Hantkeniana 10, 135–142., Budapest, 2015
Barnabás GÉCZY Jubilee Volume

Intraspecific variability of *Parascutella gibbercula* (DE SERRES, 1829) based on morphometric analysis

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Abstract

The Badenian genus *Parascutella* is common fossil in the carbonate sediments of the Paratethys. Formerly the smaller specimens were assigned to *P. gibbercula* (DE SERRES, 1829), and the larger forms to *P. vindobonensis* (LAUBE 1871). According to several authors the morphological characters are not sufficient to distinguish them, they are synonyms. This work is based on classical morphometric studies — correlation, principal component analysis, and cluster analysis — investigating the morphological changes from juvenile to adult forms of *P. gibbercula.* The analysis was made on a rich and well-preserved *Parascutella* collection from the Upper Badenian (Miocene) of Budapest, Hungary. Based on our results there are some typical differences between juvenile and mature forms.

Keywords: Parascutella gibbercula, P. vindobonensis, morphomertrics, taxonomy

Introduction

The *Parascutella* genus is an emblematic fossil of the Badenian Paratethys. It was found at several localities in Hungary, Austria, Slovakia, Poland, Serbia, and Romania. Since the 19th century numerous authors (e.g. DE SERRES 1829, AGASSIZ 1841, LAUBE 1871, VADÁSZ 1914, DURHAM 1953, SZÖRÉNYI 1953, MIHÁLY 1969, 1985, 1987, PHILIPPE 1989, KROH 2005, 2007, 2010) studied this genus and its species. Initially, there were two species, *Parascutella gibbercula* (DE SERRES, 1829) and *P. vindobonensis* (LAUBE, 1871), showing a lot of similarities, which generated long-standing questions. Now *P. vindobonensis* is considered to be the junior synonym of *P. gibbercula* (e.g. KROH 2005, 2007, 2010). Thanks to the bed by bed collecting work of the Echinodermata fauna from the Upper Badenian Leithakalk (Rákos Limestone) in Budapest, (Hungary), a large amount of well-preserved specimens were deposited in various collections. We attempted a detailed morphometric analysis (correlation, PCA and cluster analysis) to describe intraspecific variability of *Parascutella gibbercula* on the material kept in the Hungarian Geological and Geophysical Institute.

Geological setting

During the Badenian the Leithakalk localities of Budapest (Figure 1) were part of the Central Paratethys (e.g. RÖGL 1998, PILLER et al. 2004, POPOV et al. 2004). The sedimentary succession of this shallow sea is generally mixed siliciclastic-carbonate with tuffite intercalations. Basement highs, isolated from terrigenous input, bear carbonate platforms. The characteristic shallow marine limestone (generally known as Leithakalk, former name in Hungary: Rákos Limestone Formation) yielded most of the fauna (e.g. HÁMOR 2001, HÁMOR in HAAS 2012).

In most of the locations the underlying strata of Leithakalk Formation is the Carpathian/Badenian Tar Dacite Tuff Formation (PÓKA et al. 2004). There are some drill cores, where pelitic marl was found below the Leithakalk (pre-

Figure 1. Location of Budapest

sumably Szilágy Clay Marl Formation) (BARTKÓ & KÓKAY 1966). The overlying beds everywhere in the study area belong to the Sarmatian (Upper Miocene) Tinnye Limestone Formation. The Echinoderm containing layers of Leithakalk Formation arosed in two facies: weakly cemented sandy calcarenite, calcareous sand with red algae mats and mollusks on the one hand, and well cemented limestone with mollusk, coralline and benthic foraminifers on the other hand.

Material and methods

In Budapest there are five sites at two localities — namely Rákos and Budafok-Tétény — from where the studied *Parascutella* specimens were collected (Figure 2, Table 1)

