On the variability of benthic foraminiferal species of the genus *Pleurostomella* in the Tethys

Abstract

Twenty small benthic foraminiferal species of the Rotaliid genus *Pleurostomella* are common in the late Cretaceous and Paleogene from some Tethyan localities: North Atlantic (USA, Mexico, Caribbean), Europe (France, Poland, Italy, Hungaria, Bulgaria, North Sea), North Africa (Tunisia, Egypt), Southwest Asia (Iraq, UAE), Indian Ocean (Pakistan) and Southern Ocean. Seventeen well-known diagnostic species are: *Pleurostomella acuta*, *P. alternans*, *P. austinana*, *P. bellardii*, *P. brevis*, *P. clavata*, *P. cubensis*, *P. eocaena*, *P. incrassata*, *P. naranjoensis*, *P. nitida*, *P. nuttalli*, *P. obtusa*, *P. paleocenica*, *P. subnodosa*, *P. velascoensis*, *P. watersi*. Moreover, three other species of *Pleurostomella* are believed here to be new: (1) the Maastrichtian *P. osmani* n. sp. is recorded from Abu Zenima section, east Gulf of Suez, west central Sinai, northern Egypt, (2) the Paleocene *P. plummerae* n. sp. was recorded from the Midway Formation in Texas (USA), and (3) the Eocene *P. haquei* n. sp. was recorded from Quetta District, West Pakistan.

Keywords: benthic foraminifera, *Pleurostomella*, cretaceous, paleogene, Tethys

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Introduction

The rich and diverse late Cretaceous-Paleogene benthic foraminiferal assemblages from Tethys include different species of the Rotaliid genus *Pleurostomella* (early biserially alternating arrangement chambers, but later uniserial and terminal aperture with or without tooth). The paleontological occurrence of twenty species belonging to the genus *Pleurostomella* has been reported from many localities in the Tethys (Figure 1&2). The author has examined many

representatives of this genus, which has different length and width, cuneate test or rounded initial periphery, elliptical or oval-shape terminal or subterminal aperture with overhanging hood, with or without simple or bifid apertural tooth. As a whole this taxa are rarely described in the micropaleontological literature, that's why this study is dedicated, and the intent of this study is to bring together many data scattered in the literature under a unifying theme, and to detect its paleontology, stratigraphy, paleobathymetry and paleogeographic distribution of them in the Tethys.

Figure 1 The paleogeographic map of the terminal Cretaceous showing some Tethyan localities, from west to east: North Atlantic (USA, Mexico, Caribbean), Europe (France, Italy, Bulgaria, Hungary), Northeast Africa (Tunisia, Egypt), Southwest Asia (Iraq, UAE) and Indian Ocean (Pakistan), after Anan (2012).

Systematic paleontology

The taxonomy of the identified species follows that of Loeblich & Tappan¹ and the illustrated taxa have been shown in Plates 1 & 2.

Order Foraminiferida Eichwald, 1830

Suborder Rotaliina Delage & Hérouard, 1896

Superfamily Pleurostomellacea Reuss²

Family Pleurostomellidae Reuss²

Subfamily Pleurostomellinae Reuss²

Genus *Pleurostomella* Reuss²

Type Species *Dentalina subnodosa* Reuss²

Pleurostomella acuta Hantken,³ (Pl. 1, fig. 1)

1875 *Pleurostomella acuta* Hantken,³ p. 37, pl. 13, fig. 18.

1975 *Pleurostomella acuta*; Proto Decima & De Biase,⁴ p. 96, pl. 3, fig. 7.

1986 *Pleurostomella acuta*; Hulsbos,⁵ p. 531, pl. 5, fig. 11.

2000 *Pleurostomella acuta*; Sztrákos,⁶ p. 146.

2007 *Pleurostomella acuta*; Ozsvárt,⁷ p. 69, pl. 8, figs. 9–11.

2011 *Pleurostomella acuta*; Mohan et al.,⁸ p. 60, pl. 9, fig. 9.

2012 *Pleurostomella acuta*; Hayward et al.,⁹ p. 227, pl. 35, figs. 9–18.

2013 *Pleurostomella acuta*; Alegret & Thomas,¹⁰ p. 44, pl. 1, fig. 13.

