Acta Geologica Polonica, Vol. 60 (2010), No. 2, pp. 257–274

Chitons (Mollusca: Polyplacophora) from the Middle Miocene sandy facies of Ukraine, Central Paratethys

BARBARA STUDENCKA[1] AND ALFRÉD DULAI[2]

[1]*Museum of the Earth, Polish Academy of Sciences, Aleja Na Skarpie 20/26, PL-00-488 Warsaw, Poland. E-mail: bstudencka@go2.pl*
[2]*Department of Palaeontology and Geology, Hungarian Natural History Museum, H-1431 Budapest P.O.B. 137, Hungary. E-mail: dulai@nhmus.hu*

ABSTRACT:

Studencka, B. and Dulai, A. 2010. Chitons (Mollusca: Polyplacophora) from the Middle Miocene sandy facies of Ukraine, Central Paratethys. *Acta Geologica Polonica*, **60** (2), 257–274. Warszawa.

The Late Badenian (=early Serravallian of the Mediterranean) chitons of Ukraine, housed in the Museum of the Earth PAS, Warsaw, are described systematically. Eight species are identified: *Leptochiton cancellatus* (Sowerby, 1840), *Lepidopleurus cajetanus* (Poli, 1791), *Ischnochiton rissoi* (Payraudeau, 1826), *Chiton corallinus* (Risso, 1826), *Chiton olivaceus* Spengler, 1797, *Lepidochitona lepida* (Reuss, 1860), *Acanthochitona faluniensis* (Rochebrune, 1883) and *Craspedochiton profascicularis* (Boettger, 1906). Most of the material comes from Varovtsi, in the Khmelnytskyi region. The predominant faunal element is *Acanthochitona faluniensis*, comprising 55% of all investigated valves.

Key words: Polyplacophora; Badenian; Middle Miocene; Ukraine; Central Paratethys.

INTRODUCTION

The chitons form only a small part of the abundant and diverse Middle Miocene shallow-water molluscan fauna of the Central Paratethys. Most of the hitherto described forms come from the northernmost part of the area: the Polish part of the Carpathian Foredeep Basin (Skoczylasówna 1930; Bałuk 1965, 1971, 1984; Jakubowski and Musiał 1977, 1979; Macioszczyk 1988; Studencka and Studencki 1988). The richest fauna, with 18 chiton species has been reported from the Lower Badenian Korytnica clays (Bałuk 1971, 1984). A well described chiton fauna is known from the Moravian part of the Carpathian Foredeep Basin (Reuss 1860; Procházka 1895; Šulc 1934). Many students of the Paratethyan faunas provided contributions on chitons from particular intra-Carpathian basins of the Central Paratethys. Chitons from the Vienna Basin in Austria were studied by Šulc (1934), Sieber (1953, 1958, 1959) and more recently by Tomašových (1998) and Kroh (2002, 2003). Chitons from the famous localities Lăpugiu [Lapugy] and Coştei [Kostej] in the Banat Basin, Romania, were reported by Boettger (1906), Zilch (1934), Šulc (1934), Studencka and Studencki (1988) and recently by Dell'Angelo *et al*. (2007). Material from the Dacian Basin, Romania was published by Marinescu (1964), Stanku and Andreescu (1968) and Rado and Mutiu (1970). The occurrence of chitons in the Dacian Basin, Bulgaria was reported by Studencka and Studencki (1988). Chitons from the Hungarian part of the Pannonian Basin were briefly mentioned (Csepreghy-Meznerics 1950; Studencka and Studencki 1988) and later described in detail by Dulai (2001, 2005).

In contrast to the Paratethyan faunas mentioned above, the chitons of Ukraine have never been investigated in detail. Besides the paper by Studencka and Studencki (1988, p. 45) providing the list of eight species

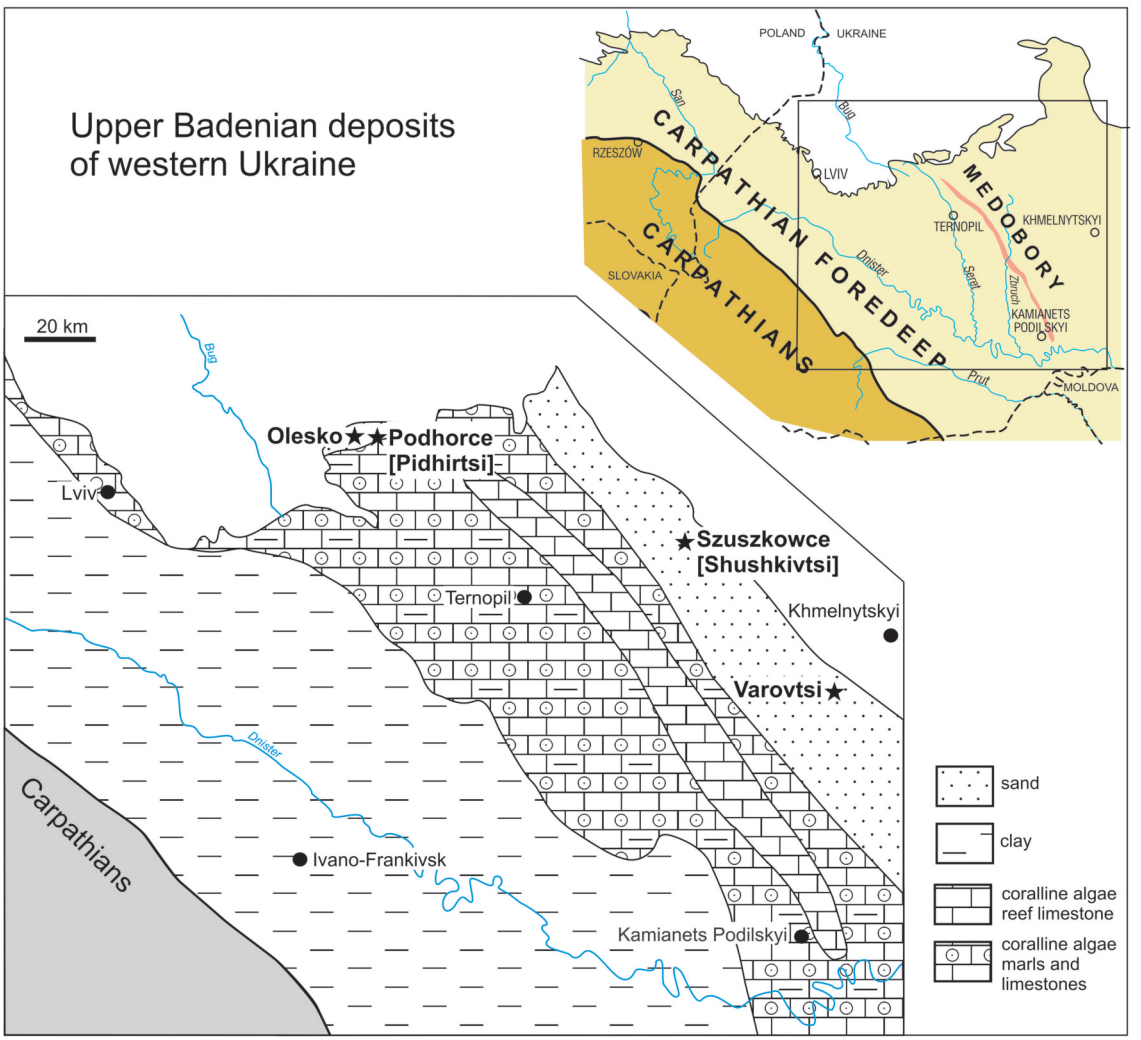
from Varovtsi, there are only sporadic literature records of chitons from Ukraine: *Chiton* sp. was mentioned from Hołubica (Hilber 1882a, p. 287; Łomnicki 1895, p. 117).

The aim of this paper is to present the Late Badenian chitons occurring in sandy facies of the Lviv, Ternopil and Khmelnytskyi regions, Ukraine.

STUDY AREA

The chitons studied come from Upper Badenian deposits representing the last interval with fully marine conditions in the history of the Central Paratethys (~13.6 to 12.7 Ma; see Kováč *et al*. 2007). At that time (age-equivalent of the early Serravallian), a vast territory of the Volhynian-Podolian region in Ukraine, along the SW margin of the East European Platform, was covered by a sea where conditions favoured the growth of coralline algal-vermetid reefs. The reefs formed a distinct belt separating deeper environments of the Carpathian Foredeep Basin with marls and clay deposition from the nearshore facies (Maslov and Utrobin 1958). This belt is clearly visible in the present-day relief in Ukraine, forming a narrow zone more than 150 km long, called the Medobory Hills [Miodobory].

The offshore part of the Volhynian-Podolian area was dominated by deposition of white quartzitic sands and sandstones, now discordantly overlying the pre-Neogene basement (Łomnicki 1895). A comprehensive description of geodynamics, sedimentology and facies development in this area was given by Maslov and Utrobin (1958).



Text-fig. 1. Map of Ukraine showing distribution of the Upper Badenian deposits during the maximum phase of transgression. Asterisks indicate locations of outcrops yielding chiton faunas. Names of the fossiliferous sites are preserved as originally used by Kowalewski in the late 1930s and in the monograph on Polish Miocene gastropods and bivalves by Friedberg (1911-1928, 1934-1936, respectively). The present-day Ukrainian spelling is given in brackets. Modified after Maslov and Utrobin (1958)

The chiton material described in this study was derived from four outcrops along the eastern slopes of the Medobory Hills (Text-fig. 1). They are: Olesko, Podhorce, Szuszkowce and Varovtsi, from which an abundant and diverse molluscan fauna has been known since the late 1830s.

The molluscan fauna from Olesko, Podhorce and Szuszkowce was studied in detail by du Bois de Montpéreux (1831), Eichwald (1853), Hilber (1882a, 1882b), Niedźwiedzki (1889), Łomnicki (1895), Friedberg (1911-1928; 1934-1936), Kazakova (1952), and more recently by Nevesskaja *et al.* (1993). Although an abundant molluscan fauna was known at Varovtsi [former Varovtsy], studies of this locality were focused on stratigraphic problems (Laskarew 1914) and only a few bivalve species were included by Nevesskaja *et al.* (1993) in their monograph on Paratethyan Miocene bivalves. Only lists of bivalves and chitons from this fossiliferous locality were published (Studencka *et al*. 1998; Studencka and Studencki 1988, respectively).

All the chitons studied come from fine-grained white unstratified quartz sands reaching 10–20 m in thickness, distinguished as the Tarnopol Beds by Maslov and Utrobin (1958), or as the Podhortse Beds by Muratov and Nevesskaja (1986), spelt Podgirtsi Beds by Andreyeva-Grigorovich *et al*. (1997). The Late Badenian age of this unit was determined by means of benthic foraminifera (Pishvanova 1970 *fide* Muratov and Neveskaja 1986). The age of sands cropping out at Biała Góra near Olesko was additionally determined on the basis of strontium isotope ratios in the bivalve shells (Král *et al*. 2000). Values for $^{87}Sr/^{86}Sr$ ratios range from 0.708809 to 0.708813. The samples give a calculated age of 13.6 Ma +/–0.4 m.y. (Late Badenian).

MATERIAL

This study is based on the material housed in the Museum of the Earth, Polish Academy of Sciences, Warsaw. An extensive molluscan collection was accumulated by Dr. Kazimierz Kowalewski during numerous exploratory field trips in the Volhynian–Podolian region in the late 1930s, sponsored by the Society of the Museum of the Earth (Passendorfer 1938). Among the very diverse and abundant bivalve and gastropod material collected from twenty-five localities, chiton skeletal remains appear to be extremely rare. Only nine valves were found: one intermediate valve of *Acanthochitona faluniensis* at Biała Góra near Olesko, one tail valve of *Lepidopleurus cajetanus* and one intermediate valve of *Lepidochitona lepida* at Podhorce, one head and three tail valves of *Lepidopleurus cajetanus*, one intermediate valve of *Acanthochitona faluniensis* and one head valve of *Acanthochitona* sp. at Szuszkowce.