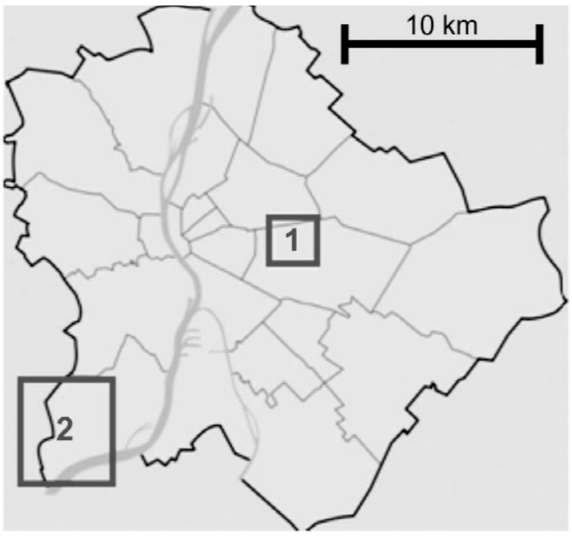

Figure 2. Localities of Echinoderms in the Rákos Member of the Leithakalk Formation. 1: District of Rákos with the localities: Gyakorló Street, Örs vezér Square, Rákos rail delta, Kerepes Street; 2: District of Budafok-Tétény

Table 1. Main facies type, number of specimens for each studied locality

Locality	Facies	Number of species (n=235)	
		Juvenile form	Adult form
Gyakorló Street	calcareous sand, sandy calcarenite	68	5
Örs vezér Square	calcareous sand, cemented limestone	21	51
Rákos rail delta	calcareous sand	0	9
Kerepes Street	sandy calcarenite	6	59
Budafok-Tétény	calcareous sand, sandy calcarenite	0	16
	Total:	95	140

A total of 235 specimens were studied. Most of the fossils are stored in the Geological and Geophysical Institute of Hungary (205 specimens, collection Echinoderm, inventory code: "Ech."), and in the Hungarian Natural History Museum Invertebrate and Vertebrate Palaeontological Collections (9 specimens, inventory character: "M") and there are some new collections which are stored in Eötvös Loránd University Department of Palaeontology (21 specimens, inventory character: Ech. ELTE).

Measurements were carried out manually with a precision of 0.5 mm. Database was built from the basic informations (name, age, locality, inventory number) and measured characters. Photographic documentation was also done.

Fifteen characters were measured (Table 2, Figure 3–5). The measures were focused on the well-preserved characters only. However, all 15 characters were measurable only on 31 specimens.

Table 2. Overview of the measured parameters

Measured parameters	Figure
Height: distance from apex to the test's lowest point	3
Length of the test (skeletal shell)	4/1
Width of the test	4/2
Distance from periproct to peristome	4/1a
Distance from peristome to upper margin	4/1b
Length of the mouth	4/3
Width of the mouth	4/3
Length of the periproct	4/4
Width of the periproct	4/4
Length of the five (1, 2, 3, 4, 5) ambulacrum	5/1 5
Average length of ambulacra	

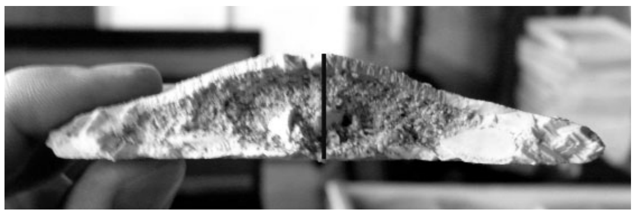

Figure 3. Height

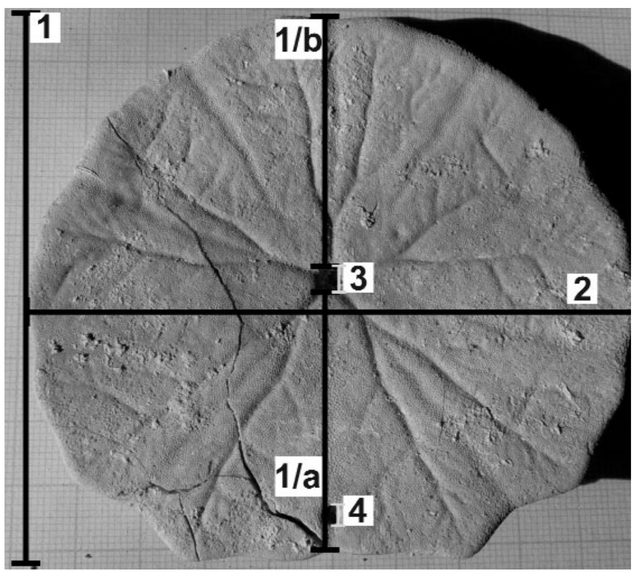

Figure 4. Length (1), width (2), distance from periproct to peristome (1/a) and from peristome to upper margin (1/b), length and width of the mouth (3), length and width of the periproct (4)

