented herein

was in a large part collected together with Professor Radwański during these excursions.

INTRODUCTION

Until the beginning of the 21st century the knowledge and state of recognition of Badenian crustaceans from western Ukraine were very limited. In contrast to the adjacent areas of Poland (Förster 1979a, b; Müller 1996) and Moldova (Yanakevich 1969, 1977) there has been no paper devoted specifically to the



Text-fig. 1. Location of the studied Badenian decapod-bearing deposits of western Ukraine: A – Location within Europe, at the Poland/Ukraine border; B – Close-up, to show the present extent of the Miocene deposits and their relationship to the most prominent geological structures; C – Close-up, to show the location of the decapod-bearing sites of Mykolaiv Beds (white rectangles), Ternopil Beds (black rectangles), and Pidhirtsi Beds (white circle). After Radwański *et al.* (2014), modified

Badenian decapods of western Ukraine. Scarce notes and/or remarks on fossil crustaceans are present in numerous publications, but they are of a very generalised character (Hilber 1882; Teisseyre 1895; Davidashvili 1937; Korolyuk 1952; Kudrin 1966).

The first papers focusing (at least partly) on the Badenian decapods of western Ukraine appeared in the mid 2000's (Jasionowski *et al.* 2005; Górka and

Jasionowski 2006; Radwański *et al.* 2006) and soon after they were followed by a more detailed description of the decapod assemblage from Maksymivka quarry (Ossó and Stalennuy 2011). Since then some minor remarks on the discussed decapods have appeared (Górka *et al.* 2012; Górka in Wysocka *et al.* 2016). The aim of the present paper is to summarise the present position as regards the recognition of

Badenian decapods from western Ukraine, including their systematic position and geographical distribution, with additional palaeoecological and eco-taphonomical conclusions.

AGE AND COMPOSITION OF THE DECAPOD-BEARING LITHOFACIES

There are two main, widely distributed lithofacies in the Badenian of western Ukraine that yield crustacean remains. The older lithofacies which is represented by quartz sands often with a significant glauconitic admixture, formally known as the Mykolaiv Beds (also referred to as Mykolaiv Sands; see Radwański *et al.* 2012; Wysocka *et al.* 2012) is of Lower Badenian age (i.e., Langhian Stage in the standard stratigraphic zonation) and its numerous outcrops are located in a large area ranging from the environs of Lviv towards the south-east to Berezhany (Radwański and Wysocka 2001; Wysocka 2002; Wysocka *et al.* 2012). The large number of outcrops has allowed field workers to obtain a widely diversified faunal assemblage from these strata which indicates a tropical and/or subtropical palaeoclimate during deposition. However, decapod remains in these beds are represented very subordinately. Scarce remains were collected in only 4 outcrops: Yasnyska, Stratyn, Khorosno and Hlibovychi (the latter site previously referred to as Gleboviti: e.g., Wysocka 2002; Wysocka *et al.* 2012; Radwański *et al.* 2014).

In contrast, the younger, Upper Badenian deposits of a biohermal variant of the Ternopil Beds (also known as the Medobory Biohermal Complex; Radwański *et al.* 2011) have yielded an abundant and highly diversified decapod fauna (see Górka and Jasionowski 2006; Radwański *et al.* 2006; Ossó and Stalennuy 2011; Górka in Wysocka *et al.* 2016; Ossó 2018). Note that these deposits, equivalent in age to the lower Serravallian Stage, were previously considered as belonging to the Lower Badenian, see Radwański *et al.* (2006). This biohermal lithofacies outcrops in the Medobory Hills which comprises the range of distinct hummocks that stretches over 150 km from the northern surroundings of Ternopil south to Kamianets Podilskyi (see Text-fig. 1) and its continuation extending further south to the Romanian–Moldovan border (see Yanakevich 1977; Pisera 1996; Jasionowski *et al.* 2005, 2006; Radwański *et al.* 2011; Górka *et al.* 2012). Decapod remains are abundant and may be easily collected at almost every site visited. Within that lithofacies, the richest decapod assemblage may be collected almost exclusively in intrabiohermal holes,

caverns, and/or crevices filled with organodetritic material. Only rarely, decapod remains are embedded in the red-algal boundstone comprising the main bodies of the discussed bioherms.

The other lithofacies contain decapod remains only exceptionally. Individual specimens were collected in fossiliferous sands of the Pidhirtsi Beds (also of Upper Badenian age, i.e., lower Serravallian) in the Zhabiak gorge near Zalistsi (see Text-fig. 2).

Repositories

The collected decapod material presented herein is housed in the Stanisław Józef Thugutt Geological Museum of the Faculty of Geology, University of Warsaw; collection number MWGUW ZI/79. The present study contains images of a few specimens that were presented previously without collection numbers (Radwański *et al.* 2006; Górka in Wysocka *et al.* 2016).

Some of the specimens figured herein show distinct features of the internal structure of the carapace (clearly visible e.g., in specimen MWGUW ZI/79/168; see Text-fig. 4.6). To avoid obscuring such detail the specimens were photographed without coating with ammonium chloride.

SYSTEMATIC ACCOUNT

In this account the described taxa are presented with their full taxonomic position. I follow in a greater part the systematics of De Grave *et al.* (2009) which seems to be very consistent, although some supplementations to this systematics have already been proposed (see e.g., Guinot *et al.* 2013). Almost all taxa recognised herein were in the past the subject of multiple detailed descriptions and are usually quite abundant in the Miocene deposits of Central Paratethys (see e.g., Müller 1984, 1996; Ossó and Stalennuy 2011; Hyžný *et al.* 2014; Hyžný 2016). Due to this fact, the morphological descriptions of most taxa are intentionally omitted herein.

Order Decapoda Latreille, 1802
Suborder Pleocyemata Burkenroad, 1963
Infraorder Axiidea de Saint Laurent, 1979
Family Axiidae Huxley, 1879
Gen. et sp. indet.

MATERIAL: Mykolaiv Beds (Lower Badenian): Yasnyska – 1 chela, destroyed.

		standard stages	Central Paratethys regional stages	local lithostratigraphic units	decapod taxa recorded in this study	localities studied						
MIOCENE	MIDDLE	SERRAVALLIAN	SARMATIAN	Middle		<i>Galathea weinfurteri</i> <i>Galathea</i> sp. <i>Pachycheles</i> sp. <i>Petrolisthes haydni</i> <i>Petrolisthes magnus</i> <i>Petrolisthes</i> sp. A <i>Petrolisthes</i> sp. <i>Dardanus</i> sp. <i>Dromia neogenica</i> Dromiidae gen. et sp. indet. <i>Aethra stalennyii</i> <i>"Pisa" cf. oroszyi</i> <i>Maja biaensis</i> <i>Lobocarcinus sismondai</i> <i>Daira speciosa</i> <i>Bathynectes muelleri</i> <i>Liocarcinus praearcuatus</i> <i>Liocarcinus rakosensis</i> <i>Liocarcinus cf. rakosensis</i> <i>Rakosia carupoides</i> <i>Necronectes cf. schafferi</i> <i>Pilumnus mediterraneus</i> <i>Panopeus wronai</i> <i>Trapezia glaessneri</i> <i>Haydnella steiningeri</i> <i>Chlorodiella juglans</i> <i>Chlorodiella tetenyensis</i> <i>Xantho moldavicus</i> <i>Xantho moldavicus</i>	Demkivtsi Ditkivtsi Hai Roztotski Haluschyntsi Horodnytsia Humentsi Komariv Maksymivka Nihyn Novosilka Polupanivka Sakhkamin Staryi Zbarazh Verbka Zakupne					
				Early	clays, sands, bentonites			sands, sandstones	sands, clays, oolitic limestones, sandstones, conglomerates			
				LANGHIAN	BADENIAN			Late		Buhliv Beds (sands)		
										clays, siltstones	Ternopil Beds (organodetrital, algal and reefal limestones)	Pidhirtsi Beds (sands, sandstones)
										Verbovets Beds (clays)		
										Ratyn Beds (limestones)		
				LANGHIAN	BADENIAN			Middle		gypsum	gypsum	
										Kryvchytsi Beds (limestones, sands and marls with <i>Ervilia pusilla</i>)		
										Naraiiv Beds (algal & organodetrital limestones)		
										Mykolaiv Beds (sands, sandstones)		
BURDIGALIAN	KARPATIAN	Early		Baraniv Beds (sandstones, limestones)								
				Berezhany Beds (marls, sandstones, clays)								
				Nahiriany Beds (sands, sandstones, limestones)								

Text-fig. 2. Position of the studied Badenian decapod-bearing deposits in Ukraine within the regional and standard zonation schemes. After Radwański *et al.* (2014), modified

REMARKS: One chela was found in the quartz sands of the Mykolaiv Beds in a large sand-pit in Yasnytska. Unfortunately, it immediately disinte-

grated when exposed to direct sunlight. However, its recorded appearance was typical for large group of axiid shrimps.

Infraorder Anomura MacLeay, 1838
 Superfamily Galatheoidea Samouelle, 1819
 Family Galatheidae Samouelle, 1819
 Genus *Galathea* Fabricius, 1793

TYPE SPECIES: *Galathea strigosa* (Linnæus, 1761).

Galathea weinfurteri Bachmayer, 1950
 (Text-fig. 3.1)

1950. *Galathea weinfurteri* sp. nov.; Bachmayer, pp. 135–137, pl. 1, figs 2–4.
 1984. *Galathea weinfurteri* Bachmayer, 1950; Müller, p. 60, pl. 21, figs 4, 5, pl. 22, figs 1–5.
 1996. *Galathea weinfurteri* Bachmayer, 1950; Müller, p. 8.
 2006. *Galathea weinfurteri* Bachmayer, 1950; Radwański *et al.*, pl. 2, fig. 1.
 2010. *Galathea weinfurteri* Bachmayer, 1950; Gatt and De Angeli, p. 1326, pl. 2, fig. 4.
 2011. *Galathea weinfurteri* Bachmayer, 1950; Ossó and Stalennuy, text-fig. 3.7.
 2014. *Galathea weinfurteri* Bachmayer, 1950; Collins, pp. 33, 34, pl. 1, figs 3, 4.
 2014. *Galathea weinfurteri* Bachmayer, 1950; Hyžný *et al.*, pp. 243–247, text-fig. 2, pl. 1, figs 1–7, pl. 2, figs 1–8.
 2016. *Galathea weinfurteri* Bachmayer, 1950; Hyžný, text-fig. 10.F.

MATERIAL: Ternopil Beds (Upper Badenian): Humentsi – 2 carapaces (MWGUW ZI/79/078, 213); Maksymivka – 1 carapace (MWGUW ZI/79/075).

REMARKS: *Galathea weinfurteri* has been frequently found in various Badenian deposits of coarse detrital-to-reefal character (Müller 1984, 1996; Górká 2002). According to Müller (1984), although it is present in different lithofacies, it is abundant within the Badenian coral buildups from Hungary. The same may be applied to other fossil representatives of the genus *Galathea*, which, regardless of age, ranging from the Late Eocene to the Pleistocene, are present in different lithofacies – from fine-detrital (marly-diatomitic; Moissette and Müller 1990) through coarse detrital deposits, to fossil reefs which are the most likely place where their remains are found (Saint Martin and Müller 1988; Müller and Collins 1991; Müller 1993; Karasawa 2000; De Angeli *et al.* 2010, 2011; Gatt and De Angeli 2010).

OCCURRENCE: Badenian of Central Paratethys in Austria, Hungary, Poland and Ukraine (Müller 1984, 1996; Górká and Jasionowski 2006; Radwański *et al.* 2006; Ossó and Stalennuy 2011; Hyžný *et al.* 2014;

Hyžný 2016). Its occurrence in the Mediterranean realm was recorded in the early Oligocene of Italy (De Angeli *et al.* 2010) and in the Messinian (late Miocene) of Malta (Gatt and De Angeli 2010).