Remarks: Test loosely biserial early stage, oval in outline and circular in cross-section, length approximately two times maximum width, chambers increasing gradually in size and final pair of chambers extremely inflated, sutures barely visible, slightly depressed and strongly curved, wall calcareous hyaline smooth and finely perforated, aperture terminal with large oval opening of final chamber. Hayward et al.,⁹ noted that *P. acuta* is more inflated than *P. incrassata*. It was recorded from the Cretaceous–Paleogene transition in Southern Ocean, Paleocene–early Eocene from Italy, early–middle Eocene from France, but middle–late Eocene from Hungary. After Hayward et al.,⁹

the paleo-bathymetric distribution of *P. acuta* in present-day depth ranges of sites: lower bathyal–middle abyssal (1200–4000 m).

***Pleurostomella alternans* Schwager,¹¹ (Pl. 1, fig. 2a–c)**

1866 *Pleurostomella alternans* Schwager,¹¹ p. 238, pl. 6, figs. 79, 80.

1927 *Pleurostomella alternans*; Plummer,¹² p. 69, pl. 4, fig. 2a (non fig. 2b).

2000 *Pleurostomella alternans*; Sztrákó,⁶ p. 146.

2007 *Pleurostomella alternans*; Ozsvárt,⁷ p. 70, pl. 8, fig. 12.

2007 *Pleurostomella alternans*; Hayward et al.,¹³ p. 8, fig. 2.4.

2011 *Pleurostomella alternans*; Mohan et al.,⁸ p. 60, pl. 9, fig. 10.

2012 *Pleurostomella alternans*; Hayward et al.,⁹ p. 228, pl. 36, figs. 9–15.

Figure 2 The paleogeographic distribution of the Tethys (left) in the Late Cretaceous (94 Ma) to (right) Middle Eocene (50.2 Ma), showing some localities in the Tethys, from west to east: North Atlantic, Europe, Northeast Africa, Southwest Asia and Indian Ocean.

Remarks: Plummer recorded two forms (1927, pl. 4, figs. 2a,b) belonging to the species of Schwager. Plummer's form (2a) belongs here to Schwager's species, while form (2b) is treated here to a different species (see below). *P. alternans* has an elongate smooth test tapering very bluntly toward the aboral extremity with 7–8 biserial arrangement of chambers but later uniserial, aperture highly arched and vertical with the sharply pointed tooth. Hayward et al.,⁹ noted that *P. acuminata* Cushman (1922) commonly co-occurs with *P. alternans*, from which it differs by its elongate rather than squat chambers. They also added that the original Novara Expedition foraminiferal specimens described by Schwager,¹¹ including *P. alternans*, have been lost from the Museum of Natural History, Vienna, during war-time upheavals. It was recorded from Paleocene–Eocene of France, Italy and USA. The age of this species was indicated by Schwager a younger or middle Paleogene age, middle–upper Eocene from Hungary, and Eocene of France. Halkyard (after Plummer, 1927) reports it from the upper Eocene of Biarritz, but upper portion of the Paleocene Midway Formation in Texas, USA. After Hayward et al.,⁹ the paleo-bathymetric distribution of *P. alternans* in present-day depth range of sites: upper bathyal–middle abyssal (400–4000 m).

***Pleurostomella austinana* Cushman,¹⁴ (Pl. 1, fig. 3)**

1933 *Pleurostomella austinana* Cushman,¹⁴ p. 64, pl. 7, fig. 13.

1946 *Pleurostomella austinana*; Cushman,¹⁵ p. 131, pl. 54, figs. 19–21.

Remarks: This late Cretaceous has long and slender test with being loosely biserial stage. It was originally recorded from Texas (USA). Hayward et al.,⁹ treated this species in the synonym list of *P. subnodosa* (Reuss).

***Pleurostomella bellardii* Hantken,³ (Pl. 1, fig. 4)**

1883 *Pleurostomella bellardii* Hantken,³ p. 25, pl. 2, fig. 1.

2000 *Pleurostomella bellardii*; Sztrákó,⁶ p. 167, pl. 5, figs. 12, 13.

Remarks: This middle Eocene species has short test, and the last two chambers occupied about $\frac{2}{3}$ of the test size. This species has less width than *P. brevis* Schwager. Hayward et al.,⁹ treated this species in the synonym list of *P. wadowicensis* Grzybowski, 1896.

