

Biostratigraphy and Systematic Palaeontology of Late Cretaceous Heterohelicidae Foraminifera from Kurdistan Region North-eastern Iraq

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ABSTRACT

The biostratigraphical importance and systematic palaeontology of Early Turonian to Early Maastrichtian Heterohelicidae Planktic foraminifera from Kurdistan region, NE Iraq are described. Some 24 species from 11 genera are recorded. Species abundance and diversity increase from the Early Turonian to Early Maastrichtian, perhaps signifying cooler sea temperatures in the Arabian sector of the Tethys Ocean during the Early Maastrichtian. Despite the long biostratigraphical ranges of some species, the importance of the biserial and multiserial Planktic foraminifers in Late Cretaceous biostratigraphy is emphasized. From a biostratigraphic perspective, heterohelicids are important for the definition of the Campanian-Maastrichtian boundary in Kurdistan region, with Planoglobulina species being especially important in this respect, as they are in Iran, Turkey and North Africa.

Key words: Late Cretaceous, Heterohelicidae, Systematic palaeontology, Kurdistan region, Iraq.

الطباقية الحياتية ودراسة تصنيفية لفورامينيفيرا الهيتيروهلوسيدا (الكريتاسي الاعلى) من اقليم كردستان، شمال شرقي العراق

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المخلص

تم وصف الأهمية الطباقية الحياتية وتصنيف الحفريات الطافية الهيتيروهلوسيدا (Heterohelicidae) العائدة لعمر التورنيان المبكر الى الماسترختيان المبكر من كردستان. تم تسجيل حوالي 24 نوعاً من 11 جنساً. أظهرت هذه الدراسة بأن وفرة الأنواع والتنوع يزداد من العصر التوروني المبكر إلى ماسترختيان المبكر، والذي ربما يدل على ان درجات حرارة البحر أكثر برودة في القطاع العربي من المحيط تيثيس خلال الماسترختي المبكر. على الرغم من النطاقات البيوستراتفرافية الطويلة لبعض الأنواع، فإن أهمية البقايا التثنائية التسلسل

والمتمعددة التسلسل تم تأكيدها في أواخر العصر الطباشيري من منظور بيوستراتغرافي. إن الهيتروهلبيدي مهمة أيضا في تعريف حدود الكامبانيان مع الماستريختي في كردستان، مع وجود أنواع *Planoglobulina* ذات الأهمية الخاصة في هذا الصدد، كما هي في إيران وتركيا وشمال إفريقيا.

الكلمات الدالة: الكريتاسي المتأخر، هيتروهلبيديا، المتحجرات النظامية، إقليم كردستان، العراق.

INTRODUCTION

The family Heterohelicidae Cushman 1927 forms one of the most common planktic foraminiferal groups in the Late Cretaceous (Early Turonian-Early Maastrichtian) Kometan and Shiranish formations in the Kurdistan region, NE Iraq (Fig. 1). Many Heterohelcid species show biostratigraphical potential, yet in Kurdistan relatively little attention has been paid to them, and their biostratigraphic and biogeographic significance are poorly known. However, more recently, Abdel-Kireem et al. (1996a), Robaszynski (1998), Li and Keller (1998a, 1998b, 1999), Li et al. (1999), Abramovich and Keller (2002, 2003), Abramovich et al. (2002, 2003, 2010, 2011), Huber et al. (2008), and Ogg and Hinnov (2012) enhanced Late Cretaceous planktic foraminiferal biozonation based on the Heterohelicidae. Two sections have been selected; the Azmer is located in the Zagros Imbricate Zone of Iraq, while the Dokan section is situated in the Zagros Foreland High Folds Zone (Lawa et al., 2013; Omar et al., 2015). The objectives of this study are: 1) to describe the species of the Heterohelicidae from the Kometan and Shiranish formations; and 2) to investigate in detail the biostratigraphical distribution of the heterohelcid planktic foraminifera in the Late Cretaceous (Early Turonian-Early Maastrichtian) of the Kurdistan region, NE Iraq.

MATERIALS AND METHODS

Two well exposed sections, at Dokan (latitude 35° 56' 15"N, longitude 44° 57' 21"E) and Azmer (latitude 35° 37' 30"N, longitude 45° 31' 45"E; see Fig. 1) were chosen for foraminiferal analysis. Some 411 samples have been collected from Kometan and Shiranish formations. For indurated rock samples, thin section analysis was used for heterohelcid identifications. For friable rock samples, a freeze-thaw method of processing was used (Jaff et al., 2014; 2015; Jaff and Lawa, 2019). Approximately 200-300 grams of each friable sample was repeatedly frozen and thawed in a supersaturated solution of sodium sulphate decahydrate until the rock disaggregated. The scattered sediments are then fully washed by a 63 µm sieve and the residues separated by filtration and dried overnight with an oven temperature of 50°C. Dried residues were sorted using sieve sizes from 500 µm down to 63 µm. Heterohelcids were picked and studied from the residue in the 63-300 µm size fractions. As a relative measure, heterohelcids are defined as rare where fewer than 5 specimens per sample are found and common where there are more than 5 specimens per sample. The heterohelcids were studied using a Hitachi S-3600N Scanning Electron Microscope (SEM) at the University of Leicester, UK. Materials for this study are stored in the collections of the British Geological Survey, Keyworth, and Nottingham, UK.

LITHOSTRATIGRAPHY

The Late Cretaceous (Early Turonian to Early Maastrichtian) strata of NE Iraq comprise two marine deposited formations: the pelagic limestone of the Kometan

Formation (Early Turonian-Early Campanian) and the marly limestones and marlstones of the Shiranish Formation (Late Campanian-Early Maastrichtian). The Late Maastrichtian successions are characterized by the interfingering of Tanjero Formation with the reef dominated facies of Aqra Formation in both studied sections (Lawa et al., 2017; Lawa, 2018).

Kometan Formation:

The type section of the Kometan Formation was first described in an unpublished report by H.V. Dunnington (1953, *fide* van Bellen et al., 2005) from the village of Kometan near Endeze in NE Iraq. At Endeze, the formation comprises some 36 m of light grey, thinly bedded, globigerinal-oligosteginal limestone, locally silicified, with chert nodules, and glauconite especially at the base of the formation. According to a number of authors (e.g. Kaddouri, 1982; Al-Jassim et al., 1989; Al-Sheikhly et al., 1989; Abawi and Hammoudi, 1997; Hammoudi and Abawi, 2006; Haddad and Amin, 2007) the age of the Kometan Formation is Late Turonian at its base and extends to the Early Campanian at the top. However, more recently according to (Jaff et al., 2015) the base of the Kometan Formation extends to the Early Turonian based on the finding of the index planktic foraminifera *Helvetoglobotruncana helvetica*. The Kometan Formation is interpreted to be an outer shelf or basinal deposit (Jassim and Goff, 2006), becoming increasingly argillaceous to the west and southwest of Iraq. The base of the Kometan Formation is unconformable on the underlying Balambo and Qamchuqa formations in NE Iraq (which are Early Cenomanian; van Bellen et al., 2005; Buday, 1980; Jassim and Goff, 2006; Ameen and Gharib, 2014; Faris et al., 2019). The Kometan Formation has thicknesses of approximately 158 m and 96.5 m in the Dokan and Azmer areas respectively. In the Dokan area the formation is composed of well-bedded, light grey or white limestone with common chert nodules. The top of the Kometan Formation shows the local extinction of large ammonites. In the Azmer area the Kometan Formation is mainly composed of light grey, medium-bedded limestone, the lower part of the formation is associated with small, centimetre-scale ammonites, but towards the upper part of the formation there is a notable increase in the size of the Ammonites, which also become more common and lacks chert nodules.

Shiranish Formation:

The Shiranish Formation was first defined in an unpublished report by F.R.S. Henson (1940, *fide* van Bellen et al., 2005) from the 'High Folded Zone' of northern Iraq near the village of Shiranish Islam, NE of Zakho. The formation in its type section is about 228 m thick, and is informally subdivided into a 'lower unit' characterised by alternating marly limestone and calcareous marlstone that is rich in foraminifera, and an 'upper unit' that is dominated by blue marlstone (van Bellen et al., 2005; Aqrabi et al., 2010). According to several authors (Kennedy and Lunn 2000; Al-Banna 2010; Aqrabi et al., 2010; Jaff et al., 2014, 2015; Farouk et al., 2018; Jaff and Lawa, 2019) the age of the Shiranish Formation is Late Campanian to Maastrichtian, but it does not extend to the Late Maastrichtian (Kassab 1973; Jaff et al., 2014, 2015; Farouk et al., 2018; Jaff and Lawa, 2019). The formation in its type locality is interpreted to be an outer shelf to basinal deposit (Jassim and Goff, 2006) that unconformably overlies the Kometan Formation, and is succeeded conformably by marine clastic deposits of the Tanjero Formation in NE Iraq (Sharbazheri, 2008). The Shiranish Formation is well

exposed in the localities studied and is about 260 m and 144 m thick in the Dokan and the Azmer areas respectively. In the Dokan area there is a glauconitic pebbly sandstone bed of around 0.5 m at the base of the 'lower unit' that may indicate a very slow rate of deposition or period of non-deposition (see Jaff et al., 2015; Farouk et al., 2018).

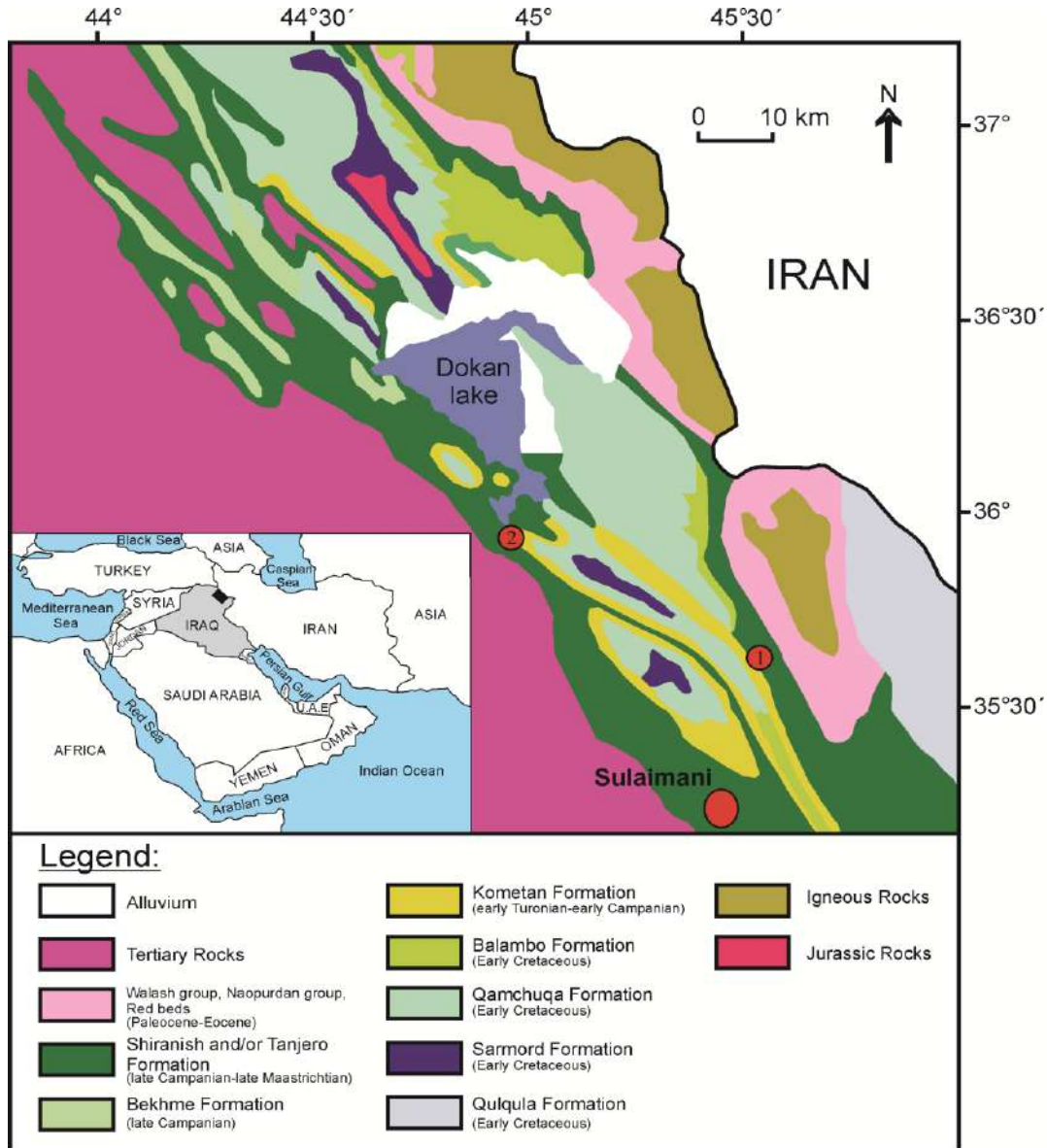


Fig. 1: Geological context for the Azmer (1) and Dokan (2) sections of the Kometan and Shiranish formations in the Kurdistan region, NE Iraq (after Sissakian, 2000).

