Larger foraminiferal biostratigraphy of the upper Cretaceous (Campanian) to Paleogene (Lutetian) sedimentary rocks in the Haymana and Black Sea regions, Turkey

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ABSTRACT: Larger foraminifera of the late Cretaceous (late Campanian) to middle Eocene (Lutetian) are recognized in the upper Cretaceous to Paleogene sedimentary rocks in the Haymana and Black Sea regions, Turkey. 114 diagnostic larger and benthonic foraminiferal species belonging to 66 genera are identified, and 89 diagnostic species are documented as local ranges. Biostratigraphically useful 11 larger foraminiferal assemblage zones are described, and are correlated with two larger foraminiferal assemblage zones, NE India and Philippines in the Tethys region. *Chaldagia haymanensis*, n. gen., n. sp. and *Scandonea samnitica* De Castro are systematically described. Associated 52 planktonic foraminiferal species belonging to 23 genera are identified, and 40 planktonic foraminifera are illustrated. Some element concentrations of the Cretaceous-Tertiary (K-T) boundary layers (28-37 cm thick with goethite layers) were found in the Medetli section, Gölpazari, Black Sea region by the author’s research group. In the K-T boundary layers, 87Sr/86Sr, 0.707885 – 0.707819) in the K-T boundary layers in the Devrekani section, Kastamonu, Black Sea region agreed well with those in the K-T boundary regions of the world by the author’s research group.

INTRODUCTION

The upper Cretaceous to Paleogene limestone, marl, alternation of limestone, marl and shale, and calcareous sandstone are widely exposed in the Sakarya zone of the Haymana region and the Pontides - Sakarya zones of the Black Sea region, respectively (Matsumaru et al. 2010). The author has researched the late Cretaceous to Paleogene (early Paleocene to middle Eocene) foraminifera in the General Directorate Mineral Research and Exploration (M.T.A.:Maden Tektik ve Arama Enstitüsü), Ankara, Turkey in 1992 by the Grant-in-Aid for Scientific Research of the Japan Society for the Promotion of Science (JSPS); as the Regional Subcommittee of West Pacific of IGCP Project No. 286, third Meeting, Ankara (Turkey), Oct. 08-13, 1992; and in its pre-research field survey of IGCP Project No. 286 Field-Trip (M.T.A. 1992). The present study has continued several times in the field and laboratory works with Turkish scientists, i.e. Oversea Field Research, Project No. 7041086 in 1995 and No. 11640486 in 1999 by the Ministry of Education, Science and Culture, Japan; Oversea research in 1998 by the Grant-In-Aid of Saitama University, and private research (Matsumaru et al. 1996, 1997, 1998; Matsumaru 1997; Matsumaru in Arakawa et al. 2003). Samples of this study were collected in all the research stated above, and also partial private comparative samples by Drs. Engin Meriç, Izver Tansel Öngen, Kemal Erdoğan, Sükrü Aca, and Erciment Sirel were considered in this study.

The purpose of this study is to describe the larger foraminiferal biostratigraphy and assemblages from the long term research of diagnostic larger and benthonic foraminifera, associated with planktonic foraminifera from the upper Cretaceous to Paleogene sedimentary rocks in the Haymana and Black Sea regions, Turkey. 114 diagnostic species of 66 genera, included *Chaldagia haymanensis*, n. gen., n. sp. (Text-figures 5A, 5B, 10A, 10B) and associated planktonic foraminifera of 52 species of 23 genera were found in this study (Text-figures 6A, 6B, 11A, 11B). *Chaldagia haymanensis*, n. gen., n. sp. and *Scandonea samnitica* De Castro are described, but not described other diagnostic foraminifera due to space limitation. The age diagnostic 90 larger and benthonic foraminifera and 40 planktonic foraminifera are, however, illustrated in Plates 1-16 and Plates 17-22, respectively. This study provides 11 larger foraminiferal assemblage zones for the international correlation, and these zones are recognized (Text-figures 12-13). Biostratigraphic synthesized ranges of 89 diagnostic larger and benthonic foraminifera are shown (Text-figure 13). Further, element profiles and Ir concentration of the Cretaceous – Tertiary (K-T) boundary layers (Taraklı Formation) were shown in the Medetli section, Gölpazari (Locality 5), Black Sea region (Matsumaru et al. 1996, 1997; Arakawa et al. 2003) (Text-figure 8), and 87Sr/86Sr values and element profiles of the Akveren Formation were shown in the Devrekani section, Kastamonu (Locality 8), Black Sea region (Matsumaru et al. 1996, 1998) (Text-figure 9). The non-occurrence of foraminifers and the effect of low foraminiferal diversity were existed into and above the K-T boundary layers, respectively. The K-T boundary layers (Ir and goethite layers) in the Black Sea region (Localities 5, 8-10) are well correlated with those (Ir and limonite layers) of the top Mahadeo Formation at the Um Sohryngkew River section, Meghalaya, NE India (Pandey 1981, 1990; Bhandari et al. 1987, 1994; Garg and Jain 1995; Murali et al. 1990).

STRATIGRAPHY, LITHOLOGY, FAUNAL SUCCESSION AND CORRELATION

The geology of Turkey has developed by complex convergence of various micro-plates between the Eurasian Plate in the north and the Menderes-Tauride Platform and Arabian Platform in the
south (Matsumaru et al. 1996; Matsumaru et al. 2010, text-fig. 1). The diverse entities of micro-continent collage are represented by numerous suture zonal complexes, island arcs, marginal basins and others, and are thought to have been amalgamated to form an Alpine orogeny. Then, two diverse Haymana and Black Sea regions are treated in this study (Text-figure 1).

**Haymana region**

The upper Cretaceous to middle Eocene rock sequences of the Haymana region are developed into the western and eastern two local areas. The sedimentary rocks in both two areas are tectonically highly distributed by foldings and faults under the influence of general characters of North-South collision belts between the Eurasian Plate and Menderes-Taurus Platform as stated above (Matsumaru et al. 2010, text-fig. 1) (Text-figure 2). The main route was mainly selected according to several field trips of IGCP No. 286, third Meeting, Ankara, 1992 (M. T. A. 1992; Sirel 1992).

In the western Haymana, the late Cretaceous (Maastrichtian) Beyobashi Formation (composed mainly of yellow coloured sandstone, conglomerate, marl and sandy limestone), early Paleocene Kartal Formation (composed of fluvial red coloured sandstone and conglomerate), which is laterally toward eastern areas changing with the shallow marine Çaldağ Formation (composed of light gray to gray coloured limestone), late Paleocene Ilginalikdere Formation (composed of alternation of yellow coloured coarse grained sandstone and sandstone and/or marl, and conglomerate) and early Eocene Eskipolatlı Formation (composed of sandstone and limestone) are widely developed (Ünalan et al. 1976) (Text-figures 2, 3). The five sections of Polatlı (Kirkkavak), Çaldağ, west Erif, east Erif, and Bahçecek localities are selected in the western Haymana for the detailed larger foraminiferal biostratigraphy.