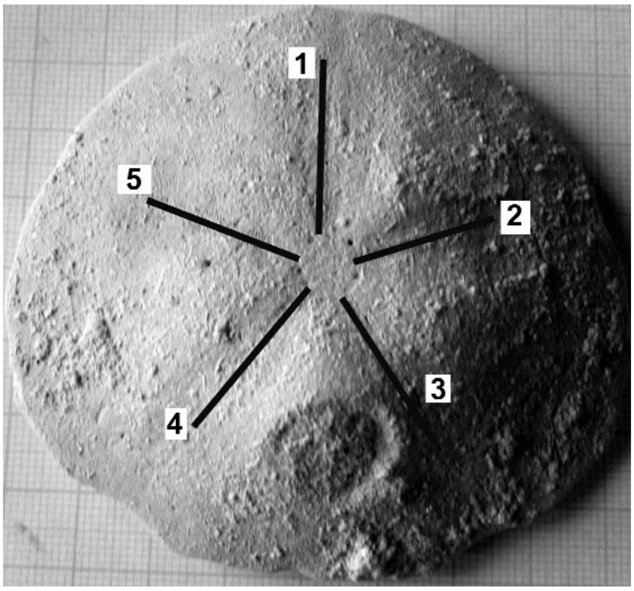

Figure 5. The length of ambulacra (1–5) is used in the morphometrics

For statistical and mathematical analyses the program R was used (R Development Core Team, 2011). The stochastic connections were studied with Pearson correlation coefficient, which describes numerically the linear connection's strength among the parameters (Kovács et al. 2012). Large number of data are grouped according to their similarity using the cluster analysis with Ward method (Euclidean distance) (Hammer et al. 2001). In this method the clusters are combined in pairs with minimal variance within groups (Hammer & Harper 2006, Hatvani et al. 2011, Kovács et al. 2012, Barbacka & Bodor et al. 2014). As the ordination methods, PCA (principal component analysis) was used (e.g. Spicer & Hill 1979, Barbacka & Bodor et al. 2014, Jagt 1999).

Results of morphometrics

Due to poor preservation only the three character-based results are shown in this paper. However, all analyses yielded almost the same results. These three size parameters show very high correlation (Figure 6). The distribution of all three characters is undoubtedly bimodal, indicating two groups in the sample. The high percent of correlation makes the ordination methods very effective, so based on main dimensions, correlation is not suitable for separation. On the PCA plot two groups are well defined (Figure 7). The first axis explains more than 95% of the variance. The same tendency can be seen on the cluster dendrogram. The morphological changes during the ontogeny clearly form different clusters (Figure 8). The petalodium is less