Galathea sp.
 (Text-fig. 3.2)

MATERIAL: Ternopil Beds (Upper Badenian): Maksymivka – 1 right propodus (MWGUW ZI/79/135).

REMARKS: This poorly preserved specimen shows resemblance to the propodi attributed to *Galathea* sp. documented from the Messinian of Algeria (Moissette and Müller 1990), and the Pleistocene of Japan (Karasawa *et al.* 2014). It is similar in shape (but also distinctly larger) than propodus of *Galathea* cf. *squamifera* Leach, 1814 from the Langhian of Catalonia (Müller 1993, fig. 4F).

Family Porcellanidae Haworth, 1825
 Genus *Pachycheles* Stimpson, 1858

TYPE SPECIES: *Pachycheles grossimanus* (Guérin-Méneville, 1835).

Pachycheles sp.
 (Text-fig. 3.3)

MATERIAL: Ternopil Beds (Upper Badenian): Haluschyntsi – 1 right propodus (MWGUW ZI/79/167); Staryi Zbarazh – 2 propodi (MWGUW ZI/79/169).

REMARKS: The studied specimens (exclusively propodi) are similar in shape to the representatives of the extant genus *Pachycheles* (see Ferreira and Tavares 2017). They are comparable to the propodi of the fossil *Pachycheles latus* Rathbun, 1918 from the Pliocene of Costa Rica (Luque *et al.* 2017).

OCCURRENCE: Extant crabs of the genus *Pachycheles* are known e.g., from the Southern Atlantic, whereas fossil representatives of the genus were recorded in the North Atlantic (Caribbean) realm (Luque *et al.* 2017) and in the lower Eocene of the Mediterranean realm (NE Italy; De Angeli and Cecon 2017).

Genus *Petrolisthes* Stimpson, 1858

TYPE SPECIES: *Petrolisthes violaceus* (Guérin-Méneville, 1831).

REMARKS: The Badenian representatives of the genus *Petrolisthes* from Central Paratethys were described in detail by Müller (1984), who established two new species. Among the diagnostic features there were also differences in the patterns of propodus surfaces. This allowed Müller (1984) to distinguish two distinct species: *P. haydni* Müller, 1984 and *P. magnus* Müller, 1984. The main difference in the propodus appearance is the presence of a granulated ridge in the first species and oblique ridges in the latter (see Müller 1984). However, study of additional Ukrainian material has revealed the presence of a third type of pattern (distinguished herein as *Petrolisthes* sp. A; see below). Moreover, numerous remains of propodi, whose state of preservation did not allow the determination of their specific attribution, were recorded as *Petrolisthes* sp.

The genus *Petrolisthes* was described as associated with coral reefs (Müller 1984; Müller and Collins 1991). It was also reported in the fossil reefs of the Eocene of Italy (De Angeli and Ceccon 2017), Hungary (Müller and Collins 1991) and in the Pleistocene of the Ryukyu Islands (Karasawa 2000).

Petrolisthes haydni Müller, 1984
(Text-fig. 3.4)

1984. *Petrolisthes haydni* sp. nov.; Müller, p. 61, pl. 26, figs 1–5.

1996. *Petrolisthes haydni* Müller, 1984; Müller, p. 8.

2014. *Petrolisthes haydni* Müller, 1984; Collins, p. 34, pl. 1, figs 5–8.

MATERIAL: Ternopil Beds (Upper Badenian): Hai Roztotski – 1 right propodus (MWGUW ZI/79/099); Humentsi – 1 right propodus, 1 fragment of chela (MWGUW ZI/79/217); Maksymivka – 1 right propodus (MWGUW ZI/79/138).

REMARKS: The studied material shows features typical of *P. haydni* – a row of granules along the median line of the propodus' outer side (see Text-fig. 3.4a). This species is known mainly as being associated with the Badenian reefs of Hungary (Müller 1984).

OCCURRENCE: The species was reported from the Badenian of Hungary and Poland (Müller 1984, 1996; Górka 2002). It is also very frequent in Fenk quarry in Austria (Hyžný *et al.* 2014).

Petrolisthes magnus Müller, 1984
(Text-fig. 3.5–3.7)

1984. *Petrolisthes magnus* sp. nov.; Müller, pp. 60, 61, pl. 23, figs 1–4, pl. 24, figs. 1–4, pl. 25, figs 4, 5.

2006. *Petrolisthes magnus* Müller, 1984; Radwański *et al.*, pl. 2, fig. 2.

part 2011. *Petrolisthes magnus* Müller, 1984; Ossó and Stalennuy, text-fig. 3.6 [non text-fig. 3.4, 3.5 – *Petrolisthes* sp. A].

MATERIAL: Ternopil Beds (Upper Badenian): Ditkivtsi – 1 propodus, (MWGUW ZI/79/033); Hai Roztotski – 5 fragments of propodi (MWGUW ZI/79/098); Haluschytsi – 1 right propodus (MWGUW ZI/79/164); Humentsi – 4 propodi, 2 dactyli, 2 carpi (MWGUW ZI/79/216, 219); Maksymivka – 1 propodus, 7 fragments of propodi, 1 palm, 1 dactylus (MWGUW ZI/79/139–141); Novosilka – 1 left propodus (MWGUW ZI/79/055); Sakhkamin – 2 left propodi, 1 imprint of propodus (MWGUW ZI/79/048); Staryi Zbarazh – 1 carapace, 6 propodi (MWGUW ZI/79/183, 184).

REMARKS: The studied material is similar in appearance to that presented by Müller (1984). The carapace is subcircular and covered with tiny scale-like granules locally arranged in a series of fine striae, and the propodi are large and ornamented with series of oblique rows (see Text-figs 3.5, 3.6). The isolated dactylus studied herein (Text-fig. 3.7) most probably also represents this species, as evidenced by its large size, a feature that was once considered characteristic of *P. magnus* (see species diagnosis in Müller 1984).

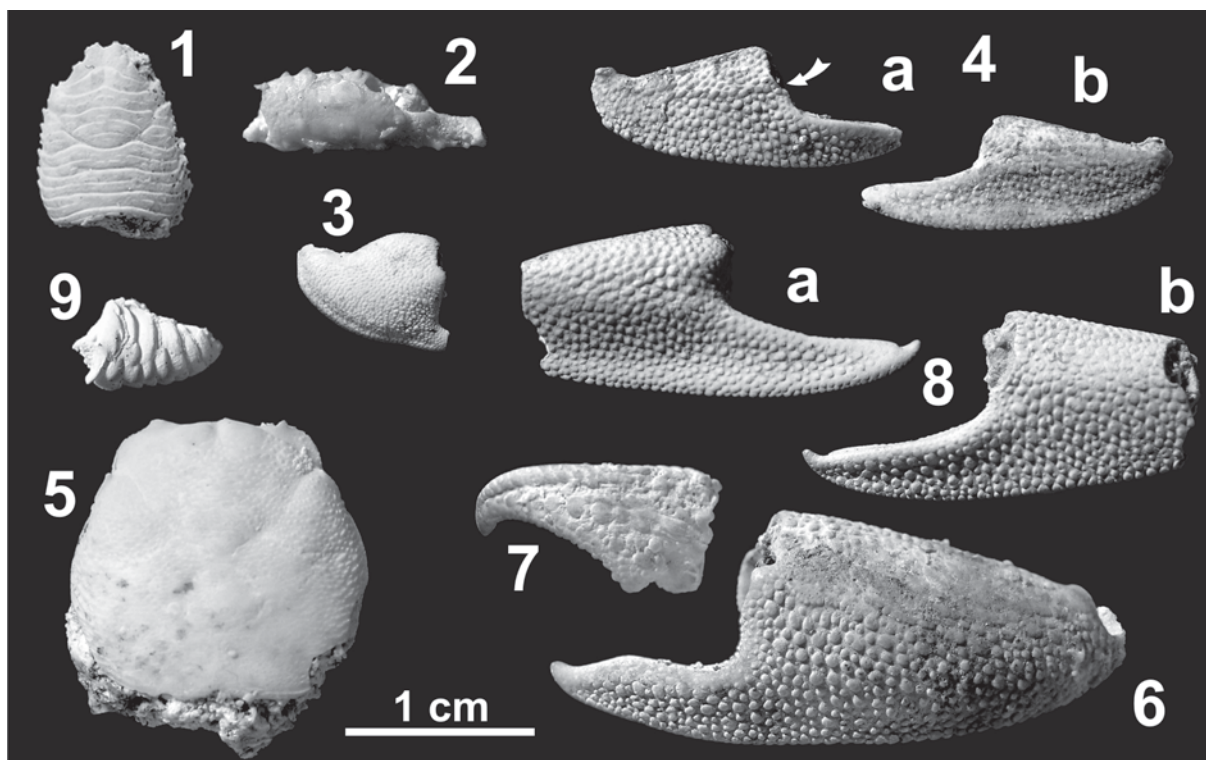
OCCURRENCE: This species was reported from the Badenian reefs of Hungary (Müller 1984), Ukraine (Górka and Jasionowski 2006; Radwański *et al.* 2006; Ossó and Stalennuy 2011) and from the Messinian reefs of Malta (Gatt and De Angeli 2010).

Petrolisthes sp. A
(Text-fig. 3.8)

part 2011. *Petrolisthes magnus* Müller, 1984; Ossó and Stalennuy, text-fig. 3.4, 3.5 [non text-fig. 3.6].

2016. *Petrolisthes magnus* Müller, 1984; Górka in Wysocka *et al.*, text-fig. 14C.

MATERIAL: Ternopil Beds (Upper Badenian): Ditkivtsi – 2 fragments of propodi (MWGUW ZI/79/031); Hai Roztotski – 3 fragments of propodi (MWGUW ZI/79/231); Humentsi – fragment of propodus (MWGUW ZI/79/233); Maksymivka – fragment of propodus (MWGUW ZI/79/232); Sakhkamin



Text-fig. 3. Decapods of the superfamilies Galattheoidea and Paguroidea from the Upper Badenian deposits of western Ukraine. 1 – *Galathea weinfurteri* Bachmayer, 1950, carapace, dorsal view (MWGUW ZI/79/075 from Maksymivka). 2 – *Galathea* sp., right propodus, outer view (MWGUW ZI/79/135 from Maksymivka). 3 – *Pachycheles* sp., right propodus, outer view (MWGUW ZI/79/167 from Haluschyntsi). 4 – *Petrolisthes haydni* Müller, 1984, right propodus, a – outer view, the arrow shows location of ridge-like row of granules, b – inner view (MWGUW ZI/79/217a from Humentsi); 5, 6 – *Petrolisthes magnus* Müller, 1984; 5 – carapace, dorsal view (MWGUW ZI/79/183 from Staryi Zbarazh); 6 – left propodus, outer view (MWGUW ZI/79/216a from Humentsi). 7 – *Petrolisthes* sp., presumably *P. magnus*, left dactylus, outer view (MWGUW ZI/79/140 from Maksymivka). 8 – *Petrolisthes* sp. A, left propodus, a – inner view, b – outer view (MWGUW ZI/79/047a from Sakhkamin). 9 – *Dardanus* sp., right fixed finger, outer view (MWGUW ZI/79/236 from Sakhkamin)

– 2 left propodi (MWGUW ZI/79/047); Zbarazh – 2 propodi (MWGUW ZI/79/185).

REMARKS: A lot of collected material shows no features diagnostic for the two previous species. Both surfaces of the propodi are adorned with granules that do not form any type of rows or ridges (see Text-fig. 3.4). These specimens might represent a new species of *Petrolisthes*, but for the time being they are described only at generic level.