***Pleurostomella brevis* Schwager,¹¹ (Pl. 1, fig. 5)**

1866 *Pleurostomella brevis* Schwager,¹¹ p. 239, pl. 6, fig. 81.

1989 *Pleurostomella brevis*; Hantken,³ p. 117, fig. 3D.

2011 *Pleurostomella brevis*; Mohan et al.,⁸ p. 60, pl. 9, figs. 11, 12.

2012 *Obesopleurostomella brevis*; Hayward et al.,⁹ p. 221, pl. 33, figs. 3–8.

Remarks: This species belongs to Hayward's new genus *Obesopleurostomella* by Hayward et al.,⁹ (which not recorded in Loeblich & Tappan¹), due to medium-large moderately inflated biserial test, overlapping last two chambers which consists about half the test-size, with small semicircular upper portion aperture and two small teeth. This species has more width and shorter length than another species of *P. alternans*. After Hayward et al.,⁹ the paleobathymetric distribution of this specie in present-day depth range of sites: middle bathyal–middle abyssal (900–4000 m).

***Pleurostomella clavata* Cushman,¹⁶ (Pl. 1, fig. 6)**

1926 *Pleurostomella clavata* Cushman,¹⁶ p. 590, pl. 16, fig. 5.

1946 *Pleurostomella clavata*; Cushman,¹⁵ p. 132, pl. 54, fig. 25.

1994 *Pleurostomella clavata*; Bolli et al.,¹⁷ p. 142, fig. 38.2.

Remarks: This Maastrichtian-early Eocene species is distinguished by its tapering initial test than the rounded one in *P. brevis* of Schwager. Hayward et al.,⁹ treated this species in the synonym list of *P. acuta* Hantken.

***Pleurostomella cubensis* Cushman & Bermudez,¹⁸ (Pl. 1, fig. 7)**

1937 *Pleurostomella alazanensis* var. *cubensis* Cushman & Bermudez,¹⁸ p. 17, pl. 1, figs. 64, 65.

1994 *Pleurostomella cubensis*; Bolli et al.,¹⁷ p. 142, fig. 38.4-5.

Remarks: This early Eocene species has shorter elongation than *P. alternans* and differs by its diagnostic apertural tooth. Hayward et al.,⁹ treated this species in the synonym list of *P. alazanensis* Cushman.

***Pleurostomella eocaena* Gümbel,¹⁹ (Pl. 1, fig. 8)**

1868 *Pleurostomella eocaena* Gümbel,¹⁹ p. 52, pl. 1, fig. 53.

1975 *Pleurostomella eocaena*; Proto Decima & De Biase,²⁰ p. 96, pl. 3, fig. 6.

2007 *Pleurostomella eocaena*; Ozsvárt,⁷ p. 70, pl. 8, fig. 13.

2007 *Pleurostomella eocaena*; Valchev,²¹ p. 136.

Remarks: Test elongate, loosely biserial, lobulate in outline and circular in cross-section; length approximately three to four times of maximum width; chambers increasing rapidly in size; sutures slightly depressed; wall calcareous, hyaline, smooth, finely perforated; aperture oval opening of final chamber. *P. alternans* Schwager has large, oval aperture contrary to *P. eocaena* Gümbel,¹⁹ which has much smaller aperture. Hayward et al.,⁹ treated this species in the synonym list of *P. subnodosa* (Reuss). It was recorded in the Paleocene-early Eocene from Italy and Bulgaria, but middle-late Eocene from Hungary.

***Pleurostomella incrassata* Hantken,³ (Pl. 1, fig. 9)**

1883 *Pleurostomella incrassata* Hantken,³ p. 25, pl. 1, fig. 4.

1975 *Pleurostomella incrassata*; Proto Decima & De Biase,²⁰ p. 96, pl. 3, fig. 5.

1986 *Pleurostomella incrassata*; Hulsbos et al.,⁵ p. 531, pl. 5, fig. 10.

2000 *Pleurostomella incrassata*; Sztrákos,⁶ p. 167, pl. 5, figs. 14, 15.

2007 *Pleurostomella incrassata*; Ozsvárt,⁷ p. 70, pl. 8, figs. 15, 16.