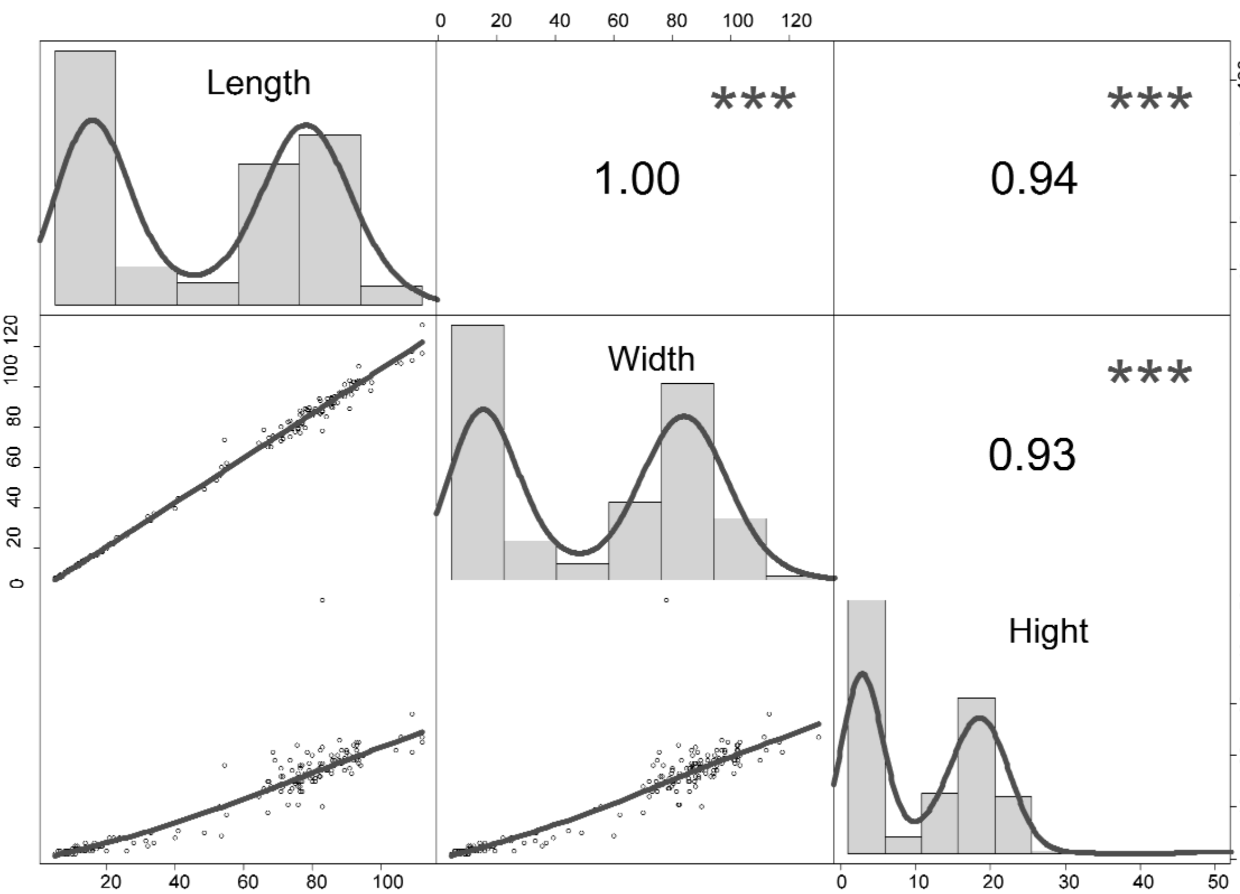

Figure 6. Pearson type of correlation and histograms of the measured characters (height, length, width) of specimens of juvenile and adult *P. gibbercula.* The number of stars shows the strength of linear connections

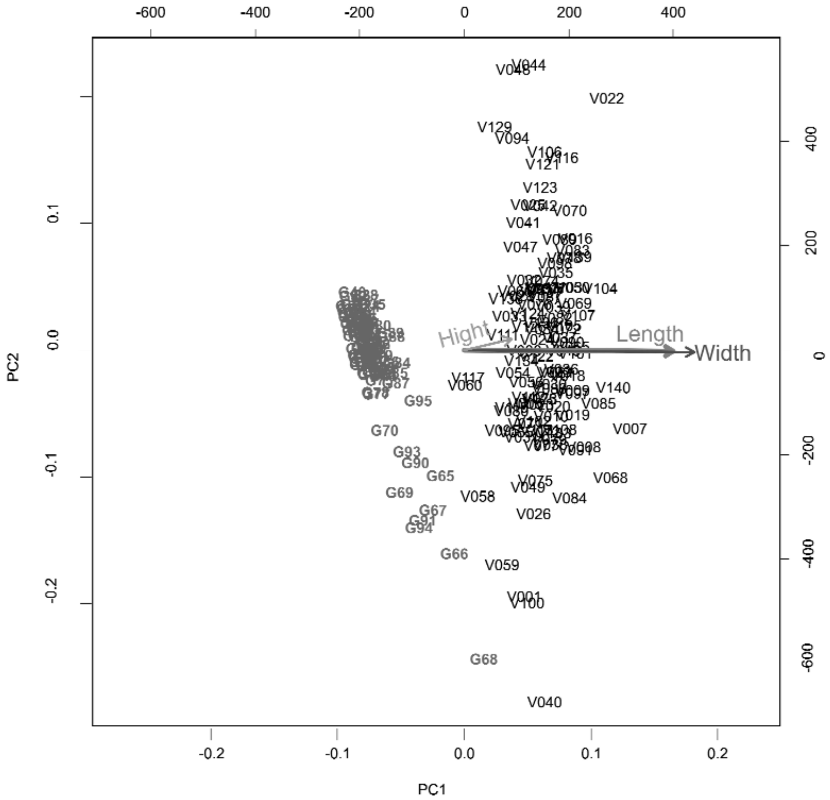

Figure 7. PCA biplot of 200 specimens based on the basic three size parameters (grey: juvenile, black: adult)