OCCURRENCE: Badenian reefs of Ukraine (Ossó and Stalennuy 2011; Górká in Wysocka *et al.* 2016). In both papers it was erroneously described as *Petrolisthes magnus* Müller, 1984.

Petrolisthes sp.

MATERIAL: Ternopil Beds (Upper Badenian):

Ditkivtsi – 3 carpi (MWGUW ZI/79/032); Hai Roztotski – 2 dactyli, 1 fixed finger, 2 fragments of leg (MWGUW ZI/79/102); Haluschyntsi – 1 carpus (MWGUW ZI/79/165); Komariv – 1 left chela (MWGUW ZI/79/009); Maksymivka – 3 dactyli, 4 fixed fingers, 3 fragments of carpi, 2 fragments of leg (MWGUW ZI/79/142–144); Sakhkamin – 1 dactylus, 1 fragment of leg (MWGUW ZI/79/046); Staryi Zbarazh – 1 carapace, 6 fragments of propodi, 1 carpus, 3 dactyli, 3 fixed fingers (MWGUW ZI/79/182, 234); Zakupne – 1 carpus (MWGUW ZI/79/024).

REMARKS: Numerous remains of propodi belonging to the representatives of the genus *Petrolisthes* have been noted in the Ternopil Beds. However, their poor state of preservation did not allow for the determination of their specific affinity. They are attributed here to as *Petrolisthes* sp.

Superfamily Paguroidea Latreille, 1802
 Family Diogenidae Ortmann, 1892
 Genus *Dardanus* Paul'son, 1875

TYPE SPECIES: *Dardanus lagopodes* (Forskål, 1775).

Dardanus sp.
 (Text-fig. 3.9)

MATERIAL: Ternopil Beds (Upper Badenian): Sakhkamin – right fixed finger (MWGUW ZI/79/236).

REMARKS: The fragmentary specimen shows a series of distinct striae, almost perpendicular to the longitudinal axis of the propodus. This feature is typical of the genus *Dardanus*. Elongated tubercles that are parallel to the striae are visible in the lower part of the propodus, thus resembling the ornamentation recorded in the specimen of *Dardanus arrosor* (Herbst, 1796) from the Badenian of Hungary (Müller 1984).

OCCURRENCE: Representatives of *Dardanus* are relatively scarce in the Miocene of Paratethys and the Mediterranean; the most abundant species is *D. hungaricus* (Lörenthey in Lörenthey and Beurlen, 1929) from the Badenian of Hungary (Müller 1984), Poland (Górka 2002), and Austria (Collins 2014), also known from the Langhian of Catalonia (Müller 1993) and the Messinian of Malta (Gatt and De Angeli 2010). Two other species, i.e., *D. arrosor* and *D. substriatiformis* (Lörenthey in Lörenthey and Beurlen, 1929) were also recorded from the Badenian of Hungary (see Müller 1984).

Infraorder Brachyura Linnæus, 1758
 Section Dromiacea De Haan, 1833
 Superfamily Dromioidea De Haan, 1833
 Family Dromiidae De Haan, 1833
 Subfamily Dromiinae De Haan, 1833
 Genus *Dromia* Weber, 1795

TYPE SPECIES: *Dromia personata* (Linnæus, 1758).

Dromia neogenica Müller, 1979
 (Text-fig. 4.6)

1979a. *Dromia neogenica* sp. nov.; Müller, pp. 274, 278, 287, pl. 8, fig. 1.

1984. *Dromia neogenica* Müller, 1979; Müller, p. 63, pl. 29, figs 1–6.

2010. *Dromia neogenica* Müller, 1979; Gatt and De Angeli, p. 1328, pl. 2, fig. 10.

MATERIAL: Ternopil Beds (Upper Badenian): Staryi Zbarazh – 1 fragment of carapace (MWGUW ZI/79/168).

REMARKS: The large carapace fragment is preserved without its original edges, therefore exact determination is difficult. However some elements of the central part of the carapace can be easily recognised. The mesogastric and urogastric lobes, with part of the right protogastric lobe are separated by a cervical groove from the right branchial lobe and part of the right mesobranchial lobe. Gastric pits are visible between the metagastric and urogastric regions. The overall look and carapace details resemble those of *D. neogenica* Müller, 1979.

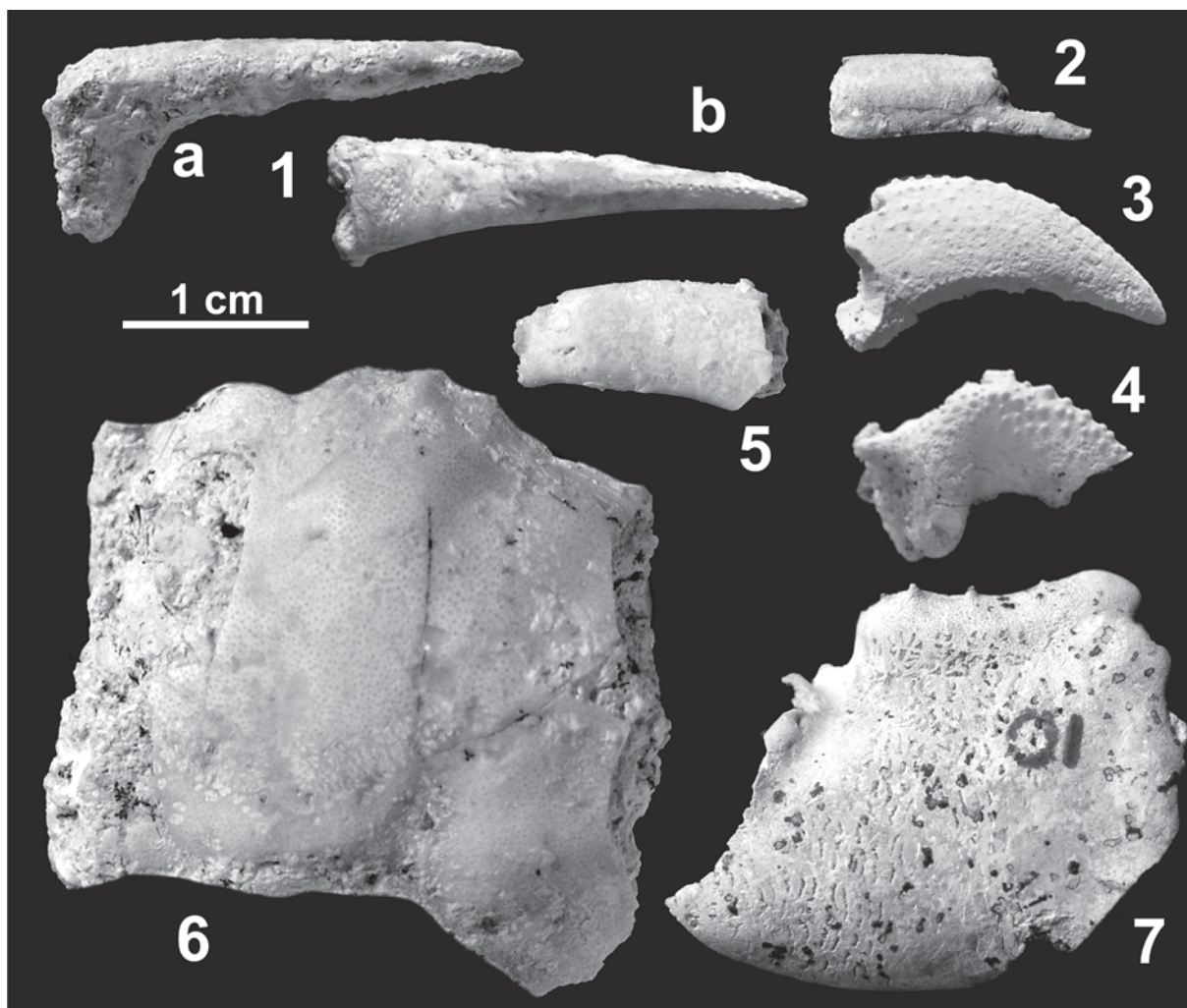
OCCURRENCE: *Dromia neogenica* is present, although not abundant, as reef-associated in the Lower Badenian of Hungary (Müller 1984). Its presence in the Ternopil Beds was previously recorded by Ossó and Stalennuy (2011) in Maksymivka quarry. In the Mediterranean domain this species was found in the Messinian of Algeria (Saint Martin and Müller 1988), Malta (Gatt and De Angeli 2010) and presumably also in the Langhian of Catalonia (Müller 1993).

Dromiidae gen. et sp. indet.
 (Text-fig. 4.7)

MATERIAL: Ternopil Beds (Upper Badenian): Staryi Zbarazh – 1 left palm (MWGUW ZI/79/196).

REMARKS: The remains of the left palm from Staryi Zbarazh may be attributed to various species of the Dromiidae family. First of all, the palm may be considered as belonging to *D. neogenica* due to its large size and ornamentation (distinct row of fine tubercles along the upper edge of the palm). This attribution is supported by fact that this particular species was described as associated almost exclusively with reefs (Müller 1984), similarly to some extant dromioid crabs (Van Bakel *et al.* 2009). However, another Badenian species, *Lucanthonisia eotvoesi* (Müller, 1976) was previously reported as absent from reefal structures (Müller 1984), but later it was also found in coralgal buildups (Müller 1996). Therefore, regarding the poor state of preservation, the attribution of the discussed palm to as *L. eotvoesi* should not be excluded.

OCCURRENCE: For details on *D. neogenica* see above; *Lucanthonisia eotvoesi* was recorded e.g., in the Upper Badenian of Hungary (Müller 1984) and Poland (Müller 1996).



Text-fig. 4. Decapods of the infraorder Brachyura from the Upper Badenian deposits of western Ukraine: **1, 2** – *Maja biaensis* Lörenthey in Lörenthey and Beurlen, 1929; **1** – right dactylus, a – upper view, b – outer view (MWGUW ZI/79/005 from Khorosno); **2** – right propodus, outer view (MWGUW ZI/79/133 from Maksymivka). **3, 4** – *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; **3** – right dactylus, outer view (MWGUW ZI/79/004a from Khorosno); **4** – right dactylus, outer view (MWGUW ZI/79/004b from Khorosno). **5** – “*Pisa*” cf. *oroszyi* (Bachmayer, 1953), right propodus, outer view (MWGUW ZI/79/134 from Maksymivka); **6** – *Dromia neogenica* Müller, 1979, fragment of carapace, dorsal view (MWGUW ZI/79/168 from Saryi Zbarazh); **7** – Dromiidae gen. et sp. indet., left palm, inner view (MWGUW ZI/79/196 from Saryi Zbarazh)

Section Eubranchyura de Saint Laurent, 1980
 Subsection Heterotremata Guinot, 1977
 Superfamily Aethroidea Dana, 1851
 Family Aethridae Dana, 1851
 Genus *Aethra* Latreille, 1816

TYPE SPECIES: *Aethra scruposa* (Linnæus, 1764).

Aethra stalennyii Ossó, 2018

2018. *Aethra stalennyii* sp. nov.; Ossó, pp. 587–591, text-figs 3A–C, 4A–E.

REMARKS: This is the newly described species from the Ternopil Beds of Maksymivka quarry.

Superfamily Calappoidea De Haan, 1833
 Family Calappidae De Haan, 1833
 Genus *Calappa* Weber, 1795

TYPE SPECIES: *Calappa granulata* (Linnæus, 1758).