SYSTEMATIC PALAEOONTOLOGY

The terminology used to describe heterohelicids is shown in Figure (2). The stratigraphic ranges of the species as recorded by different authors, as well as in the present study, are shown in Figures (3-5). The taxonomic classification followed here is that of Pessagno (1967), Martin (1972), Smith and Pessagno (1973), Abdel-Kireem (1986), Nederbragt (1989, 1991), Abdel-Kireem et al. (1996b), Georgescu et al. (2008), Georgescu (1995, 2009), Haynes et al. (2015).

Order Foraminiferida Eichwald, 1830
Suborder Globigerinina Delage and Hérourard, 1896
Superfamily Heterohelicacea Cushman, 1927
Family Heterohelcidae Cushman, 1927
Subfamily Heterohelicinae Cushman, 1927
Genus *Praegublerina* Georgescu, Saupe and Huber, 2008

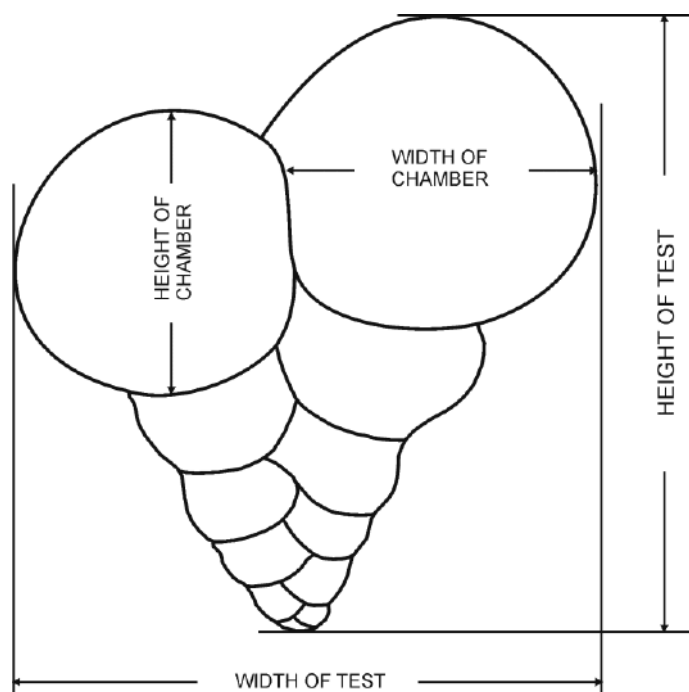


Fig. 2: Idealized biserial heterohelcid showing terminology used to measure and describe the morphology of the test after Abdel-Kireem et al. (1996b).

Genus ***Praegublerina*** Georgescu, Saupe and Huber, 2008

Praegublerina acuta (de Klsz, 1953), Plate 1, figs. 1-3

Gublerina acuta de Klsz, 1953, p. 246, 247, pl. 8, fig. 3; Weiss, 1983, p. 38, 39, pl. 1, figs. 1, 2; Nederbragt, 1989, p. 194, pl. 1, fig. 1; Nederbragt, 1991, p. 339, pl. 1, figs. 1, 2; Abramovich et al., 2003, p. 9, pl. II, fig. 9.

Praegublerina acuta (de Klsz). Georgescu et al., 2008, p. 408, 409, pl. 1, fig. A (3), pl. 4, figs. 1-4, pl. 6, figs 4-6.

-Material. 32 specimens from 20 samples.

-Dimensions. 12 specimens measured give the following dimensions: height of test 0.47-0.70 mm, width of test 0.33-0.63 mm.

-Remarks. In Kurdistan, *Pg. acuta* is differentiated from material of the type species of *Gublerina*, *Gublerina cuvillieri* Kikoine, 1948, by the more acute shape of the initial part of its test and by its overall less widely flaring shape: it can also be distinguished by having fewer chambers in the biserial part of the test, by having a narrow area of divergence between two rows of chambers, by the commencement of chamber divergence in the middle stage of the test, and by the presence of progressive elongate, sub-rectangular to reniform chambers over the divergence area in the multiserial portion of the test.

-Occurrence. (Early Maastrichtian; Fig. 3).

Genus *Gublerina* Kikoine, 1948*Gublerina cuvillieri* Kikoine, 1948, Plate 1, figs. 4-6

Gublerina cuvillieri Kikoine, 1948, p. 26, pl. 2, figs. 10a-c; de Klasz, 1953, p. 251, pl. 8, figs. 1, 2; Darmonoian, 1975, p. 196, 197, pl. 2, fig. 16; Weiss, 1983, p. 39-41, pl. 1, fig. 4; Abdel-Kireem, 1986, p. 220, pl. 1, fig. 1, pl. 3, fig. 4; Nederbragt, 1989, p. 194, pl. 1, figs. 2, 3; Georgescu et al., 2008, pl. 1, figs. A (5, 6), pl. 5, figs. 6-11, pl. 6, figs. 7-9.

-Material. 23 specimens from 11 samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.50-0.77 mm, width of test 0.40-0.60 mm.

-Remarks. In Kurdistan this species can be differentiated from *Pg. acuta* (de Klasz, 1953) by more widely flaring shape, by having more chambers in the biserial part of the test, by having a wider area of divergence between the two rows of chambers, and by the commencement of chamber divergence at an early stage of the test.

-Occurrence. (Early Maastrichtian; Fig. 3).

Genus *Planoheterohelix* Georgescu and Huber, 2009*Planoheterohelix globulosa* (Ehrenberg, 1840), Plate 1, figs. 7-9, Plate 5, figs. 1-4

Textularia globulosa Ehrenberg, 1840, p. 135, pl. 4, figs. 1B, 2B, 4B, 5B, 7B, 8B.

Gümbelina globulosa (Ehrenberg). White, 1929, p. 36, pl. 4, fig. 10; Cushman, 1938, p. 6, 7, pl. 1, figs. 28-33; Loeblich, 1951, p. 108, pl. 12, figs. 4, 5.

Heterohelix globulosa (Ehrenberg). Montanaro Gallitelli, 1957, p. 137, pl. 31, figs. 12-15; Pessagno, 1967, p. 260, pl. 87, figs. 5-9, 11-13; Govindan, 1972, p. 167, pl. 1, figs. 1, 2; Kassab, 1974, p. 80, 81, pl. 1, fig. 1; Frerichs et al., 1975, p. 300, pl. 1, figs. 1, 2; Masters, 1980, p. 100, 101, pl. 1, figs. 6-8; Odébodé, 1982, p. 238, 239, pl. I, figs. 6, 7; Weiss, 1983, p. 44, pl. 1, figs. 8, 9; Abdel-Kireem, 1986, p. 222, pl. 1, figs. 2-4, pl. 3, figs. 5, 6; Abdel-Kireem et al., 1996b, p. 244, 245, fig. 5 (1, 2); Abramovich et al., 2003, p. 9, pl. II, figs. 1, 2; Abramovich et al., 2011, p. 147, pl. 2, figs. 1-6.

Planoheterohelix globulosa (Ehrenberg). Haynes et al., 2015, p. 55, 56, fig. 11 (1-14).

-Material. Over 10,000 specimens from all the samples of the Kometan and Shiranish formations.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.22-0.45 mm, width of test 0.15-0.26 mm, height of last chamber 0.10-0.15 mm, width of last chamber 0.08-0.15 mm.

-Remarks. The Kurdistan specimens of *Pl. globulosa* have a range of surface ornamentation ranging from smooth to weakly developed discontinuous costae. *Pl. globulosa* can be distinguished from *Heterohelix striata* by the inflated and globular last pair of chambers.

-Occurrence. (Early Turonian-Early Maastrichtian; Fig. 3).

Planoheterohelix moremani (Cushman, 1938), Plate 5, figs. 5-6

Gümbelina moremani Cushman, 1938, p. 10, pl. 2, figs. 1-3; Cushman, 1946, p. 103, pl. 44, figs. 15-17.

Heterohelix moremani (Cushman). Pessagno, 1967, p. 260, 261, pl. 48, figs. 10, 11, pl. 89, figs. 1, 2; Darmonoian, 1975, p. 191, 192, pl. 1, fig. 3; Odébodé, 1982, p. 239, 240, pl. I, fig. 12; Nederbragt, 1991, p. 344, pl. 2, figs. 6, 7, pl. 3, figs. 1, 2;

Georgescu, 1995, p. 95, 96, pl. 1, figs. 3-5, 13; de Klasz et al., 1995, p. 363, pl. 2, fig. 4; Abdel-Kireem et al., 1996b, p. 245, fig. 5 (3).

Planoheterohelix moremani (Cushman). Georgescu and Huber, 2009, p. 244, 245, pl. 4, figs. 1-13; Haynes et al., 2015, p. 52, 53, fig. 9 (1-5).

-Material. 51 specimens from 17 samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.27-0.42 mm, width of test 0.10-0.15 mm, height of last chamber 0.07-0.09 mm, width of last chamber 0.05-0.09 mm.

-Remarks. In Kurdistan, *Pl. moremani* can be separated from other biserial heterohelcids by having a smooth test surface, a larger number of chambers (reaching a maximum of 16; up to 18 chambers have been reported by Caron, 1985; Nederbragt, 1991; Abdel-Kireem et al., 1996b; Georgescu and Huber, 2009), and an elongate, slender shape.

-Occurrence. (Early Turonian-Coniacian; Fig. 3).

Planoheterohelix planata (Cushman, 1938), Plate 1, figs. 10-12, Plate 5, fig. 7

Gümbelina planata Cushman, 1938, p. 12, 13, pl. 2, figs. 13, 14; Cushman, 1946, p. 105, pl. 45, figs. 6, 7.

Heterohelix planata (Cushman). Pessagno, 1967, p. 261, 262, pl. 86, figs. 3, 4, pl. 89, figs. 6, 7; Kassab, 1974, p. 82, 83, pl. 1, fig. 3; Darmonoian, 1975, p. 192, pl. 1, fig. 8; Frerichs et al., 1975, p. 300, 301, pl. 1, figs. 5, 6; Odébodé, 1982, p. 240-242, pl. I, fig. 13, pl. II, fig. 1; Weiss, 1983, p. 44, 45, pl. 2, figs. 1-3; Abramovich et al., 2003, p. 9, pl. II, fig. 4; Georgescu et al., 2008, p. 402, pl. 1, fig. A (1), pl. 3, figs. 1-5; Abramovich et al., 2011, p. 147, pl. 2, figs. 15-17.

-Material. Over 500 specimens from Late Santonian to Early Maastrichtian samples of the Kometan and Shiranish formations.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.24-0.40 mm, width of test 0.15-0.28 mm, height of last chamber 0.08-0.13 mm, width of last chamber 0.10-0.15 mm.