2012 *Pleurostomella incrassata*; Hayward et al.,⁹ p. 230, pl. 37, figs. 16-21, pl. 38, 1-4.

Remarks: Test loosely biserial, lobulate in outline and circular in cross-section, length approximately two to three times of maximum width, pre-final chamber extremely inflated globular and large, inflated final chamber, sutures distinct and strongly depressed, wall calcareous hyaline smooth and finely perforated, aperture small oval opening of final chamber. Hayward et al.,⁹ noted that this species has often been referred to *P. alternans*, but differs in being more distinctly inflated and has less tendency to become staggered uniserial in larger specimens. They also noted that the paleo-bathymetric distribution of late Cretaceous–late Pliocene *P. incrassata* in present-day depth range of sites: lower bathyal–middle abyssal (1200–3600 m).

***Pleurostomella haquei* Anan,²² n. sp. (Pl. 1, fig. 10)**

1960 *Pleurostomella* n. sp. Haque,²³ p. 28, pl. 5, fig. 7.

Holotype: Plate 1, fig. 10.

Type locality: KSR (Sor Range), Quetta District, West Pakistan.

Type sample: sample 5, KSR.

Age: middle-late Eocene.

Etymology: In the memory of the late Pakistanian micropaleontologist Mohsenul Haque.

Diagnosis: This species has short and cuneate test, the initial chambers arrangement varying from biserial to nearly uniserial, sutures distinct and depressed, wall calcareous and finely perforate, the last chamber inflated, but the terminal part is broken, fore that the aperture not exist.

Remarks: This Eocene species has erected and elongate test with lax biserial arrangement, and the final uniserial chamber inflated and nearly globular, but the terminal part is unfortunately broken.

***Pleurostomella naranjoensis* Cushman & Bermudez,¹⁸ (Pl. 1, fig. 11)**

1937 *Pleurostomella naranjoensis* Cushman & Bermudez,¹⁸ p. 16, pl. 1, figs. 59, 60.

1994 *Pleurostomella naranjoensis*; Bolli et al.,¹⁷ p. 143, fig. 38.6-7.

Remarks: This Paleocene-early Eocene species has short test, but more width than *P. cubensis* and its biserial portion has rounded periphery. After Hayward et al.,⁹ the holotype of *P. naranjoensis* has small, incompletely developed aberrant final chambers with small, terminal apertures. They also treated this species in the synonym list of *P. acuta* Hantken. Moreover, they also treated the figured specimen *P. naranjoensis* of Bignot,²⁴ (pl. 4, fig. 10) as a junior synonym of *P. incrassata* Hantken.

***Pleurostomella nitida* Morrow,²⁵ (Pl. 1, fig. 12)**

1934 *Pleurostomella nitida* Morrow,²⁵ p. 196, pl. 30, fig. 22.

1946 *Pleurostomella nitida*; Cushman,¹⁵ p. 132, pl. 54, fig. 24.

Remarks: This late Cretaceous American species has compressed test, nearly straight sides and tapering initial base, subterminal elliptical without toothed aperture. Hayward et al.⁹ treated this species in the synonym list of *P. tenuis* Hantken.³

***Pleurostomella nuttalli* Cushman & Siegfus,²⁶ 1939 (Pl. 1, fig. 13)**

1939 *Pleurostomella nuttalli* Cushman & Siegfus,²⁶ p. 29, pl. 6, figs. 17, 18.

1975 *Pleurostomella nuttalli*; Proto Decima & De Biase,²⁰ p. 96, pl. 3, fig. 8.

2000 *Pleurostomella nuttalli*; Sztrákös,⁶ p. 167, pl. 5, fig. 16.

2012 *Pleurostomella nuttalli*; Hayward et al.,⁹ p. 231, pl. 38, figs. 7-14.