This zone is correlitive with Sirrel (1992, p. 5-6, fig. 4)’s Maastrichtian Assemblage I due to occurrence of Siderolites calcitrapoides, Omphalocyclus macroporus and Loftusia elongate Cox. The basal Çaldağ Formation (sample KM32) yields Anomalinoidea rubiginosus (Cushman), Laffitteina bibensis Marie, Mississippina binkhorsti, Sulcoperculina dickersoni, Chrysalidina spp., Minouxia spp., Moncharmontia appenninica (De Castro), Pseudolithonia spp., Textularia spp., Idalina sinjarica Grimsdale, Ophthalmidium spp., Rhapydionina liburrica Stache and Scandonea samnitica De Castro (Text-figure 5A). Asterisk five species are reworked. The present fauna is assigned to the Assemblage 6 due to common occurrences of Laffitteina bibensis, Idalina sinjarica, Mississippina binkhorsti and Scandonea samnitica. This fauna may partial be correlated with the Thanetian Assemblage III.
due to occurrence of *Planorbulina cretae, Laffitteina mengaudi* (Astre), *Scandonea* sp. and *Miscellanea primitiva* Rahaghi. According to Sirel (1999), the Haymanella Sirel (type species, *H. paleocenica*) and *Kayseriella* Sirel (type species, *K. decastroi*) occur from the Danian Çaldağ/Limestone (Assemblage I of Sirel 1992), but there is unknown of Danian planktonic foraminifera. The Assemblage 6 in this study is correlated with the fauna of the basal Çaldağ Formation (samples E1033.5, KM5, KM21 and KM33) in the east Erif section, NW Haymana, as stated later, due to common occurrences of *Laffitteina bibensis, Mississippina binkhorsti, Idalina sinjarica* and *Scandonea samnitica* (text-figure 5A). In addition, samples E1033.5 and KM5 yield the planktonic foraminifera, *Subbotina* spp., which is similar to *S. triloculinoides* (Plummer), and *Parasubbotina trinidadensis* (Bolli), *Morozovella* spp. and *Rugoglobigerina rugosa* (Plummer) (Text-figure 6A), and these species except asterisk species indicate the Zone P2 (Blow 1969; Postuma 1971; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995).

The lower Çaldağ Formation (samples KM2, KM7, KM20, KM22, KM46, KM28 and KM44) in the Çaldağ section yields Anomalinoideos rubiginosus, *Assilina dandotica* Davies, *Laffitteina bimensis, Miscellanea globularis* Rahaghi, *M. primitiva, Mississippina binkhorsti, Planorbulina cretae* (Marsson), *Planorbulinella dordoniensis, Rotalia trochidiiformis* (Lamarck), *Sulcoperculina dickersoni, Chrysalidina* spp., *Pseudochrysalidina* spp., *Pseudolituonella* spp., *Textularia* spp., *Chaldagia haymanensis* n. gen., n. sp., *Idalina sinjarica*, *Opthalmidium* spp., and *Scandonea samnitica* (Text-figure 5A). Asterisk species are reworked from the Beyobasi Formation. *Assilina dandotica* occur the Ilginlikdere Formation (sample KM23) in the Çayraz section, and this occurrence is considered to be transported (Text-figures 5B, 13). The present fauna is assigned to the Assemblage 7 due to common occurrences of *Miscellanea globularis, M. primitiva, Laffitteina bimensis* and *Idalina sinjarica*. Also samples KM 2,
KM20 and KM46 yield the planktonic foraminifera, *Subbotina* spp., *Parasubbotina pseudobulloides* (Plummer), and *Morozovella* spp. (Text-figure 6A). These species indicate the Zone P3 (Blow 1969; Postuma 1971; Berggren and Van Couvering 1985; Berggren et al. 1995). The present Assemblage 7 is correlated with the *Broeckinella arabica* Henson - *Coskinon rajkae* Hottinger and Drobne – *Idalina sinjarica* Grimsdale – Miscellanea primitiva – Pseudolituonella sp. (nov.) – *Rotalia trochidiformis* Assemblage (Assemblage 1) from the lower Masungit Limestone (sample 7451105b), Maybangain Formation, Luzon Island and lower limestone of the Barcelona Group, East Mindanao, Philippines due to common occurrences of *Miscellanea globularis*, *Idalina sinjarica*, Rotalia trochidiformis, *Chrysalidina* spp., *Pseudochrysalidina* spp., *Pseudolituonella* spp., *Parasubbotina pseudobulloides*, *P. trinidadensis* and *Globanomalina compressa* (Matsumaru 2011) (Text-figure 12). The Ilginlikudere Formation (samples KM24, KM4, KM6, KM10, KM26, and KM17) in the Çaldağ section yields *Anomalinoides rubiginous*, *Miscellanea globularis*, *M. primitiva*, *M. spp.*, *Mississippina binkhorsti*, *Orbitosiphon tibetica* (Douvillé), *Rotalia trochidiformis*, Sivasella monolateralis, *Chrysalidina* spp., *Pseudochrysalidina* spp., *Valbulina* spp., *Idalina sinjarica*, *Miliolina* spp., *Ophthalmidium* spp., *Peneroplis* spp., *Pseudolacazina donatae* (Drobne) and *Scandonea samnitica* (Text-figure 5A). This fauna is assigned to the Assemblage 8 due to common occurrences of *Orbitosiphon tibetica*, *Miscellanea globularis*, *M. primitiva*, and *Idalina sinjarica*. Also samples KM4, KM10 and KM26 yield the planktonic foraminifera, *Acarinina* spp., *Parasubbotina pseudobulloides*, *P. trinidadensis* (Bolli), *Morozovella* spp., *Globanomalina compressa* (Plummer), *G. pseudomenardii* (Bolli) and *G. spp.* (Text-figure
TEXT-Figure 5A
Distribution chart of larger benthonic foraminifera from the Beyobashi, Çaldığ, Ilginikdere and Eskipolatli Formations in Çaldığ, west Haymana; Polatlı (Kirkkavak), western Haymana; and west and east Erif, NW Haymana, all of the Haymana region (Text-figures 2, 3).
TEXT-Figure 5B
Distribution chart of larger benthic foraminifera from the Beyobashi, Haymana, Çaldıragöl, Yesilyurt, İğinlikdere, and Çayraz Formations in west Erif, NW Haymana; Bahçeçek, south Haymana; Çayraz, north Haymana; and the main route of and around Haymana (Text-figures 2, 3).
6A). These species indicate the Zone P4 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). The present Assemblage 8 is correlated with the *Idalina sinjarica* - *Miscellanea primitiva* - *M. miscella* - *Kathina selveri* - *Lockhartia haimei* - *Miscellanea miscella* - *Kathina selveri* - *Lockhartia diversa* Assemblage (Assemblage 1) and *Aberisphaera gambanica* – *Daviesina khatiyahi* – *Lockhartia haimei* – *Miscellanea miscella* – *Ranikothalia nuttalli* Assemblage (Assemblage 2) from the middle to late Paleocene Lakadong Limestone, Meghalaya, NE India due to common occurrences of *Idalina sinjarica*, *Miscellanea primitiva*, *Rotalia trochidiformis*, *Orbitosiphon tibetica*, *Pseudochrysalidina* spp. and *Pseudolituonella* spp. (Matsu-maru and Sarma 2010) (Text-figure 12). Also, Assemblage 8 is correlated with the *Daviesina danieli* – *Kathina selveri* – *Orbitoclypeus ramaraoi* – *Lockhartia haimei* – *Miscellanea miscella* – *Ranikothalia nuttalli* Assemblage (Assemblage 2) from the middle to late Paleocene lower Masungit Limestone (sample 7451105a), Maybangain Formation, Luzon Island, Philippines; lower Sula Formation, Cagraray Island, Philippines; and Talutunan-Tumicob Formation, Marinduque Island, Philippines, based on common occurrences of *Miscellanea globularis*, *M. primitiva*, *Rotalia trochidiformis*, *Parasubbotina ex gr. P. pseudobulloides*, *P. trinidadensis*, *Globanomalina compressa*, *Igorina pusilla* (Bolli) and *Acarinina mckannai* (White) (Matsumaru 2011) (Text-figure 12).