-Remarks. The ovate and reniform adult chambers of this species are the characteristic feature for identification. Moreover, in some adult specimens an early stage of divergence between the two adult rows of chambers is seen. Cushman (1938) and Georgescu (1995) recorded *Pl. planata* with a keeled feature in the early portion of the test, but this feature is absent in Iraqi material (Kassab, 1974; Darmonoian, 1975), Tunisia (Nederbragt, 1991), Egypt (Abdel-Kireem et al., 1996b), including that from Kurdistan. There is a superficial resemblance between the tests of *Pl. planata* and *Laeviheterohelix pulchra* (Brotzen, 1936); however, *Pl. planata* differs by lacking broad reniform chambers and flanges.

-Occurrence. (Late Santonian-Early Maastrichtian; Fig. 3).

Planoheterohelix reussi (Cushman, 1938), Plate 1, figs. 13-15, Plate 5, figs 8-9

Gümbelina reussi Cushman, 1938, p. 11, pl. 2, figs. 6-9; Cushman, 1946, p. 104, pl. 44, figs. 18, 19.

Heterohelix reussi (Cushman). Montanaro Gallitelli, 1957, p. 137, pl. 31, fig. 18; Pessagno, 1967, p. 263, pl. 85, figs. 1-9; pl. 86, figs. 1, 2; Darmonoian, 1975, p. 194, pl. 1, figs. 16-20; Frerichs et al., 1975, p. 301, pl. 1, figs. 3, 4; Odébodé, 1982, p. 242, pl. II, figs. 11, 12; Weiss, 1983, p. 47, 48, pl. 3, figs. 1, 2; Abdel-Kireem,

1986, p. 222, 223, pl. 1, figs. 11, 12; Georgescu, 1995, pl. 2, figs. 1-3; Abdel-Kireem et al., 1996b, p. 247, fig. 5 (8, 9).

Planoheterohelix reussi (Cushman). Haynes et al., 2015, p. 57-59, fig. 18 (1-9).

-Material. Over 1000 specimens from Coniacian to Early Maastrichtian samples of the Kometan and Shiranish formations.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.15-0.30 mm, width of test 0.10-0.20 mm, height of last chamber 0.05-0.12 mm, width of last chamber 0.05-0.10 mm.

-Remarks. In Kurdistan, *Pl. reussi* can be distinguished from material of *Pl. globulosa* by having more compressed chambers, a triangular depression between the adult chambers, and a gradual increase of the last two adult chambers (rather than rapidly inflated chambers). *Pl. reussi* can be distinguished from material of *H. striata* by the absence of strong, continuous, closely spaced costae.

-Occurrence. (Coniacian-Early Maastrichtian; Fig. 3).

Genus *Heterohelix* Ehrenberg, 1843

Heterohelix semicostata (Cushman, 1938), Plate 2, figs. 1-2

Gümbelina semicostata Cushman, 1938, p. 16, pl. 3, fig. 6; Cushman, 1946, p. 107, pl. 46, figs. 1-5.

Heterohelix semicostata (Cushman). Pessagno, 1967, p. 263, pl. 98, fig. 21; Darmonoian, 1975, p. 194, pl. 2, fig. 3; Nederbragt, 1991, p. 348, pl. 4, figs. 2, 4.

-Material. 11 specimens from 8 samples.

-Dimensions. 11 specimens measured give the following dimensions: height of test 0.30-0.36 mm, width of test 0.21-0.25 mm, height of last chamber 0.05-0.10 mm, width of last chamber 0.12-0.15 mm.

-Remarks. In Kurdistan, *H. semicostata* can be distinguished from material of *Pseudoguembelina excolata* by showing a more compressed test shape in edge view, by having a longer test, and by having costae concentrated along the periphery of the test.

-Occurrence. (Latest Campanian-Earliest Maastrichtian; Fig. 3).

Heterohelix striata (Ehrenberg, 1840), Plate 2, figs. 3-4

Textularia striata Ehrenberg, 1840, p. 135, pl. 4, figs. 1-3.

Gümbelina striata (Ehrenberg). Cushman, 1938, p. 8, 9, pl. 1, figs. 34-40; Cushman, 1946, p. 104, pl. 45, figs. 4, 5.

Pseudoguembelina striata (Ehrenberg). Brönnimann and Brown, 1953, p. 154, text fig. 6.

Heterohelix striata (Ehrenberg). Pessagno, 1967, p. 264, pl. 78, figs. 4, 5, pl. 88, figs. 3-7, pl. 98, fig. 16; Govindan, 1972, p. 168, pl. 1, figs. 13, 14; Smith and Pessagno, 1973, p. 19, 20, pl. 3, figs. 8-11, pl. 4, figs. 1-4; Darmonoian, 1975, p. 194-196, pl. 2, figs. 4-7; Frerichs et al., 1975, p. 301, pl. 1, figs. 11, 12; Masters, 1980, p. 101, pl. 1, figs. 9-11; Weiss, 1983, p. 48, pl. 3, figs. 5, 6; Abramovich et al., 2011, p. 147, pl. 2, figs. 7-11.

-Material. Over 200 specimens from Late Campanian to Early Maastrichtian samples.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.22-0.38 mm, width of test 0.12-0.20 mm, height of last chamber 0.10-0.12 mm, width of last chamber 0.06-0.12 mm.

-Remarks. In Kurdistan, the species can be distinguished from material of *Pl. globulosa* (Ehrenberg, 1840) in its well-developed, continuous, stronger costae, and less inflated adult chambers.

-Occurrence. (Late Campanian-Early Maastrichtian; Fig. 3).

Heterohelix ultimumida (White, 1929), Plate 2, figs. 5-6

Gümbelina ultimumida White, 1929, p. 39, pl. 4, fig. 13; Cushman, 1938, p. 13, 14, pl. 2, figs. 17, 18; Cushman, 1946, p. 107, pl. 46, figs. 6, 7.

Heterohelix ultimumida (White). Pessagno, 1967, p. 264, 265; Govindan, 1972, p. 168, pl. 1, figs 3, 4; Darmonoian, 1975, p. 196, pl. 2, figs. 10-13; Abdel-Kireem et al., 1996b, p. 248, fig. 5 (11); Abramovich et al., 2011, p. 147, pl. 2, fig. 14.

-Material. 86 specimens from Late Campanian to Early Maastrichtian samples.

-Dimensions. Height of test 0.33-0.50 mm, width of test 0.25-0.33 mm, height of last chamber 0.12-0.26 mm, width of last chamber 0.18-0.23 mm.

-Remarks. The species is closely related to *H. striata* (Ehrenberg, 1840), but is distinguished by the presence of the enlarged penultimate and ultimate, and weaker costae. *H. ultimumida* can be distinguished from material of *Pl. globulosa* (Ehrenberg, 1840) by having fewer chambers, and by the final chamber being more inflated than the previous chambers.

-Occurrence. (Late Campanian-Early Maastrichtian; Fig. 3).

Genus ***Braunella*** Georgescu, 2007

Braunella punctulata (Cushman, 1938), Plate 2, figs. 7-9, Plate 5, fig. 10

Gümbelina punctulata Cushman, 1938, p. 13, pl. 2, figs. 15, 16; Cushman, 1946, p. 108, pl. 46, figs. 13, 14.

Pseudoguembelina punctulata (Cushman). Brönnimann and Brown, 1953, text figs 7, 8.

Heterohelix punctulata (Cushman). Pessagno, 1967, p. 262, 263, pl. 86, figs. 7-10; Kassab, 1974, p. 84, 85, pl. 1, fig. 5; Nederbragt, 1989, p. 198, pl. 3, figs. 5-7; Nederbragt, 1991, p. 346, pl. 3, fig. 6; Abdel-Kireem et al., 1996b, p. 246, fig. 5 (6, 7); Abramovich et al., 2003, p. 9, pl. II, fig. 5.

Braunella punctulata (Cushman). Georgescu, 2007, p. 158-160, pl. 1, figs. 1-5, pl. 3, figs. 1, 3, 4.

-Material. 92 specimens from Late Campanian to Early Maastrichtian samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.45-0.53 mm, width of test 0.30-0.37 mm, height of last chamber 0.20-0.25 mm, and width of last chamber 0.15-0.20 mm.

-Remarks. The Kurdistan material of *B. punctulata* is often recognised by the short initial portion of the test forming a 'V' shape and the rapidly increasing adult portion of the test with nearly uniform width in the last two or three pairs of chambers.

-Occurrence. (Late Campanian-Early Maastrichtian; Fig. 3).

Genus ***Paraspiroplecta*** Georgescu and Abramovich, 2008

Paraspiroplecta navarroensis (Loeblich, 1951), Plate 2, figs. 10-12

Heterohelix navarroensis Loeblich, 1951, p. 107, 108, pl. 12, figs. 1-3b; Montanaro Gallitelli, 1957, p. 137, pl. 31, figs. 5-11; Pessagno, 1967, p. 261, pl. 89, figs. 8, 9; Smith and Pessagno, 1973, p. 18, 19, pl. 3, figs. 4-7; Kassab, 1974, p. 81, 82, pl. 1,

fig. 2; Weiss, 1983, p. 44, pl. 1, figs. 10, 11 Abramovich et al., 2011, p. 147, pl. 3, figs. 1-4.

Paraspiroplecta navarroensis (Loeblich). Georgescu and Abramovich, 2008, p. 109, 110, pl. 4, figs. 1-11.

-Material. Over 500 specimens from Early Maastrichtian samples.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.22-0.35 mm, width of test 0.15-0.23 mm, height of last chamber 0.12-0.13 mm, width of last chamber 0.08-0.13 mm.

-Remarks. In the Kurdistan material, the initial planispiral coil is distinctive and well developed. On the basis of this character, the species can be distinguished from all other biserial heterohelicids.

-Occurrence. (Early Maastrichtian; Fig. 3).