The richest chiton assemblage was collected by B. Studencka and W. Studencki during the joint Polish-Soviet palaeontological expedition to the West Ukraine, organized in 1988 by the Palaeontological Institute, Academy of Sciences of the USSR, Moscow. Chitons (92 valves) form only a subordinate component of the rich molluscan material collected during the expedition and were found in only one of six fossiliferous localities, i.e. in Varovtsi. The specimens of *Acanthochitona faluniensis* were picked manually. Considerable amounts of bulk sediment were sieved (mesh size 0.5 mm) during the field work and almost 15 kg sieved material was later examined under a binocular microscope.

The material comes from the basal part of the Upper Badenian–Lower Sarmatian sequence cropping out along the right bank of the river Smotrych near the village of Varovtsi, 20 km west of Khmelnytskyi. The most common species in this assemblage is *Acanthochitona faluniensis* (60% of the 92 valves), *Chiton olivaceus* and *Lepidochitona lepida* are relatively common (15% and 12%, respectively) while *Leptochiton cancellatus*, *Ischnochiton rissoi*, *Chiton corallinus* and *Craspedochiton profascicularis* are very rare.

The specimens documented herein are deposited in the Museum of the Earth (abbr. MZ), Warsaw, under the inventory numbers MZ VIII Ma 111 to Ma 122.

SYSTEMATIC ACCOUNT

During the last decade the suprageneric systematics of chitons have been largely modified by Dell'Angelo and Smriglio (1999) and by Sirenko (2006). Here we follow the systematic system proposed by Sirenko (2006), who considered *Lepidopleurus* Risso, 1826 and *Leptochiton* Gray, 1847 to be distinct genera, based on the thickness of the valves and the type of sculpture. Solid valves with a heavily sculptured tegmentum and strong concentric ridges are diagnostic of the genus *Lepidopleurus* whereas thin valves with a finely granulated tegmentum and equal-sized granules are characteristic of *Leptochiton*.

Since detailed descriptions of all these chiton species recognised in the Ukrainian material were already presented from the Central Paratethys (e.g. Bałuk 1971, 1984, Macioszczyk 1988; Studencka and Studencki 1988; Dulai 2001, 2005 and Dell'Angelo *et al*. 2007) only a short synonymy, some comments and stratigraphic ranges are given below. The geographic range and habitat of present-day species were described by Malatesta (1962), Kaas and van Belle (1981), Poppe and Goto (1991) and Dell'Angelo and Smriglio (1999).

Class Polyplacophora Gray, 1821
Subclass Loricata Schumacher, 1817
Order Lepidopleurida Thiele, 1910
Suborder Lepidopleurina Thiele, 1910
Family Leptochitonidae Dall, 1889
Genus *Leptochiton* Gray, 1847

TYPE SPECIES: *Chiton cinereus* Montagu, 1803 [= *Chiton asellus* Gmelin, 1791] by subsequent designation by Gray, 1847 [non *Chiton cinereus* Linnaeus, 1767]

Leptochiton cancellatus (Sowerby, 1840)
(Text-fig. 2 A-D)

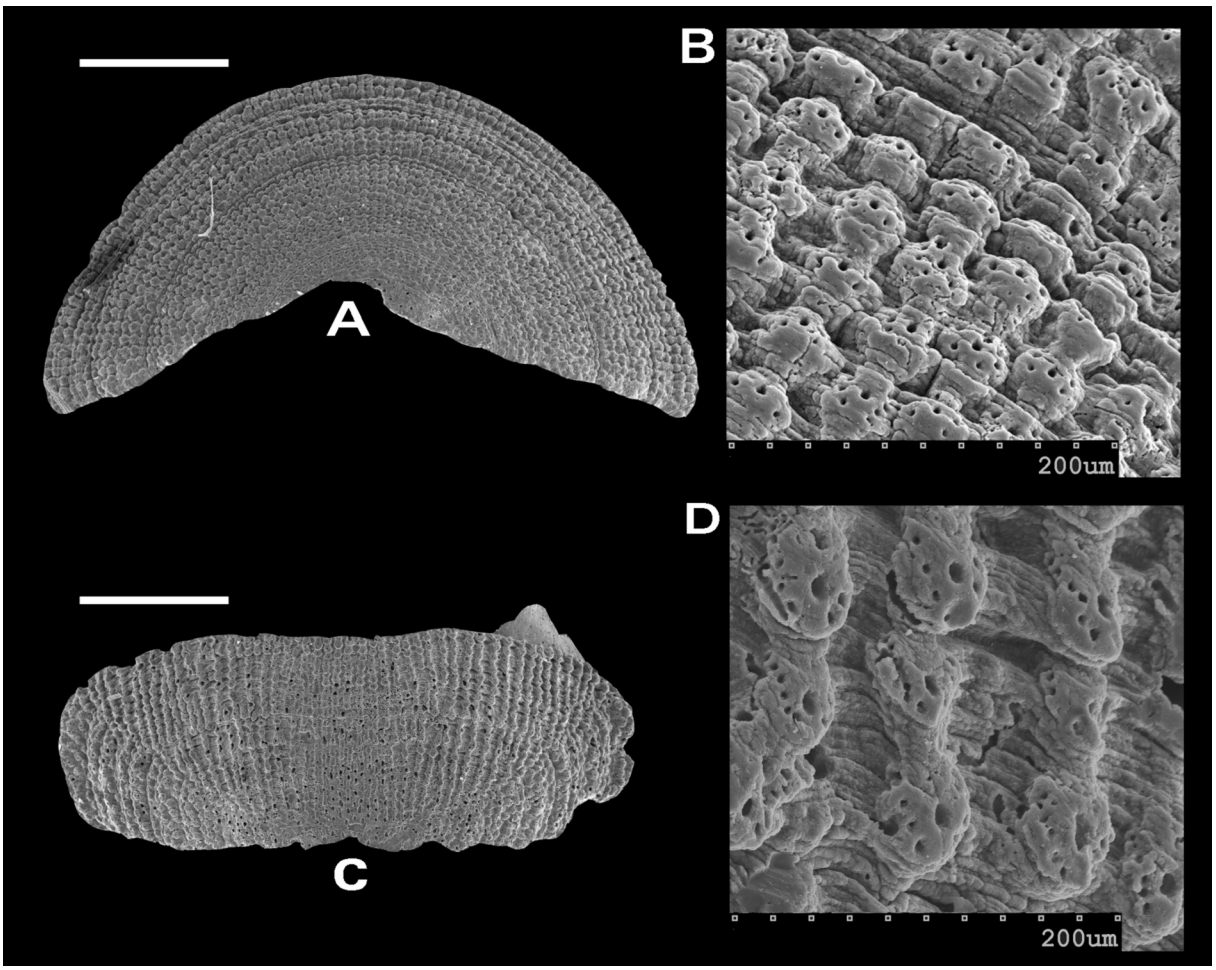
1988. *Leptochiton cancellatus* (Sowerby); W. Macioszczyk, pp. 51–52, pl. 1, figs 6, 7a and 7b.
2001. *Lepidopleurus* (*Leptochiton*) *cancellatus* (Sowerby); B. Dell'Angelo, M. Forli and C. Lombardi, pp. 146–147, fig. 5.
2004. *Lepidopleurus cancellatus* (Sowerby); C. Chirli, pp. 5–6, pl. 1, figs 16–18, pl. 2, figs 1–2.

MATERIAL: 1 head and 1 intermediate valve from Varovtsi.

Dimensions (in mm):

	L	W
Head valve, MZ VIII Ma-111/1	2.3	4.4
Intermediate valve, MZ VIII Ma-111/2	1.7	3.8

COMMENTS: The head valve is nearly semicircular, with a wide inverted V-shaped posterior margin, and sculptured with 75 radially arranged granulated rows, which are very closely and regularly spaced (Text-fig.



Text-fig. 2. *Leptochiton cancellatus* (Sowerby, 1840). A – Head valve, Varovtsi (MZ VIII Ma-111/1); B – Fragment of the same specimen, to show the granules of the radial ribs and arrangement of asteathetes; C – Intermediate valve, Varovtsi (MZ VIII Ma-111/2); D – Close-up of central area of intermediate valve with characteristic cluster of macro- and microasteathetes. Scale bars 1 mm in figs A and C

2A). The pattern of the macroaesthete and the series of microaesthetes can be seen in Text-fig. 2B. The rectangular intermediate valve is twice as wide as long, with an almost straight non-carinated, regularly arched posterior margin. Its central area is sculptured with 48 longitudinal striae of united granules. Each granule has the macroaesthete in the centre and six microaesthetes forming two series on the lateral sides (Text-fig. 2D, and Dell'Angelo and Smriglio 1999, pl. 11, fig. L).

The ornamentation and outline of the intermediate valve from Varovtsi are very similar to those of the specimens reported from the Pliocene of Tuscany, Italy (Dell'Angelo *et al*. 2001, fig. 5; Chirli 2004, pl. 1, figs 16–17 and pl. 2, fig. 2); the only difference is in the presence of some bifurcating granule series in the central area.

The specimens under study were reported by Studencka and Studencki (1988, p. 45) as *Leptochiton* (*L*.) *sulci* (Bałuk, 1971), a very closely allied species described from the Middle Miocene (Early Badenian) Paratethys Sea, seemingly restricted to that province. The species *L. sulci*, interpreted by Bałuk (1971, pp. 455–456) as an ancestral form of the present-day species *L. cancellatus*, was considered by Laghi (1977, p. 98) to be conspecific with *L. cancellatus*. Perhaps Laghi's opinion had an influence on subsequent papers by Dell'Angelo and Palazzi (1989), Dell'Angelo and Smriglio (1999) and Dell'Angelo and da Silva (2003), who interpreted *L. sulci* as a junior synonym of *L. cancellatus* but this opinion has not been supported by any evidence.

The species *L. sulci* differs clearly from *L. cancellatus* in having a different number and arrangement of the microaesthetes as well as different tegmentum ornamentation of the intermediate valves. The central area of the intermediate valve of *L. sulci* is sculptured with 60–70 ribs ornamented with more or less circular granules (each with 2–3 microaesthetes) greater than on *L. cancellatus.* Granules of neighbouring ribs display a regular quincuncial pattern (see Bałuk 1984, pl. 2, fig. 2; pl. 3, figs 1–2).

The pattern and number of striae covering the intermediate valves of the investigated Ukrainian specimens are similar to those of *L. srameki* (Šulc 1934) but the different outline of the intermediate valves in anterior view distinguishes the two species. The intermediate valve is regularly arched in *L. cancellatus* whereas it has a conspicuously carinated jugal area and flattened lateral areas in *L. srameki*.

STRATIGRAPHIC RANGE: Middle Miocene: Late Badenian (Macioszczyk 1988)–Recent (Kaas 1981). The species *L. cancellatus* was reported from the Polish part of the Carpathian Foredeep Basin (Macioszczyk 1988). Its occurrence in two Middle Miocene localities *i.e.* Steinabrunn in the Vienna Basin and in Montegibbo in Italy was only presumed (Šulc 1934, pp. 6–7; Sieber 1959, p. 274 and Chirli 2004, p. 6, respectively). Its occurrence in the Mediterranean has been documented in the Pliocene of Italy: Tuscany (Dell'Angelo *et al*. 2001; Chirli 2004), northern Apennines and Sicily (Laghi 1977). Recently, it was recorded from both the European and North American coasts of the Atlantic as well as in the Mediterranean (Poppe and Goto 1991). Along the Italian coast it is mainly found in detritus of the coralligenous biocenosis (Dell'Angelo and Smriglio 1999).