The Polatli (Kirkkavak) section (Text-figures 2, 3), sample 921013-1 of the Ilginlikdere Formation, which conformably overlies the Kartal Formation, about 25 km western extension of the Çalışdağ section, yields *Daviesina danieli* Smout, *Discocyclina archiacci* (Schlumberger), *D. seunesi* Douvillé, *Operculina canalifera* d’Arcich, O. heberti Munier-Chalmas and *Rotalia trochidiformis* (Text-figure 5A). This fauna is assigned to the Assemblage 8 due to occurrences of *Rotalia trochidiformis*, and is traced the same biostratigraphic horizon with the Ilginlikdere Formation carrying Assemblage 8 in the Çalışdağ section. The Eskipolatli Formation (sample 921013-2), which is placed at about 345 m higher horizon than the Ilginlikdere Formation (sample 921013-1), yields *Assilina pustulosa* Doncieux, *Daviesina danieli*, *Discocyclina archiacci*, *Nummulites atacicus* Leymerie, *Alveolina canavari* Checchia-Rispoli and *A. vredenburgi* Davies (Text-figure 5A). Asterisk species occur as reworked, because they don’t yield with *Nummulites atacicus* (Matsumaru and Sarma 2010; Matsumaru 2011). This fauna is assigned to the Assemblage 9 due to common occurrences of *Assilina pustulosa* and *Nummulites atacicus*. The present Assemblage 9 is correlated with the *Alveolina oblonga* – *A. schwageri* – *Assilina laxispira* – *A. placentula* Assemblage (Assemblage 3-1) from the early Eocene Umlatdoh Limestone (samples L2C41 to L2C62), Meghalaya, NE India (Matsumaru and Sarma 2010, text-fig. 2b), and the *Alveolina subpyrenaica* – *Nummulites atacicus* – *N. burdigalensis* – *N. globulus* – *N. millecaput* – *Opertorbitolites douvillei* Assemblage (Assemblage 3) from the early Eocene upper Masungit Limestone (sample 7451215), Maybangain Formation, Luzon Island, Philippines, due to common occurrences of *Nummulites atacicus* (Matsumaru 2011) (Text-figure 12).

In the west Erif section (Text-figures 2, 3), the Beyobasi Formation (sample KM40, KM48 and KM49) yields *Anomalimoides*...
rubiginosus, Cuvillierina sireli Inan, C. soczerii Sirel, Hellenocyclina beotica, Omphalocyclus macroporus, Orbitoides apiculata, O. gruenbachensis, O. media, O. megaloformis, O. tissoti, Siderolites calcitrapoides, Simplorbites papyraceus, Sirtina orbitoidiformis, Loftusia ketini and Textularia spp. (Text-figure 5A). This fauna is assigned to the Assemblage 4 due to common occurrences of Orbitoides apiculata, Siderolites calcitrapoides, Loftusia ketini, Hellenocyclina beotica and Omphalocyclus macroporus. Then, Assemblage 4 lacks Planorbulinella dordoniensis, Moncharomontia apenninica, Navarella joaguini and Idalina antiqua. Also, sample KM48 yields the planktonic foraminifera, Globotruncanina spp. and Globotruncana stuartiformis (Dalbiez) (Text-figure 6A). These species indicate the Zone KS31 or Abathomphalus mayaroensis zone (Sliter 1989; Caron 1985; Postuma 1971). This is correlated with Sirel (1992, p. 1, fig. 2)’s Maastrichtian Assemblage I due to occurrence of Siderolites calcitrapoides, Omphalocyclus macroporus and Hellenocyclina beotica. The lower Çaldağ Formation (samples KM31, KM37, KM30, KM38 and KM36) yields Anomalinoidea rubiginosus, Daviesina danieli, Laffitteina bibensis, Miscellaneous primitiva, M. spp., Mississippina binkhorsti, Sistantes iranca Rahaghi, Chrysaidina spp., Textularia spp., Valulina spp. and Idalina sinjarica (Text-figure 5B). This fauna is assigned to the faunal Assemblage 7, due to common occurrences of Miscellaneous primitiva, Laffitteina bibensis and Idalina sinjarica from the Çaldağ Formation (samples KM2 to KM44) in the Çaldağ section. Also, sample KM 30 yields Morozovella spp. (Text-figure 6B). This zone is at least correlated with Sirel (1992, fig. 2)’s lower Thanetian Assemblage III due to occurrence of Laffitteina mengaudi and ?Scandonea sp.