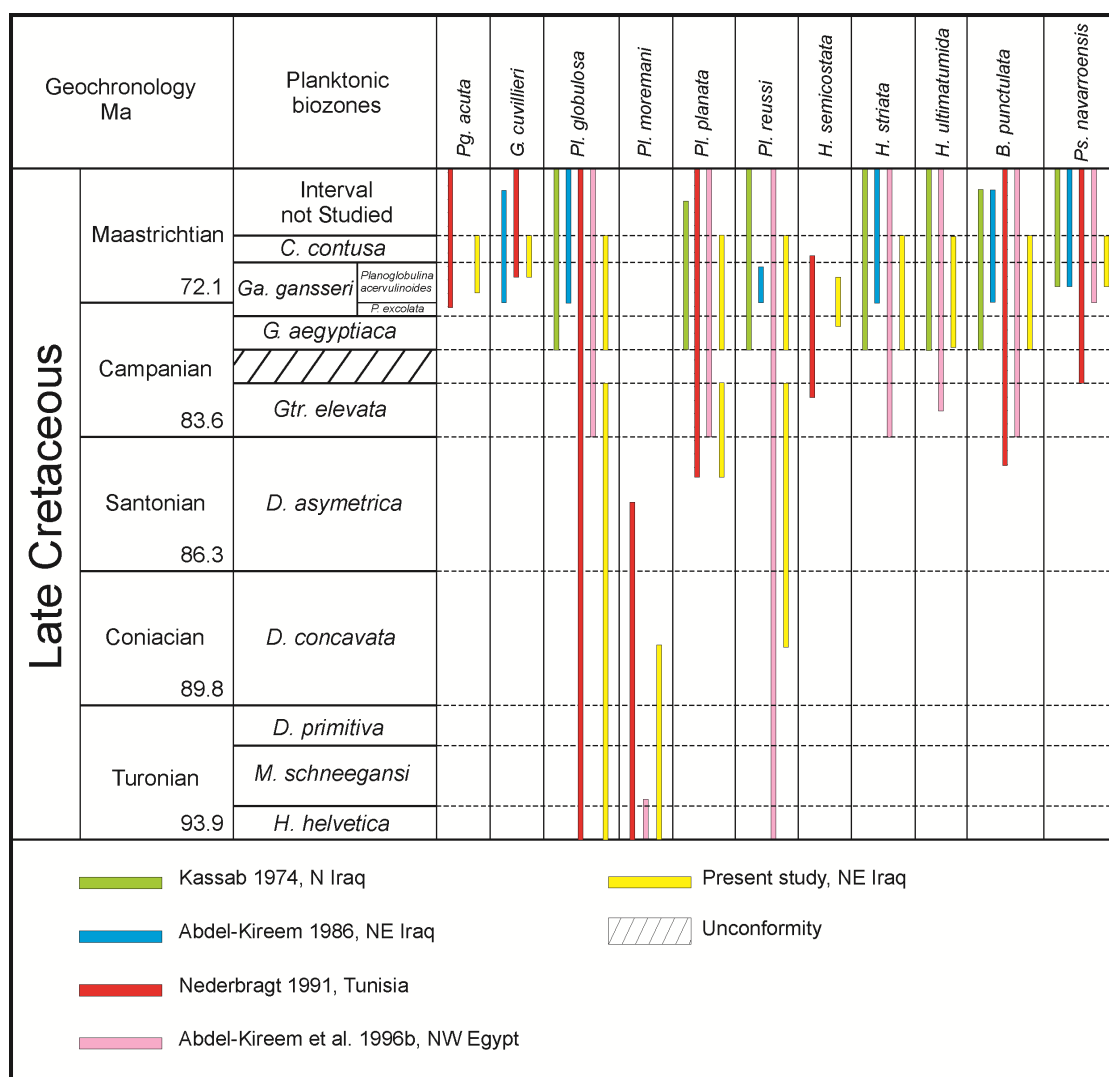


Fig. 3: Biostratigraphic ranges of *Praegublerina* (*Pg.*), *Gublerina* (*G.*), *Planoheterohelix* (*Pl.*), *Heterohelix* (*H.*), *Braunella* (*B.*) and *Paraspiroplecta* (*Ps.*) species recorded in Kurdistan region, NE Iraq and their equivalent ranges in North Africa. Planktonic foraminiferal biozones after Jaff et al. (2015). Time scale adapted from Ogg and Hinnov (2012). Planktonic biozones abbreviations: *H.* = *Helvetoglobotruncana*; *M.* = *Margino-truncana*; *D.* = *Dicarinella*; *Gtr.* = *Globotruncanita*; *G.* = *Globotruncana*; *Ga.* = *Gansserina*; *P.* = *Pseudoguembelina*; *C.* = *Contusotruncana*.

Genus ***Laeviheterohelix*** Nederbragt, 1991

Laeviheterohelix dentata (Stenestad, 1968), Plate 2, figs. 13-15, Plate 5, figs. 11, 12
Heterohelix dentata Stenestad, 1968, p. 67, pl. 1, figs. 3-6, 8, 9, pl. 2, figs. 1-3;
 Nederbragt, 1989, p. 194, pl. 1, figs. 4-7.

Laeviheterohelix dentata (Stenestad). Nederbragt, 1991, p. 350, pl. 5, figs. 1, 2.

Laeviheterohelix dentata (Stenestad). Nederbragt, 1991, p. 350, pl. 5, figs. 1, 2.

-Material. 54 specimens from 36 samples.

-Dimensions. 12 specimens measured give the following dimensions: height of test 0.28-0.45 mm, width of test 0.15-0.30 mm, height of last chamber 0.06-0.12 mm, width of last chamber 0.10-0.20 mm.

-Remarks. In Kurdistan, material of *L. dentata* can be distinguished by its sub-quadrate to reniform adult chambers and chambers overlapping in the adult portion of the test.

-Occurrence. (Latest Campanian-Early Maastrichtian; Fig. 4).

Laeviheterohelix glabrans (Cushman, 1938), Plate 3, figs. 1-3

Gümbelina glabrans Cushman, 1938, p. 15, pl. 3, figs. 1, 2; Cushman, 1946, p. 109, pl. 46, figs. 17, 18.

Heterohelix glabrans (Cushman). Pessagno, 1967, p. 259, pl. 88, figs. 1, 2, 10, 11; Govindan, 1972, p. 169, pl. 1, figs. 11, 12; Smith and Pessagno, 1973, p. 17, 18, pl. 2, figs. 8-10, pl. 3, figs. 1-3; Darmonoian, 1975, p. 191, pl. 1, fig. 7; Weiss, 1983, p. 43, pl. 1, figs. 6, 7;

Laeviheterohelix glabrans (Cushman). Nederbragt, 1991, p. 352, pl. 5, fig. 6; Abramovich et al., 2003, p. 9, pl. II, fig. 6; Abramovich et al., 2011, p. 147, pl. 3, figs. 10-12.

-Material. Over 100 specimens from 46 samples.

-Dimensions. 20 specimens measured give the following dimensions: height of test 0.28-0.35 mm, width of test 0.18-0.24 mm, height of last chamber 0.10-0.16 mm, width of last chamber 0.10-0.15 mm.

-Remarks. The species shows a close resemblance to *L. dentata* (Stenestad, 1968). The two species can be differentiated by the shape of the initial and penultimate chambers: those of *L. glabrans* are rounded to sub-rounded; while in *L. dentata* the chambers are sub-quadrate to reniform. *L. glabrans* can also be differentiated from *L. pulchra* (Brotzen, 1936) by the shape of its penultimate and ultimate chambers, which are almost as broad as high, rather than reniform.

-Occurrence. (Latest Campanian-Early Maastrichtian; Fig. 4).

Laeviheterohelix pulchra (Brotzen, 1936), Plate 3, figs. 4-5, Plate 5, fig. 13

Gümbelina pulchra Brotzen, 1936, p. 121, pl. 9, fig. 3; Cushman, 1938, p. 12, pl. 2, fig. 12.

Heterohelix pulchra (Brotzen). Montanaro Gallitelli, 1957, p. 137, pl. 31, fig. 20; Pessagno, 1967, p. 262, pl. 87, fig. 4; Govindan, 1972, p. 168, pl. 1, figs. 9, 10; Kassab, 1974, p. 83, 84, pl. 1, fig. 4; Darmonoian, 1975, p. 192, 193, pl. 1, figs. 9-15; Frerichs et al., 1975, p. 301, pl. 1, figs. 7, 8; Odébodé, 1982, p. 242, pl. II, figs. 6-10; Weiss, 1983, p. 46, 47, pl. 2, figs. 9-13; Nederbragt, 1989, p. 198, pl. 3, figs. 3, 4; Georgescu, 1995, p. 96, pl. 1, figs. 6-8.

Laeviheterohelix pulchra (Brotzen). Nederbragt, 1991, p. 352-354, pl. 5, fig. 7, pl. 6, fig. 1; Georgescu, 2009, p. 322, fig. 7 (1-5), fig. 8 (1-3); Abramovich et al., 2011, p. 147, pl. 3, fig. 13.

-Material. Over 200 specimens from Late Santonian to Late Campanian samples of the Kometan and Shiranish formations.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.26-0.46 mm, width of test 0.18-0.30 mm, height of last chamber 0.16-0.20 mm, width of last chamber 0.10-0.12 mm.

-Remarks. The species can be distinguished by its broad, reniform, final elongate chambers and smooth test. In Kurdistan, the important characteristic feature of *L. pulchra* is the presence of flanges in the last two or three rows of the adult chambers.

-Occurrence. (Latest Santonian-Latest Campanian; Fig. 4).

Genus *Planoglobulina* Cushman, 1927

Planoglobulina acervulinoides (Egger, 1899), Plate 3, figs. 6-8, Plate 5, figs. 14-15
Gümbelina acervulinoides Egger, 1899, p. 36, pl. 14, fig. 20 (not figs. 14-18, 21-22).

Planoglobulina acervulinoides (Egger). White, 1929, p. 33, pl. 4, fig. 6; Cushman, 1938, p. 23, pl. 4, figs. 5-8; Cushman, 1946, p. 111, pl. 47, figs. 12-15; Pessagno, 1967, p. 271, pl. 87, fig. 14; Martin, 1972, p. 81, pl. 3, figs. 3-6; Kassab, 1978, p. 73-75, pl. 1, figs. 1, 2; Weiss, 1983, p. 50, pl. 4, figs. 5-7; Abdel-Kireem, 1986, p. 223, pl. 2, fig. 1; Nederbragt, 1989, p. 200, pl. 4, figs. 4-6, pl. 5, figs. 1, 2; Nederbragt, 1991, p. 356, pl. 6, figs. 5, 6, pl. 7, fig. 1; Georgescu, 1995, p. 97, pl. 2, figs. 4-6, 9; Abramovich et al., 2003, p. 13, pl. IV, fig. 11.

-Material. 85 specimens from 41 samples.

-Dimensions. 15 specimens measured give the following dimensions: height of test 0.50-0.56 mm, width of test 0.50-0.68 mm.

-Remarks. In Kurdistan it can be distinguished from material of *P. brazoensis* Martin, 1972 by having a less inflated test and more numerous chambers in the multiserial portion of the test.

-Occurrence. (Early Maastrichtian; Fig. 4).

Planoglobulina brazoensis Martin, 1972, Plate 3, figs. 9-11, Plate 5, fig. 16
Planoglobulina brazoensis Martin, 1972, p. 82, 83, pl. 3, fig. 7, pl. 4, figs. 1, 2; Smith and Pessagno, 1973, p. 20, pl. 4, figs. 5-10, pl. 5, figs. 1, 2; Weiss, 1983, p. 51, pl. 4, figs. 1-4; Abdel-Kireem, 1986, p. 223, pl. 2, fig. 4; Abramovich et al., 2003, p. 13, pl. IV, fig. 10; Abramovich et al., 2011, p. 148, pl. 4, figs. 11, 12.

-Material. 22 specimens from 17 samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.53-0.58 mm, width of test 0.40-0.47 mm.

-Remarks. The Kurdistan specimens can be distinguished from other species of *Planoglobulina* by its globular chambers, which are greatly inflated in the later stage of the biserial portion, and the early stage of the multiserial portion of the test. The species is also separated from material of *P. acervulinoides* (Egger, 1899) by having a more inflated test and smaller number of chambers in the multiserial portion of the test.

-Occurrence. (Early Maastrichtian; Fig. 4).

Planoglobulina carseyae (Plummer, 1931), Plate 3, fig. 12, Plate 4, figs. 1-2
Ventilabrella carseyae Plummer, 1931, p. 178, 179, pl. 9, figs. 7-9, not fig. 10;
 Cushman, 1938, p. 26, 27, pl. 4, figs. 20-24; Cushman, 1946, p. 112, pl. 48, figs. 1-5; Loeblich, 1951, p. 109, pl. 12, figs. 6-8.

Planoglobulina carseyae (Plummer). Montanaro Gallitelli, 1957, p. 141, pl. 32, fig. 13; Pessagno, 1967, p. 271, 272, pl. 87, figs. 10, 15, 16; Martin, 1972, p. 83, pl. 4, figs. 4-7; Govindan, 1972, p. 171, 172, pl. 1, fig. 17; Smith and Pessagno, 1973, p. 21, 22, pl. 5, figs. 3-12; Weiss, 1983, p. 51, 52, pl. 5, figs. 1-4; Abdel-Kireem, 1986, p. 223, pl. 2, figs. 2, 3, pl. 3, fig. 9; Nederbragt, 1989, p. 200, pl. 5, figs. 3-5; Nederbragt, 1991, p. 356, pl. 7, figs. 2, 3; Abramovich et al., 2003, p. 13, pl. IV, fig. 9; Abramovich et al., 2011, p. 148, pl. 4, figs. 13-16.

-Material. 33 specimens from 31 samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.40-0.50 mm, width of test 0.30-0.35 mm.

-Remarks. In Kurdistan, *P. carseyae* can be distinguished from other *Planoglobulina* species by its early biserial chambers occupying more than half of the test, followed by one or two sets of the multiserial chambers in the later portion of the test.

-Occurrence. (Early Maastrichtian; Fig. 4).