Genus *Lepidopleurus* Risso, 1826

TYPE SPECIES: *Chiton cajetanus* Poli, 1791 by subsequent designation by Herrmannsen, 1846

Lepidopleurus cajetanus (Poli, 1791)
(Text-fig. 3 A–G)

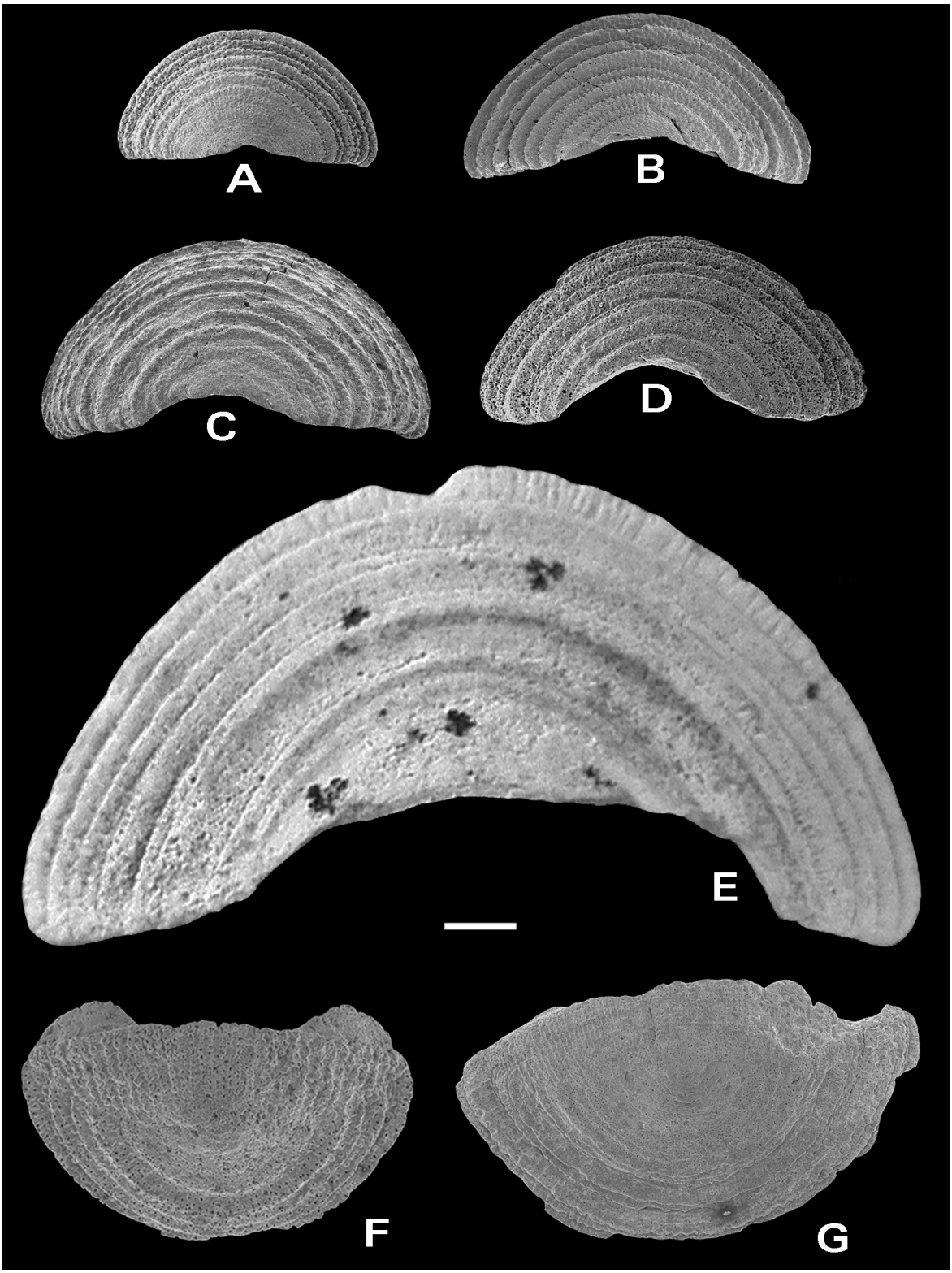
1860. *Chiton decoratus* m.n.sp.; A. E. Reuss, p. 257, pl. 8, fig. 7.
1897. *Middendorffia subcajetana* (d'Orb.); F. Sacco, p. 90, pl. 7, figs 21–25.
1999. *Lepidopleurus* (*Lepidopleurus*) *cajetanus* (Poli); B. Dell'Angelo and C. Smriglio, pp. 38–40, pls 6–7 (*cum syn*.)
2005. *Lepidopleurus* (*Lepidopleurus*) *cajetanus* (Poli); A. Dulai, pp. 30–33, pl. 1, figs 1–10; pl. 2, figs 1–6 (*cum syn*.)

MATERIAL: 1 tail valve from Podhorce, 1 head and 3 tail valves from Szuszkowce.

Dimensions (in mm):

	L	W
Head valve, MZ VIII Ma-122/1	6.3	12.5
Tail valve, MZ VIII Ma-122/2	4.8	8.4
Tail valve, MZ VIII Ma-122/3	2.2	3.6
Fragmentary tail valve, MZ VIII Ma-119/1	3.7	(4.4)

COMMENTS: Successive ontogenetic stages of this species have been described under two specific names: small individuals as *cajetanus*, and the largest specimens as *subcajetanus*. The tail valves (width from 5 to 15 mm) found in the Burdigalian of Sciolze, Italy were as-



Text-fig. 3. *Lepidopleurus cajetanus* (Poli, 1791). A – Head valve, Węglin, Late Badenian, Roztocze Hills, Poland (specimen kept at the Naturalis Museum, Leiden); B and C – Head valve, Bánd, Early Badenian, Bakony Mountains, Hungary (Hungarian Natural History Museum, Budapest); D – Head valve, Lapugiu, Early Badenian, Banat Basin, Romania, (Naturalis Museum, Leiden); E – Head valve, Szuszkowce (MZ VIII Ma-122/1); F – tail valve, Szuszkowce (MZ VIII Ma-122/2) and G – Tail valve, Szuszkowce (MZ VIII Ma-122/3). Scale bar 1 mm

signed by Sacco (1897, p. 90, pl. 7, figs 21–25) to *Middendorffia subcajetana* (d'Orbigny, 1852). Šulc (1934, pp. 3–4) was the first to note that the tail valve (width of 18 mm) from the Middle Miocene of Pötzleinsdorf, Austria and those illustrated by Sacco represent a very large form of *Lepidopleurus decoratus* (Reuss, 1860), and the name *Chiton subcajetanus* d'Orbigny, 1852 was recognised to be a *nomem nudum*. In the opinion of Šulc, especially large specimens are known from sandy facies at Pötzleinsdorf (almost 75 % of all investigated specimens) and Speising in Austria, Coştei [Kostej] in Romania, Perpignan in France as well as in the north Italian localities. It is noticeable that Šulc (1934), who examined Sacco's material, generally adopted his opinion and regarded *Lepidopleurus virgifer* (Sandberger, 1859), *L. decoratus* (Reuss, 1860) and *L. cajetanus* (Poli, 1791) as different, albeit closely allied, species.

In contrast to the statement of Šulc (1934), Laghi (1977, p. 99), who examined Sacco's material, considered *Middendorffia subcajetana* Sacco, 1897 to be a valid species while he recognised *Chiton decoratus* Reuss, 1860 as a junior synonym of *Chiton cajetanus* Poli, 1791. In addition, Laghi was of the opinion that Sacco's species is closely allied to Poli's species, which differs from the former only in its size: the tail valve of *L. subcajetanus* reaches a width of up to 18 mm, whereas the largest *L. cajetanus*, both fossil and extant, reach a maximum width of around 8 mm. However, recent representatives of *L. cajetanus* can also attain a large size. Malatesta (1962, p. 146) and Poppe and Goto (1991, p. 55) mentioned specimens with a total length of 30 mm and Dell'Angelo and Smriglio (1999, pp. 38–40) also reported a maximum length of 30 mm, with an average of 15–20 mm.

Until now, Sacco's name *subcajetanus* refers only to the tail valves recorded in both the Mediterranean and Paratethyan Miocene provinces. Its occurrence in the Early Miocene of the Mediterranean is supported only by records from the Burdigalian at Sciolze, Italy (Sacco 1897, pl. 7, figs 21–25; Laghi 1977, pl. 1, fig. 21, and Ferrero Mortara *et al*. 1984, pl. 55, fig. 6). On the other hand, its occurrence in the Middle Miocene Paratethyan fauna has been confirmed only by Kroh (2003, pl. 2, fig. 1), who illustrated one heavily abraded tail valve from the Early Badenian at Niederleis, Austria. Finally, Laghi (1977, p. 99) considered that the tail valve (width of 12 mm) from Salies-de-Béarn, in the Aquitanian Basin, France, described by Cossmann and Peyrot (1917, pp. 32–33, pl. 2, figs 21–22) as *Chiton miocaenicus* Michelotti also belongs to *subcajetanus*.

Having investigated numerous head valves from Hungarian, Romanian and Polish Middle Miocene localities, the present authors regard the opinion of Šulc (1934) as the most convincing. The shape and ornamentation of the head valve from Szuszkowce (Text-fig. 3E: width 12.5 mm) are the same as those from other Paratethyan localities, the difference being only in dimensions (Text-fig. 3 A–D).

The shape of the valves of *L. cajetanus* changes with size. The head valve is semicircular, with an almost straight posterior margin (other species are generally characterized by upside-down V-shape) (Text-fig. 3 E). The number of concentric folds on the head valve, on the lateral areas and on the postmucronal area also varies according to the size of the specimens (Dell'Angelo and Smriglio 1999). The central areas of the intermediate valves and antemucronal area of the tail valve are sculptured with 36–40 or 40–50 prominent longitudinal cords (Text-figs 3 F–G; Dell'Angelo and Smriglio 1999, pl. 6, figs B and E, respectively), transversely intersected by thinner cords. There are branching or anastomosing longitudinal chains of granules in the central and antemucronal areas (Text-fig. 3F). Similar features have been observed on specimens from Lăpugiu by Dell'Angelo *et al*. (2007, fig. 4a).

The great variability of tail valves was already recognized by Šulc (1934). Through the kindness of Professor Wacław Bałuk it was possible for the authors to study tail valves of *L. cajetanus* from the Late Badenian fauna at Kamienica Nawojowska near Nowy Sącz, Poland. They are semicircular, with a prominent mucro which is almost central in juvenile specimens but moves backward (even to the end of the valve) as individuals grew older. The outline is more triangular in adult specimens. This variability was also observed by Dulai (2005) in the material from the Lower Badenian coral-bearing clays at Báand, Hungary. A sharply-pointed, backward-directed mucro can be seen in the posterior third of large tail valves (Dulai 2005, pl. 2, fig. 2). Thus, the shape and convexity of the tail valve as well as the position of the mucro appear sufficient to distinguish *L. cajetanus* from *L. virgifer.* In the latter, typical Oligocene species, the central area of the tail valve is very low and bears finer ornamentation than in *L. cajetanus*. Moreover, the mucro is shifted anteriorly to one-third of the valve length in *L. virgifer* (Janssen 1978, pp. 218–219, pl. 14, figs 8–9) whereas it is centrally located or shifted posteriorly in *L. cajetanus* (*see* Laghi 1977, p. 95, fig. 3 and Ferrero Mortara *et al*. 1984, pl. 55, fig. 6). Therefore, in the opinion of the present authors, there is no evidence to support Dell'Angelo and Palazzi's (1989) assertion, repeated by Dell'Angelo and Smriglio (1999), that the large specimens in both Šulc's and Sacco's material, determined by Šulc (1934) as *L. decoratus*, represent *L. virgifer*.

STRATIGRAPHIC RANGE: Early Miocene: Burdigalian (Ferrero Mortara *et al*. 1984)–Recent (Dell'Angelo and Smriglio 1999). According to Studencka and Studencki (1988, tables 2 and 3), *L. cajetanus* is one of the most common species in both the Early and Late Badenian chiton faunas of the Middle Miocene Paratethys. Together with *Chiton corallinus* (Risso), it is the commonest species in the Early Badenian assemblage at Korytnica (253 valves collected by Bałuk 1984). As reported by Dulai (2005), the most common species in the Early Badenian assemblage at Bánd (Pannonian Basin, Hungary) is *L. cajetanus* (63% of the 153 valves). It is also known from the Early Miocene (Italy: Sacco 1897), Pliocene (Spain: Malatesta 1962, and Italy: Laghi 1977) and Pleistocene (Italy: Laghi 1977, and Greece: Garilli *et al*. 2005) of the Mediterranean Province.