Calappa praelata Lörenthey in Lörenthey and Beurlen, 1929

(Text-fig. 4.3, 4.4)

1929. *Calappa praelata* sp. nov.; Lörenthey in Lörenthey and Beurlen, pp. 132, 133, pl. 6, fig. 3a–c.
 1979b. *Calappa* aff. *heberti* Brocchi, 1883; Förster, pp. 255–257, text-figs 2, 3, pl. 1, figs 2, 4.
 1984. *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; Müller, pp. 66, 67, pl. 35, figs 1, 2, 7, ?figs 3–6, pl. 36, fig. 6.
 1996. *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; Müller, p. 9, pl. 1, fig. 11.
 2010. *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; Gatt and De Angeli, p. 1329, pl. 2, fig. 12.
 2014. *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; Collins, pp. 36–38, pl. 2, fig. 9.
 2017. *Calappa praelata* Lörenthey in Lörenthey and Beurlen, 1929; Díaz-Medina *et al.*, pp. 180, 181, text-figs 9A–C.

MATERIAL: Mykolaiv Beds (Lower Badenian): Khorosno – 12 poorly preserved dactyli and/or their fragments (MWGUW ZI/79/004); Stratyn – 1 poorly preserved dactylus (MWGUW ZI/79/235).

REMARKS: The collected material is quite poorly preserved, but it still possesses characteristic tubercles scattered along the upper part of the dactyli. It is the most frequently represented taxon in the siliciclastic lithofacies of the Mykolaiv Beds. Müller (1984) described this species as completely absent from reefs and attributed its occurrence in Hungary to the Lower Badenian only. This was later supported by further observations from Poland and Hungary (Müller 1996, 2006).

OCCURRENCE: The species was previously noticed almost exclusively from the Lower Badenian clastics of Hungary (Lörenthey in Lörenthey and Beurlen 1929; Müller 1984, 2006) and Poland (Förster 1979b; Müller 1996). This species was also recorded in the late Miocene of Malta (Gatt and De Angeli 2010) and Spain (Díaz-Medina *et al.* 2017).

Superfamily Majoidea Samouelle, 1819
 Family Epialtidae MacLeay, 1838
 Subfamily Pisinae Dana, 1851
 Genus *Pisa* Leach, 1816

TYPE SPECIES: *Pisa armata* (Latreille, 1803).

“*Pisa*” cf. *oroszyi* (Bachmayer, 1953)
 (Text-fig. 4.5)

1953. *Maia oroszyi* sp. nov.; Bachmayer, pp. 245–247, pl. 2, fig. 3.

1984. “*Pisa*” *oroszyi* (Bachmayer, 1953); Müller, p. 73, pl. 51, figs 3–6, pl. 52, figs 1–3.

1996. “*Pisa*” *oroszyi* (Bachmayer, 1953); Müller, p. 9.

MATERIAL: Ternopil Beds (Upper Badenian): Maksymivka – 1 right propodus (MWGUW ZI/79/134).

REMARKS: The overall shape of this poorly preserved propodus only allows an approximate attribution to the propodus depicted by Müller (1984, pl. 51, fig. 6). This assignment may be supported by the presence of well-preserved carapaces of “*Pisa*” *oroszyi* in the coralgal reefs from Poland that are coeval with the Ternopil Beds (see Müller 1996).

OCCURRENCE: Previously noted in the Badenian of Hungary (Müller 1984), Poland (Müller 1996) and the Vienna Basin (Hyžný 2016).

Family Majidae Samouelle, 1819
 Subfamily Majinae Samouelle, 1819
 Genus *Maja* Lamarck, 1801

TYPE SPECIES: *Maja squinado* (Herbst, 1788).

Maja biaensis Lörenthey in Lörenthey and Beurlen,
 1929
 (Text-fig. 4.1, 4.2)

1929. *Maia biaensis* sp. nov.; Lörenthey in Lörenthey and Beurlen, pp. 148–150, pl. 7, fig. 1.

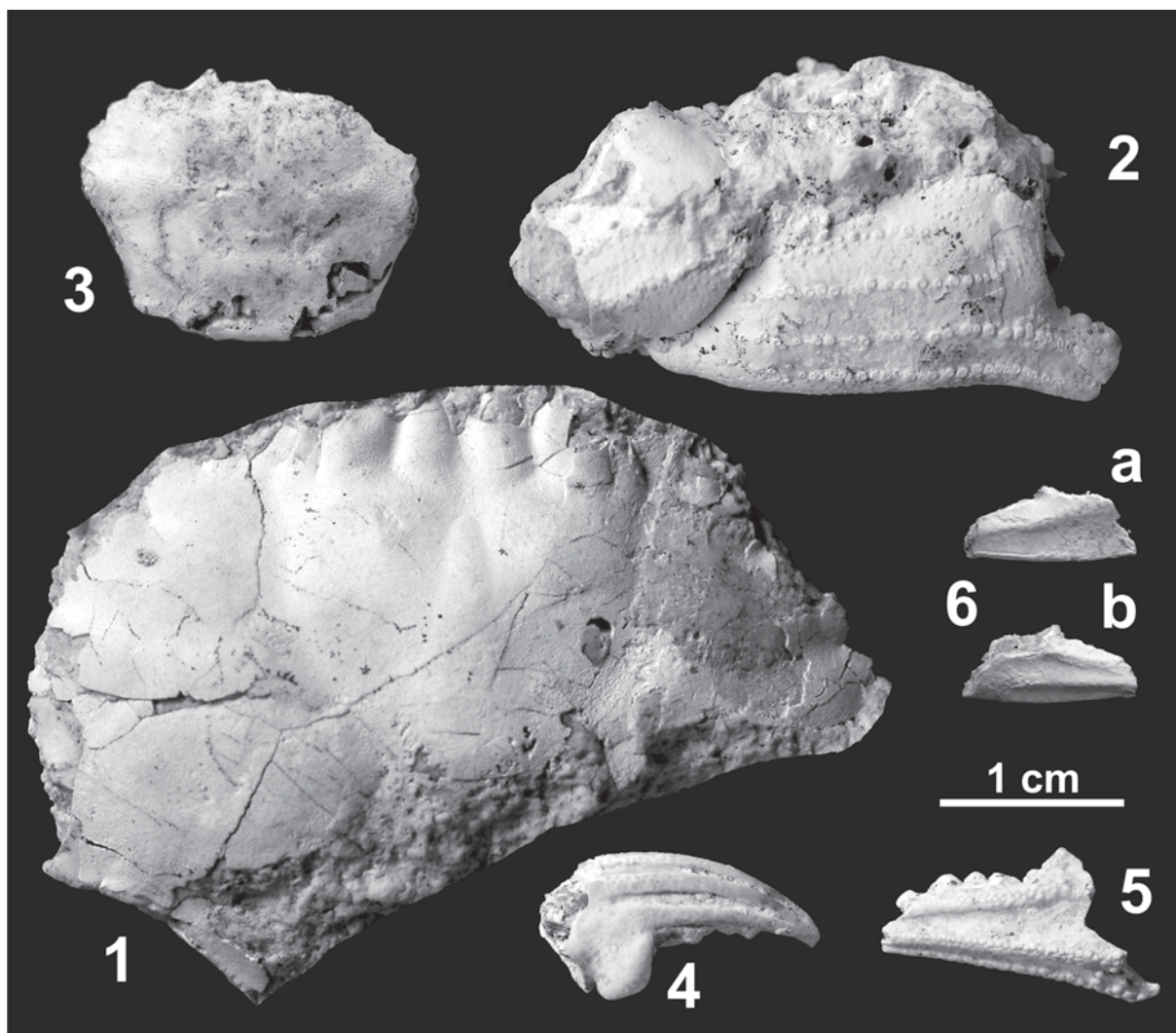
1984. *Maja biaensis* Lörenthey in Lörenthey and Beurlen, 1929; Müller, pp. 71, 72, pl. 48, figs 1–6, pl. 49, figs 1–3.

1996. *Maja biaensis* Lörenthey in Lörenthey and Beurlen, 1929; Müller, p. 9.

2010. *Maja biaensis* Lörenthey in Lörenthey and Beurlen, 1929; Gatt and De Angeli, p. 1331, pl. 2, fig. 11.

MATERIAL: Mykolaiv Beds (Lower Badenian): Khorosno – 1 right dactylus (MWGUW ZI/79/005). Ternopil Beds (Upper Badenian): Maksymivka – 1 right propodus (MWGUW ZI/79/133).

REMARKS: The two remains of chelae are similar to the material depicted by Müller (1984) from Hungary. It is also significant that the present Ukrainian material was found in two lithostratigraphic units of different age i.e., Lower and Upper Badenian, which



Text-fig. 5. Decapods of infraorder Brachyura from Upper Badenian deposits of western Ukraine. **1, 2** – *Lobocarcinus sismondai* (von Meyer, 1843); **1** – carapace, dorsal view (MWGUW ZI/79/223 from Humentsi); **2** – right propodus with carpus, outer view (MWGUW ZI/79/020 from Zakupne). **3** – *Liocarcinus praeaeuatus* Müller, 1996, carapace, dorsal view (MWGUW ZI/79/050 from Sakhkamin). **4, 5** – *Liocarcinus rakosensis* Lörenthey in Lörenthey and Beurlen, 1929; **4** – right dactylus, outer view (MWGUW ZI/79/025a from Zakupne); **5** – left fixed finger, outer view (MWGUW ZI/79/100 from Hai Roztotski). **6** – *Liocarcinus* cf. *rakosensis* Lörenthey in Lörenthey and Beurlen, 1929, left fixed finger, a – outer view, b – inner view (MWGUW ZI/79/006a from Khorosno)

corresponds to the age range of the Hungarian material (see Müller 1984).

OCCURRENCE: *Maja biaensis* was recorded in the Badenian of Hungary (Lörenthey in Lörenthey and Beurlen 1929; Müller 1984) and Poland (Müller 1996). Unidentified remains of majid decapods that may also possibly represent *M. biaensis* were reported from the Ternopil Beds in Maksymivka quarry (Ossó and Stalennuy 2011). The species was also found in the Messinian of Malta (Gatt and De Angeli 2010).

Superfamily Cancroidea Latreille, 1802
Family Cancridae Latreille, 1802
Subfamily Lobocarcininae Beurlen, 1930
Genus *Lobocarcinus* Reuss, 1857

TYPE SPECIES: *Lobocarcinus paulinowuerttembergensis* von Meyer, 1847.

Lobocarcinus sismondai (von Meyer, 1843)
(Text-fig. 5.1, 5.2)

1843. *Cancer sismondai* sp. nov.; von Meyer, pp. 589, 590.

1984. *Cancer sismondai* (Meyer, 1843); Müller, pp. 75, 76.
 1990. *Cancer sismondai* (Meyer, 1843); Moissette and Müller, pp. 739, 740, pl. 1, fig. 1, pl. 2, figs 1, 2.
 2014. *Lobocarcinus* sp. aff. *Lobocarcinus sismondai* (von Meyer, 1843); Collins, p. 38, pl. 2, fig. 10.

MATERIAL: Ternopil Beds (Upper Badenian): Demkivtsi – 1 right fixed finger (MWGUW ZI/79/016); Hai Roztotski – 3 fixed fingers (MWGUW ZI/79/101); Haluschyntsi – 1 left propodus with carpus (MWGUW ZI/79/074); Humentsi – 1 carapace (MWGUW ZI/79/223); Zakupne – 1 right propodus (MWGUW ZI/79/020).

REMARKS: The overall appearance of a large fragment of carapace from Humentsi and of the collected propodi is similar in most aspects to the specimen depicted by Moissette and Müller (1990). The very common Paratethyan species *Cancer styriacus* Bittner, 1884, though possessing a very similar carapace, differs from the present Ukrainian material in having less prominent ridges of tubercles on outer surfaces of the propodi and a much shorter fixed finger (see Müller 1984, pl. 47, figs 3, 4 and pl. 48, fig. 1; Müller 1996, pl. 2, fig. 4).

OCCURRENCE: Widely distributed in the middle Miocene to middle Pliocene deposits of the Mediterranean realm (see Müller 1984; Moissette and Müller 1990). It is however very rare in the Badenian of Paratethys (Müller 1984; see also Collins 2014 and Hyžný 2016).