In the east Erif section (Text-figures 2, 3), the lower Beyobasi Formation (sample KM9) yields Orbitoides tissoti, Planorbulinella dordoniensis, Siderolites calcitrapoides, Sirtina orbitoidiformis, Sulcoperculina dickersoni, Textularia spp. and Pseudedomia hamaouii (Text-figure 5A). This fauna is regarded as the Assemblage 2 due to common occurrences of Orbitoides tissoti, Siderolites calcitrapoides, Sirtina orbitoidiformis, Sulcoperculina dickersoni and lack of both Orbitolina apiculata and Lepidorbitoides socialis, which are representative species of the Assemblage 3. The upper Beyobashi Formation (samples KM3, E1044, E1043, E1034 and KM25) in the east Erif section yields Cuvillierina spp., Hellenocyclina beotica, Lepidorbitoides socialis, L. spp., Omphalocyclus macroporus, Orbitoides apiculata, O. gruenbachensis, O. media, O. megaloformis, O. tissoti, O. spp., linella dordoniensis, Pseudomphalocyclus blumenthali Merig, Pseudorbitoides trechimanni Douvillé, Siderolites calcitrapoides, Simplorbites papyraceus, Sirtina orbitoidiformis, Sulcoperculina dickersoni, Loftusia ketini, Pseudolituonella spp., Keramosphaerina spp., Nummofallotia cretacea (Schlumberger) and Pseudedomia hamaouii (Text-figure 5A). The present fauna is assigned to the faunal Assemblage 3, due to common occurrences of the same fauna such as Hellenocyclina beotica, Lepidorbitoides socialis, Omphalocyclus macroporus, Orbitoides apiculata, O. tissoti,
Siderolites calcitrapoides and Sirtina orbitoidiformis from the Beyobasi Formation (samples KM34 to KM41) in the Çalda section. Also, samples E1044, E1043, E1034 and KM25 yields the planktonic foraminifera, Hedbergella spp., Heterohelix spp., Globotruncanana arca (Cushman), G. spp., Globotruncanita cf. subspinosa, Rugoglobigerina rugosa, Rugotruncanana subpenny (Gondolfi) and Ruguotruncanana spp. (Text-figure 6A).


In the eastern Haymana, The rock sequences in the eastern Haymana are the upper Cretaceous (Campanian – Maas trichtian) Haymana Formation (composed of dark gray coloured marls intercalated with sandstone, conglomerate and sandy limestone), early Paleocene Yesilyurt Formation (composed of dark grey coloured sandy marl or marly sandstone intercalated with limestone), late Paleocene Iğilnikdere Formation (composed of alternate layer of gray colored sandy limestone, dark gray colored marl, gray colored sandstone and/or conglomerate) and early to middle Eocene Çayraz Formation (composed of pale yellow and grey coloured sandstone intercalated with limestone and marl) (Ünal et al. 1996; Toker 1980). Viewing field observations, the authors found the lack of outcrop between the Iğilnikdere Formation and Çayraz Formation, and this is considered the effects of environmental condition and tectonic events. Two sections are treated in the eastern Haymana (Text-figures 2-4).

In the Çayraz section (Text-figures 2-3), the Haymana Formation (sample 921011-1a) yields the planktonic foraminifera Globotruncanana spp. (Text-figure 6B), but nothing else occurs in this sample. The upper Haymana Formation is correlated with the Beyobasi Formation (Ünal et al. 1996; Toker 1980). Sirel (1992, p. 8, fig. 6) found the Maasrichtian fauna of Siderolites calcitrapoides, Omphalocyclus macroporus and Hellenocyclus beotica. The Yesilyurt Formation (samples KM19, KM27 and KM13) in the Çayraz section yields Anomalinoideas rubiginosus, Kathina major, K. selveri, Laffiteine bivensis, Miscellanea globularis, M. primitiva, Rotalia trochiformis, Sistanites iranica, *Sulcoperculina dickersoni, Chrysaldina spp., Parasubbotina trinidadensis (Text-figure 6A). Asterisk species is reworked. This sample is assigned to the faunal Assemblage 8, based on common occurrences of Anomalinoideas rubiginosus, Kathina major, K. selveri, Laffiteine bivensis, Miscellanea globularis, M. primitiva, Sistanites iranica and Idalina sinjarica from the Iğilnikdere Formation (samples KM24 to KM17) in the Çalda section, west Haymana. Also, these three samples from the Yesilyurt Formation yield the planktonic foraminifera, Globococonus ex gr. G. daubjergensis (Brönnimann), Subbotina triloculinoideas (Plummer), S. spp., Parasubbotina pseudobulloides, P. trinidadensis,
Columnar sections with sampling stations of the upper Cretaceous (K) Kakarca, Tarakl and Seben Formations, Paleocene (T) Yaghane, Salvipinari and Halidiye Formations and upper Cretaceous–Paleocene transitional Akveren and Hisarköy Formations, all of the Black Sea region, Turkey are shown in surveyed localities 1–13 (Tavşantepe, Gebze) to 13 (Yesilcay, Ağva) except point 11 (Sabirli, Alaplı) (Text-figure 1).
Praemurica ex gr. P. uncinata (Bolli), Morozovella angulata (White), M. aequa (Cushman and Renz), M. spp., Igorina pusilla (Bolli), Guembelitria cretacea Cushman, Rugoglobigerina spp. and Rugotruncana subpenny (Gondolfi) (Text-figure 6B). The first six species and last three species are regarded as reworking. Morozovella angulata and M. aequa indicate the Zone P4 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). Sirel (1992, p. 8, fig. 6) found the Thanetian fauna. Also, the Ilginlikdere Formation (samples 921011-4, KM23, KM42, KM29 and 921011-7), which overlies the Yesilyurt Formation in the Çayraz section yields Assilina dandotica, A. leymerie d’Archiac and Haime, A. placentula, Assilina pustulosa Doncieux, *Daviesina danielli, Discocyclina archiaci (Schlumberger), D. spp., *Lockhartia conditi (Nuttall), *L. haimei (Davies), Nummulites atacicus Leymerie, N. deserti de la Harpe, N. globulus Leymerie, N. irregulararis Deshayes, N. partschi de la Harpe, Operculina canalifera, Alveolina canavalii Checcia-Rispoli, A. oblonga d’Orbigny, A. spp., and Orbitolites complanatus (Text-figure 5B). Asterisk three species are reworked. In the present fauna, sample 921011-4 from the lower Ilginlikdere Formation yields only two species Assilina pustulosa and Nummulites deserti, while samples KM29 and 921011-7 from the upper Ilginlikdere Formation yield Nummulites irregularis in association with Assilina leymerie, A. placentula, Nummulites atacicus, N. globulus, N. partchi, Alveolina canavartii, A. oblonga and Orbitolites complanatus (Text-figure 5B). Although there is limited of samples, the present fauna is assigned to the Assemblage 9, due to common occurrences of Nummulites atacicus, N. globulus, N. partchi, Assilina leymerie, A. pustulosa, Operculina canalifera and Orbitolites complanatus. This fauna is correlated with the Alveolina oblonga – A. schwageri – Assilina laxispira – A. placentula Assemblage (Assemblage 3-1) in the Umlatdoh.
Limestone, Meghalaya, NE India, due to common occurrences of *N. atacicus*, *N. globulus* and *O. complanatus* (Matsumaru and Sarma 2010), and the *Alveolina subpyrenaica* - *Nummulites atacicus - N. burdigalensis - N. globulus - N. millecaput - Opertorbitolites douvillei* Assemblage (Assemblage 3) in the upper Masungit Limestone, Maybangain Formation, Luzon, Philippines, due to common occurrences of *Nummulites atacicus* and *N. globulus* (Matsumaru 2011) (Text-figure 12).