Remarks: This late Cretaceous–middle Miocene cosmopolitan species has elongate test, loosely biserial, lobulate in outline and circular in cross-section, inflated final chamber, sutures distinct, wall hyaline smooth and finely perforated, aperture small oval opening of final chamber. After Hayward et al.,⁹ this species was recorded from North Atlantic (early Eocene–late Oligocene; Sweden; Brotzen, 1936; Sites 548, 608), South Atlantic (Late Cretaceous; Sliter²⁷), Indian Ocean (late Eocene–middle Miocene, Sites 758, 763), Southern Ocean (Late Cretaceous–late Oligocene; Sites 689, 690, 738, 744), North Pacific (latest Cretaceous–late Eocene, California, Cushman and Siegfus;²⁶ Sites 865, 1211), equatorial Pacific Ocean (middle Eocene–middle Oligocene, Site 317); Southwest Pacific (late Eocene, New Zealand; GNS collections, U24/f270), Europe (Eocene, Italy and France). Hayward et al. (2012) noted that the paleo-bathymetric distribution of this species in present-day depth range of sites: lower bathyal–middle abyssal (1200–3600 m).

***Pleurostomella obtusa* Berthelin²⁸ (Pl. 1, fig. 14)**

1880. *Pleurostomella obtusa* Berthelin,²⁸ p. 29, pl. 1, fig. 9.

1989 *Fursenkoina* sp. Hulsbos et al.,⁵ p. 270, pl. 3, fig. 6.

1994. *Pleurostomella obtusa*; Bolli et al.,¹⁷ p. 143, figs. 38.8-10.

Remarks: This Cretaceous–early Eocene species is distinguished by loose alternating biserial arrangement with rounded initial test and periphery. It was recorded from Albian of France, Cenomanian–Coniacian of Trinidad. The figured early Eocene specimen of Hulsbos et al.,⁵ from Norwegian Sea is closely related to *P. obtusa*.

***Pleurostomella osmani* Anan,²⁹ n. sp. (Pl. 2, fig. 15)**

Holotype: Plate 2, fig. 15.

Type locality: Abu Zenima section, Red Sea coast, west central Sinai, Egypt.

Type sample: sample 9, Sudr Chalk.

Age: late Maastrichtian, *Abathomphalus mayaroensis* Zone.

Depository: Department of Geology, Al-Azhar University-Gaza, Palestine (AZUGGD A48).

Etymology: In the honor of Dr. Osman Abdelghany, UAE University, in recognition for his contributions to the field of paleontology in Egypt and UAE.

Stratigraphy: The geological map of Abu Zenima area is shown in Figure 3, while the litho- and biostratigraphic section of Abu Zenima is presented in Figure 4. The oldest exposed rocks belong to the Maastrichtian Sudr Chalk (about 31m), overlain by 16m thick sequence of calcareous shales and marls belonging to Paleocene Dakhla Shale, which rest unconformably on the Sudr Chalk. After Anan³⁰ twelve samples were collected from the chalk represent the top of the Maastrichtian *Gansserina gansseri* Zone (samples

1-5) and *Abathomphalus mayaroensis* Zone (samples 6-12). The topmost of the Sudr Formation is missing, due to recovered planktic foraminifera *Plummerita hantkeninoides* Zone. Based on the faunal assemblages, by Hewaidy³¹ named the northern Egypt “*Bolivinoidea* province”, while the central and southern Egypt “*Orthokarstenia* province”. According to Anan^{29,30} the Maastrichtian of Abu Zenima section yield some diagnostic benthic foraminifera: *Verneuilina aegyptiaca*, *Coryphostoma incrassata*, *Cibicidoides abudurbensis*, *Angulogavelinella avnimelechi*, *Gyroidinoides girardanus* and *Bolivinoidea draco* group.

Diagnosis: This new species has short test with rounded initial periphery. The initial chambers commonly are obscured, whereas others have a chamber arrangement varying from biserial to nearly uniserial. Chambers becoming slightly inflated. Sutures initially are indistinct, but later distinct and depressed. Wall calcareous and finely perforate. Aperture subterminal elliptical with overhanging hood, without apertural teeth.

Remarks: This species is distinguished by its short test than the other species of the genus, subterminal elliptical without toothed aperture.

***Pleurostomella paleocenica* Cushman,³² (Pl. 2, fig. 16a-d)**

1947 *Pleurostomella paleocenica* Cushman,³² p. 86, pl. 18, figs. 14, 15.

1951 *Pleurostomella paleocenica*; Cushman,³³ p. 45, pl. 12, figs. 31-33.