Superfamily Dairoidea Serène, 1965
 Family Dairidae Serène, 1965
 Genus *Daira* De Haan, 1833

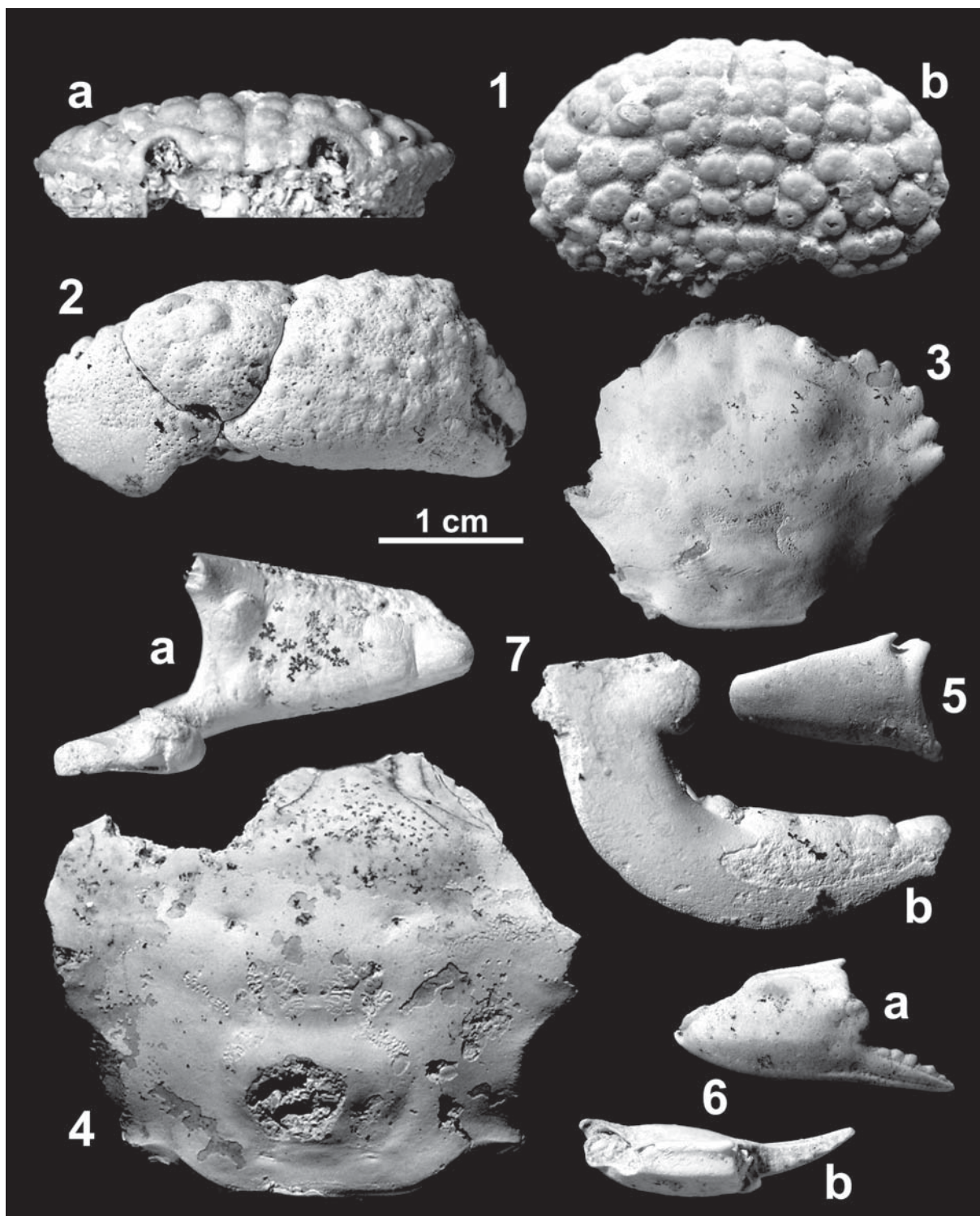
TYPE SPECIES: *Daira perlata* (Herbst, 1790).

Daira speciosa (Reuss, 1871)
 (Text-fig. 6.1, 6.2)

1871. *Phymatocarcinus speciosus* sp. nov.; Reuss, pp. 325–330, figs 1–4.
 1929. *Daira speciosa* (Reuss, 1871); Lörenthey in Lörenthey and Beurlen, pp. 197, 198, pl. 12, figs 10, 11.
 1969. *Daira speciosa* (Reuss, 1871); Yanakevich, pp. 26, 27, pl. 1, figs 1–3.
 1977. *Daira speciosa* (Reuss, 1871); Yanakevich, pp. 79, 80, pl. 10, figs 5, 6.
 1984. *Daira speciosa* (Reuss, 1871); Müller, p. 60, pl. 79, figs 1–6, pl. 80, figs 1, 2.
 1988. *Daira speciosa* (Reuss, 1871); Saint Martin and Müller, p. 253, pl. 1, fig. 7.
 1996. *Daira speciosa* (Reuss, 1871); Müller, p. 11, pl. 2, fig. 5.
 2006. *Daira speciosa* (Reuss, 1871); Radwański *et al.*, pl. 2, figs 3, 4.
 2010. *Daira speciosa* (Reuss, 1871); Gatt and De Angeli, p. 1334, text-figs 8A–C.
 2011. *Daira speciosa* (Reuss, 1871); Ossó and Stalennuy, text-figs 3.13, 3.14, 6.1, 6.2, 6.4, 9.4.
 2014. *Daira speciosa* (Reuss, 1871); Collins, p. 38, pl. 2, fig. 10.
 2016. *Daira speciosa* (Reuss, 1871); Górka in Wysocka *et al.*, text-fig. 14D.
 2016. *Daira speciosa* (Reuss, 1871); Hyžný, text-fig. 10J.
 2016. *Daira speciosa* (Reuss, 1871); Hyžný and Gross, pp. 108, 109, text-fig. 15.2.
 2016. *Daira speciosa* (Reuss, 1871); Hyžný and Zorn, pp. 133, 134, pl. 7, figs 6–9.

MATERIAL: Ternopil Beds (Upper Badenian): Demkivtsi – 2 fragments of carapaces (MWGUW ZI/79/015); Ditkivtsi – 3 carapaces, 1 palm, 1 carpus (MWGUW ZI/79/028, 029); Hai Roztotski – 2 carapaces, 6 fragments of carapaces, right propodus (MWGUW ZI/79/108, 109, 111, 112); Haluschyntsi – 4 carapaces, 8 fragments of carapaces, 8 carpi (MWGUW ZI/79/147–152); Humentsi – 12 carapaces, 10 fragments of carapaces, 2 right chelae with carpi, 1 left chela and carpus, 1 left propodus with carpus, 1 left chela, 1 dactylus (MWGUW ZI/79/220, 224–230); Maksymivka – 12 carapaces, 8 fragments of carapaces, 2 chelae, 1 right propodus with carpus (MWGUW ZI/79/057–062); Nihyn – 2 carapaces (MWGUW ZI/79/039); Novosilka – 8 carapaces (MWGUW ZI/79/054); Sakhkamin – 2 carapaces, 2 fragments of carapaces, 2 propodi with carpi (MWGUW ZI/79/044, 045); Staryi Zbarazh – 28 carapaces, 2 right chelae with carpi and meri, 1 right chela with carpus, 1 left propodus with carpus and merus, 1 left propodus with carpus (MWGUW ZI/79/186–192); Zakupne – 1 fragments of carapace (MWGUW ZI/79/017).

REMARKS: This particular species is the most recognisable crab of the Upper Badenian assemblage of reef-associated decapods. It is a representative of a genus whose members are almost exclusively related with the reefal environment since at least the late Eocene until today (see Müller and Collins 1991). Examples of extinct species of this genus that were found in fossil reefs include e.g., *D. depressa* (A. Milne-Edwards, 1865) from the early Oligocene of



Text-fig. 6. Decapods of the infraorder Brachyura from the Upper Badenian deposits of western Ukraine: **1, 2** – *Daira speciosa* (Reuss, 1871); 1 – carapace, a – frontal view, b – dorsal view (MWGUW ZI/79/061 from Maksymivka); 2 – right chela with carpus and merus, outer view (MWGUW ZI/79/188 from Staryi Zbarazh). **3-6** – *Bathynectes muelleri* Ossó and Stalennuy, 2011; 3 – carapace, dorsal view (MWGUW ZI/79/070 from Humentsi); 4 – carapace, dorsal view (MWGUW ZI/79/069 from Humentsi); 5 – right carpus, outer view (MWGUW ZI/79/080 from Hai Roztotski); 6 – right propodus, a – outer view, b – upper view (MWGUW ZI/79/081 from Hai Roztotski). **7** – *Necronectes cf. schafferi* Glaessner, 1928, fragment of right fixed finger, a – upper view, b – outer view (MWGUW ZI/79/170 from Staryi Zbarazh)

Italy (see De Angeli *et al.* 2010) and *D. eoacaenica* (Lörenthey, 1897) from the late Eocene of Hungary (see Müller and Collins 1991).

OCCURRENCE: *Daira speciosa* is widely distributed in the Miocene deposits of the Mediterranean and Paratethyan realms. In Paratethys it was recorded in the Lower Badenian of Poland (Förster 1979a; Müller 1996; Górka 2002), Lower and Upper Badenian of Hungary (Lörenthey in Lörenthey and Beurlen 1929; Müller 1996) and Austria (Hyžný 2016; Hyžný and Gross 2016), Upper Badenian of Ukraine (Górka and Jasionowski 2006; Radwański *et al.* 2006; Ossó and Stalennuy 2011) and Moldova (Yanakevich 1977). In the Mediterranean it is present in the Messinian of Algeria (Saint Martin and Müller 1988), Mallorca (García-Socias 1989), and Malta (Gatt and De Angeli 2010) and possibly also in the Langhian of Catalonia (Müller 1993).

Superfamily Portunoidea Rafinesque, 1815
Family Polybiidae Ortmann, 1893
Subfamily Polybiinae Paul'son, 1875
Genus *Bathynectes* Stimpson, 1871

TYPE SPECIES: *Bathynectes longispina* Stimpson, 1871.

Bathynectes muelleri Ossó and Stalennuy, 2011
(Text-fig. 6.3–6.6)

2011. *Bathynectes muelleri* sp. nov.; Ossó and Stalennuy, p. 41, text-figs 3.1–3.3 and 7.1–7.6.

MATERIAL: Ternopil Beds (Upper Badenian): Hai Roztotski – 1 right propodus, 1 carpus, 1 dactylus (MWGUW ZI/79/080, 081, 107); Haluschytsi – 1 carapace (MWGUW ZI/79/073); Humentsi – 4 carapaces, 1 left propodus (MWGUW ZI/79/068–071, 206); Maksymivka – 1 carapace, 1 right propodus (MWGUW ZI/79/072, 145); Zakupne: 1 right propodus (MWGUW ZI/79/018).

REMARKS: The collected material corresponds to that described by Ossó and Stalennuy (2011). Its presence shows that *B. muelleri* is a relatively abundant species within the reef-associated decapods of the Ternopil Beds.

OCCURRENCE: This species was recorded only in the Upper Badenian reefal deposits of the Ternopil Beds from western Ukraine.

Genus *Liocarcinus* Stimpson, 1871

TYPE SPECIES: *Liocarcinus holsatus* (Fabricius, 1798).

Liocarcinus praeearcuatus Müller, 1996
(Text-fig. 5.3)

1996. *Liocarcinus praeearcuatus* sp. nov.; Müller, p. 10, pl. 2, figs 2, 3.

MATERIAL: Ternopil Beds (Upper Badenian): Sakhkamin – 1 carapace (MWGUW ZI/79/050).