Also, sample KM23 in the Çayraz section yields the planktonic foraminifera, *Acarina* spp. and *Subbotina* spp. (Text-figure 6B). Sirel (1992) found the Ilerdian fauna of *Nummulites praelucasi* Douvillé, *N. exilis* Douvillé, *Alveolina cucumiformis* Hottinger and *Assilina pustulosa* Doncieux. The lower Çayraz Formation (samples KM11, KM1, 921011-10, 921011-11 and 921011-12) in the Çayraz section yields *Assilina cuvillieri* Schaub, *A. exponens* (Sowerby), *A. laxispira* de la Harpe, *A. medanica* Pavlovec, *A. placentula* (Dasheyes), *A. spirata* (De Roisy), *A. tenuimarginata* Heim, *A. spp.*, *Daviesina danieli*, *Discocyclina archiaci*, *D. seunesi*, *D. trabayaensis* Neumann, *D. spp.*, *Miscellanea* spp., *Eorupertia boninensis* (Yabe and Hanzawa), *Nummulites atacicus*, *Nummulites distans* Deshayes, *N. globulus*, *N. irregularis*, *N. laevigatus* (Bruguère), *N. lehneri* Schaub, *N. partchi*, *Opirculina canavarii* canavarii, *O. heberti*, *Ranikothalia nuttalli* Davies, *Alveolina canavarii*, *A. oblonga*, *A. spp.*, *Keramosphaerina heberti*, and *Orbitolites complanatus* (Text-figure 5B). Asterisk five species are reworked, and *Assilina exponens* and *A. spira* are considered to be transported from the upper Çayraz Formation (Text-figure 13). The present fauna is assigned to the Assemblage 10, due to common occurrences of *Assilina cuvillieri*, *A. medanica*, *A. laxispira*, *A. placentula*, *Nummulites atacicus*, *N. globulus*, *N. distans*, *N. irregularis*, *N. laevigatus*, *N. lehneri*, *N. partchi*, *Alveolina canavarii*, *A. oblonga* and *Orbitolites complanatus*. This assemblage is correlated with the *Nummulites atacicus - N. globulus* Assemblage (Assemblage 3-2) in the upper Umlatdoh Limestone, both of Meghalaya, NE India (Matsumaru and Sarma 2010), and also correlated with the Assemblage 3 as stated above of the upper Masungit Limestone, Maybangain Formation, Luzon Island (Matsumaru 2011) (Text-figure 12). Also, sample 921011-11 yields the planktonic foraminifera, *Subbotina* spp. (Text-figure 6B). Further, the top Çayraz Formation (samples 921014-14 and KM43) in the Çayraz section yields *Assilina cuvillieri*, *A. exponens*, *A. medanica*, *A. spirata*, *A. tenuimarginata*, *Daviesina danieli*, *Discocyclina* spp., *Nummulites atacicus*, *N. laevigatus*, *N. lehneri*, *N. planulatus* (Lamarck), *Opirculina heberti*, *Alveolina canavarii*, *Alveolina* spp., *Keramosphaerina* spp., and *Orbitolites complanatus* (Text-figure 5B). Asterisk six species are reworked. The present fauna is assigned to the Assemblage 11 due to common occurrences of *Assilina exponens* and *A. medanica*, *A. spirata* *A. tenuimarginata*, *Nummulites atacicus*, *N. globulus - N. laevigatus*, *N. lehneri* and *Orbitolites complanatus* (Text-figure 13). This fauna is correlated with the *Nummulites acutus - N. beamontii - N. gizehensis* - *N. millecaput* - *N. perforatus* Assemblage (Assemblage 4-2) of the middle Prang Limestone, Meghalaya, NE India due to common occurrences of *Orbitolites complanatus* (Matsumaru and Sarma 2010) and the *Nummulites gizehensis* - *N. perforatus* - *N. ptukhiani* - *N. striatus - Assilina exponens* Assemblage (Assemblage 4) of the Caraballo Group (sample H502), NE Luzon, and Talutuman-Tunicob Formation, Marinduque Island (sample MQ28), Philippines, due to common occurrences of *Assilina exponens* (Matsumaru 2011) (Text-figure 12). Sample KM43 in the Çayraz section yields the planktonic foraminifera *Acarina* spp. (Text-figure 6B). Sirel (1992, p. 8-9, fig. 6) found two faunal zones of “*Nummulites atacicus - Assilina placentalu* - Alveolina canavarii" fauna and "*Nummulites lehneri - Assilina exponens" fauna" in the Çayraz section. The former is correlated with the Assemblage 9 to Assemblage 10, while the latter is correlated with the Assemblage 11.

In spot samples in the Haymana section (Text-figures 2, 4), the author examined samples W1 to W4, N1, Y2, Y1, N2 and S1,
which were collected by Dr. Kemal Erdoğan, M.T.A., Turkey, from the same sampling stations by Özcan and Özcan Altiner (1991, fig. 1) (Text-figures 2, 4). The lower Haymana Formation (samples W1, W2, W3 and W4) yields *Lepidorbitoides bisambergensis* (Jaeger), *L. campaniensis* Van Gorsel, *L. pembergeri* Papp, *L. socialis*, *L. spp.*, *Orbitoides gruenbachensis*, *O. media*, *O. megaliformis*, *O. tissoti*, *Planorbulina cretae*, *Pseudorbitoides trechimanni* Douville, *Pseudosidero-

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**TEXT-Figure 10A**
Distribution chart of larger benthic foraminifera from the upper Cretaceous (K) Kakarca, Tarakl and Seben Formations, Paleocene (T) Yağhane, Salvipinari and Halidiye Formations and upper Cretaceous-Paleocene transitional Akveren and Hisalköy Formations in the Black Sea region (Text-figures 1, 7).
lites vidali, Simplorbites papyrusceus, Sirtina orbitoidiformis, Sivasella monolateralis, Sulcoperculina dickersoni, Minouxia spp., Pseudolithonella spp., Textularia spp. and Pseudedomia hamaouii (Text-figure 5B). The present fauna is assigned to the Assemblage 1 due to occurrences of Lepidorbitoides campaniensis, L. bisambergensis, Orbitoides tissoti, O. media, O. megalofornis, O. gruenbachensis, Planorbulina cretae and Pseudosiderolites vidali (Text-figure 13). The Assemblage 1 is
correlated with the late Campanian fauna of CVIa to CVIII benthonic foraminiferal zones of Charentes and Dordogne, France, due to common occurrences of *Orbitoides tissoti*, *Lepidorbitoides campaniensis*, *Siderolites (= Pseudisiderolites) vidali* and *Planorbulina cretae* (Bignot and Neumann 1991, tables 2-3). *Lepidorbitoides pembergeri*, *Pseudorbitoides trechimanni* and *Sulcoperculina dickersoni* in the Assemblage 1 have not yet been known in France. Also, sample W1 yields the planktonic foraminifera *Globotruncanita stuartiformis*, but nothing else is occurred (Text-figure 6B).