Order Chitonida Thiele, 1910
Suborder Chitonina Thiele, 1910
Superfamily Chitonoidea Rafinesque, 1815
Family Ischnochitonidae Dall, 1889

Subfamily Ischnochitoninae Dall, 1889
Genus *Ischnochiton* Gray, 1847

TYPE SPECIES: *Chiton textilis* Gray, 1828 by original designation

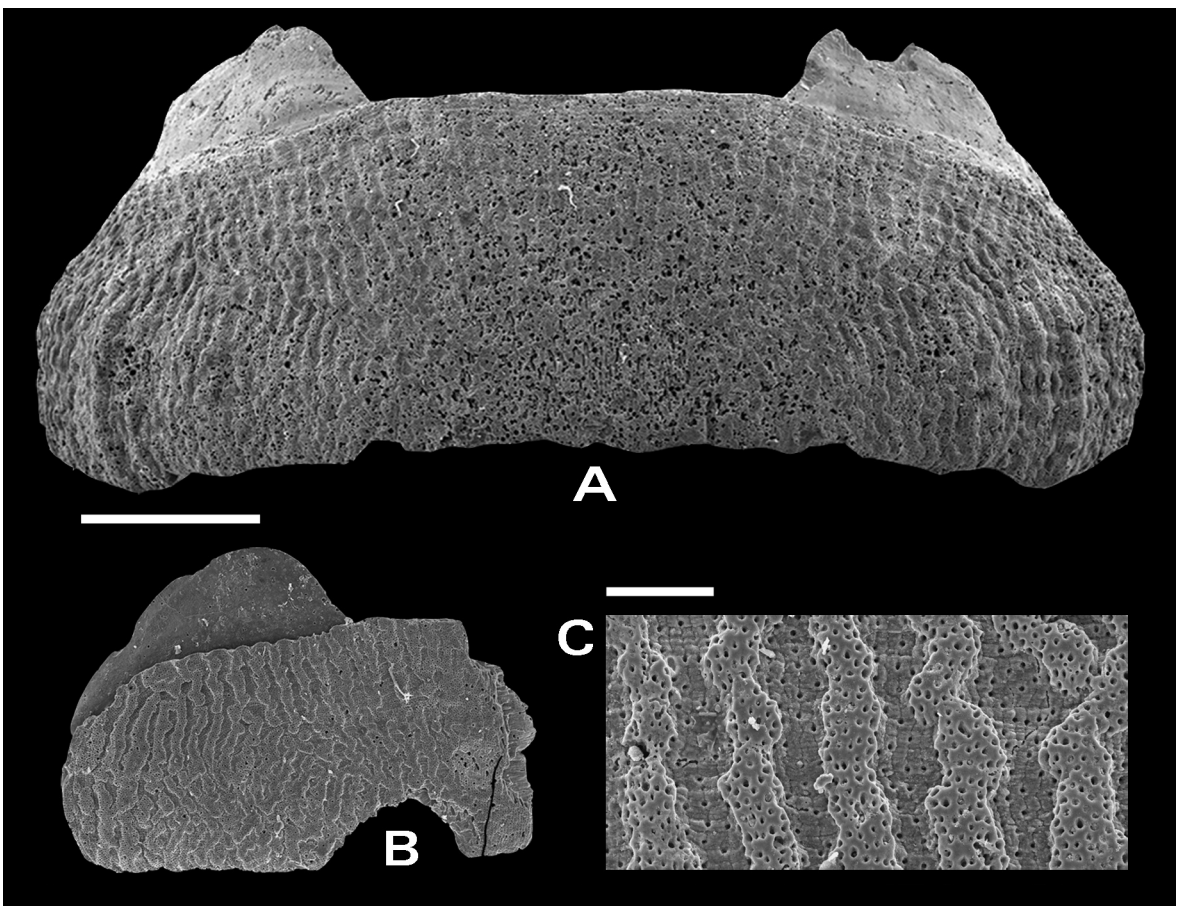
Ischnochiton rissoi (Payraudeau, 1826)
(Text-fig. 4 A-C)

1934. *Ischnochiton rudolticensis* n. sp.; J. Šulc, pp. 23–24, pl. 2, figs 41–43.
1999. *Ischnochiton* (*Ischnochiton*) *rissoi* (Payraudeau); B. Dell'Angelo and C. Smriglio, pp. 100–102, pls 29–31 (*cum syn*.)

MATERIAL: 8 intermediate valves from Varovtsi.

Dimensions (in mm):

	L	W
Intermediate valve, MZ VIII Ma-113/1	2.7	6.2



Text-fig. 4. *Ischnochiton rissoi* (Payraudeau, 1826). A – Intermediate valve, Varovtsi (MZ VIII Ma-113/1); B – Intermediate valve, Varovtsi (MZ VIII Ma-112); C – Fragment of the same specimen, to show details of lateral area ornamentation. Scale bars 1 mm in figs A and B; 100 μm in fig C

Intermediate valve, MZ VIII Ma-113/2	2.6	5.8
Fragmentary intermediate valve, MZ VIII Ma-112	1.9	(2.7)

COMMENTS: The specimens from Varovtsi are entirely consistent with the descriptions and illustrations referred to in the synonymy. Intermediate valves are rectangular, with a slightly convex anterior margin and a straight posterior margin without an apex. Lateral sides are straight, the corners obliquely truncated and the lateral areas moderately elevated. The tegmentum of the lateral areas is ornamented by concentric vermicular ribs, sometimes intersected by fine radial furrows (which give a granulose appearance). The ribs on the central areas of the intermediate valves are longitudinal. Ribs in the jugal area are thinner and closely spaced. Apophyses are rounded, asymmetrical and trapezoidal.

The Ukrainian material conforms well to the illustration of *I. rissoi* from the Early Pliocene of Estepona, Spain given by Dell'Angelo *et al*. (2004, pl. 4, fig. 3). It is also indistinguishable from the valve illustrated from Korytnica by Bałuk (1971, pl. 3, fig. 6) while the other one found in Korytnica (1971, pl. 3, fig. 7) is much more rectangular and the separation of lateral and central areas is more distinct. Also the fragmentary intermediate valve from the Pliocene of Serre di Rapolano in Tuscany, Italy illustrated by Dell'Angelo *et al*. (2001, p. 151, fig. 20) shows some difference in ornamentation: radial ribbing is stronger than concentric ribbing in the lateral areas and the ribs on the central area bifurcate. On the other hand, strong concentric ornamentation dominates in the lateral areas and the ribs in the central area are undulated but not bifurcated in the specimens from Varovtsi.

Examination of the type of *Ischnochiton korytnicensis* Bałuk, 1971 has shown, however, that the fragmentary intermediate valve from Varovtsi listed by Studencka and Studencki (1988, p. 45) as *I.* cf. *korytnicensis* represents *I. rissoi.*

STRATIGRAPHIC RANGE: Middle Miocene: Early Badenian (Šulc 1934)–Recent (Dell'Angelo and Smriglio 1999). The species *Ischnochiton rissoi* (in older literature under the name *I. rudolticensis*) is known from the Middle Miocene (Badenian) of the whole Central Paratethys (see Dulai 2005). It was reported from the Late Miocene (Tortonian and Messinian of Italy: Laghi 1977 and Chirli 2004, respectively), Pliocene (Spain: Dell'Angelo *et al*. 2004, and Italy: Chirli 2004) and Pleistocene (Italy: Dell'Angelo *et al*. 2001, and Greece: Garilli *et al.* 2005) of the Mediterranean. The present-day *I. rissoi* is very common in the Mediterranean Sea, having very variable size and ornamentation. Therefore, Poppe and Goto (1991) distinguished four different forms of this species: form *carinata* (Issel, 1870), form *fragilis* (Monterosato, 1878), form *dautzenbergi* (Ancey, 1898) and form *meneghinii* (Capellini, 1859).

Family Chitonidae Rafinesque, 1815
Subfamily Chitoninae Rafinesque, 1815
Genus *Chiton* Linnaeus, 1758

TYPE SPECIES: *Chiton tuberculatus* Linnaeus, 1758, by monotypy

Chiton corallinus (Risso, 1826)

1999. *Chiton* (*Rhyssoplax*) *corallinus* (Risso); B. Dell'Angelo and C. Smriglio, pp. 174–178, pls 58–59 (*cum syn*.)
2005. *Chiton corallinus* (Risso); A. Dulai, pp. 36–38, pl. 4, figs 1–4 (*cum syn*.)

MATERIAL: Fragment of intermediate valve from Varovtsi.

Dimensions (in mm):

	L	W
Fragmentary intermediate valve, MZ VIII Ma-115	1.1	(1.8)

COMMENTS: The intermediate valve of *Ch. corallinus*, with elevated lateral areas neatly separated from the central area by a conspicuous step, is generally rectangular and carinate. Its anterior margin is convex, the lateral margins are straight and the posterior margin shows a small apex. The outline of the studied specimen – pentagonal with a large apex – is similar to that of the specimens from the Pliocene of Melograni and Colle val d'Elsa in Tuscany, Italy (Chirli 2004, pl. 4, figs 17–18, and pl. 5, fig. 1) as well as in those from Kyllini, Pleistocene of Peloponnese, Greece (Garilli *et al*. 2005, pl. 4, fig. 6).

STRATIGRAPHIC RANGE: Middle Miocene: Early Badenian (Bałuk 1984)–Recent (Dell'Angelo and Smriglio 1999). Fossil records of *Chiton corallinus* are known from all Neogene European bioprovinces. It is one of the commonest chitons in both the Early and Late Badenian Paratethyan faunas (Studencka and Studencki 1988, tables 2 and 3). It was also reported from the Pliocene of both the Mediterranean (Italy: Sacco 1897; Laghi 1977; Ferrero Mortara *et al*. 1984; Dell'Angelo *et al*. 2001) and the Atlantic provinces (Portugal: Dell'Angelo and da Silva 2003), and from the Pleis-

tocene of the Mediterranean (Italy: Malatesta 1962, Peloponnese, Greece: Garilli *et al*. 2005).

Chiton olivaceus Spengler, 1797
(Text-fig. 5 A–B)

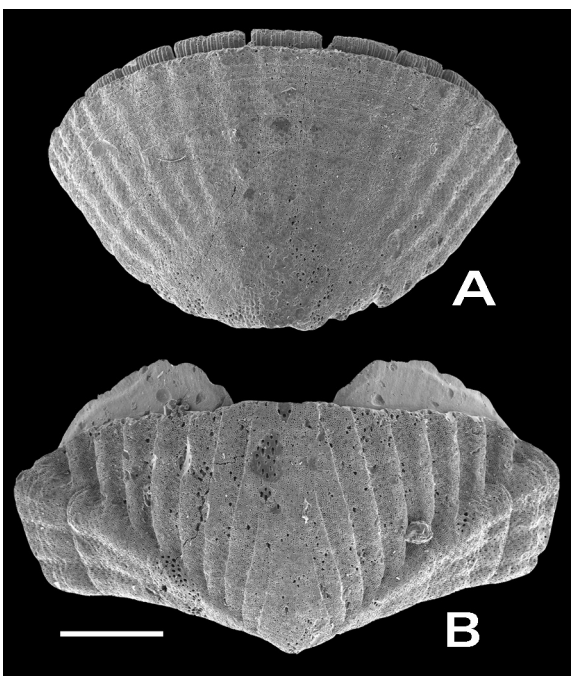
1999. *Chiton* (*Rhyssoplax*) *olivaceus* Spengler; B. Dell'Angelo and C. Smriglio, pp. 169–173, pls 56–57 (*cum syn*.)
2005. *Chiton* (*Rhyssoplax*) *olivaceus* Spengler; A. Dulai, pp. 38–39, pl. 3, figs 6–8 (*cum syn*.)