REMARKS: The collected carapace is similar to that pictured by Müller (1996) and differs distinctly from *Liocarcinus rakosensis* Lörenthey in Lörenthey and Beurlen, 1929 (see below) which is more ornamented dorsally (cf. Müller 1984, p. 83).

OCCURRENCE: Upper Badenian of Poland and Hungary (see Müller 1996).

Liocarcinus rakosensis Lörenthey in Lörenthey and Beurlen, 1929
(Text-fig. 5.4, 5.5)

1929. *Liocarcinus rakosensis* sp. nov.; Lörenthey in Lörenthey and Beurlen; pp. 171–174, pl. 12, figs 20–23, pl. 13, fig. 1.

1984. *Liocarcinus rakosensis* Lörenthey in Lörenthey and Beurlen, 1929; Müller, p. 83, pl. 69, figs 2, 5, 6, pl. 70, figs 1–8.

2014. *Liocarcinus* sp. aff. *Liocarcinus rakosensis* (Lörenthey in Lörenthey and Beurlen, 1929); Collins, pp. 40–42, pl. 3, figs 3, 5.

MATERIAL: Ternopil Beds (Upper Badenian): Hai Roztotski – 1 left fixed finger, 1 left dactylus (MWGUW ZI/79/100, 238); Humentsi – 1 dactylus (MWGUW ZI/79/221); Maksymivka – 1 right dactylus (MWGUW ZI/79/131); Staryi Zbarazh – 1 right dactylus (MWGUW ZI/79/195); Zakupne – 3 dactyli, 1 fragment of dactylus (MWGUW ZI/79/025).

REMARKS: The collected dactyli and fixed fingers are very similar to the material described as *L. rakosensis* (see Müller 1984). However, some of the dactyli from Ukraine seem to be a little more robust than the Hungarian material (see Text-fig. 5.4). Thus, at least several of them possibly may be assigned to another species, presumably *L. praeearcuatus*. Since the dactyli of the latter have not been

described yet, this issue remains unsolved (see also Müller 1984, p. 10).

OCCURRENCE: *Liocarcinus rakosensis* was recorded in the very diversified (sandy and/or detrital, reefal) deposits of the Lower and Upper Badenian in Poland and Hungary (see Müller 1984, 1996; Górka 2002), and Austria (Collins 2014; Hyžný 2016).

Liocarcinus cf. *rakosensis* Lörenthey in Lörenthey and Beurlen, 1929
(Text-fig. 5.6)

MATERIAL: Mykolaiv Beds (Lower Badenian): Khorosno – 2 fixed fingers (MWGUW ZI/79/006).

REMARKS: The figured specimen is a partly abraded fragment of a presumably left propodus. The most prominent features are longitudinal ridges resembling those depicted in *L. rakosensis* (see Müller 1984, pl. 70).

Family Portunidae Rafinesque, 1815
Subfamily Carupinae Paul'son, 1875
Genus *Rakosia* Müller, 1984

TYPE SPECIES: *Rakosia carupoides* Müller, 1984.

Rakosia carupoides Müller, 1984

1984. *Rakosia carupoides* sp. nov.; Müller, p. 82, pl. 68, figs 1–7.

2011. *Rakosia carupoides* Müller, 1984; Ossó and Stalennuy, text-fig. 6.3.

2016. *Rakosia carupoides* Müller, 1984; Hyžný, text-fig. 10H.

REMARKS: The presence of *R. carupoides* in the Ternopil Beds was previously recorded by Ossó and Stalennuy (2011) in Maksymivka quarry.

OCCURRENCE: Middle (or lowermost upper) Miocene reefal deposits of Austria and Hungary (Müller 1984). Another species, *R. rectifrons* Müller, 1996 was described from the Lower Badenian reef in Grobie, Poland (Müller 1996).

Subfamily Necronectinae Glaessner, 1928
Genus *Necronectes* A. Milne-Edwards, 1881

TYPE SPECIES: *Necronectes vidalianus* A. Milne-Edwards, 1881.

Necronectes cf. *schafferi* Glaessner, 1928
(Text-fig. 6.7)

1928. *Necronectes schafferi* sp. nov.; Glaessner, pp. 179–182, text-fig. 4, pl. 3, fig. 6.

1984. *Necronectes schafferi*; Müller, p. 82, pl. 66, figs 8, 9, ?pl. 69, fig. 1.

MATERIAL: Ternopil Beds (Upper Badenian): Saryi Zbarazh – 1 fragment of fixed finger of right propodus (MWGUW ZI/79/170).

REMARKS: The most probable affinity of this large and robust fragment is the genus *Necronectes*, but it still should not be excluded that the discussed specimen may represent another closely related genus. i.e., *Scylla* de Haan, 1833 (see discussion in Hyžný and Gross 2016). Considering *Necronectes* as the most probable affinity, this specimens probably represents the Paratethyan species *N. schafferi* Glaessner, 1928.

OCCURRENCE: Badenian of Hungary and Austria (Müller 1984; see also Hyžný and Gross 2016).

Superfamily Pilumnoidea Samouelle, 1819
Family Pilumnidae Samouelle, 1819
Subfamily Pilumninae Samouelle, 1819
Genus *Pilumnus* Leach, 1816

TYPE SPECIES: *Pilumnus hirtellus* (Linnæus, 1761).

Pilumnus mediterraneus (Lörenthey, 1897)
(Text-fig. 7.6, 7.7)

1897. *Pilodius mediterraneus* sp. nov.; Lörenthey, pp. 160, 167, 169.

1929. *Chlorodopsis mediterranea* (Lörenthey, 1897); Lörenthey in Lörenthey and Beurlen; pp. 1225–1227, pl. 12, figs 13–17, 19.

1984. *Pilumnus mediterraneus* (Lörenthey, 1897); Müller, pp. 93, 94, pl. 87, figs 2–5, 88, figs 1–5.

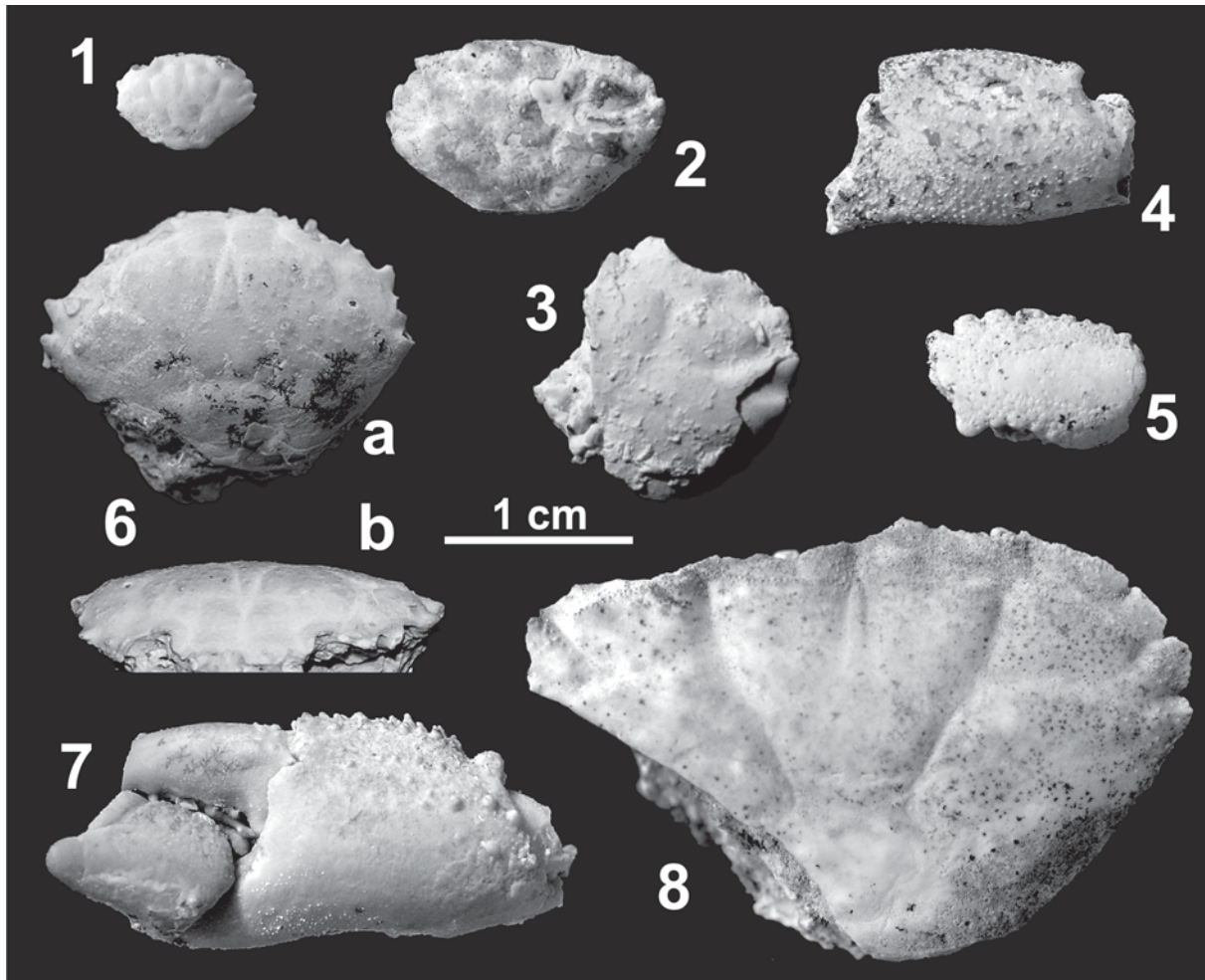
1996. *Pilumnus mediterraneus* (Lörenthey, 1897); Müller, p. 12.

2006. *Pilumnus mediterraneus* (Lörenthey, 1897); Radwański *et al.*, pl. 2, fig. 7.

2011. *Pilumnus mediterraneus* (Lörenthey, 1897); Ossó and Stalennuy, text-fig. 9.3.

2014. *Pilumnus* sp. aff. *Pilumnus mediterraneus* (Lörenthey, 1897); Collins, p. 39, pl. 2, fig. 16, pl. 4, fig. 11.

2016. *Pilumnus mediterraneus* (Lörenthey, 1897); Górka in Wysocka *et al.*, text-fig. 14E.



Text-fig. 7. Decapods of the infraorder Brachyura from the Upper Badenian deposits of western Ukraine. 1, 2 – *Chlorodiella juglans* Müller, 1984; 1 – carapace, dorsal view (MWGUW ZI/79/214 from Humentsi); 2 – carapace, dorsal view (MWGUW ZI/79/215 from Humentsi). 3 – *Chlorodiella tetenyensis* Müller, 1984, fragment of carapace, dorsal view (MWGUW ZI/79/077 from Maksymivka). 4 – *Haydnella steiningeri* Müller, 1984, left propodus, outer view (MWGUW ZI/79/049 from Sakhkamin). 5 – *Trapezia glaessneri* Müller, 1976, right merus, outer view (MWGUW ZI/79/162 from Haluschyntsi). 6, 7 – *Pilumnus mediterraneus* (Lörenthey, 1897); 6 – carapace, a – dorsal view, b – frontal view (MWGUW ZI/79/076 from Maksymivka); 7 – left chela with attached fragment of propodus of *Xantho moldavicus* (Yanakevich, 1977), outer view (MWGUW ZI/79/163 from Haluschyntsi). 8 – *Panopeus wronai* Müller, 1984, carapace, dorsal view (MWGUW ZI/79/067 from Humentsi)

MATERIAL: Ternopil Beds (Upper Badenian): Hai Roztotski – 1 right propodus, 3 dactyli (MWGUW ZI/79/094, 095); Haluschyntsi – 1 left chela, 2 carpi (MWGUW ZI/79/163, 211); Humentsi – 2 palms (MWGUW ZI/79/212); Maksymivka – 7 carapaces and fragments, 4 propodi (MWGUW ZI/79/076, 129, 130); Nihyn – 1 right propodus (MWGUW ZI/79/040); Polupanivka – 1 right propodus (MWGUW ZI/79/011); Sakhkamin – 1 palm with carpus, 1 right propodus, 1 fixed finger (MWGUW ZI/79/041, 051); Staryi Zbarazh – left propodus with carpus (MWGUW ZI/79/193); Zakupne – 1 fragment of carapace (MWGUW ZI/79/019).