Özcan and Özcan Altiner (1997, 1999) announced the Unit C (samples HAY-W-82, HAY-W-91 and HAY-W-95) of the Haymana Formation to be the *Radotruncana calcarata* planktic foraminiferal zone of the upper Campanian, which is equivalent to Sliter’s Zone KS27 (Sliter 1989). The author couldn’t, however, find *Globotruncanita calcarata* (Cushman), except *Globotruncanita elevata* and *G. cf. subspinosa* (Text-figures 6A, 6B). Toker (1980) described the planktonic foraminifera such as *Globotruncanita elevata*, *G. stuarti*, *Globotruncanina lapparenti* Boll, *G. ventricosa* White and *G. tricarinata* (Quereau) from the lower Haymana Formation, and regarded to be the Campanian age, but she couldn’t find *G. calcarata*. The present Assemblage 1 in this study is tentatively regarded as the Zone KS27 of planktonic foraminiferal zones (Sliter 1989), which is correlated with the late Campanian age. Sample N1 from the Unit C yields *Anomalinooides rubinosus*, *Mississippina binkhorsti*, *Orbitoides media*, *Pseudolituonella spp.* and *Textularia spp.* (Text-figure 5B), in association with the planktonic foraminifera *Heterohelix spp.* and *Globotruncanita stuartiformis* (Text-figure 6B). The present assemblage is assigned to the Assemblage 2, and don’t yield *Orbitoides apiculata* and *Lepidorbitoides socialis*, which indi-
cate the Assemblage 3. The Assemblage 2 is tentatively regarded as the Zones KS28? to KS30 (Text-figure 13). Rock samples Y2, Y1, N2 and S1 from the Haymana or Beyobasi Formations yield *Amomalinoides rubiginosus*, *Lepidorbitoides* spp., *Mississippina binkhorsti*, *Omphalocyclus macroporus*, *Orbitoides media*, *Planorbulinella cretae*, *Siderolites calcitrapoides*, *Sivasella monolateralis*, *Chrysalidina* spp., *Textularia* spp., *Opthalmidium* spp. and *Scandonea samnitica* (Text-figure 5B). Further, samples Y1 and S1 yield the planktonic foraminifera *Hedbergella* spp. and *Abathomphalus mayaroensis* (Bolli) (Text-figure 6B). The present assemblage is poor occurrences due to the low diversity of species, but may be regarded as the Assemblage 3 or Assemblage 4, because Assemblages 3 and 4 are characterized by common occurrences of *Orbitoides apiculata*, *Lepidorbitoides socialis* and *Omphalocyclus macroporus* together with *Abathomphalus mayaroensis* of the Zone KS31 (Sliter 1989). This zone is known from the Hisalköy Formation in the Cide section (section 9), the Black Sea region as stated later.

The Black Sea region

The total 12 columnar sections in sampling localities in the Black sea region except Sabirli, Alapli (section 11) are treated to examine the upper Cretaceous to Paleocene sedimentary rocks of the Sakarya-Pontid Platform, main tectonic units of Turkey (Matsumaru et al. 1996, 1997; Text-figures 1, 7). The Maastrichtian Kakarca Formation in the western Pontid zone is composed of gray colored sandy limestone and dark gray colored claystone, which is laterally graded into the Tarakli Formation, composed of yellow colored sandstone (Matsumaru et al. 2010, text-fig. 1; Text-figure 7). Both formations are overlain by the Paleocene Yaghane Formation (composed of gray col-

TEXT-Figure 11B
Distribution chart of planktonic foraminifera from the same formations (Text-figure 10B) in the Black Sea region.
ored marl, limestone, alternation of marl and limestone, and limestone) and Salvipinari Formation (composed of yellow colored limestone and sandstone) in Tavşantepe, Gebze (section 1) through Kızderbent, Karamursel (section 2), Yağhane, İznik (section 3) and Güneytepe, İznik (section 4) to Medetli, Gölpazari (section 5) localities (Bargu and Sakinc 1987, 1989; Dizer and Meşet 1983; Meşet and Şengül 1986; Altınli 1973; Text-figure 7). The Maastrichtian Seben Formation in Kayabogazi, Göynük (section 6) is composed of gray colored limestone and alternation of yellowish brown colored sandstone and gray colored marl, and is overlain by the Paleocene Halidiye Formation (composed of alternation of gray colored limestone and yellowish brown colored sandstone, limestone and yellowish brown colored limestone and limestone) (Meşet and Şengül 1986; Text-figure 7). The Maastrichtian to Danian-Thanetian Hisarköy Formation (composed of alternation of light gray colored limestone and green and dark red colored shale) and Thanetian-Ilerdian? Akgünêy Formation (composed of thinly bedded clayey limestone) has developed widely in Cide (section 9) (Akyl et al. 1974; Sirel 1973, 1991; Özcan and Özkan Altiner 1999; Text-figure 7). The Maastrichtian-Paleocene (Thanetian) Akveren Formation (composed of a sequence of interbedded light gray colored limestone and marl, and minor lava flows, tuffs and sandstone) has developed in Siyamoğlu, Mengen (section 7), Devrekani, Kastamonu (section 8), Kökaksoz, Zonguldak (section 10), Avdal, Ağva (section 12) and Yelșiçay, Ağva (section 13) (Ketin and Görüm 1963; Kaya et al. 1984; Tansel 1989; Text-figure 7).