1975 *Pleurostomella paleocenica*, Berggren & Aubert,³⁴ p. 160, pl. 2, fig. 12.

1976 *Pleurostomella paleocenica*; Aubert & Berggren,³⁵ p. 426, pl. 7, fig. 5.

1982 *Pleurostomella paleocenica*; Proto Decima & Bolli,²⁰ p. 118.

1994 *Pleurostomella paleocenica*; Bolli et al.,¹⁷ p. 143, fig. 38. 11-12.

2003 *Pleurostomella paleocenica*; Ali,³⁶ p. 123, pl. 7, fig. 19.

2005 *Pleurostomella paleocenica*; Sztrákös,³⁷ p. 188, pl. 15, fig. 27.

2005 *Pleurostomella paleocenica*; Clemmensen & Thomsen,³⁸ p. 358, pl. 1, fig. 17.

Remarks: This Paleocene–early Eocene species has a wide geographic distribution from both sides of Atlantic Ocean (USA, Trinidad, France, Italy, North Sea), and also from North Africa (Tunisia and Egypt). It is characterized by its few chambers, distinctly inflated in the later portion, nearly as wide as high, increasing rapidly in size in the early portion, only slightly in the later portion, sutures distinct and later ones strongly on the upper part of the inner face of the last-formed chamber, wall smooth, aperture on the upper part of the inner face of the last-formed chamber, with a deeper reentrant toward the base of the opening. Hayward et al.,⁹ treated this species as a junior synonym of *P. alternans* Schwager.

***Pleurostomella plummerae* Anan,³⁹ n. sp. (Pl. 2, fig. 17)**

1927 *Pleurostomella alternans* Plummer,¹² p. 69, pl. 4, fig. 2b (non fig. 2a).

Holotype: Plate 2, fig. 17.

Figure 3 Geologic map of east Gulf of Suez, west central Sinai, Egypt and the location of Abu Zenima section, after Anan (1992).

Type locality: Midway Formation, Nicobar Island, Walker Museum Coll. 33007, Sta. 46 University of Chicago, USA.

Age: Paleocene.

Etymology: In the memory of the late American micropaleontologist H. J. Plummer.

Diagnosis: This Paleocene species has short and cuneate test. The initial chambers commonly are obscured, whereas others have a chamber arrangement varying from biserial to nearly uniserial. Chambers becoming slightly inflated. Sutures initially are indistinct, but later distinct and depressed. Wall calcareous and finely perforate. Aperture terminal with overhanging hood with a deeper reentrant toward the base of the opening.

Remarks: This species is distinguished by its short test than the other species of the genus and oval aperture. It seems to be closely resemble with the Paleocene-early Eocene *P. paleocenica* Cushman and other new Maastrichtian species *P. osmani* Anan, but it differs from the first species it by its older stratigraphic state, and the younger stratigraphic state for the second species.

Pleurostomella subnodosa Reuss,² (Pl. 2, fig. 18a, b)

1860 *Pleurostomella subnodosa* Reuss,² p. 204, pl. 8, fig. 2.

1946 *Pleurostomella subnodosa*; Cushman,¹⁵ p. 132, pl. 55, figs. 1-9.

1956 *Pleurostomella subnodosa*; Said & Kenawy,⁴⁰ p. 145, pl. 4, fig. 26.

1968 *Pleurostomella subnodosa*; Sliter,²⁷ p. 110, pl. 19, fig. 10.

1983 *Pleurostomella subnodosa*; Abdel-Kireem,⁴¹ p. 173.

1987 *Pleurostomella subnodosa*; Anan,⁴² p. 222, pl. 1, fig. 15.

1993 *Pleurostomella subnodosa*; Anan,⁴³ p. 316, pl. 3, fig. 1.

2003 *Pleurostomella subnodosa*; Ali,³⁶ p. 123, pl. 7, fig. 21.

2011 *Pleurostomella subnodosa*; Mohan et al.,⁸ p. 60, pl. 9, fig. 16.

2012 *Pleurostomella subnodosa*; Hayward et al.,⁹ p. 231, pl. 38, figs. 20-27.