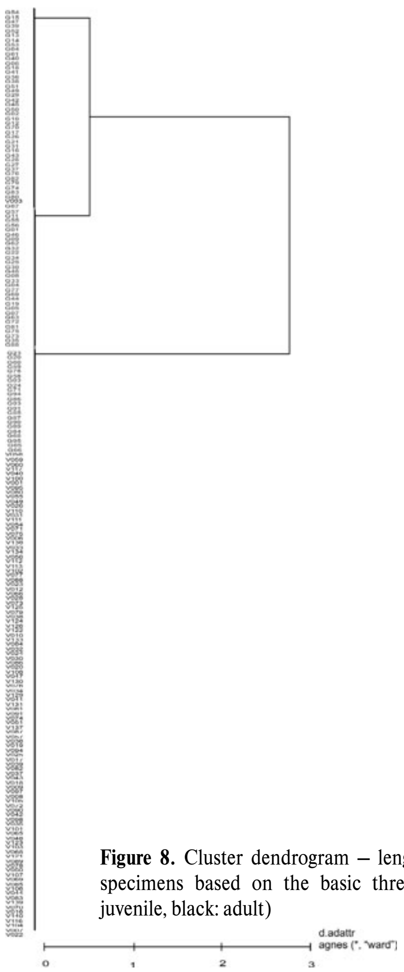

Figure 8. Cluster dendrogram – length, width, height of 200 specimens based on the basic three size parameters (grey: juvenile, black: adult)

preserved on the juvenile *P. gibbercula* species, therefore less specimens represent this species in ambulacra-based detailed morphometrics.

Based on the morphometrics there are two distinct groups in the samples, however, the determination of some specimens is questionable. For example on V093 the length is larger than the width which is data capture error.

The taxonomical classification is based on the KROH & SMITH (2010) system. The echinoids' most important parameters (L= length, W= width, H= height in millimetre) are displayed in tables. In the synonymy "(L.)" mean bibliographical reference without depiction "v" means specimens have seen by the authors.

Systematic palaeontology

Infraclassis: Irregularia LATREILLE, 1825
Superordo: Neognathostomata SMITH, 1981
Ordo: Clypeasteroidea AGASSIZ, 1873
Subordo: Scutellina HAECKEL, 1896
Familia: Scutellidae GRAY, 1825
Genus: *Parascutella* DURHAM, 1953

Parascutella gibbercula DE SERRES, 1829
Plate I, Figure 1–3

1829 *Scutella gibercula*; (DE SERRES), p. 156.
1841 *Scutella gibbercula* DE MARCEL DE SERRES; AGASSIZ, p. 86.
1871 *Scutella Vindobonensis*; LAUBE, p. 62, pl. 17, fig. 1.
1877 *Scutella vindobonensis* LAUBE; LÓCZY, p. 43. (L.)

1887 *Scutella pygmea* nov. sp.; KOCH, p. 262-263, fig. 1a-c
1906 *Scutella vindobonense* LBE.; VADÁSZ, p. 261. (L.)
v. 1914 *Scutella gibbercula* M. DE SERR.; VADÁSZ, p. 117–118, fig. 14.
v. 1914 *Scutella pygmea* KOCH; VADÁSZ, p. 104, pl. III, fig. 10–11.
v. 1914 *Scutella vindobonensis* LBE.; VADÁSZ, p. 99, fig. 12–13.
v. 1914 *Scutellina hungarica* nov. sp.; VADÁSZ, p. 96, pl. 2, fig. 2–3.
1953 *Scutella vindobonensis* LAUBE, 1871; SZÖRÉNYI, pl. I, fig. 4a–b.
1962 *Scutella vindobonensis;* SCHAFFER, pl.19, fig. 3.
v. 1969 *Scutellina hungarica* VADÁSZ; MIHÁLY, p. 255–256, pl. II, fig. 2–3.
v. 1969 *Scutellina szoerenyiae* nov. sp.; MIHÁLY, p. 255, pl. II, fig. 1.
v. 1969 *Scutella vindobonensis* LAUBE; MIHÁLY, p. 254. (L.)
v. 1984 *Scutella* („*Scutellina*") *hungarica* (VADÁSZ); KÓKAY et al., p. 288. (L.)
v. 1984 *Scutella vindobonensis* LAUBE; KÓKAY et al., p. 288, 299. (L.)
v. 1985 *Scutella hungarica* (VADÁSZ, 1914) nov. comb.; MIHÁLY, p. 239–240, pl. I., fig. 6–10.
v. 1985 *Scutella muelleri* n. sp.; MIHÁLY, p. 241, pl. III, fig. 5–6, pl. IV, Fig. 1.
v. 1985 *Scutella pygmea* KOCH, 1887; MIHÁLY, p. 240, pl. III, fig. 1-4.
v. 1985 *Scutella romani* n. sp.; MIHÁLY, p. 240, pl. II, Fig. 4–6.
v. 1985 *Scutella vindobonensis* LAUBE, 1871; MIHÁLY, p. 241–242. (L.)
2005 *Parascutella gibbercula* (DE SERRES, 1829); KROH, p. 85. (L.)
2010 *Parascutella gibbercula* (DE SERRES, 1829); KROH, p. 297.