Planoglobulina riograndensis (Martin, 1972), Plate 4, fig. 3
Ventilabrella riograndensis Martin, 1972, p. 88, 89, pl. 2, figs. 1-4.

Planoglobulina riograndensis (Martin). Weiss, 1983, p. 54, pl. 5, figs. 5, 6;
 Nederbragt, 1989, p. 200, pl. 6, figs. 1, 2; Nederbragt, 1991, p. 358, pl. 7, figs. 6, 7.

-Material. 1 specimen.

-Dimensions. height of test 0.56 mm, width of test 0.55 mm.

-Remarks. The Kurdistan specimen closely resembles to *P. riograndensis* recorded by Nederbragt (1991, p. 357, pl. 7, fig. 7) in Tunisia. Martin (1972) mentioned that *P. riograndensis* resembles *Ventilabrella eggeri* Cushman, 1928 in test shape, but the two differ in ornamentation. The Iraqi *P. riograndensis* also differs from *V. eggeri* by the shape of the penultimate and ultimate chambers.

-Occurrence. (Early Maastrichtian; Fig. 4).

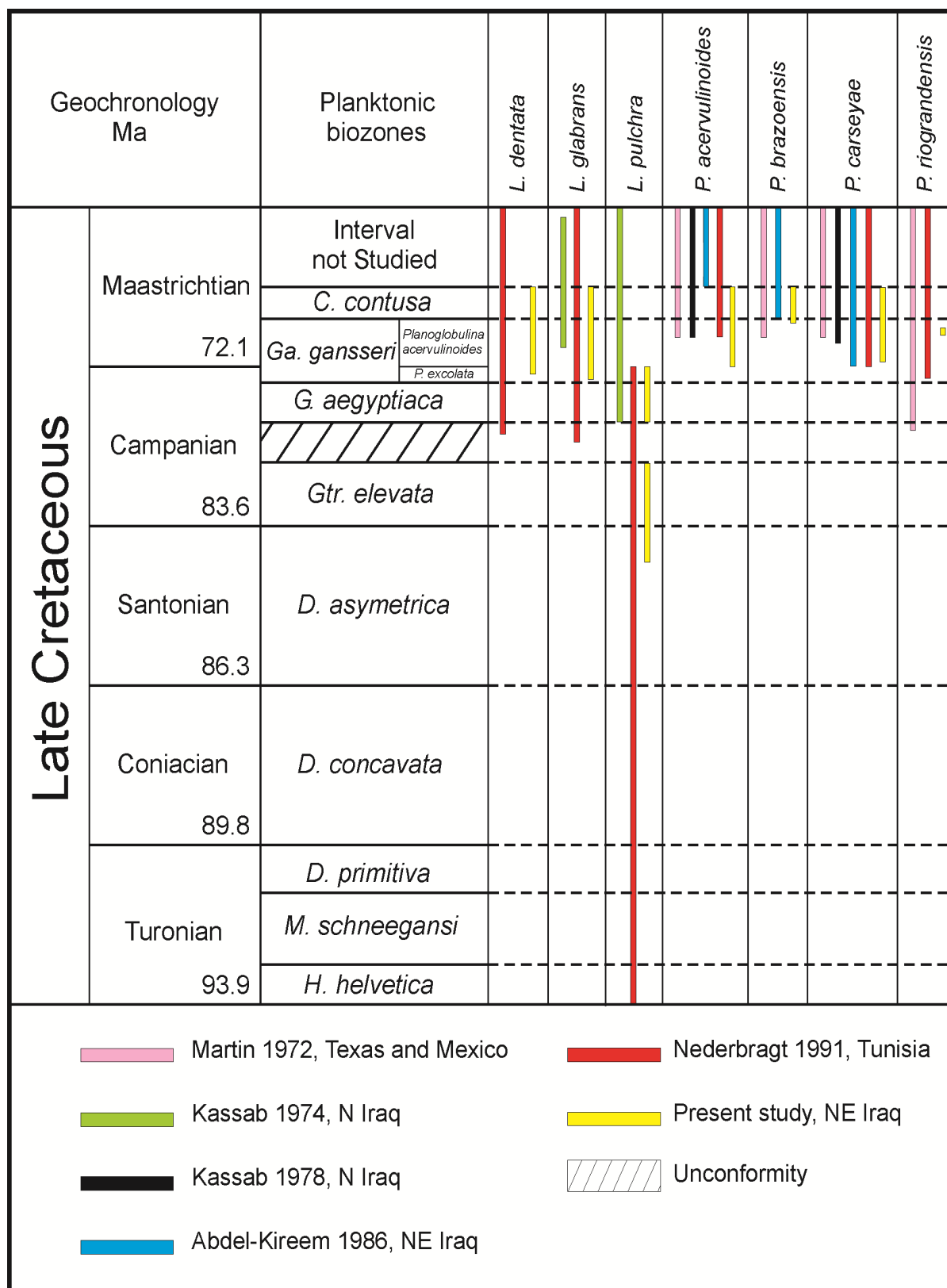


Fig 4: Biostratigraphic ranges of *Laeviheterohelix* (*L.*) and *Planoglobulina* (*P.*) species recorded in Kurdistan region, NE Iraq and their equivalent ranges in North Africa, Texas and Mexico. Planktonic foraminiferal biozones after Jaff et al. (2015). Time scale adapted from Ogg and Hinnov (2012). Planktonic biozones abbreviations: *H.* = *Helvetoglobotruncana*; *M.* = *Marginotruncana*; *D.* = *Dicarinella*; *Gtr.* = *Globotruncanita*; *G.* = *Globotruncana*; *Ga.* = *Gansserina*; *P.* = *Pseudoguembelina*; *C.* = *Contusotruncana*.

Genus ***Pseudoguembelina*** Brönnimann and Brown, 1953

Pseudoguembelina costulata (Cushman, 1938), Plate 4, figs. 4, 5

Gümbelina costulata Cushman, 1938, p. 16, 17, pl. 3, figs. 7-9; Cushman, 1946, p. 108, pl. 46, figs. 10-12.

Pseudoguembelina costulata (Cushman). Brönnimann and Brown, 1953, p. 153, 154, text fig. 5; Montanaro Gallitelli, 1957, p. 139, pl. 31, figs. 21, 22; Pessagno, 1967, p. 266, pl. 79, fig. 1, pl. 88, figs. 8, 9, pl. 90, fig. 3; Govindan, 1972, p. 169, pl. 1, figs. 15, 16; Smith and Pessagno, 1973, p. 24, 25, pl. 6, figs. 1-5; Darmonoian, 1975, p. 197, 198, pl. 3, figs. 1-5; Weiss, 1983, p. 56, pl. 6, figs. 8-10; Abdel-Kireem, 1986, p. 224, pl. 1, fig. 15; Nederbragt, 1989, p. 200, pl. 6, figs. 3-5; Nederbragt, 1991, p. 358, pl. 8, figs. 3, 4; Georgescu, 1995, p. 101, pl. 4, figs. 1-3; Abdel-Kireem et al., 1996b, p. 250, fig. 5 (16); Abramovich et al., 2003, p. 9, pl. II, fig. 12; Abramovich et al., 2011, p. 147, pl. 3, figs. 14, 15.

-Material. Over 500 specimens from Latest Campanian to Early Maastrichtian samples.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.20-0.30 mm, width of test 0.12-0.20 mm, height of last chamber 0.06-0.10 mm, width of last chamber 0.08-0.12 mm.

-Remarks. The Kurdistanian specimens can be differentiated from material of *Psg. excolata* (Cushman, 1926) by having a narrow and slender test, and by more closely spaced and finer costae.

-Occurrence. (Latest Campanian-Early Maastrichtian; Fig. 5).

Pseudoguembelina excolata (Cushman, 1926), Plate 4, figs. 6-7

Gümbelina excolata Cushman, 1926, p. 20, pl. 2, fig. 9; White, 1929, p. 34, pl. 4, fig. 7; Cushman, 1938, p. 17, pl. 3, fig. 11; Cushman, 1946, p. 108, pl. 46, fig. 16.

Pseudoguembelina excolata (Cushman). Brönnimann and Brown, 1953, p. 153, text figs 1-4; Montanaro Gallitelli, 1957, p. 139, pl. 31, fig. 23; Pessagno, 1967, p. 266, 267, pl. 68, figs. 4, 5, pl. 90, fig. 5; Smith and Pessagno, 1973, p. 25, 26, pl. 6, figs. 6-10; Darmonoian, 1975, p. 198, pl. 2, fig. 20; Abdel-Kireem, 1986, p. 224, pl. 1, fig. 16; Nederbragt, 1989, p. 202, pl. 6, figs. 6, 7; Nederbragt, 1991, p. 360, pl. 8, fig. 5; Georgescu, 1995, p. 101, 102, pl. 4, figs. 4-6; Abdel-Kireem et al., 1996b, p. 250, fig. 5 (17, 18); Abramovich et al., 2003, p. 9, pl. II, fig. 13; Abramovich et al., 2011, p. 147, pl. 3, figs. 16-19.

-Material. Over 100 specimens from Latest Campanian to Early Maastrichtian. -

Dimensions. 15 specimens measured give the following dimensions: height of test 0.25-0.30 mm, width of test 0.20-0.28 mm, height of last chamber 0.08-0.10 mm, width of last chamber 0.10-0.13 mm.

-Remarks. *Psg. excolata* can be differentiated from material of *Psg. costulata* (Cushman, 1938) in having a wider test, by being triangular in outline, and by possessing more widely spaced and thicker costae.

-Occurrence. (Latest Campanian-Early Maastrichtian; Fig. 5).

Genus ***Pseudotextularia*** Rzehak, 1891

Pseudotextularia deformis (Kikoine, 1948), Plate 4, figs. 8-9

Gümbelina striata (Ehrenberg) var. *deformis* Kikoine, 1948, p. 20, pl. 1, fig. 8.

Pseudotextularia deformis (Kikoine). Pessagno, 1967, p. 269, pl. 90, fig. 16, pl. 92, figs. 19-21, pl. 97, figs. 16, 17, pl. 98, figs. 15, 17, 18; Smith and Pessagno, 1973, p. 29, pl. 9, figs. 1-4, pl. 10, fig. 1; Kassab, 1978, p. 77, pl. 1, figs. 4, 5; Weiss, 1983, p. 60, 61, pl. 8, figs. 1, 2; Abdel-Kireem, 1986, p. 226, pl. 2, figs. 10-12, pl. 3, fig. 11; Abramovich et al., 2003, p. 13, pl. IV, fig. 1.

-Material. 18 specimens from 13 samples.

-Dimensions. 10 specimens measured give the following dimensions: height of test 0.40-0.45 mm, width of test 0.26-0.35 mm, height of last chamber 0.12-0.13 mm, width of last chamber 0.18-0.22 mm.

-Remarks. The Kurdistanian specimens can be distinguished from material of the type species *Pst. elegans* (Rzehak, 1891) by its broad, triangular outline in side view, chambers that expand slowly in height but rapidly in width, and by its coarser and less massive discontinuous costae and much thicker test wall.

-Occurrence. (Latest Campanian-Early Maastrichtian; Fig. 5).

Pseudotextularia elegans (Rzehak, 1891), Plate 4, figs. 10-11, Plate 5, figs. 17-18
Cuneolina elegans Rzehak, 1891, p. 4.

Gümbelina elegans (Rzehak). White, 1929, p. 34, 35, pl. 4, fig. 8.