Remarks: This species slender, elongate and small to medium size smooth test, early biserial and staggered cuneate to uniserial at least in the latter portion, aperture hooded. It was originally described

from the late Cretaceous of Europe, USA and Mexico, Maastrichtian of Abu Rawash section, west Cairo, Egypt by Anan,⁴² while in the Maastrichtian-Paleocene of Sinai (Egypt) by Said & Kenawy⁴⁰ and Paleocene from UAE by Anan.⁴³ On the other hand, Plummer¹² noted that the main differences between *P. subnodosa* Reuss and *P. alternans* Schwager lies in the character of the aperture, that of the former being simple and that of the latter toothed. *P. subnodosa* has 2 small apertural teeth by Sliter.²⁷ Hayward et al.,⁹ noted that *P. subnodosa* is more slender and usually smaller than *P. alternans*. Moreover, the paleobathymetric distribution of *P. subnodosa* in present-day depth range of sites: middle-upper abyssal (2000–4000 m); rare at lower bathyal (1200–2000 m).

Figure 4 Schematic stratigraphic log of Abu Zenima section, west central Sinai of Egypt including the stratigraphic ranges of some diagnostic benthic foraminiferal Maastrichtian species (after Anan, 2004) with the stratigraphic range of the *Pleurostomella osmani* Anan, n. sp.

Pleurostomella velascoensis Cushman,¹⁶ (Pl. 2, fig. 19)

1926 *Pleurostomella velascoensis* Cushman,¹⁶ p. 590, pl. 16, fig. 4.

1946 *Pleurostomella velascoensis*; Cushman,¹⁵ p. 133, pl. 55, fig. 12.

1994 *Pleurostomella velascoensis*; Bolli et al.,¹⁷ p. 143, fig. 38. 14-15.

2003 *Pleurostomella velascoensis*; Ali,³⁶ p. 123, pl. 7, fig. 20.

2005 *Pleurostomella paleocenica*; Sztrákos,³⁷ p. 188, pl. 15, fig. 28.

Remarks: This Maastrichtian-early Eocene species has erected shape with three loosely biserial segment with terminal aperture and

mainly a pointed base. Hayward et al.⁹ treated this species as a junior synonym of *P. incrassata* Hantken.

Pleurostomella watersi Cushman,¹⁴ (Pl. 2, fig. 20)

1933 *Pleurostomella watersi* Cushman,¹⁴ p. 63, pl. 63, figs. 11, 12.

1946 *Pleurostomella watersi*; Cushman,¹⁵ p. 132, pl. 54, figs. 22, 23.

Remarks: This late Cretaceous species has elongate and slender test, gradually increasing in breadth toward the apertural end and the axis somewhat twisted with lobulate sides. Its aperture large and high without tooth-like projections.

Paleoenvironment, paleoecology and paleobathymetry

- Said & Kenawy⁴⁰ described and recorded more than two hundred benthic foraminiferal species from the Upper Cretaceous-Lower Tertiary strata of the two sections in northern Sinai, Egypt. These taxa shown an affinity with Midway-Type faunas (MTF) of American Gulf Coastal Plain, which indicate a similarity with fauna of Trinidad and Tampico Embayment of Mexico (about 70%), together with a few forms from northern Europe. Abu Zenima section is also related to MTF.
- Berggren & Aubert³⁴ noted that the lower Tertiary fauna in the northern part of Sinai Peninsula of Said & Kenawy⁴⁰ shows an affinity with the MTF.
- Keller⁴⁴ also noted that based on foraminiferal morphotype distributional patterns in the Negev-Sinai fauna across the K-T boundary have strong survivorship preference for species of epifaunal Habitat.
- Anan⁴³ noted that the Maastrichtian benthic foraminiferal species of Qarn El Barr section (UAE) and some other sections in Iraq, Jordan and Egypt are closest to the Maastrichtian fauna of Sinai, Egypt. The Maastrichtian chalk of Jiran El Ful section, west Cairo may indicative to open marine middle-outer neritic environment.
- Issawi & Osman⁴⁵ noted that during the Cretaceous and Paleogene span of time, the land of Egypt witnessed many phases of transgressions and regressions of Tethys over a paleorelief (highs and lows of Syrian Arcs) by the syntectonic structures, which varied considerably from one place to other, and Lat. 28°N was considered by them to be detected the contact between the deep-water facies in the north and shallower in the south, but around Lat. 27°N (Anan⁴²). In the Maastrichtian time, deep marine sediments were deposited in the north Egypt, whereas gradually becoming shallower and less thick southward to the coeval lithofacies predominated, as mentioned by other authors (i.e. Youssef,⁴⁶ Anan^{30,39,47,29}).
- Sztrákos³⁷ noted that the Midway type species from the North Pyrenean trough (Aquitaine, France) were transported by the turbidite currents from the lower to middle neritic environments are frequent as well as Cretaceous reworked species.
- Valchev²¹ noted that the taxa were recorded from the Paleocene of the coastal part of east Stara Planina (Eastern Bulgaria) belongs to Midway-type benthic foraminifera.
- Anan⁴⁸ noted that the probable environment for the northern Egypt