REMARKS: The collected material matches well with the diagnosis of Müller (1984). Representatives of the genus *Pilumnus* of Miocene age were reported previously from both reefal (Müller 1993) and marly-siliceous facies (Moissette and Müller 1990). This applies also to *P. mediterraneus* described by Müller (1984) as a tolerant species inhabiting various shallow environments.

OCCURRENCE: Frequent in the Badenian of Hungary (Müller 1984), Upper (possibly also Lower) Badenian of Poland (Müller 1996), Upper Badenian of Ukraine (Górka and Jasionowski 2006; Radwański

et al. 2006; Ossó and Stalennuy 2011). It is known from the Langhian of Austria (Collins 2014), and the Messinian of Malta (Gatt and De Angeli 2010) and Italy (De Angeli *et al.* 2011).

Superfamily Xanthoidea MacLeay, 1838
Family Panopeidae Ortmann, 1893
Subfamily Panopeinae Ortmann, 1893
Genus *Panopeus* H. Milne Edwards, 1834

TYPE SPECIES: *Panopeus herbstii* H. Milne Edwards, 1834.

Panopeus wronai Müller, 1984
(Text-fig. 7.8)

1984. *Panopeus wronai* sp. nov.; Müller, p. 91, pl. 81, figs 5, 6, pl. 82, figs 1–4, pl. 83, figs 1–4.
1996. *Panopeus wronai* Müller, 1984; Müller, p. 11.
2011. *Panopeus wronai* Müller, 1984; Ossó and Stalennuy, text-fig. 3.9, 3.10.
2014. *Panopeus wroni* [sic] Müller, 1984; Collins, p. 42, pl. 3, figs 12, 13, 15, 16.

MATERIAL: Ternopil Beds (Upper Badenian): Hai Roztotski – 1 fragment of carapace (MWGUW ZI/79/079); Haluschyntsi – 1 dactylus (MWGUW ZI/79/166); Humentsi – 2 carapaces (MWGUW ZI/79/066, 067); Sakhkamin – 3 dactyli (MWGUW ZI/79/043); Staryi Zbarazh – 1 fixed finger (MWGUW/ZI/79/197).

REMARKS: Remains of *P. wronai* are relatively scarce in the Ternopil Beds. As pointed out by Müller (1984, 1993, 1996), the species of *Panopeus* in the European Neogene dwelled in reefal environments, unlike their extant representatives which inhabit muddy or sandy soft bottoms.

OCCURRENCE: In the Paratethys the species has been recorded in the Lower Badenian of Poland, Hungary (Müller 1984, 1996), Austria (Müller 1984; Collins 2014; Hyžný 2016), and in the Upper Badenian of Ukraine (Ossó and Stalennuy 2011). Mediterranean occurrences are known from the Messinian of Malta (Gatt and De Angeli 2010).

Family Trapeziidae Miers, 1886
Genus *Trapezia* Latreille, 1825

TYPE SPECIES: *Trapezia cymodoce* (Herbst, 1801).

Trapezia glaessneri Müller, 1976
(Text-fig. 7.5)

1976. *Trapezia glaessneri* sp. nov., Müller, pp. 517, 518, pl. 1, fig. 3, pl. 2, figs 1–3.
1984. *Trapezia glaessneri* Müller, 1976; Müller, p. 92, pl. 84, figs 5, 6, pl. 85, figs 1–4.

MATERIAL: Ternopil Beds (Upper Badenian): Haluschyntsi – 1 merus (MWGUW ZI/79/162); Maksymivka – 1 merus (MWGUW ZI/79/132); Sakhkamin – 1 merus (MWGUW ZI/79/052); Staryi Zbarazh – 1 merus (MWGUW ZI/79/194).

REMARKS: The collected material is composed exclusively of right meri. Although such material may appear insufficient for exact determination, it is in fact indistinguishable from the specimen depicted by Müller (1984). It is noteworthy that the Ukrainian material is the first Upper Badenian occurrence of *T. glaessneri*. This reef-associated species has so far been attributed exclusively to the Lower Badenian (see Müller 1984, 2006).

OCCURRENCE: Lower Badenian of Hungary (Müller 1984, 2006).

Family Xanthidae MacLeay, 1838
Genus *Haydnella* Müller, 1984

TYPE SPECIES: *Haydnella steiningeri* Müller, 1984.

Haydnella steiningeri Müller, 1984
(Text-fig. 7.4)

1984. *Haydnella steiningeri* sp. nov.; Müller, pp. 90, 91, pl. 80, figs 3–5, pl. 81, figs 1–4.
1996. *Haydnella steiningeri* Müller, 1984; Müller, pp. 11, 12, pl. 2, fig. 9.
2014. *Haydnella steiningeri* Müller, 1984; Collins, p. 43, pl. 4, figs 13, 14.

MATERIAL: Ternopil Beds (Upper Badenian): Ditkivtsi – 1 palm (MWGUW ZI/79/030); Sakhkamin – 1 left propodus (MWGUW ZI/79/049).

REMARKS: The scarce remains of chelae show a palm, relatively slender, with a pattern of tubercles arranged in irregular rows. They differ from the chelae of *Actumnus telegdii* (Müller, 1974), which bear a similar pattern but are stouter.

OCCURRENCE: *Haydnella steiningeri* has been found in the Lower to Upper Badenian red-algal reefs of Austria, and in the Lower Badenian of Hungary and Poland (Müller 1984, 1996; see also Collins 2014). It is also presumably present in the Messinian of Italy (De Angeli *et al.* 2011). The present record is the first Upper Badenian occurrence of this species.

Subfamily Chlorodiellinae Ng and Holthuis, 2007
Genus *Chlorodiella* Rathbun, 1897

TYPE SPECIES: *Chlorodiella nigra* (Forskål, 1775).

REMARKS: The carapaces of this genus are weakly ornamented, and a poor state of preservation may hamper further determination. Representatives of this genus have been recorded in reefal deposits of Badenian (see Müller 1984, 1996; also Hyžný *et al.* 2014) and Pleistocene (Karasawa 2000) age.

Chlorodiella juglans Müller, 1984
(Text-fig. 7.1, 7.2)

1984. *Chlorodiella juglans* sp. nov.; Müller, p. 89, pl. 78, figs 5, 6.

2011. *Chlorodiella juglans* Müller, 1984; Ossó and Stalennuy, text-fig. 3.8.

2014. *Chlorodiella juglans* Müller, 1984; Collins, p. 43, pl. 3, fig. 14.

MATERIAL: Ternopil Beds (Upper Badenian): Humentsi – 3 carapaces (MWGUW ZI/79/214, 215); Maksymivka – 1 carapace (MWGUW ZI/79/146).

REMARKS: The collected carapaces are similar to those depicted by Müller (1984) due to the presence of strong teeth on the anterolateral margin and the relatively distinct ornamentation of the carapace.

OCCURRENCE: Badenian of Hungary (Müller 1984), Austria (Collins 2014), and Upper Badenian of Ukraine (Ossó and Stalennuy 2011).

Chlorodiella tetenyensis Müller, 1984
(Text-fig. 7.3)

1984. *Chlorodiella mediterranea tetenyensis* ssp. nov.; Müller, pp. 88, 89, pl. 77, figs 5–7.

1993. *Chlorodiella* cf. *mediterranea tetenyensis* Müller, 1984; Müller, pp. 19, 20, text-fig. 9B.

MATERIAL: Ternopil Beds (Upper Badenian):

Maksymivka – 1 fragment of carapace (MWGUW ZI/79/077).

REMARKS: The collected fragment of carapace shows a relatively distinct ornamentation, similar to that observed in *Chlorodiella tetenyensis*. It is also significantly larger than the corresponding parts of *Ch. juglans*.

OCCURRENCE: Langhian of Catalonia (Müller 1993) and Austria (Collins 2014), Upper Badenian of Hungary (Müller 1984), and Ukraine (Górka and Jasionowski 2006; Radwański *et al.* 2006). It is presumably also present in the Lower Badenian of Poland (Müller 1996).

The closely related species *Ch. mediterranea* (Lörenthey in Lörenthey and Beurlen, 1929) was frequently found in the Badenian reefal or coral-bearing facies of Austria and Hungary (Müller 1984; see also Collins 2014; Hyžný *et al.* 2014) as well as in the Lower Badenian reefal deposits of Poland (Müller 1996; Górka 2002).

Subfamily Xanthinae MacLeay, 1838
Genus *Xantho* Leach, 1816

TYPE SPECIES: *Xantho hydrophilus* (Herbst, 1790).

Xantho moldavicus (Yanakevich, 1977)
(Text-fig. 8.1–8.4)

1969. *Medaeus* sp.; Yanakevich, pp. 26, 27, pl. 1, figs 4–6.

1977. *Medaeus moldavicus* sp. nov.; Yanakevich, pp. 80, 81, pl. 10, fig. 4.

1984. *Xantho moldavicus* (Yanakevich, 1977); Müller, pp. 92, 93, pl. 85, figs 5–8, pl. 86, figs 1–5, pl. 87, fig. 1.

1993. *Xantho* aff. *moldavicus* (Yanakevich, 1977); Müller, p. 20, text-fig. 10E.

1996. *Xantho moldavicus* (Yanakevich, 1977); Müller, pp. 11, 12, pl. 2, fig. 6.

2006. *Xantho moldavicus* (Yanakevich, 1977); Radwański *et al.*, pl. 2, figs 5, 6.