Measurment:

Mean average parameters in mm		
L	W	H
52.5	56.5	11

Material: MFGI Ech. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 87, 95, 96, 97, 98, 98, 99, 343, 344, 348, 349, 350, 351, 358, 359, 360, 361, 362, 363, 371, 372, 373, 374, 376, 378, 379, 380, 381, 382, 383, 385, 386, 387, 388, 389, 390, 391, 392, 397, 398, 399, 401, 410, 415, 1768, 1769, 1770, 1771, 1773, 1776, 1777, 1785, 1788, 1802, 1803, 1804, 1807, 1817, 1822, 1823, 1825, 2004; Ech. ELTE 003, 004, 005, 009, 010, 011, 012, 013, 014, 015, 016, 017, 018, 020, 023, 028, 029, 030, 031, 032, 033, 035, 036), M.60.6078, M.60.5947, 6088, M.60.5971, M.61.5640, M.61.5693, M.61.6220, M.66.34, M.66.66 (Total: 235) Gyakorló utca (79), Örs vezér Square (77), Kerepes Street (70), Rákos railway delta (8), District of Budafok-Tétény (29).

Description of the juvenile forms: The juvenile specimens' description is based on "Ech. 363": the test is flat, discoidal, on the apex show slight, conical convexity. The edge is slightly rounded with little, bay-like inclusion at the lower part. The maximum width is slightly posterior. The ambulacra are petaloid, extend to the center of the test. At its two ends occurs a little narrowing. The pore pairs are parallel; they are closed to the ambulacrum. The interambulacra are covered by small tubercles, which are slightly larger adorally than adapically. At the apex there are no gonopores. The ventral side is flat. The round peristome is in central position. It is relatively big compared to the size of body. The discoid periproct is in marginal position in the lower part of the test on the adoral surface. A little bay-like V-shaped inclusion is detectable at the peristome.

Description of the adult forms: The same as the juvenile type, with the following differences: the adapical conical convexity is much larger than on juvenile forms, which increases the height of the specimens. The ambulacra extend near the margin of the test, while on the juvenile specimens reach only the centre of the test. The growth of the ambulacra from the smallest juvenile to the biggest specimens is gradual (Figure 9). At the apex the gonopores are appreciable. The periproctal bay-like inclusion is less angular, typical long drown U-shaped. By the juvenile specimens the periproctal margin are convex, while the adult forms have straight or concave margin.

Remarks: In the case of each specimen the contour lines are the same (Pl. I, figures 1–2.).

Occurrence: Widespread within the Paratethyan Badenian formations. Lower and Upper Badenian in Hungarian: Kemence, Biatorbágy, Egyházbér, Érd, Fazekasboda, Harka, Himesháza, Hird, Hosszúhetény,