1. Tavşantepe Section, Gebze (Text-figures 1, 7). The Yağhane Formation (samples 101 to 104) yields Anomalinoïdes rubiginosus, Discocyclina seunesi, Kathina spp., Planorbulina cretae, *Sirtina orbitoidiformis, Pseudochrysalidina spp., Pseudotulioneella spp., Valculina spp., Hoeglundina elegans (d’Orbigny), and Lenticulina (Text-figure 10A). Asterisk species is reworked. The present fauna is assigned to the Assemblage 8 due to common occurrences of Anomalinoïdes rubiginosus, Discocyclina seunesi and Kathina spp. (Text-figure 11A). Also samples 101 and 102 yield the planktonic foraminifera, *Subbotina spp., Praemurica ex gr. P. uncinita, Morozovella velascoensis (Cushman), Acarinitina mckannaii (White) and Igorina pusilla (Text-figure 11A), and these species indicate the Zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). Further, the present assemblage is partial correlated to the Assemblage 8 due to common occurrences of Anomalinoïdes rubiginosus, Discocyclina seunesi and Kathina spp. (Text-figure 11A). Also samples 101 and 102 yield the planktonic foraminiferan, *Subbotina spp., Praemurica ex gr. P. uncinita, Morozovella velascoensis (Cushman), Acarinitina mckannaii (White) and Igorina pusilla (Text-figure 11A), and these species indicate the Zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995).

2. Kişderbent Section, Yağlakdere, Karamursel (Text-figures 1, 7). The Karakaça Formation (samples 202 and 203) yields Anomalinoïdes rubiginosus, which is very poor in the low diversity, and the faunal zone is obscure (Text-figure 10A). It may be the Assemblage 2 or 3. Sample 201 yields the planktonic foraminifera *Heterohelix spp., Contusotruncana fornicata, Globotruncana arca (Cushman), *G. falsostuartii, G. spp., Globotruncana conica (White), *G. stuartii (De Lapparent), *G. stuartii, G. spp., Globotruncana citrea (Bolli), *Rugoglobigerina spp., Gansserina gansseri (Bolli), and *Pseudo- textularia elegans (Rzehak) (Text-figure 11A). The fauna indicates the Zone KS30 or lower KS31 (Sliter 1989; Caron 1985). The Yağhane Formation (sample 204), which overlies the Karakaça Formation, yields Anomalinoïdes rubiginosus, *Lepidorbidotoideae spp., Missellessa globularis, M. primitiva, Mississippina binkhorsti, *Orbitoidae apiculata, *O. gruenbachensis, *O. megaloforismis, *Siderolites calci-trapoides, *Simplicorbites paryraeus Rotalia spp., Pseudochrysalidina spp., and Idalina sinjarica (Text-figure 10A). Asterisk six species are reworked. The present assemblage is assigned to the Assemblage 7 due to common occurrences of Kathina selveri, Missellessa globularis, M. primitiva and Idalina sinjarica (Text-figure 13). Also, sample 204 yields the planktonic foraminiferan, *Subbotina spp., Morozovella spp., Acarinitina spp., Globonalmena compressa, *Globotruncana stuartii, *Globotruncana citrea, *Rugoglobigerina spp. and *Gansserina gansseri (Text-figure 11A). Asterisk four species are reworked. These planktonic foraminiferan species indicates the Zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). The Yağhane Formation carrying the Assemblage 7 is correlated with the Çaldık Formation (samples KM2 to KM44) in the Çaldık section, west Haymana; Çaldık Formation (samples KM31 to KM36) in the west Haymana section; Çaldık Formation (samples E1033 to E1031) in the east Erif section; and the Çaldık Formation (samples KM8 to KM18) in the Başçaycık section, south Haymana, based on common occurrences of Anomalinoïdes rubiginosus, Missellessa globularis, M. primitiva and Idalina sinjarica.

3. Yağhane Section, Derbent, İznik (Text-figures 1, 7). The Yağhane Formation (samples 302 and 303) yields Anomalinoïdes rubiginosus, Kathina selveri, Chrysalidina spp., Pseudolituonella spp., and Idalina sinjarica (Text-figure 10A). The fauna is very poor due to low diversity, but is assigned to the Assemblage 6 due to common occurrences of Anomalinoïdes rubiginosus, Kathina selveri and Idalina sinjarica. The Yağhane Formation, which overlies the upper Cretaceous Taraklı Formation, is widely distributed from Yağhane (section 3) through Mugek (section 4) to Medetli (section 5), and in the Medetli it is inter-fingering with the Salvipinari Formation. Also, the Salvipinari Formation is correlated with the Halidiye Formation in the Kayabogazi section (section 6) due to Laffitteina-bearing beds and similar rock facies (Matsumaru et al. 1996).

4. Güneytepe Section, Yenisehir, İznik (Text-figures 1, 7). The Taraklı Formation (sample 401) yields Anomalinoïdes rubiginosus, and Textularia sp. (Text-figure 10A). The fauna is very poor and the assemblage is obscure. The Yağhane Formation (samples 403 and 405) yields Anomalinoïdes rubiginosus, Laffitteina bicensis, Mississippina binkhorsti, Planorbulina cretae, Sistances iranica, Idalina sinjarica and Scandonea sammitica (Text-figure 10A). The present assemblage is assigned to the Assemblage 6 due to common occurrences of Anomalinoïdes rubiginosus, Laffitteina bicensis, Planorbulina cretae, Idalina sinjarica and Scandonea sammitica.

5. Medetli Section, Gölpazari (Text-figures 1, 7-8). The yellow sandstone of the top Taraklı Formation underlying the Paleocene Salvipinari Formation yields the upper Cretaceous (Maastrichtian) bivalve Exogyra spp. The basal Salvipinari Formation (sample 504) yields Anomalinoïdes rubiginosus, Pseudolituonella spp. and Scandonea sammitica and this fauna is assigned to the Assemblage 5 without Laffitteina bicensis.
(Text-figures 10A, 13). The Salvipinari Formation (sample 505) yields *Laffitteina bibensis* and *Chrysalidina* spp., *Pseudolituitella* spp. (Text-figure 10A), and this fauna is assigned to the Assemblage 6 due to occurrences of *Laffitteina bibensis*. In a series of author et al.’s research group works, the K-T boundary have been decided into the yellow colored fine grained goethite sandstone (samples 502 and 501) of the topmost Tarakli Formation (Matsumaru et al. 1996, p.24, 1997; Text-figures 7-8). After that, Iridium concentrations for goethite-rich layers (samples 502 (3-02a to 3-02c) and 502’ (3-01)) of the Tarakli Formation were relative low (0.05 - 0.10 ppb), but was slightly elevated (0.24 ppb) in sample MD01 (= sample 501) over the samples 3-10 or 3-18 of the Tarakli Formation (Arakawa et al. 2003, fig. 6, tab. 3; Text-figure 8). As such, the authors concluded that Iridium has been diluted by the sedimentation and diagenesis during the K-T boundary and its successive events. The actual K-T boundary was put on the goethite layers (samples 502 to 501) over the *Exogyra*-bearing sandstone (sample 500) of the Tarakli Formation (Text-figures. 7-8). The authors have analysed major element concentrations for 24 goethite samples in Medetli, Gölpazarı (Arakawa et al. 2007, table 1). All the 87 Sr/ 86 Sr ratios (0.7077-0.7078) were very close to the measured ratios by DePaolo and Ingram (1985) and Palmer and Elderfield (1985), and it is considered to indicate the condition of the sea water at the K-T boundary time (65-66 Ma). The Ir bearing K-T boundary layers (28-37 cm thick) in the Medetli sections, Turkey is correlated well with the Ir bearing K-T boundary limonite layers (5 cm thick) in sample W 8 (= J85-26) of the top Mahadeo Formation, Um Sohringkew River section, Meghalaya, NE India (Bhandari et al. 1987, 1994; Murali et al. 1990, fig. 1c). A series of foraminiferal biostratigraphy below and above the K-T boundary is explained in the fauna found from the Hisarköy Formation in the Cide Section (section 9), Turkey. The fauna is correlated with the fauna from the upper Mahadeo Formation in the Um Sohringkew River section, Meghalaya, NE India (Pandey 1981, 1990; Bhandari et al. 1987, 1994; Murali et al. 1990; Garg and Jain 1995), but not with the uppermost Langpar Formation in the Um Sohringkew River and Mahadeo sections, Meghalaya (Mukhopadhyay 2008).