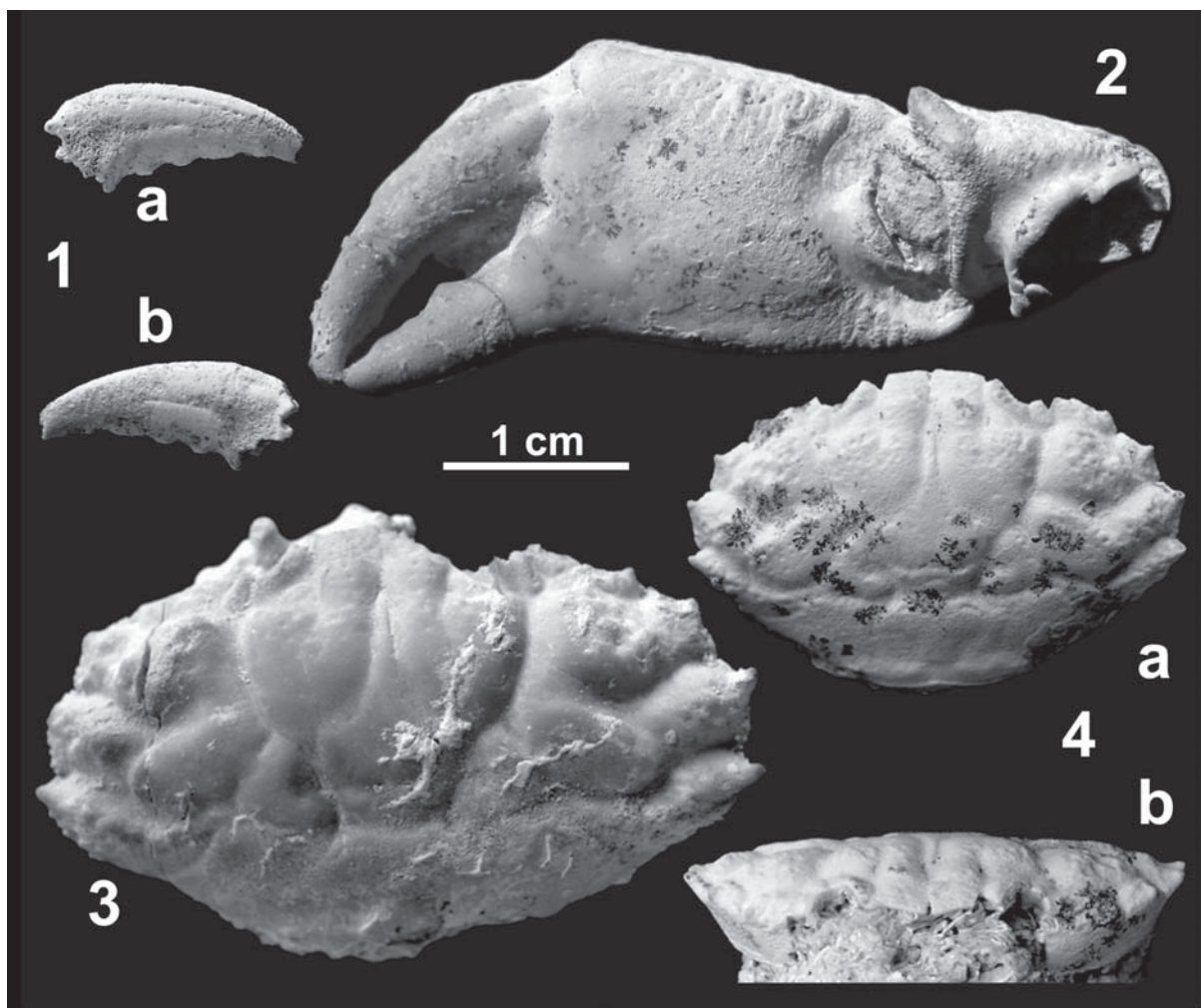
2010. *Xantho moldavicus* (Yanakevich, 1977); Gatt and De Angeli, p. 1339, text-fig. 8G–8.K.

2011. *Xantho moldavicus* (Yanakevich, 1977); Ossó and Stalennuy, text-figs 3.11, 3.12, 9.1, 9.2.

2014. *Xantho moldavicus* (Yanakevich, 1977); Collins, pp. 43, 44, pl. 4, figs 9, 10, 12.

2016. *Xantho moldavicus* (Yanakevich, 1977); Górka in Wysocka *et al.*, text-fig. 14F, G.

2016. *Xantho moldavicus* (Yanakevich, 1977); Hyžný, text-fig. 10M.



Text-fig. 8. *Xantho moldavicus* (Yanakevich, 1977) from the Upper Badenian deposits of western Ukraine. 1 – dactylus, a – outer view, b – inner view (MWGUW ZI/79/002 from Stratyn); 2 – right chela with carpus, inner view (MWGUW ZI/79/160 from Haluschyntsi); 3 – large carapace, dorsal view (MWGUW ZI/79/064 from Maksymivka); 4 – carapace, a – dorsal view, b – frontal view (MWGUW ZI/79/063 from Maksymivka)

MATERIAL: Mykolaiv Beds (Lower Badenian): Hlibovytchi – right dactylus (MWGUW ZI/79/003); Stratyn – 1 right dactylus (MWGUW ZI/79/002). Pidhirtsi Beds (Upper Badenian): Zalistsi (Zhabiak) – 1 dactylus (MWGUW ZI/79/001). Ternopil Beds (Upper Badenian): Demkivtsi – 5 dactyli, 1 fixed finger (MWGUW ZI/79/014); Ditkivtsi – fragment of carapace, right chela, left propodus (MWGUW ZI/79/026, 027, 237); Hai Roztotski – 2 carapaces, 3 fragment of carapace, 1 right chela with carpus, 1 right palm with carpus, 1 left chela with carpus, 1 left propodus with carpus, 1 right chela, 5 propodi, 7 palms, 13 fixed fingers, 20 dactyli, 1 carpus (MWGUW ZI/79/082–093, 096, 097); Haluschyntsi – 1 carapace, 4 fragment of carapace, 1 right chela with

carpus, 1 right propodus with carpus, 1 left propodus with carpus, 1 propodus, 4 palms, 5 fixed fingers, 4 dactyli (MWGUW ZI/79/153–161); Humentsi – 1 carapace, 1 fragment of carapace, 1 right chela, 1 right propodus with carpus, 11 propodi, 1 palm with carpus, 1 palm, 10 fixed fingers, 12 dactyli (MWGUW ZI/79/201–205, 207–210, 218); Komariv – 1 dactylus (MWGUW ZI/79/008); Maksymivka: 13 carapaces, 23 fragments of carapace, 1 right chela with carpus, 3 left chelae with carpi, 7 left propodi with carpi, 5 right propodi with carpi, 2 right chelae, 1 left chela, 20 right propodi, 13 left propodi, 9 carpi, 3 palms, 14 fixed fingers, 15 dactyli (MWGUW ZI/79/063–065, 113–128); Nihyn – 3 fragments of carapace, 1 left chela with carpus, 2 propodi with carpi, 2 propodi, 4 carpi,

1 dactylus (MWGUW ZI/79/034–038); Novosilka – 1 carapace (MWGUW ZI/79/053); Polupanivka: 1 right fixed finger (MWGUW ZI/79/010); Sakhkamin – 1 left propodus, 1 fixed finger (MWGUW ZI/79/042); Verbka – 1 carapace (MWGUW ZI/79/056); Saryi Zbarazh – 2 carapace, 1 fragment of carapace, 1 right propodus with carpus, 1 right chela, 3 left chelae, 3 right propodi, 4 left propodi, 1 palm, 1 carpus, 5 fixed fingers, 11 dactyli (MWGUW ZI/79/171–181, 199); Zakupne – 1 carapace, 1 left propodus with carpus, 1 right propodus (MWGUW ZI/79/021–023).

REMARKS: This is the most widely distributed species in the Badenian of western Ukraine. In the reefal Ternopil Beds its abundant and varied remains are very common. The size of specimens (width of carapace) ranges from approximately 10 mm up to over 60 mm. Fragments of chelipeds – carpi, propodi, chelae or isolated fingers are very abundant and they are usually easily recognisable. In contrast, the other deposits examined (i.e., Mykolaiv and Pidhirtsi Beds) contain only scarce dactyli. In this case, their specific determination may be somewhat doubtful, but they possess typical longitudinal grooves and (when preserved) spooned tips (see Müller 1984).

OCCURRENCE: Frequently recorded in the Lower to Upper Badenian deposits of Poland (Müller 1984, 1996), Austria and Hungary (Müller 1984; Collins 2014; Hyžný 2016), and Ukraine (Górka and Jasionowski 2006; Radwański *et al.* 2006). It is present in the Upper Badenian of Moldova (Yanakevich 1977). In the Mediterranean realm it has been found in the Langhian of Catalonia (Müller 1993), and in the Messinian of Algeria (Moissette and Müller 1990), Malta (Gatt and De Angeli 2010) and Italy (De Angeli *et al.* 2011).

ECO-TAPHONOMIC REMARKS

Studies of the Badenian deposits of western Ukraine show that the decapod-bearing strata may be confined almost exclusively to coralgal reefal lithofacies. The siliciclastic lithofacies of the Mykolaiv and Pidhirtsi Beds bear decapod remains only exceptionally.

The decapod material of the Mykolaiv Beds is evidently allochthonous, similarly to the other fossils occurring there (see Radwański and Wysocka 2001; Wysocka *et al.* 2012; Radwański *et al.* 2014). Decapod remains together with the skeletons of other invertebrates were redeposited from different biotopes and during that transport only their most robust

skeletal elements (i.e., dactyli and fixed fingers) survived (see also Müller 2004).

Numerous remains of decapods were collected in the Upper Badenian coralgal reefs of the Ternopil Beds. They are most common in the coarse detrital shell-grit which infills numerous crevices, holes and fissures in reefal boundstone. They are also abundant in the detrital material within cylindrical channels that were in the past interpreted as systems of burrows attributed to alpheid shrimps (Radwański *et al.* 2006). The skeletons of decapods are strongly disarticulated, the largest non-dismembered elements found being fragments of chelipeds, composed of chela (or propodus) with carpus, occasionally also with the attached merus (see Text-fig. 6.2).

It is noteworthy that one of the most frequent species, *Daira speciosa*, is often represented by mass-occurrences of carapaces that are amassed in the mentioned channels and crevices. Up to five carapaces, often of similar size can be found within a distance of centimetres. What caused this unusual accumulation is still an enigma. Previously, it was supposed either that the origin of such a phenomenon was purely inorganic (i.e., the accumulation of similar-in-size elements due to hydrodynamic conditions; cf. also Müller 2004) or strictly biogenic – the accumulations were considered to be “wardrobes” of moulting crabs or “kitchen middens” of unknown predators (see Górka and Jasionowski 2006; Radwański *et al.* 2006). The latter possibility was discussed by Ossó and Stalennuy (2011) who proposed octopuses as the possible predators. These authors, however, did not record the presence of the specific holes that could be attributed to predating octopuses (see Arnold and Okerlund Arnold 1969; Klompaker *et al.* 2013). In the material investigated for the present study such holes were not found either. This leaves the observed phenomenon invariably puzzling.

PALAEOECOLOGICAL AND BIOGEOGRAPHIC REMARKS

Among the decapod assemblage recorded in the Ternopil Beds there is a large group of taxa whose co-occurrence is characteristic of an environment of shallow water reefal bodies of warm-temperate climate (see Müller 1984, p. 109). These taxa include the genera *Chlorodiella*, *Daira*, *Petrolisthes*, *Galathea* and the species *Dromia neogenica* with the additional presence of the genus *Panopeus*. In the studied material these taxa are accompanied by very abundant *Xantho* and less common *Pilumnus*, both typical

of inhomogenous, partly hard substrates with coarse calcarenites in a temperate climate. Such a decapod assemblage helps to define the sedimentary environment on the Late Badenian sea bottom where the deposition of the Ternopil Beds took place. Coralgal reefs built up in the littoral zone of relatively warm waters with oceanic salinity. The surface of the reefal bodies was a patchwork of a hard bottom of red-algal boundstone and loose shell-grit sediment. Numerous crevices, holes and accumulations of coarser material gave excellent shelter for smaller individuals of decapods (see Müller 2004).

The studied decapod assemblage of the Ternopil Beds is the last occurrence of such a ubiquitous crustacean fauna in the geological history of the Fore-Carpathian Basin comprising the northernmost part of Central Paratethys. Surprisingly, its taxonomic composition is relatively rich, considering its northern location. The decapod assemblage of Medobory Hills shows some affinities with faunas from the Badenian reefs of Austria (see Collins 2014; Hyžný *et al.* 2014) and Hungary (e.g., Müller 1984, 1996), or from the Messinian reefs of Malta (Gatt and De Angeli 2010).

In a similar manner to all these occurrences, some of the taxa recorded in the Ternopil Beds are typical of the Indo-Pacific bioprovince (see Yanakevich 1969; Förster 1979a; Müller 1979b); this phenomenon has also been recorded in numerous groups of other Badenian invertebrates from the Polish part of the Fore-Carpathian Basin (see Bałuk and Radwański 1977, 1979, 1984). This suggests that the main paths of migration of invertebrate faunas were from the Indo-Pacific realm. However, the latest report from Paratethys and the Mediterranean (Hyžný 2016) puts this view in doubt by stating that in the long time-span, the actual direction of migration of decapod faunas was opposite, i.e., towards the south-east (see Hyžný 2016, p. 488).

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