Pseudotextularia elegans (Rzehak). Pessagno, 1967, p. 268, 269, pl. 75, figs. 12-17, pl. 85, figs. 10, 11, pl. 88, figs. 14-16, pl. 89, figs. 10, 11, pl. 97, fig. 18, pl. 98, figs. 19, 20; Govindan, 1972, p. 170, 171, pl. 1, figs. 5, 6, pl. 2, figs. 6, 7; Smith and Pessagno, 1973, p. 30-32, pl. 9, figs. 5-15, pl. 10, figs. 2-6; Darmonoian, 1975, p. 199, pl. 3, figs. 16, 17; Frerichs et al., 1975, p. 301, 302, pl. 1, figs. 13, 14; Kassab, 1978, p. 79, pl. 1, figs. 6, 7; Weiss, 1983, p. 61-63, pl. 8, figs. 5-7; Abdel-Kireem, 1986, p. 226, pl. 2, figs. 13-16, pl. 3, figs. 12, 13; Georgescu, 1995, p. 97, pl. 3, figs. 1-3; Abdel-Kireem et al., 1996b, p. 249, fig. 5 (14, 15); Abramovich et al., 2003, p. 13, pl. IV, fig. 2; Abramovich et al., 2011, p. 148, pl. 4, figs. 7, 8.

-Material. Over 500 specimens from Late Campanian to Early Maastrichtian samples.

-Dimensions. 50 specimens measured give the following dimensions: height of test 0.30-0.58 mm, width of test 0.15-0.30 mm, height of last chamber 0.12-0.20 mm, width of last chamber 0.10-0.16 mm.

-Remarks. As noted above, *Pst. elegans* can be distinguished from material of *Pst. deformis* (Kikoine, 1948) by its narrower outline in side view, chambers that expand rapidly in height but slowly in width, more massive, closely spaced, discontinuous costae, and thinner test wall.

-Occurrence. (Late Campanian-Early Maastrichtian; Fig. 5).

Pseudotextularia nuttalli (Voorwijk, 1937), Plate 4, figs. 12-13

Gümbelina nuttalli Voorwijk, 1937, p. 192, pl. 2, figs. 1-9.

Heterohelix nuttalli (Voorwijk). Darmonoian, 1975, p. 192, pl. 1, figs. 4-6.

Pseudotextularia nuttalli (Voorwijk). Kassab, 1978, p. 81, 82, pl. 1, fig. 15; Nederbragt, 1989, p. 204, pl. 8, figs. 2, 3; Nederbragt, 1991, p. 364-366, pl. 10, figs. 4, 6.

-Material. Over 100 specimens from Late Campanian to Early Maastrichtian samples,

-Dimensions. 20 specimens measured give the following dimensions: height of test 0.47-0.67 mm, width of test 0.32-0.40 mm, height of last chamber 0.18-0.23 mm, width of last chamber 0.16-0.20 mm.

-Remarks. In Kurdistan it differs from both *Pst. elegans* (Rzehak, 1891) and *Pst. deformis* (Kikoine, 1948) by its wider test in side view, very thin discontinuous costae developed on the surface of the test, and by its low arched aperture.

-Occurrence. (Late Campanian-Early Maastrichtian; Fig. 5).

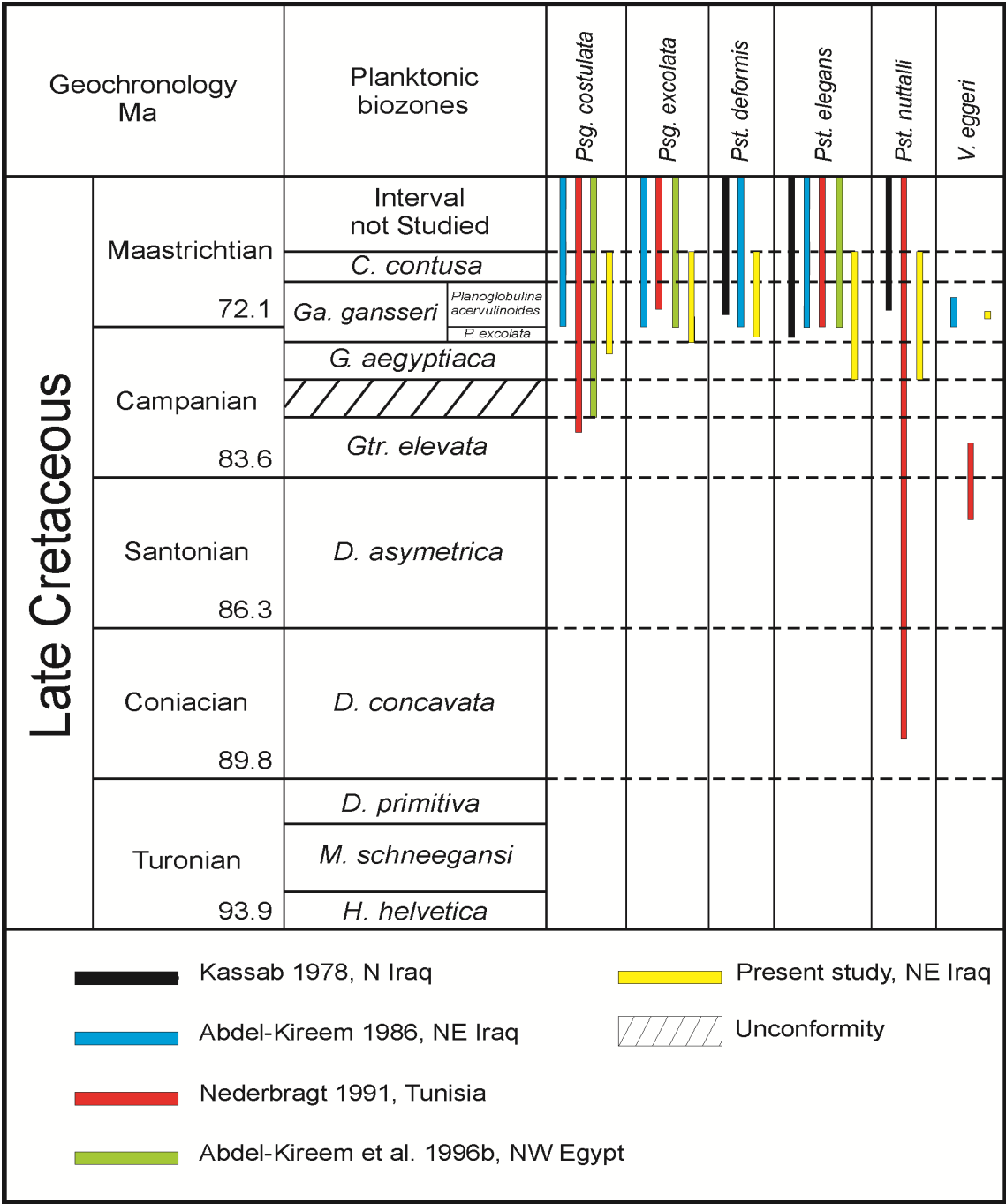


Fig. 5: Biostratigraphic ranges of *Pseudoguembelina* (*Psg.*), *Pseudotextularia* (*Pst.*) and *Ventilabrella* (*V.*) species recorded in Kurdistan region, NE Iraq and their equivalent ranges in North Africa. Planktonic foraminiferal biozones after Jaff et al. (2015). Time scale adapted from Ogg and Hinnov (2012). Note that *Ventilabrella eggeri*, has been reported from an earlier stratigraphic interval in Tunisia by (Nederbragt, 1991). Planktonic biozones abbreviations: *H.* = *Helvetoglobotruncana*; *M.* = *Marginotruncana*; *D.* = *Dicarinella*; *Gtr.* = *Globotruncanita*; *G.* = *Globotruncana*; *Ga.* = *Gansserina*; *P.* = *Pseudoguembelina*; *C.* = *Contusotruncana*.

Genus *Ventilabrella* Cushman, 1928

Ventilabrella eggeri Cushman, 1928, Plate 4, figs. 14-15

Ventilabrella eggeri Cushman, 1928, p. 2, pl. 1, figs. 10-12; Cushman, 1938, p. 25, pl. 4, figs. 12-14; Cushman, 1946, p. 111, pl. 47, figs. 17-22; Martin, 1972, p. 85, pl. 1, figs. 6, 7; Darmonoian, 1975, p. 202, pl. 4, fig. 13; Weiss, 1983, p. 66, 67, pl. 9, figs. 6-8; Abdel-Kireem, 1986, p. 228, pl. 3, fig. 1; Nederbragt, 1991, p. 369, pl. 12, figs. 5-7.

-Material. 5 specimens from 3 samples.

-Dimensions. 5 specimens measured give the following dimensions: height of test 0.35-0.38 mm, width of test 0.30-0.37 mm.

-Remarks. The species in Kurdistan is similar to *Planoglobulina carseyae* (Plummer, 1931), but can be differentiated by its regular arrangement of chambers in the last row of the test, which give a 30° to 35° degree angle of inclination.

-Occurrence. (Early Maastrichtian; Fig. 5).

DISCUSSION: ROLE OF HETEROHELICIDAE IN LATE CRETACEOUS BIOSTRATIGRAPHY

The studied heterohellicids are characterised by increasing numerical abundance, species diversity and intraspecific variability from the Turonian to the Maastrichtian. Heterohellicids are abundant in Kurdistan, except during the Early Turonian, where only two species, *Planoheterohelix moremani* and *Pl. globulosa* are recorded within the *Helvetoglobotruncana helvetica* Total Range Zone (see Fig. 3). From the mid-Turonian to mid-Santonian, heterohellicids are dominated by *Pl. globulosa* and *Pl. reussi*, and this is the case also in Tunisia (Nederbragt, 1991), Egypt (Abdel-Kireem et al., 1996a, b) and Syria (Pecimotika et al., 2014). Due to long temporal ranges for these two species; their biostratigraphical utility in the Turonian to Santonian is only general where other index planktonic species of *Dicarinella* or *Marginotruncana* are absent: because of the low diversity of heterohellicids, Abdel-Kireem et al. (1996a) recognised only one heterohellicid biozone (*Pl. reussi* Biozone) for the Turonian to mid-Santonian interval in Egypt. In the late Santonian the diversity of heterohellicids increased towards the top of the *Dicarinella asymetrica* Total Range Zone (see Fig. 3). Both *Pl. planata* and *L. pulchra* have their first occurrence in the Late Santonian, but the latter species has an earlier stratigraphic occurrence elsewhere (Darmonoian, 1975; Odébodé, 1982; Nederbragt, 1991; Georgescu, 2009). Nevertheless, *Pl. planata* defines the Late Santonian in Tunisia (Nederbragt, 1991), Egypt (Abdel-Kireem et al., 1996b), and in a number of DSDP and ODP sites around the world (Georgescu et al., 2008), and is therefore important for regional correlation at the level of the *Dicarinella asymetrica* Total Range Zone (see Fig. 3). Most other biserial heterohellicid species have their first occurrence in the Late Campanian, at the level equivalent to the *Globotruncana aegyptiaca* and *Gansserina gansseri* interval biozones, and their first occurrences are thus a proxy for these biozones where keeled planktonic foraminifera are rare or absent. Taxa appearing at this level include *B. punctulata*, *H. striata*, *H. ultimatimida*, *Pst. elegans*, *Psg. costulata* and *Psg. excolata* (Figs 3 and 5). The first occurrences of most of the above species are diachronous globally (Kassab, 1974, 1978; Abdel-Kireem, 1986; Nederbragt, 1989; 1991; Abdel-Kireem et al., 1996b; see Figs 3 and 5). However, *Pst. elegans* and *Psg. excolata* can be used to define the Late

and Latest Campanian in Kurdistan and other regions (e.g., Martin, 1972 in the USA; Robaszynski, 1998 for several regions; Güray, 2006 for Turkey; Pecimotika et al., 2014 for Syria; Jaff et al., 2015 for Kurdistan). The maximum species diversity and abundance of heterohellicids in Kurdistan is recorded in the Early Maastrichtian part of the *Gansserina gansseri* interval Biozone, as is the case for Tunisia and Egypt (Nederbragt, 1991; Abdel-Kireem et al., 1996b). The multiserial heterohellicids in Kurdistan, including species of *Praegublerina*, *Gublerina* and *Planoglobulina*, are recorded in the Early Maastrichtian that can be used to define the Campanian-Maastrichtian boundary, or the Early Maastrichtian at most Tethys Ocean sites (Fig. 4). The First Appearance Datum (FAD) of *Planoglobulina acervulinoides* defines the Campanian-Maastrichtian boundary in Kurdistan (Jaff et al., 2014, 2015) and other regions (e.g., Robaszynski, 1998; Güray, 2006). According to Ogg and Hinnov (2012 and references therein) its FAD is estimated at 72.97 Ma, which is very close to the age datum assigned to the Campanian-Maastrichtian boundary at 72.1 Ma (Ogg and Hinnov *op. cit.*). In some areas such as Iran and Tunisia, the FAD of *Planoglobulina carseyae* defines the Campanian-Maastrichtian boundary instead of *Planoglobulina acervulinoides* (see Li et al., 1999; Darvishzad and Abdolalipour, 2009). However, the species is very rare in Kurdistan and occur intermittently (see Fig. 4).