(which represented by Abu Zenima section) is outer neritic-upper bathyal (200–400 m), which is deeper than the many locations in

central Egypt, which are deposited in the middle-outer neritic (75–200 m).

Plate I The species of the genus *Pleurostomella*: **1: *P. acuta*** (after Ozsvárt, 2007 × 40), **2a-c: *P. alternans*** (a, after Schwager, 1866 × 60; b, after Plummer, 1927 × 60; c, after Ozsvárt, 2007 × 45), **3: *P. austinana*** (after Cushman, 1946 × 80), **4: *P. bellardii*** (after Sztrákó, 2000 × 60), **5: *P. brevis*** (after Schwager, 1866 × 50), **6: *P. clavata*** (after Bolli et al, 1994 × 65), **7: *P. cubensis*** (after Bolli et al, 1994 × 65), **8: *P. eocaena*** (after Ozsvárt, 2007), **9: *P. incrassata*** (after Ozsvárt, 2007), **10: *P. haquei*** Anan, n. sp. × 90, **11: *P. naranjoensis*** (after Bolli et al, 1994 × 65), **12: *P. nitida*** (after Cushman, 1946 × 110), **13: *P. nuttalli*** (Sztrákó, 2000 × 50), **14: *P. obtuse*** (after Bolli et al, 1994 × 55).

- i. Hayward et al.,¹³ recorded some species of the genus *Pleurostomella* from 700 > 3000 m in some deep-water sites from upper bathyal-middle abyssal of the Oceans. Hayward et al.,⁹ presented more detailed valuable study on five families (Chrysalogoniidae, Glandulo-nodosariidae, Stilostomellidae, Ellipsoidinidae, Pleurostomellidae) of benthic foraminiferal species belonging to 30 genera (105 species) of cosmopolitan, mainly deep-sea (600–4000 m), became extinct during the late Pliocene–middle Pleistocene interval (3.6–0.13 Ma). These declines occurred in pulses mostly coinciding with glacial episodes of expansion of polar ice sheets, initially in Antarctica but during

the mid-Pleistocene Climate Transition (MPT, 1.2–0.55 Ma) in the Arctic.⁴⁹ The Cretaceous–Cenozoic Extinction Group (Ext. Gp.) species had an even spread of species durations between 5–85 myrs (except plectofrondiculariids), with mean species durations of 50 myrs (Pleurostomellidae). Cenozoic faunas are dominated by mostly long-lived species of just three genera: *Strictocostella*, *Siphonodosaria* and *Pleurostomella*. Moreover, the Last Global Extinction (LGE) and regional highest occurrence levels of Ext. Gp. species have considerable biostratigraphic value in providing rapid age assessments of Quaternary oceanic sediment where planktic foraminiferal age datum's are rare.

Plate 2 The species of the genus *Pleurostomella*: **15: *P. osmani*** Anan, n. sp. x 30, **16a-d: *P. paleocenica*** (a, after Cushman, 1951 x 80; b, Berggren & Aubert, 1975 x 80; c, after Ali, 2003 x 60; d, after Clemmensen & Thomsen, 2005 x 35), **17: *P. plummerae*** Anan, n. sp. x 110, **18a, b: *P. subnodosa*** (a, after Said & Kenawy, 1956 x 65; b, after Sliter, 1968 x 40), **19: *P. velascoensis*** (after Bolli et al, 1994 x 55; **20: *P. watersi*** (after Cushman, 1946 x 65).

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Conflicts of interest

Author declares that there is no conflict of interest.

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