MATERIAL: 2 head and 11 intermediate valves from Varovtsi.

Dimensions (in mm):

	L	W
Head valve, MZ VIII Ma-116/1	2.9	4.5
Intermediate valve, MZ VIII Ma-116/2	4.0	7.4
Intermediate valve, MZ VIII Ma-116/3	2.9	5.3

COMMENTS: The head valve is semicircular, with a straight posterior margin. This species is easily recognizable by its characteristic ornamentation of rather thick but very variable radial grooves on terminal valves and lateral areas, and of longitudinal grooves on pleural areas: 30–40 grooves on the head valve, 3–6 on the lateral areas of intermediate valves and 25–35 on the postmucronal area of the tail valve.



Text-fig. 5. *Chiton olivaceus* Spengler, 1797. A – Head valve, Varovtsi (MZ VIII Ma-116/1); B – Intermediate valve, Varovtsi (MZ VIII Ma-116/3). Scale bar 1 mm

According to Dell'Angelo and Smriglio (1999, pl. 56, fig. E, pl. 57, fig. L), the intermediate valves of *Ch. olivaceus* are generally rectangular, carinate, with more or less straight anterior and posterior margins, and a not very prominent apex. The specimens from Varovtsi are pentagonal, with a clearly visible high apex. The same valve outline and number and position of the ribs on the central area as observed on the Ukrainian valves are also conspicuous on specimens from Lăpugiu in Romania (Dell'Angelo *et al*. 2007, figs 4d–f), Montegibbio and Montenero in Italy (Laghi 1977, pl. 2, figs 6 and 13 and Dell'Angelo *et al*. 2001, fig. 28, respectively), Kyllini in Greece (Garilli *et al*. 2005, pl. 4, figs 1–2) and those from Lautraki in Greece (Dell'Angelo and Vardala-Theodorou 2006, figs on pp. 328–329). According to Dell'Angelo and Vardala-Theodorou (2006) the longitudinal grooves are convergent towards the jugum in many intermediate valves, a feature that can also be found in the studied material (Text-fig. 5B). The lateral areas are neatly separated from the central area.

STRATIGRAPHIC RANGE: Middle Miocene: Early Badenian (Bałuk 1984)–Recent (Dell'Angelo and Smriglio 1999). This is the most common and best known chiton species living in the Mediterranean Sea; it is adapted to a wide range of ecological requirements, reflected in very variable ornamentation. *Chiton olivaceus* is also common in the fossil record of both the Paratethyan and Mediterranean provinces. It was described from the Carpathian Foredeep Basin in both the Moravian (Šulc 1934) and Polish parts (Bałuk 1971, 1984; Macioszczyk 1988; Studencka and Studencki 1988). Its occurrence is also known from the Vienna Basin, Austria (Reuss 1860; Šulc 1934; Sieber 1953, 1959), from the Pannonian Basin, Hungary (Dulai 2005) and the Dacian Basin, Romania (Marinescu 1964). In the Mediterranean region *Chiton olivaceus* has been reported from the Miocene (Burdigalian, Tortonian and Messinian of Italy: Sacco 1897; Laghi 1977; Dell'Angelo *et al*. 1999, respectively), Pliocene (Italy: Laghi 1977) and Pleistocene as well (Spain and Italy: Malatesta 1962, and Greece: Garilli *et al*. 2005, Dell'Angelo and Vardala-Theodorou 2006). It was also found in the Pliocene of Normandy, France (Malatesta 1962).

Suborder Acanthochitonina Bergenhayn, 1930
Superfamily Mopalioidea Dall, 1889

Family Tonicellidae Simroth, 1894
Subfamily Tonicellinae Simroth, 1894
Genus *Lepidochitona* Gray, 1821

TYPE SPECIES: *Chiton marginatus* Pennant, 1777 [= *Chiton cinereus* Linnaeus, 1767] by monotypy

Lepidochitona lepida (Reuss, 1860)
(Text-fig. 6 A–B)

1988. *Lepidochitona* (*Lepidochitona*) *lepida* (Reuss); B. Studencka and W. Studencki, pp. 39–40, pl. 2, figs 1 and 3 (*cum syn*.)
2001. *Lepidochitona lepida* (Reuss); A. Dulai, pp. 41–43, pl. 1, figs 1–6 (*cum syn*.)

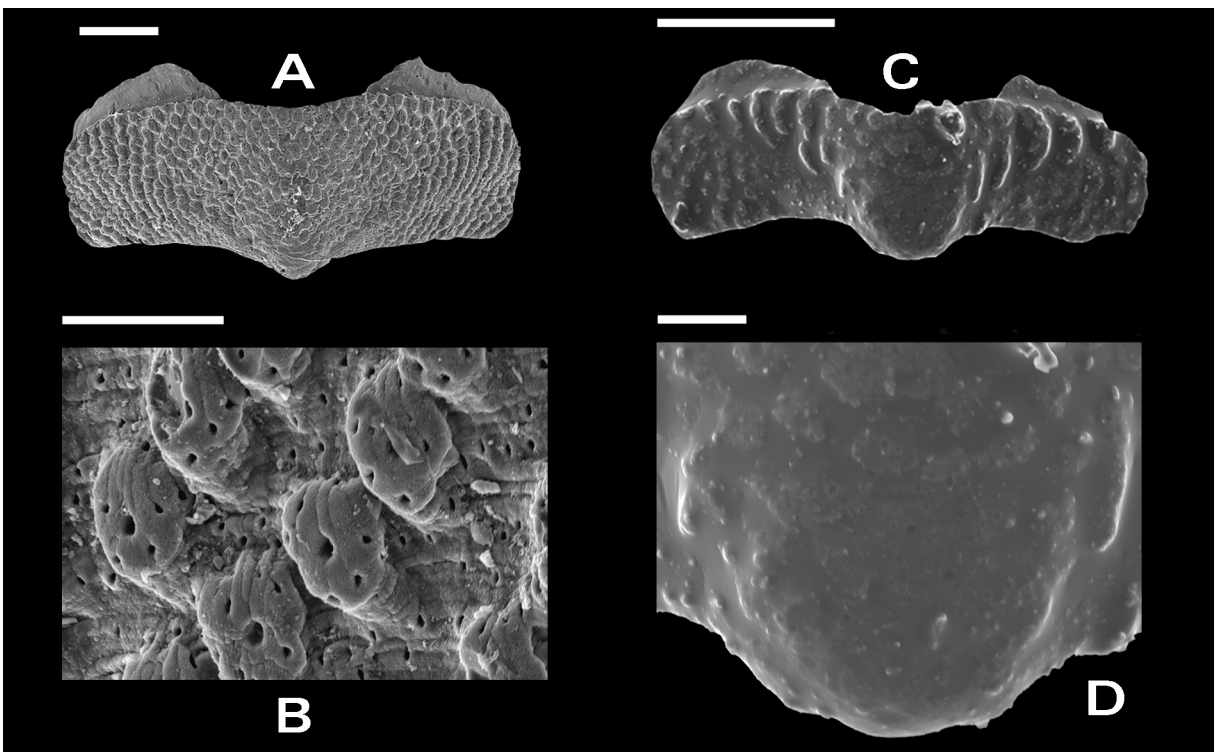
MATERIAL: 1 intermediate valve from Podhorce, 12 intermediate valves from Varovtsi.

Dimension (in mm):

	L	W
Intermediate valve MZ VIII Ma-114/1	1.4	2.9
Intermediate valve MZ VIII Ma-114/2	1.3	3.2

COMMENTS: The specimens are entirely consistent with the descriptions and illustrations referred to in the synonymy. As stated by Studencka and Studencki (1988, pp. 39–40), the fossil form described as *L. lepida* (Reuss, 1860) clearly differs from *L. cinerea* (Linnaeus, 1767) on the basis of the jugal sinus, the form of apophyses in the tail valve, the location of the mucro, as well as the ornamentation of the tegmentum (*i. e.* shape and arrangement of the granules). A comprehensive description and discussion of *L. cinerea* was given by Kaas and Van Belle (1981). The species *Chiton lepidus* was erected by Reuss (1860, p. 259, pl. 8, figs 12–13) on the basis of an intermediate valve found at Rudoltice in the Lower Badenian (Middle Miocene) strata of the Moravian part of the Carpathian Foredeep Basin in the Czech teritory. The first head and tail valves of this species were described and illustrated from the same locality by Šulc (1934, pp. 10–11, pl. 1, figs 13 and 15). The taxonomic status of *L. lepida* was comprehensively documented by Schwabe (2000).

On the other hand the first occurrence of *L. cinerea* is recorded in the Pliocene of the Loire Basin, France. According to Malatesta (1962, pp. 155–157), this species, which originated in the Late Miocene, did not become widely distributed in both the Mediterranean and North Atlantic until the Pleistocene.



Text-fig. 6. *Lepidochitona lepida* (Reuss, 1860). A – Intermediate valve, Varovtsi (MZ VIII Ma-114); B – Fragment of the same valve, to show shape and arrangement of granules; *Craspedochiton profascicularis* (Boettger, 1896). C – Intermediate valve, Varovtsi (MZ VIII Ma-118); D – Fragment of the same valve, to show jugal area with prominent apex Scale bars 1 mm in figs A and C; 100 μm in figs B and D

The very close affinities between *L. lepida* and the Recent *L. corrugata* (Reeve, 1848) were also discussed by Studencka and Studencki (1988, pp. 39–40).

STRATIGRAPHIC RANGE: Middle Miocene: Early Badenian (Reuss 1860)–Late Miocene: Tortonian (Sacco 1897). In the Central Paratethys it is recorded from the Banat Basin, Romania (Šulc 1934), the Pannonian Basin, Hungary (Csepreghy-Meznerics 1950; Dulai 2001) and from the Carpathian Foredeep Basin in both the Moravian (Reuss 1860; Šulc 1934) and Polish parts (Bałuk 1971, 1984; Macioszczyk 1988; Studencka and Studencki 1988). In the Mediterranean region *L. lepida* has been reported from the Late Miocene (Tortonian) of Italy (Sacco 1897) under the name *Lepidopleurus marginatus* (Pennant, 1777). According to Malatesta (1962), *L. lepida* seems to have persisted in the Mediterranean until the Late Pliocene.

Superfamily Cryptoplacoidea H. Adams et A. Adams, 1858
Family Acanthochitonidae Pilsbry, 1893
Subfamily Acanthochitoninae Pilsbry, 1893
Genus *Acanthochitona* Gray, 1821

TYPE SPECIES: *Chiton fascicularis* Linnaeus, 1767 designated by Gray (1821)

Acanthochitona faluniensis (Rochebrune, 1883)
(Text-fig. 7 A–F)

1971. *Acanthochitona faluniensis* (Rochebrune); W. Bałuk, pp. 463–464, pl. 2, figs 10–15 (*cum syn*.)
2003. *Acanthochitona faluniensis* (Rochebrune); A. Kroh, pp. 134–135, pl. 1, figs 6–7 (*cum syn*.)
2005. *Acanthochitona faluniensis* (Rochebrune); A. Dulai, pp. 39–40, pl. 4, figs 5–10, pl. 5, figs 1–4 (*cum syn*.)

MATERIAL: 1 intermediate valve from Olesko, 1 intermediate valve from Szuszkowce, 5 head valves, 46 intermediate valves and 4 tail valves from Varovtsi.