CONCLUSIONS

The biostratigraphical importance and systematic palaeontology of Early Turonian to Early Maastrichtian Heterohellicidae planktonic foraminifera from Kurdistan are described. Some 24 species from 11 genera are recorded. The Early Turonian-Early Maastrichtian succession of Kurdistan yields diverse heterohellicid species which can be used for planktonic foraminiferal biozonation when the index species of dicarinelids, marginotruncanids and globotruncanids are absent. The maximum species diversity and abundance of Heterohellicidae in Kurdistan is recorded in the Early Maastrichtian, which is consistent with the global record. The first occurrences of the flaring heterohellicids with more than two chambers per row (e.g. *Praegublerina*, *Gublerina* and *Planoglobulina*) are recorded in the Earliest Maastrichtian; this can be used to define the Campanian-Maastrichtian boundary throughout Tethys Ocean Cretaceous successions.

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Plate 1: Foraminifera of the Shiranish Formation, Scale bars 100 µm

- Figs. 1-3: *Praegublerina acuta* (de Klasz). Figs. 1, 2, Dokan section, sample number DSH-117; Fig. 3, Azmer section, sample number ASH-50.
- Figs. 4-6: *Gublerina cuvillieri* Kikoine. Figs. 4, 5, Dokan section, sample number DSH-117, Fig. 6, Azmer section, sample number ASH-62.
- Figs. 7-9: *Planoheterohelix globulosa* (Ehrenberg). Figs. 7, 8, Dokan section, sample number DSH-64; Fig. 9a, Azmer section, sample number ASH-40; Fig. 9b, discontinuous costae on the surface of ultimate chamber of *Pl. globulosa*.
- Figs. 10-12: *Planoheterohelix planata* (Cushman). Fig. 10, Dokan section, sample number DSH-117; Figs. 11, 12, Azmer section, sample number ASH-30.
- Figs. 13-15: *Planoheterohelix reussi* (Cushman). Fig. 13, Dokan section, sample number DSH-64; Figs. 14, 15, Azmer section, sample number ASH-05.

Plate 2: Foraminifera of the Shiranish Formation, Scale bars 100 µm

- Figs. 1, 2: *Heterohelix semicostata* (Cushman). Fig. 1, Dokan section, sample number DSH-80; Fig. 2, Dokan section, sample number DSH-88.
- Figs. 3, 4: *Heterohelix striata* (Ehrenberg). Fig. 3, Dokan section, sample number DSH-90; Fig. 4a, Dokan section, sample number DSH-117; Fig. 4b, continuous costae on the surface of ultimate chamber of *H. striata*.
- Figs. 5, 6: *Heterohelix ultimumida* (White). Fig. 5, Azmer section, sample number ASH-48; Fig. 6, Dokan section, sample number DSH-117.
- Figs. 7-9: *Braunella punctulata* (Cushman). Fig. 7, Azmer section, sample number ASH-09; Fig. 8, Azmer section, sample number ASH-10; Fig. 9, Dokan section, sample number DSH-45.
- Figs. 10-12: *Paraspiroplecta navarroensis* (Loeblich). Fig. 10, Dokan section, sample number DSH-105; Fig. 11, Dokan section, sample number DSH-117; Fig. 12, Azmer section, sample number ASH-58.
- Figs. 13-15: *Laeviheterohelix dentata* (Stenestad). Fig. 13, Dokan section, sample number DSH-82, Fig. 14, Dokan section, sample number DSH-117; Fig. 15, Azmer section, sample number ASH-50.

Plate 3: Foraminifera of the Shiranish Formation Scale bars 100 µm

- Figs. 1-3: *Laeviheterohelix glabrans* (Cushman). Figs. 1, 2, Dokan section, sample number DSH-110; Fig. 3, Azmer section, sample number ASH-60.
- Figs. 4, 5: *Laeviheterohelix pulchra* (Brotzen). Figs. 4, Dokan section, sample number DSH-60, Figs. 5, Dokan section, sample number DSH-64. Figs. 4b and 5b side views of *L. pulchra* show well developed flanges in the last pair of chambers.
- Figs. 6-8: *Planoglobulina acervulinoides* (Egger). Fig. 6, Azmer section, sample number ASH-60, Fig. 7, Dokan section, sample number DSH-88; Fig. 8, Dokan section, sample number DSH-117.
- Figs. 9-11: *Planoglobulina brazoensis* Martin. Figs. 9, 10, Dokan section, sample number DSH-117, Fig. 11, Azmer section, sample number ASH-52.
- Fig. 12: *Planoglobulina carseyae* (Plummer). Dokan section, sample number DSH-115.

Plate 4: Foraminifera of the Shiranish Formation, Scale bars 100 µm

- Figs. 1, 2: *Planoglobulina carseyae* (Plummer). Fig. 1, Dokan section, sample number DSH-117; Fig. 2, Azmer section, sample number ASH-47.
- Fig. 3: *Planoglobulina riograndensis* (Martin). Dokan section, sample number DSH-117.
- Figs. 4, 5: *Pseudoguembelina costulata* (Cushman). Fig. 4, Dokan section, sample number DSH-86; Fig. 5, Azmer section, sample number ASH-55.
- Figs. 6, 7: *Pseudoguembelina excolata* (Cushman). Fig. 6, Azmer section, sample number ASH-42; Fig. 7, Dokan section, sample number DSH-70.
- Figs. 8, 9: *Pseudotextularia deformis* (Kikoine). Fig. 8, MPK14520, Azmer section, sample number ASH-54; Fig. 9, Azmer section, sample number ASH-60.
- Figs. 10, 11: *Pseudotextularia elegans* (Rzehak). Fig. 10, Azmer section, sample number ASH-02; Fig. 11, Dokan section, sample number DSH-05.
- Figs. 12, 13: *Pseudotextularia nuttalli* (Voorwijk). Fig. 12, Dokan section, sample number DSH-20; Fig. 13, Azmer section, sample number ASH-55.
- Figs. 14, 15: *Ventilabrella eggeri* Cushman. Fig. 14, Dokan section, sample number DSH-90; Fig. 15, Dokan section, sample number DSH-92.

Plate 5: Foraminifera of the Kometan and Shiranish formations, Scale bar as for Figure 1 Plate 5

- Figs. 1-4: *Planoheterohelix globulosa* (Ehrenberg). Fig. 1, Azmer section, sample number AK-17; Fig. 2, Dokan section, sample number DK-24; Fig. 3, Dokan section, sample number DK-74; Fig. 4, Dokan section, sample number DSH-48.
- Figs. 5, 6: *Planoheterohelix moremani* (Cushman). Fig. 5, Dokan section, sample number DK-12; Fig. 6, Dokan section, sample number DK-2.
- Fig. 7: *Planoheterohelix planata* (Cushman). Dokan section, sample number DK-36.
- Figs. 8, 9: *Planoheterohelix reussi* (Cushman). Fig. 8, Azmer section, sample number AK-35; Fig. 9, Dokan section, sample number DK-34.
- Fig. 10: *Braunella punctulata* (Cushman). Azmer section, sample number ASH-57.
- Figs. 11, 12: *Laeviheterohelix dentata* (Stenestad). Fig. 11, Dokan section, sample number DSH-82, Fig. 12, Dokan section, sample number DSH-117.
- Fig. 13: *Laeviheterohelix pulchra* (Brotzen). Dokan section, sample number DK-68.

Figs. 14, 15: *Planoglobulina acervulinoides* (Egger). Fig. 14, MPK14540, Azmer section, sample number ASH-59; Fig. 15, Dokan section, sample number DSH-88.

Fig. 16: *Planoglobulina brazoensis* Martin. Azmer section, sample number ASH-60.

Figs. 17, 18: *Pseudotextularia elegans* (Rzehak). Fig. 17, Dokan section, sample number DSH-48; Fig. 18, Azmer section, sample number ASH-15.