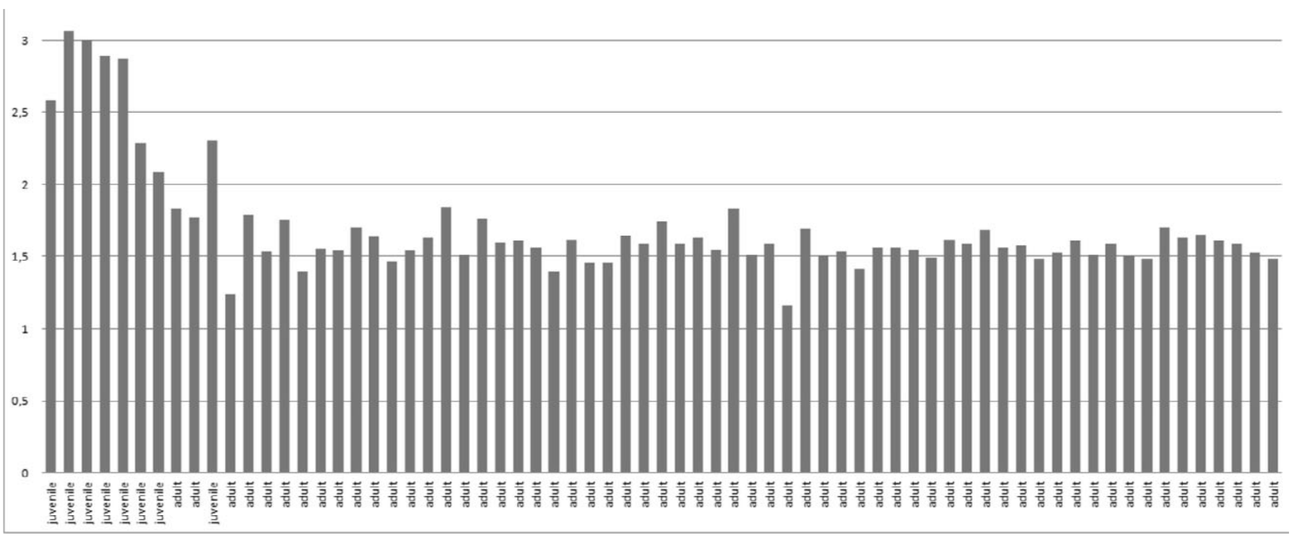

Figure 9. Half length / frontal ambulacrum ratio on juvenile and adult specimens from smallest to biggest size

Mátraverebély, Sámsonháza, Sopron, Szatina, Zebegény: Leithakalk Formation (calcarenite), Upper Badenian: Budapest, District of Budafok-Tétény, Örs vezér Square, Gyakorló Street canalization, Kerepes Street canalization, Rákos railway delta: Leithakalk Formation (calcareous sand, calcarenite); Upper Badenian; France, Austria, Slovak Republic, Ukraine, Romania: calcarenite, limestone, Badenian.

Summary

Based on our detailed morphological and morphometric study (correlation, principal component analysis and cluster analysis) on the Late Badenian *Parascutella gibbercula* collection from Budapest, Hungary there are some typical differences between juvenile and mature forms. The study's results confirmed the understanding that *Parascutella vindobonensis* is the adult form of *P. gibbercula.* We described intraspecific variability during ontogeny. The most distinctive characters of the juvenile and adult forms are the followings:

— the adapical conical convexity of the adult forms is much larger than juveniles, the length/height (L/H) ratio is more than 1.5 times larger at adult specimens;

— the ambulacra extend to near the margin of the test at mature specimens, while at juvenile forms reach only the half of the test;

— periproctal bay-like inclusion is elongated U-shaped at *P. vindobonensis*, while at adult forms it is V-shaped;

— specimens of juvenile forms the periproctal margin are convex, while the adult forms have straight or concave margin.

Acknowledgement

We are grateful to KLÁRA PALOTÁS (Geological and Geophysical Institute of Hungary) and ALFRÉD DULAI (Hungarian Natural History Museum) for permissions to study the Echinodermata collections. The critical review of ANDREAS KROH (Naturhistorisches Museum, Wien) significantly improved this study. Sincere thanks are due to Professor MIKLÓS KÁZMÉR, ATTILA VIRÁG and ISTVÁN SZENTE (Department of Palaeontology, Eötvös Loránd University Budapest) for valuable discussions. We benefited from the assistance of ZOLTÁN LANTOS (Geological and Geophysical Institute of Hungary) for taking the photographs, and VIKTOR KARÁDI (Department of Paleontology, Eötvös Loránd University Budapest) for editing the plate. Sincere thanks are due to all of them. This study was supported by the Hantken Foundation.