Dimensions (in mm):

	L	W
Head valve, MZ VIII Ma-117/1	2.6	4.2
Head valve, MZ VIII Ma-117/2	3.7	6.2
Intermediate valve, MZ VIII Ma-117/3	2.8	4.2
Intermediate valve, MZ VIII Ma-117/4	5.5	7.7
Tail valve, MZ VIII Ma-117/5	2.0	3.5
Tail valve, MZ VIII Ma-117/6	3.8	5.9

COMMENTS: Both fossil and present-day representatives of the genus *Acanthochitona* Gray, 1821 have caused a lot of confusion. As pointed out by Kaas (1985), as early as in the middle of 19th century scientists confounded *Chiton discrepans* Brown, 1827 and *Chiton fascicularis* Linnaeus, 1767 and erroneously identified *Ch. fascicularis* as *Chiton crinitus* Pennant, 1777. Indeed, all three species are represented in the Recent European fauna but the occurrence of *A. discrepans* is limited to the northeastern Atlantic. After detailed investigation of European material from the Atlantic and Mediterranean, Kaas (1985) designated neotypes of Linnaeus' species *fascicularis* and Pennant's species *crinitus* and selected a lectotype of *A. discrepans.* He also considered *Acanthochites communis* Risso, 1826 to be a junior synonym of *Chiton fascicularis* Linnaeus, 1767.

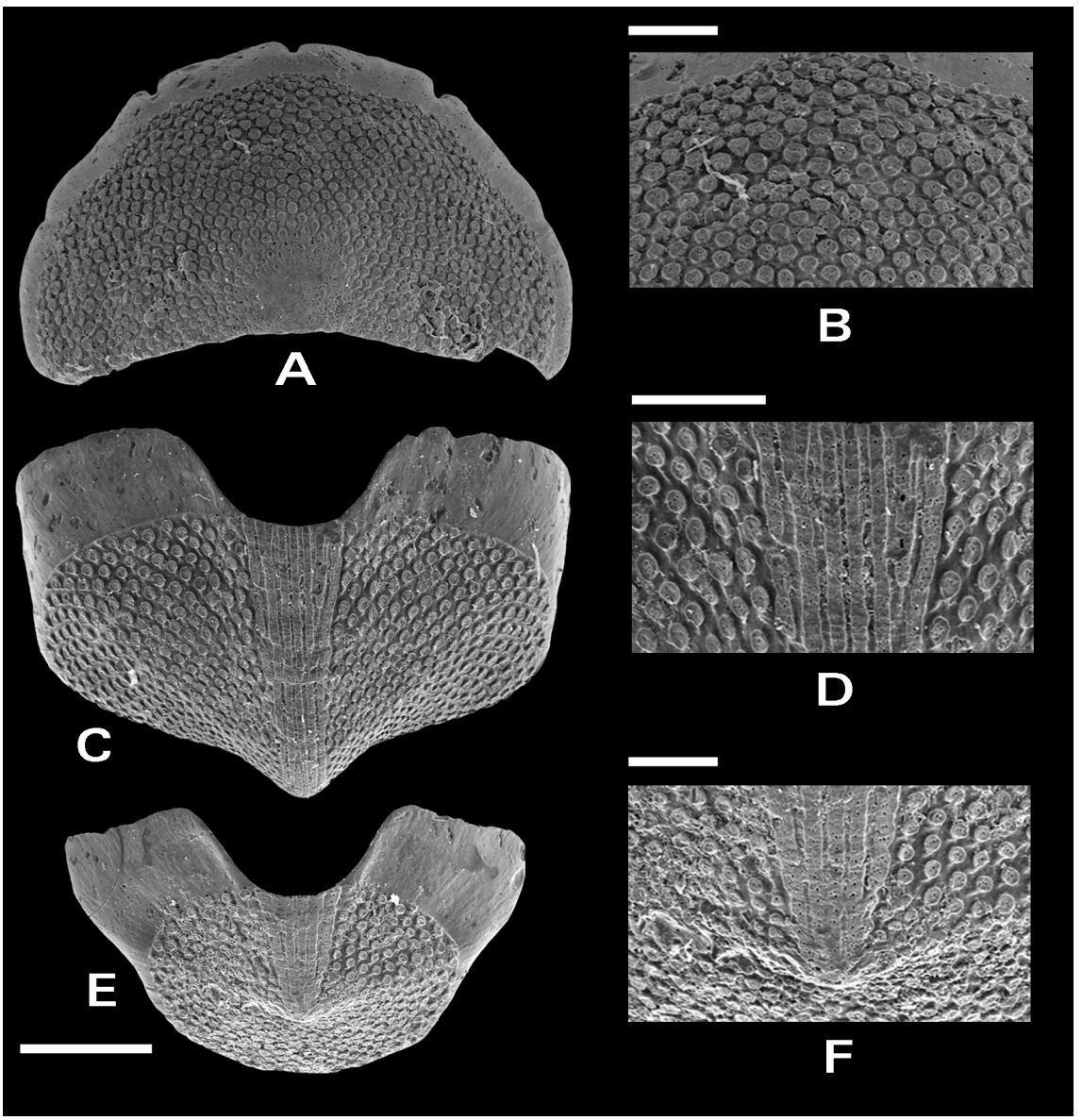
In the Polish Middle Miocene material from Niskowa and Korytnica, Bałuk (1965, 1971, 1984) succeeded in distinguishing three distinct species: *A. sandeciana* Bałuk, 1965, *A. lacrimulifera* Bałuk, 1971 and *A. faluniensis* (Rochebrune, 1883). The main differences are the shape and size of granules covering the tegmentum as well as the ornamentation of the jugal area.

The species *A. sandeciana* differs clearly from *A. faluniensis* in the different ornamentation of the tegmentum: the granules are smaller and more densely spaced while the longitudinal ribs are more distinct on the jugal area, separated by flattened and very narrow striae with concentric slits. *A. sandeciana* is quite uncommon; it was found at Niskowa (128 valves) and Korytnica (1 head valve) in the Carpathian Foredeep Basin, Poland and at Pötzleinsdorf (1 tail valve) in the Vienna Basin, Austria (Bałuk 1984). It is apparently restricted to the Paratethyan region.

The species *A. lacrimulifera* was treated by Bałuk (1971) as a direct ancestral form of the present-day species identified as *A. fascicularis*. Laghi (1977) considered *A. lacrimulifera* to be the same as *A. fascicularis* and Bałuk (1984, p. 291) accepted this statement. According to Kaas' (1985), Bałuk's species *lacrimulifera* should be treated as a junior synonym of *A. crinita* (Pennant, 1777). In addition, specimens from Rybnica identified by Studencka and Studencki (1988, p. 41, pl. 4, figs 1–2) as *A. fascicularis* also represent *A. crinita*.

The investigated specimens from Olesko,

Szuszkowce and Varovtsi, following Šulc (1934) and Bałuk (1971, 1984), are recognized as *A. faluniensis* (Rochebrune, 1883). The species *A. faluniensis* has been frequently misidentified with the Recent *A. fascicularis* (comp. Laghi 1977, Dell'Angelo *et al*. 1999, 2004, Dell'Angelo and Vardala-Theodoru 2006) from which it differs in its tegmentum outline and ornamentation. As far as it can be judged from the illustration in Kaas (1985, p. 587, figs 1–6), the tegmentum of *A. fascicularis* is ornamented with small, rounded and very crowded granules arranged in curved series in two directions: parallel to the jugum and radiating from it towards the outer margin. Two radiating series are observed on the head valve. In contrast, the tegmentum of *A. faluniensis*, except for the jugal area, is uniformly covered with finer granulation consisting of smaller numbers of distinctly larger rounded granules (each with 1–3 microaesthetes) arranged along orderly arched lines on the intermediate valves and arranged irregularly on the head valve. *A. faluniensis* is distinguished from *A. fascicularis* by the outline of the lateral margin of the tegmentum which usually is arched, rarely falciform in



Text-fig. 7. *Acanthochitona faluniensis* (Rochebrune, 1883). A – Head valve, Varovtsi (MZ VIII Ma-117/1); B – Fragment of the same valve, to show details of ornamentation; C – Intermediate valve, Varovtsi (MZ VIII Ma-117/3); D – Fragment of the same valve, to show shape of granules and ornamentation of jugal area; E – Tail valve, Varovtsi (MZ VIII Ma-117/5); F – Detail of the sculpture of mucronal area. Scale bars 1mm in figs A, C and E; 250 μm in figs B, D and F

the posterior part, compared to more or less concave near the jugal area in *A. fascicularis.* Additionally, the postmucronal slope of the almost circular to more ellipsoidal tail valve of *A. faluniensis* is gentle, compared to deeply concave directly behind the sharp mucro in *A. fascicularis*.

The species *A. faluniensis* is also different from *A. crinita* (Pennant, 1777), mainly in the shape of the granules covering the tegmentum of both head and tail valves as well as the lateral-pleural areas of intermediate valves. Individuals of *A. crinita* have a tegmentum sculptured with moderately widely separated drop-shaped flat granules, the dimensions of which increase gradually but markedly proportionally to the growth of the valve (see Bałuk 1971, pl. 2, figs 6–9, and Kaas 1985, figs 12, 16, 19, 22, 28–30, 39–40, 45–46) while the granules on the tegmentum of *A. faluniensis* are smaller, rounded, flat, very crowded, and on the intermediate valves arranged in curved series radiating from the jugal area towards the outer margin (see Bałuk 1971, pl. 2, figs 12–13; Dulai 2005, pl. 5, figs 1–3, pl. 4, fig. 8).

STRATIGRAPHIC RANGE: Middle Miocene: Early Badenian (Šulc 1934)–? Early Pliocene (Dell'Angelo *et al.* 2004). The species *A. faluniensis* was reported only from the Badenian localities of the Central Paratethys but specimens found in the Early Pliocene fauna of Spain (Dell'Angelo *et al*. 2004, p. 40, pl. 3, fig. 8, pl. 4, fig. 1) are considered to be probably *A. faluniensis*. Within the Central Paratethys it is widely distributed in both the Early and Late Badenian faunas (Studencka and Studencki 1988). In many localities it is the most abundant chiton species.

Genus *Craspedochiton* Shuttleworth, 1853

TYPE SPECIES*: Chiton laqueatus* Sowerby, 1841 by monotypy

Craspedochiton profascicularis (Boettger, 1906) (Text-fig. 6 C–D)

1984. *Craspedochiton profascicularis* (Boettger); W. Bałuk, pp. 292–293, pl. 12, figs 1–2.

MATERIAL: 1 intermediate valve from Varovtsi.

Dimensions (in mm):

	L	W
Intermediate valve, MZ VIII Ma-118	0.6	1.4

COMMENTS: The studied specimen is characterized by a tegmentum ornamented with large, irregular, ellipsoidal elevated granules, except for the jugal area. This type of ornamentation agrees well with that of the intermediate valves from Korytnica (Early Badenian, Poland) illustrated by Bałuk (1971, pl. 4, figs 13–14, and 1984, pl. 12, fig. 2) and identified as *Craspedochiton profascicularis* (Boettger, 1906).

Unfortunately, Boettger's species *profascicularis* is at present in a state of taxonomic chaos. Boettger (1906, p. 208, Nr. 702) established a new species *Acanthochites profascicularis* on the basis of a single head valve found at Coştei (Early Badenian, Romania). The name was adopted by Zilch (1934, p. 199, pl. 1, fig. 17), who illustrated Boettger's material, and by Šulc (1934, p. 13) in combination with *Cryptoconchus* (*Craspedoplax*) Iredale et Hull, 1925. Both Šulc (1934) and Zilch (1934) claimed that Early Miocene specimens from Piemont (Sciolze near Turin, Italy) identified by Sacco (1897, p. 91, pl. 7, figs 33–37) as *Acanthochiton costatus* (Rovereto *in litt.*) belong to the same species, with the name *profascicularis* keeping priority. Šulc (1934, p. 13) realized that the specific name used by Sacco (1897) is a junior primary homonym of *Acanthochites costatus* H. Adams et Angas, 1864. In spite of that, subsequent authors treated Boettger's species *profascicularis* either as a distinct species or as a synonym of Sacco's species *costatus*.