PLATE 1

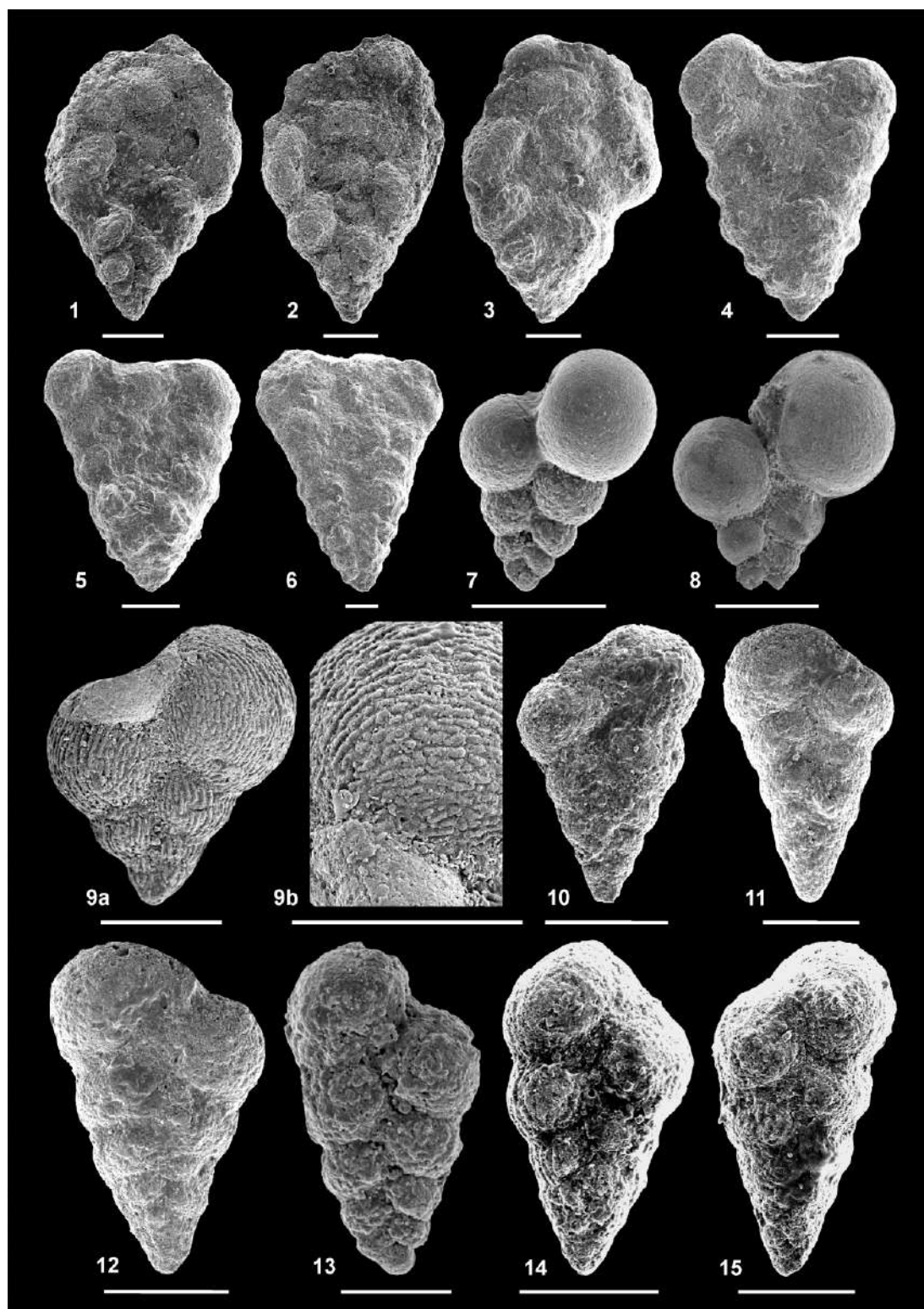


PLATE 2

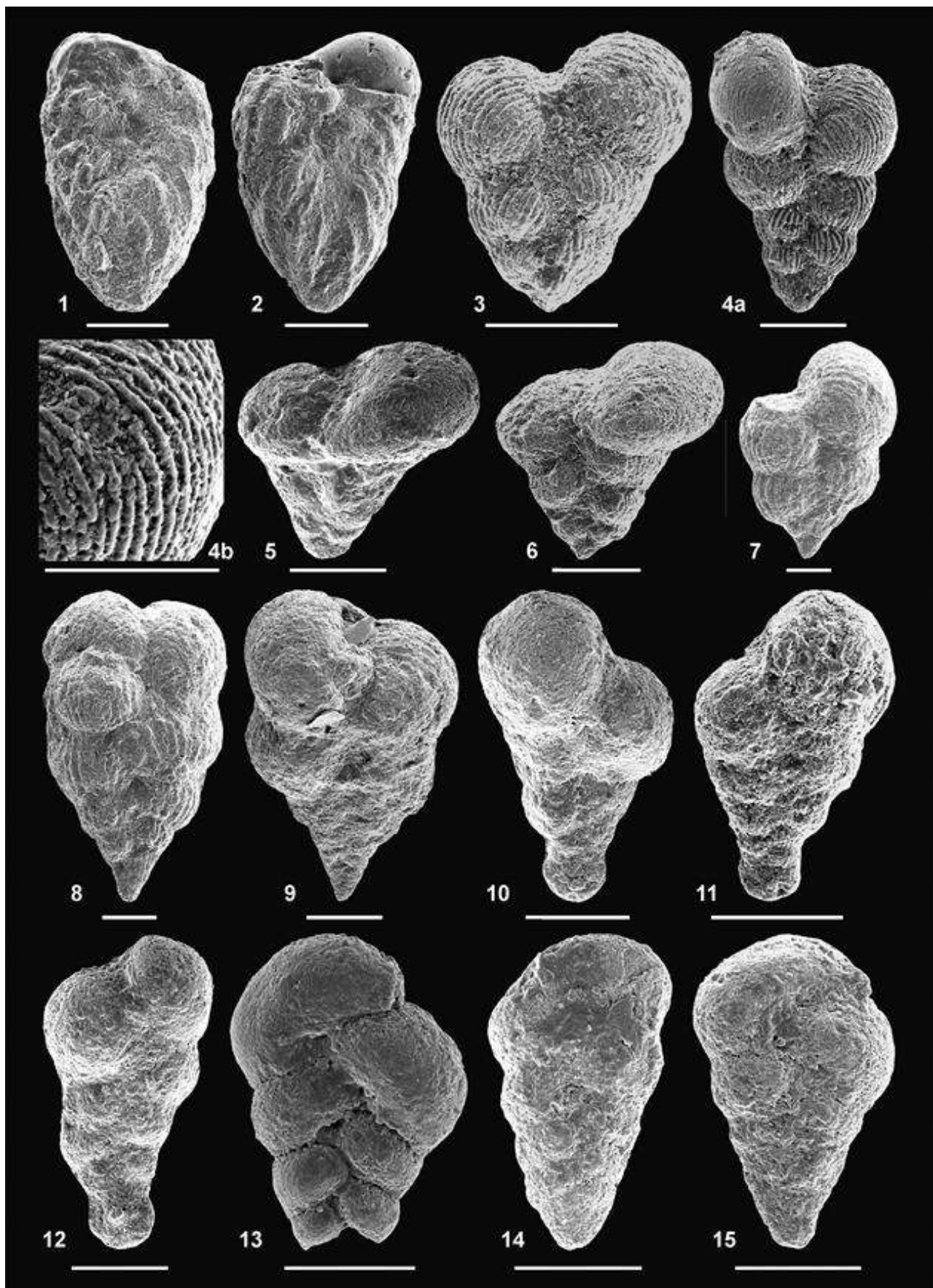


PLATE 3

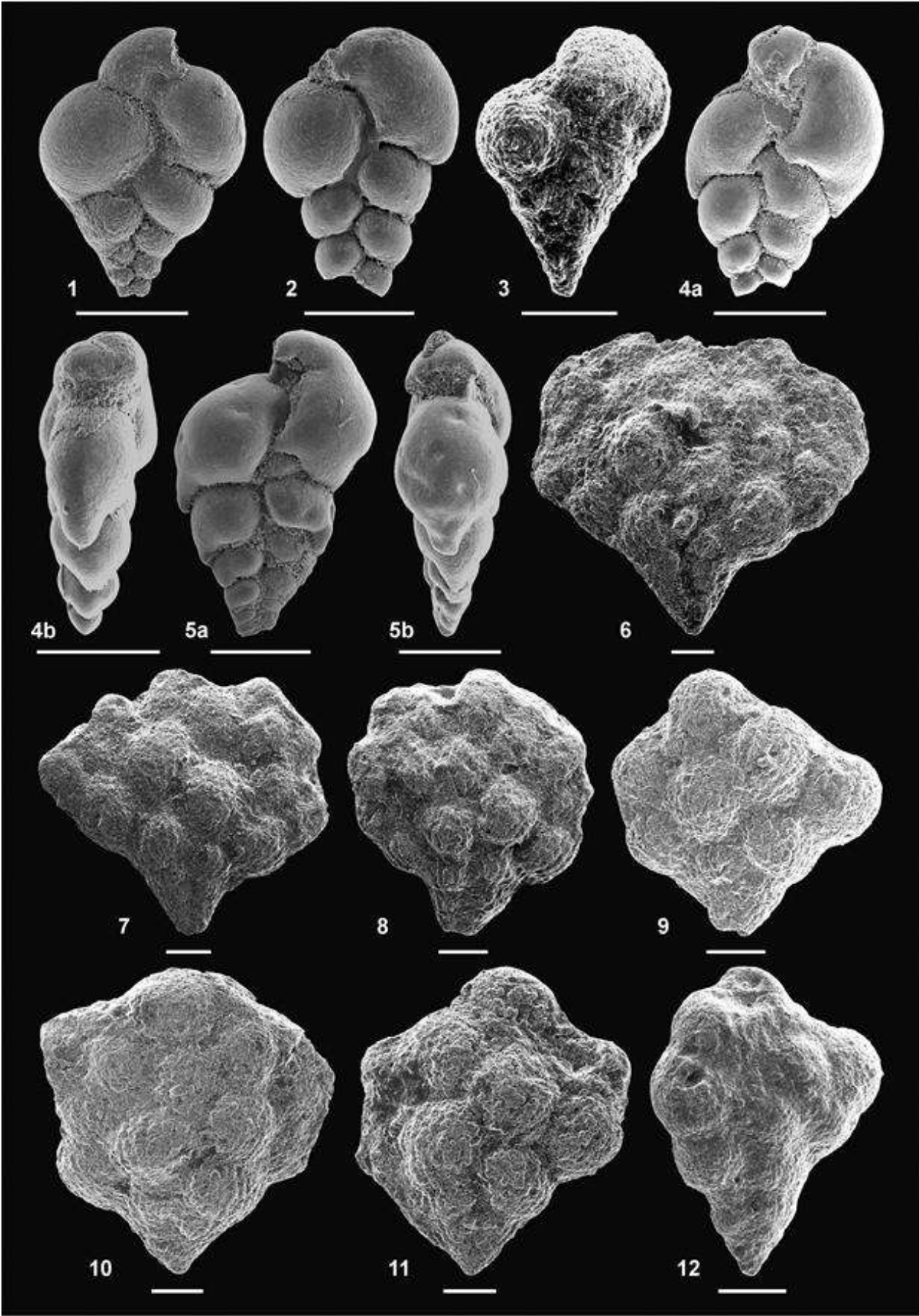


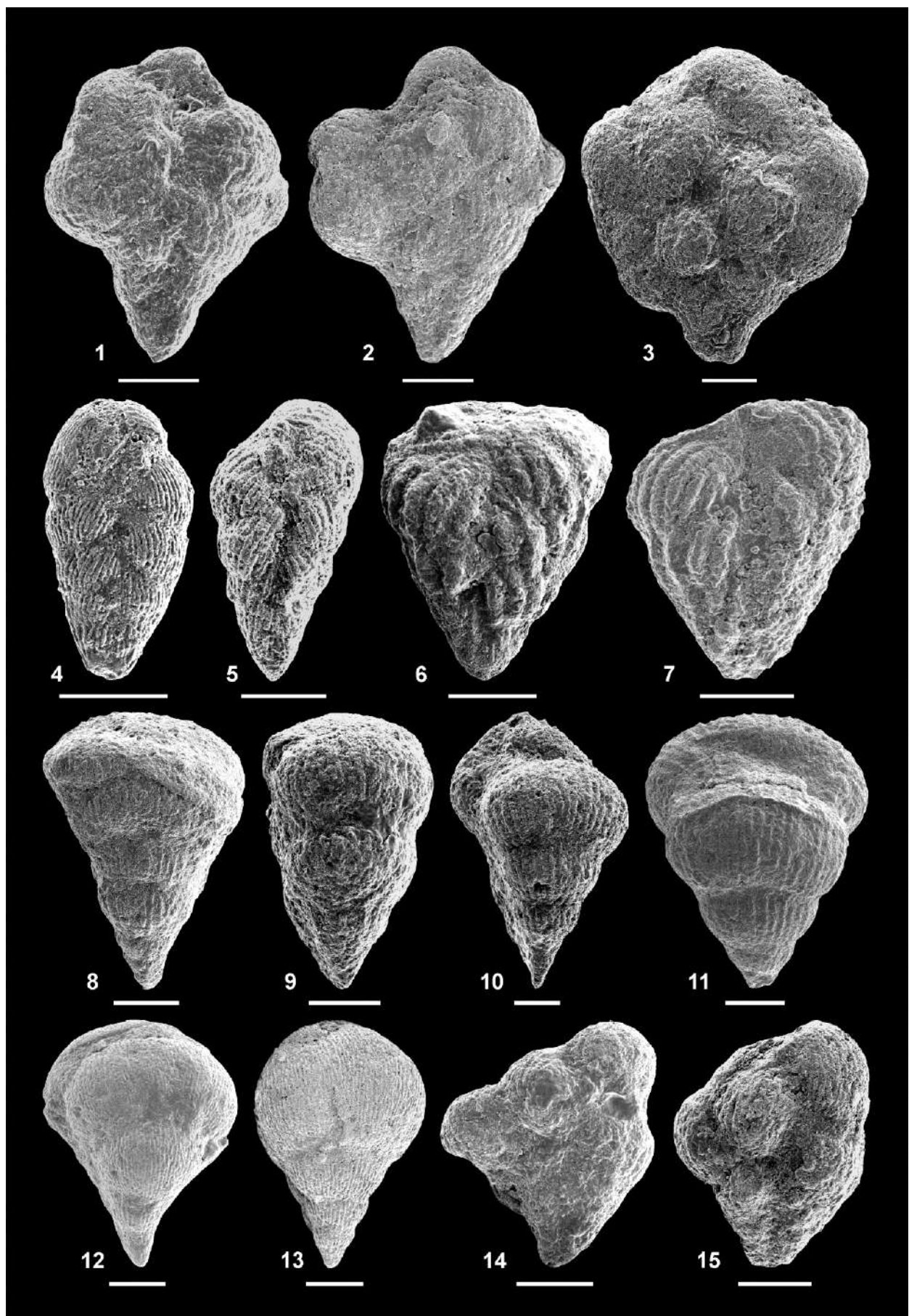
PLATE 4

PLATE 5