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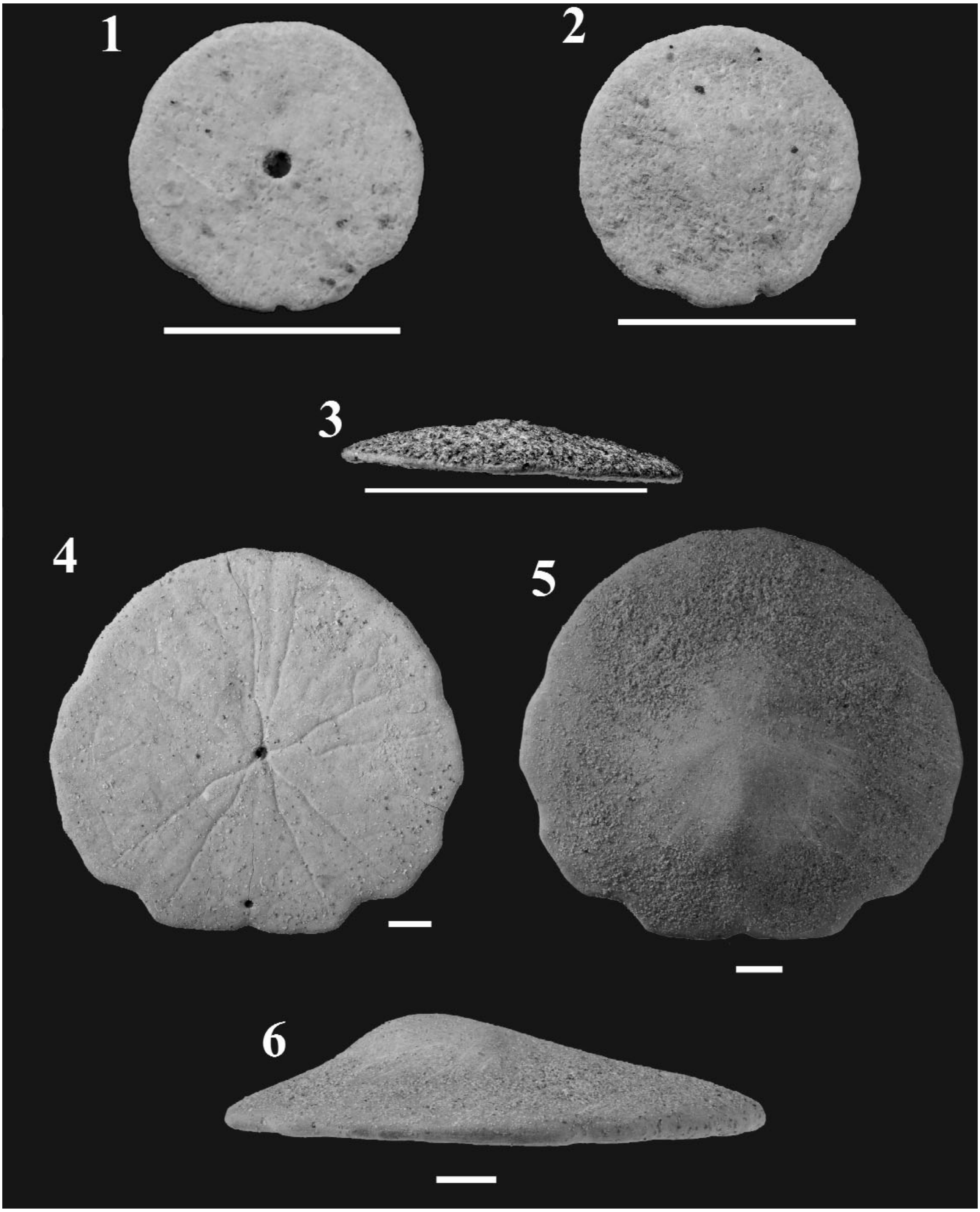

Plate I

1, 2, 3. *Parascutella gibbercula*, DE SERRES, 1829 – juvenile, 1: adoral view, 2: adapical view, 3: side view, inventory number: Ech. 363, Gyakorló Street canalization

4, 5, 6. *Parascutella gibbercula* DE SERRES, 1829 – mature, 4: adoral view, 5: adapical view, 6: side view, inventory number: Ech. 391, Sugár Shopping Centre, Örs vezér Square

Scale: 1 cm