When Laghi (1977) re-examined Miocene and Pliocene chitons of Piemont, Italy, which had previously been placed in *Acanthochiton costatus* (Rovereto *in litt.*) by Sacco (1897) he realized that they represent two distinct species of the genus *Craspedochiton* Shuttleworth, 1853. Miocene (Burdigalian) specimens from Sciolze identified by Sacco (1897, p. 91, pl. 7, figs 33–35) as *Acanthochiton costatus* (Rovereto *in litt.*) and those from Montegibbo (Tortonian) named as *Acanthochiton costatus* var. *mutinocrassa* Sacco (1897, p. 91, pl. 7, fig. 38) represent *Craspedochiton costatus* (Sacco, 1897) while specimens from Astigiana (Pliocene) called by Sacco (1897, p. 91, pl. 7, figs 39–47) *Acanthochiton costatus* ? var. *astensis* belong to *Craspedochiton deslongchampsi* (Rochebrune, 1883), a species that was originally described from the Pliocene at Altavilla, Sicily. According to Laghi (1977), a specimen from Val Andona near Asti illustrated by Šulc (1934, p. 13, pl. 1, figs 20–21) as *Cryptoconchus* (*Craspedoplax*) sp. 1, also represent this species. Additionally, in the opinion of Laghi (1977, p. 112), *A. profascicularis* Boettger, 1906 could be treated as a junior synonym of *A. costatus* Sacco, 1897. In contrast to the statement of Laghi (1977), Bałuk (1984, p. 293) considered *A. profascicularis* and *A. costatus* to be separate species which differ distinctly in their size and ornamentation, and in the re-

lationship of the surface of the tegmentum to that of the whole head valve.

The status of Boettger's species *profascicularis* was also debated by Dell'Angelo *et al*. (1999, pp. 276–277, 282–283). They were of the opinion that both *Acanthochiton costatus* Sacco, 1897 and *Acanthochites profascicularis* Boettger, 1906 are junior synonyms of *Chiton altavillensis* Seguenza, 1876. Before that, Dell'Angelo and Palazzi (1988) stated that *Gymnoplax deslongchampsi* de Rochebrune, 1883 is a junior synonym of *Chiton altavillensis* Seguenza, 1876 and they designated a neotype from Pliocene material from Altavilla (Dell'Angelo and Palazzi 1988, p. 174, fig. 1).

However, based on the illustrations of Italian specimens of *C. costatus* [= *C. profascicularis*] and *C. deslongchampsi* [= *C. altavillensis*] given by Laghi (1977, pl. 4, figs 1–3, and pl. 4, figs 4–8, respectively), the interpretation that they are separate species which differ distinctly in their ornamentation seems correct. After all, the intermediate valve of *C. altavillensis* from Kyllini (Pleistocene, Greece) illustrated by Garilli *et al*. (2005, pl. 5, figs 4 and 6) differs from the Ukrainian specimen in its characteristic sculpture of coarse radially elongated granules in the lateral area.

To get a better understanding of the relationship between *profascicularis* and *altavillensis*, revision of Mediterranean and Paratethyan material is needed. This could determine either that *profascicularis* is a distinct species or that it is conspecific with *altavillensis.* The latter species named as C. *deslongchampsi* was listed from Middle Miocene (Middle/Late Badenian) of Gainfarn, in the Vienna Basin, Austria (Kroh 2002, p. 10).

STRATIGRAPHIC RANGE: Early Miocene: Burdigalian–Late Miocene: Tortonian (Sacco 1897). Specimens referred to the species *C. profascicularis* are scarcely noted from Middle Miocene Paratethyan fauna from Coştei in the Banat Basin, Romania (Boettger 1906; Zilch 1934), Forchtenau in the Vienna Basin, Austria (Šulc 1934), and from Korytnica in the Carpathian Foredeep Basin, Poland (Bałuk 1971, 1984) but no tail valve is known so far. Its occurrence in the Mediterranean has been documented in the Early Miocene (Burdigalian) at Sciolze and in the Late Miocene (Tortonian) at Montegibbio of Piemont, Italy (Sacco 1897; Laghi 1977).

RESULTS

Twenty polyplacophoran species belonging to nine different genera and representing seven different families are known so far from the Late Badenian Paratethyan fauna. These are:

Leptochiton cancellatus (Sowerby, 1840)
Leptochiton srameki (Šulc, 1934)
Leptochiton sulci Bałuk, 1971
Lepidopleurus cajetanus (Poli, 1791)
Ischnochiton korytnicensis Bałuk, 1971
Ischnochiton rissoi (Payraudeau, 1826)
Callochiton septemvalvis (Montagu, 1803)
Chiton corallinus (Risso, 1826)
Chiton olivaceus Spengler, 1797
Lepidochitona baluki Macioszczyk, 1988
Lepidochitona lepida (Reuss, 1860)
Lepidochitona subgranosa Bałuk, 1971
Acanthochitona crinita (Pennant, 1777)
Acanthochitona faluniensis (Rochebrune, 1883)
Acanthochitona plana (Šulc, 1934)
Acanthochitona sandeciana Bałuk, 1965
Craspedochiton minutulus Bałuk, 1971
Craspedochiton profascicularis (Boettger, 1906)
Craspedochiton steinabrunensis (Šulc, 1934)
Cryptoplax weinlandi Šulc, 1934

All of the eight chiton species reported herein belong to seven different genera and represent five different families and were already known from contemporaneous fauna described from the Carpathian Foredeep Basin (Bałuk 1965; Macioszczyk 1988; Studencka and Studencki 1988). Most of the species have a stratigraphic range from Middle Miocene to Recent whereas the species *Lepidopleurus cajetanus* and *Craspedochiton profascicularis* originated in the Mediterranean province during the Early Miocene. The latter species is scarcely noted in both Early and Late Miocene of the Mediterranean (Sacco 1897; Laghi 1977) as well as in the Middle Miocene of the Paratethys (Boettger 1906; Zilch 1934; Šulc 1934; Bałuk 1971, 1984). On the other hand, *Lepidopleurus cajetanus* is widespread and abundant in both the Paratethys and Mediterranean. At present, it is known from the coasts of northern Spain and Portugal, and as far south as the Canaries. It is also common in the Mediterranean (Poppe and Goto 1991). As mentioned in the systematic chapter, the specimens previously assigned to *L. subcajetanus* actually represent the largest specimens of *L. cajetanus*.

Leptochiton cancellatus, *Ischnochiton rissoi*, *Lepidochitona lepida* and *Acanthochitona faluniensis,* all seem to have originated in the Central Paratethys Sea during the Middle Miocene. *Acanthochitona faluniensis* seems to have been restricted to the Central Paratethys (Bałuk 1971, 1984; Macioszczyk 1988; Studencka and Studencki 1988) whereas *Leptochiton cancellatus, Ischnochiton rissoi* and *Lepidochitona lepida*

migrated to the Mediterranean. Within this province, *Leptochiton cancellatus* has been documented in the Pliocene fauna of Italy (Laghi 1977; Dell'Angelo *et al*. 2001; Chirli 2004) and it is at present recorded sporadically from the Catalan coast and the Adriatic Sea (Poppe and Goto 1991). According to Malatesta (1962), *Lepidochitona lepida* existed in the Mediterranean until the late Pliocene whereas *Ischnochiton rissoi* is a typical Recent Mediterranean species that is locally very common under smooth stones on a clean sandy bottom (Poppe and Goto 1991).

Out of the four chiton species that occur most commonly in the Late Badenian fauna, *Lepidopleurus cajetanus*, *Chiton corallinus*, *Chiton olivaceus* and *Acanthochitona faluniensis* (comp. Studencka and Studencki 1988), only the last is also common in the material studied. It is widely distributed within the Central Paratethys in both Early and Late Badenian faunas (Studencka and Studencki 1988) whereas its occurrence in the Early Pliocene of the western part of the Mediterranean is only presumed.

Acknowledgements

Professor Wacław Bałuk is warmly acknowledged for making available the unpublished chiton material from Kamienica Nawojowska near Nowy Sącz and the types of *Leptochiton sulci* (Bałuk, 1971) and *Ischnochiton korytnicensis* Bałuk, 1971 as well as for constructive remarks that improved this paper. Special gratitude is due to Bruno Dell'Angelo, who reviewed this text.

This paper is a contribution to the joint Hungarian-Polish Project *Paleogene and Neogene brachiopods and molluscs from the Paratethyan and Mediterranean provinces* realized within the framework of bilateral cooperation between the Hungarian Academy of Sciences and the Polish Academy of Sciences. A. Dulai was supported through a János Bolyai Research Scholarship and by the Hungarian Scientific Research Fund (OTKA T 49224). A. Dulai had the possibility of examining the collection of the Naturalis Museum in Leiden in the framework of a Synthesys project (NL-TAF-3270) supported by the European Commission's Research Infrastructure Action. The SEM micrographs were taken in the SEM laboratory of the Hungarian Natural History Museum (Budapest).

REFERENCES

Andreyeva-Grigorovich, A.S., Kulchytsky, Y.O., Gruzman, A.D., Lozynyak, P.Y., Petrashkevich, M.I., Portnyagina, L.O., Ivanina, A.V., Smirnov, S.E., Trofimovich, N.A., Savitskaya, N.A. and Shvareva, N.J. 1997. Regional stratigraphic scheme on Neogene formations of the Central Paratethys in the Ukraine. *Geologica Carpathica*, **48** (2), 123–136.

Bałuk, W. 1965. Chitons from the Tortonian of the Nowy Sącz Depression, Poland. *Acta Palaeontologica Polonica*, **10** (3), 365–378.

Bałuk, W. 1971. Lower Tortonian chitons from the Korytnica Clays, southern slopes of the Holy Cross Mts. *Acta Geologica Polonica*, **21** (3), 449–472.

Bałuk, W. 1984. Additional data on chitons and cuttlefish from Korytnica Clays (Middle Miocene; Holy Cross Mountains, Central Poland). *Acta Geologica Polonica*, **34** (3-4), 281–297.

Boettger, O. 1906. Zur Kenntnis der Fauna der mittelmiocänen Schichten von Kostej im Krassó-Szörényer Komitat. *Verhandlungen und Mittheilungen des siebenbürgischen Vereines für Naturwissenschaften zu Hermannstadt*, **55**, 102–217.

Chirli, C. 2004. Malacofauna Pliocenica Toscana. Vol. 4. Polyplacophora Gray J.E., 1821, Monoplacophora Odhner, 1940, Archaeogastropoda, Thiele, 1925, 1–113, 1–41 Plates. [Private edition, without indication of any Publisher]. Firenze

Cossmann, M. and Peyrot, A. 1917. Conchologie néogénique de l'Aquitaine. Vol. III Gastropodes, 1–384. A. Saugnac & E. Drouillard; Bordeaux.

Csepreghy-Meznerics, I. 1950. A Hidasi (Baranya M.) tortonai fauna. (Die tortonische Fauna von Hidas, Kom. Baranya, Ungarn). *Annales Instituti Geologici Publici Hungarici*, **39** (2), 1–106.

Dell'Angelo, B. and Palazzi, S. 1988. *Gymnoplax deslongchampsi* de Rochebrune, 1883, sinonimo di *Chiton altavillensis* G. Seguenza, 1876 (Mollusca: Polyplacophora). *Il Naturalista Siciliano*, **12**, 174–175.

Dell'Angelo, B. and Palazzi, S. 1989. Considerazioni sulla famiglia Leptochitonidae Dall, 1889 (Mollusca: Polyplacophora). III. Le specie terziarie e quaternarie europee, con note sistematiche e filogenetiche. Atti della Prima Giornata di Studi Malacologici CISMA, 19–140.

Dell'Angelo, B. and da Silva, C.M. 2003. Polyplacophora from the Pliocene of Vale de Freixo: Central-West Portugal. *Bollettino Malacologico*, **39** (1–4), 7–16.

Dell'Angelo, B. and Smriglio, C. 1999. Chitoni viventi del Mediterraneo, 1–256. Edizioni Evolver, Rome.

Dell'Angelo, B. and Vardala-Theodorou, G.-E. 2006. Pleistocene Polyplacophoran species from Perachora Peninsula (Corinth, Greece). *Annales Musei Goulandris*, **11**, 321–339.

Dell'Angelo, B., Forli, M. and Lombardi, C. 2001. I Polyplacophora plio-pleistocenici della Toscana. *Bollettino Malacologico*, **36** (9–12), 143–154.

Dell'Angelo, B., Grigis, M. and Bonfitto, A. 2007. Notes on fossil chitons. 2. Polyplacophora from the Middle

Miocene of Lăpugiu (Romania). *Bollettino Malacologico*, **43**, 39–50.

Dell'Angelo, B., Landau, B. and Marquet, R. 2004. Polyplacophora from the early Pliocene of Estepona (Málaga, southwest Spain). *Bollettino Malacologico*, Supplemento **5**, 25–44.

Dell'Angelo, B., Palazzi, S. and Pavia, G. 1999. I Molluschi del Messiniano Inferiore di Borelli (Torino). 4. Polyplacophora. *Bollettino del Museo regionale di Scienze naturali Torino*, **16** (1–2), 257–302.

du Bois de Montpéreux, F. 1831. Conchiologie fossile et aperçu des formations du Plateau Wolhyni-Podolien, 1–76. Simon Schropp et Comp.; Berlin

Dulai, A. 2001. Middle Miocene (Badenian) Polyplacophora (Mollusca) remains from borehole Szokolya-2 (Börzsöny Mts, Hungary, Central Paratethys). *Fragmenta Palaeontologica Hungarica*, **19**, 39–49.

Dulai, A. 2005. Badenian (Middle Miocene) Polyplacophora from the Central Paratethys (Bánd and Devecser, Bakony Mountains, Hungary). *Fragmenta Palaeontologica Hungarica,* **23**, 29–50.

Eichwald, E. 1853. Lathaea Rossica ou paléontologie de la Russie. Dernière période, 1–268. E. Schweizerbart; Stouttgart.

Ferrero Mortara, E., Montefameglio, L., Novelli, M., Opesso, G., Pavia, G. and Tampieri, R. 1984. Catalogo dei tipi e degli esemplari figurati della collezione Bellardi e Sacco. Parte II. *Cataloghi Museo Regionale di Scienze Naturali*, **7**, 1–484.

Friedberg, W. 1911–1928. Mięczaki mioceńskie Ziem Polskich. Część I – Ślimaki i łodkonogi, 1–628. Muzeum im. Dzieduszyckich; Lwów.

Friedberg, W. 1934–1936. Mięczaki mioceńskie Ziem Polskich. Część II – Małże, 1–274. Polskie Towarzystwo Geologiczne; Kraków.

Garilli, V., Dell'Angelo, B. and Vardala-Theodorou, E. 2005. Polyplacophora from Pleistocene of Kyllini (NW Peloponnese, Greece). *Bollettino delle Società Paleontologica Italiana*, **44** (2), 127–144.

Hilber, V. 1882a. Geologische Studien in den ostgalizischen Miocän-Gebieten. *Abhandlungen der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **32** (2), 194–323.

Hilber, V. 1882b. Neue und wenig bekannte Conchylien aus dem Ostgalizischen Miocän. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **7** (6), 1–33.

Jakubowski, G. and Musiał, T. 1977. Lithology and fauna from the Upper Tortonian sands of Monastyrz and Długi Goraj (Southern Roztocze, Poland). *Prace Muzeum Ziemi*, **26**, 63–126.

Jakubowski, G. and Musiał, T. 1979. Lithology and fauna of the Middle Miocene deposits of Trzęsiny (Roztocze Tomaszowskie Region, South-eastern Poland). *Prace Muzeum Ziemi*, **32**, 37–70.

Janssen, R. 1978. Revision der Polyplacophora des Oligozäns in Mitteleuropa. *Archiv für Molluskunde*, **108** (4), 215–235.

Kaas, P. 1981. Scandinavian species of *Leptochiton* Gray, 1847 (Mollusca, Polyplacophora). *Sarsia,* **66** (3), 217–229.

Kaas, P. 1985. The genus *Acanthochitona* Gray, 1821 (Mollusca, Polyplacophora) in the north-eastern Atlantic Ocean and in the Mediterranean Sea, with designation of neotypes of *A. fascicularis* (L., 1767) and of *A. crinita* (Pennant, 1777). *Bulletin du Museum National d'Histoire Naturelle, Paris*. 4e serie, **7**, section A (3), 579–609.

Kaas, P. and van Belle, R.A. 1981. The genus *Lepidochitona* Gray, 1821 (Mollusca: Polyplacophora) in the Northeastern Atlantic Ocean, the Mediterranean Sea and the Black Sea. *Zoologische Verhandelingen*, **185**, 3–43.

Kazakova, W.P. 1952. Stratigraphy and bivalve fauna from the Middle Miocene deposits of Opole. *Transaction of the Moscow Institute of Geology and Exploitation*, **27**, 171–263. [In Russian]

Kováč, M., Andreyeva-Grigorovich, A., Bajraktarević, Z., Brzobohatý, R., Filipescu, S., Fodor, L., Harzhauser, M., Oszczypko, N., Nagymarosy, A., Pavelić, D., Rögl, F., Saftić, B., Sliva, L. and Studencka, B. 2007. Badenian evolution of the Central Paratethys Sea: paleogeography, climate and eustatic sea level changes. *Geologica Carpathica,* **58** (6), 479–606.

Král, J., Studencka, B., Barath, I. and Zieliński, G. 2000. Strontium isotope stratigraphy in some Paratethyan Middle Miocene molluscan shells. The XIth Congress Regional Committee on Mediterranean Neogene Stratigraphy, p. 36. Fes.

Kroh, A. 2002. Die Polyplacophoren des Badenium (Mittel-Miozän) von Gainfarn, Niederösterreich. 9. Jahrestagung der Österreichischen Paläontologischen Gesellschaft (20.-22. September 2002, Nassfeld). *Berichte des Institutes für Geologie und Paläontologie der Karl-Franzens-Universität Graz*, **5**, 10–11.

Kroh, A. 2003. The Polyplacophora (Mollusca) of the Langhian (Lower Badenian) of the Molasse Zone and the northern Vienna Basin (Austria). *Annalen des Naturhistorischen Museums in Wien*, **104A**, 129–143.

Laskarew, W. 1914. Carte géologique générale de la Russie d'Europe. Feuille 17. *Transaction of the Geological Committee*, New series, **77**, 1–669. [In Russian]

Laghi, G.F. 1977. Polyplacophora (Mollusca) neogenici dell'Appennino settentrionale. *Bollettino della Società Paleontologica Italiana*, **16** (1), 87–115.

Łomnicki, A.M. 1895. Atlas Geologiczny Galicyi. Tekst do zeszytu siódmego, 1–128. Wydawnictwo Komisyi Fizyograficznej Akademii Umiejętności; Kraków.

Macioszczyk, W. 1988. Polyplacophora from the Badenian deposits of Węglinek, Węglin and Łychów (Western Roztocze – Poland). *Prace Muzeum Ziemi*, **40**, 48–58.

Malatesta, A. 1962. Mediterranean Polyplacophora Cenozoic and Recent. *Geologica Romana*, **1**, 145–171.

Marinescu, J. 1964. Reprezentați ai clasei Amphineura în Miocenul din Oltenia. *Dări de Seamă ale Şedinţelor*, **50** (1), 179–185.

Maslov, V.P. and Utrobin V.N. 1958. Distribution of the Tertiary Rhodophyceae of the Ukrainian Soviet Socialist Republic and their connection with sea transgression. *Bulletin of the Academy of Sciences of the USSR, series Geology*, **1958** (12), 73–93. [In Russian]

Muratov, M.V and Nevesskaja, L.A. (Eds) 1986. Stratigraphy of the USSR. Neogene. Vol. 1, 1–419. Nedra; Moscow. [In Russian]

Nevesskaja, L.A., Gontsharova, I.A., Paramonova, N.P., Popov, S.V., Babak, E.V., Bagdasarjan, K.G. and Voronina, A.A. 1993. Identification book of Miocene bivalve molluscs of south-western Eurasia. *Transactions of the Paleontological Institute, Russian Academy of Sciences*, **247**, 1–412. [In Russian]

Niedźwiedzki J. 1889. Ergänzung zur Fossilliste der Miocäns bei Podhorce in Ostgalizien. *Verhandlungen der Kaiserlich-Königlichen Geologischen Reichsanstalt*, **6**, 134–135.

Passendorfer, E. 1938. Rzut oka na dotychczasową działalność Towarzystwa Muzeum Ziemi. *Wiadomości Muzeum Ziemi*, **1** (2-3), 72–80.

Procházka, V.J. 1895. Miocean východočeský. *Archiv pro přirodovĕcké prozkoumáni Čech*, **10** (2), 1–149.

Poppe, G.T. and Goto, Y. 1991. European Seashells. Volume I (Polyplacophora, Caudofoveata, Solenogastra, Gastropoda), 1–340. Christa Hemmen Verlag; Wiesbaden.

Rado, G. and Mutiu, R. 1970. Studiul faunei tortoniene din forajele de la Islaz. *Analele Universitatu Bucuresti, Geologie*, **19**, 141–171.

Reuss, A.E. 1860. Die marinen Tertiärschichten Böhmens und ihre Versteinerungen. *Sitzungsberichte der Matematisch-Naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften*, **39**, 207–285.

Sacco, F. 1897. Classe Amphineura v. Ihering 1876. In: I Molluschi dei terreni terziarii del Piemonte e della Liguria, 89–91. Parte 22. Carlo Clausen; Torino.

Schwabe, E. 2000. *Chiton lepidus* Reuss, 1860 (currently *Lepidochitona lepida*; Mollusca, Polyplacophora): proposed conservation of the specific name. *Bulletin of Zoological Nomenclature*, **57** (4), 207–209.

Sieber, R. 1953. Die Tortonfauna von Pötzleinsdorf (Wien, 18 Bezirk). *Verhandlumgen der Geologischen Bundesanstalt,* **1953**, (3), 184–195.

Sieber, R. 1958. Die Tortonfauna von Steinabrunn bei Drasenhofen (Bez. Mistelbach, N-Ö). *Verhandlumgen der Geologischen Bundesanstalt,* **1958**, (2), 142–155.

Sieber, R. 1959. Systematische Übersicht der jungtertiären Amphineura, Scaphopoda und Cephalopoda des Wiener Beckens. *Annalen der Naturhistorisches Museums in Wien*, **63**, 274–278.

Sirenko, B. 2006. New Outlook on the System of Chitons (Mollusca: Polyplacophora). *Venus*, **65**, 27–49.

Skoczylasówna, K. 1930. Przyczynek do znajomości miocenu kotliny sądeckiej (Beitrag zur Kenntnis der Miozänablagerungen in der Umgebung von Nowy Sącz). *Rocznik Polskiego Towarzystwa Geologicznego*, **6**, 50–72.

Stanku, J. and Andreescu, E. 1968. Fauna tortonianã din regiunea Rugi-Delineşti (Bazinul Caransebeşului). *Studii si cercetari, Seria geologie*, **13**, 455–471.

Studencka, B. and Studencki, W. 1988. Polyplacophora from the Badenian (Middle Miocene) marine sandy facies of the Holy Cross Mts (Central Poland). *Prace Muzeum Ziemi*, **40**, 37–46.

Studencka, B., Gontsharova, I.A. and Popov, S.V. 1998. The bivalve fauna as a basis for reconstruction of the Middle Miocene history of the Paratethys. *Acta Geologica Polonica*, **48**, 285–342.

Šulc, J. 1934 (1936). Studien über die fossilen Chitonen. I. – Die fossilen Chitonen im Neogen des Wiener Beckens und angrenzenden Gebieten. *Annalen des Naturhistorischen Museums in Wien*, **47**, 1–31.

Tomašových, A. 1998. Bádenské mäkkyse z tehelne Devinska Nová Ves (Bratislava, Slovensko). *Mineralia Slovakia,* **30**, 357–386.

Zilch, A. 1934. Loricata. In: Zur Fauna des Mittel-Miocäns von Kostej (Banat). Typus-Bestimmung und Tafeln zu O. Boettger's Bearbeitungen. *Senckenbergiana*, **16**, 198–200.

Manuscript submitted: 19th March 2009
Revised version accepted: 15th May 2010