6. Kayabogazi Section, Göynük (Text-figures 1, 7). The Halidiye Formation (samples 601 to 606) yields *Anomalinoideas rubiginosus, Laffitteina bibensis, Planorbulina cretae, Chrysalidina* spp., *Textularia* spp., *Hoeglundina elegans, Idalina* sinjarica, *Lenticulina* spp., *Dentalina* spp. and *Scandonea samnifica* (Text-figure 10A). The present fauna is assigned to the faunal Assemblage 6, due to common occurrences of *Anomalinoideas rubiginosus, Kathina selveri, Laffitteina bibensis, Planorbulina cretae, Idalina sinjarica*, and *Scandonea samnifica* from the lower Yağthane Formation in Yağthane (section 3) to Medetli (section 5). Also, the Halidiye Formation (samples 602, 603 and 604) yield the planktonic foraminifera, *Subbotina* spp., *Parasubbotina pseudobuloides, P. trinidadiensis, Praemurica* ex gr. *P. uncinata*, and *Morozovella* spp. (Text-figure 11A). These planktonic foraminifera indicate the Zone P2 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). Samples 607 and 608 yield *Dictyokathina simplex* Smout, *Laffitteina bibensis*, *Mississippina binkhorsti*, *Rotalia trochidiformis* and *Idalina sinjarica* (Text-figure 10A), and this fauna is assigned to the Assemblage 8 due to occurrences of *Dictyokathina simplex, Laffitteina bibensis*, *Rotalia trochidiformis* and *Idalina sinjarica*.

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**TEXT-FIGURE 12**

Correlation chart between the larger benthic foraminiferal assemblages of Turkey in this study; those of Meghalaya, NE India (Matsumaru and Sarma 2010); and those of Philippine Archipelago (Matsumaru 2011); the late Cretaceous to middle Eocene Time scale (official website of ICS (International Commission on Stratigraphy), GTS2012, www.tscreator.org and Berggren et al. 1995; Anthonissen and Ogg 2012); planktonic foraminiferal zones (Sliter 1989; Berggren et al. 1995; Garg and Jain 1995), but not with the uppermost Langpar Formation in the Um Sohringkew River and Mahadeo sections, Meghalaya (Mukhopadhyay 2008).

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7. Siyamoğlu Section, Mengen (Text-figures 1, 7). The Akveren Formation (samples 701 and 702) yields *Asterocyclina stella* (Gümbel), *A. spp., Discocyclina seunesi, D. spp., Kathina selveri, Miscellanea primitiva, Orbitocythere ramaraoi* (Samanta), and *Randolithia nuttalli* (Text-figure 10A). The fauna is assigned to the Assemblage 8 due to common occur-
rences of Discocyclina seunesi, Orbitoclypeus ramaraoi, Ranikothalia nutalli, Kathina selveri and Miscellanea primitive. This fauna is correlated with the Assemblage 8 of the Ilgınlukdere Formation (sample 92103-1) in the Polatlı (Kirkkavak) section, Ilgınlukdere Formation (samples KM24 to KM17) in the Çaldık section and Yezilyurt Formation (samples KM19 to KM13) in the Çayraz section, Haymana region, and the Yağhanе Formation (samples 101 to 104) in Tavşantepe, Gebze (section 1) and Halidiye Formation (samples 607 and 608) in Kayabogazı, Göynük (section 6), Black Sea region (Text-figures 5A-5B and 11A).

8. Devrekâni Section, Kastamonu (Text-figures 1, 7, 9). The Akveren Formation (samples 801 to 806) yields Anomalainoides rubiginosus, Cuvillierina soezieri, Hellenocyclina beotica, Omphalocyclus macroporus, Orbitoides apiculata, O. gruenbachensis, O. media, O. megaliformis, O. tissoti, Planorbulina cretae, Pseudo-siderolites vidali, Rotalia spp., Siderolites calcitrapoides, Simplorbites papyraceus, Sirtina orbitoidiformis, Sulcoperculina dickersoni, Cuvillierina soezerii, Loftusia spp., Pseudochrsyalida spp., Pseudolituonella spp., Lenticulina spp. and Dentalina spp. (Text-figure 10A). This fauna is assigned to the Assemblage 4 due to common occurrences of Anomalainoides rubiginosus, Hellenocyclina beotica, Omphalocyclus macroporus, Orbitoides apiculatus, Siderolites calcitrapoides, Simplorbites papyraceus, and Sirtina orbitoidiformis from the Beyobasi Formation (samples KM40, KM48 and KM49) in the west Erif section, Haymana region. The Akveren Formation (sample 805) yields planktonic foraminifera Heterohelix spp. (Text-figure 11A). 87Sr/86Sr values of the Akveren Formation (samples 806 and 807) indicate the age nearly 65-66 Ma, and the actual K-T boundary is put on the top of limestone sample 806 of the Akveren Formation (Matsumaru et al. 1996, fig. 3, table 1; Text-figures 7, 9). The upper Akveren Formation (samples 807 to 810) yield Anomalainoides rubiginosus, Daviesina danieli, Mississippina binkhorsti, Chrysalidina spp., Pseudochrsyalida spp., Valvulina spp., Hoeglundiana elegans, Lenticulina sinjarica, Lenticulina sinjarica, Ophtalmidium spp. and Dentalina spp. (Text-figure 10A). This fauna is assigned to the Assemblage 6 due to occurrences of Daviesina danieli and Idalina sinjarica.

TEXT-Figure 13
Biostatigraphic synthesized occurrence and phylogenetic relationship of main larger and important benthic foraminiferal species from the Haymana and Black Sea regions, Turkey is shown, and these data become the base of the assemblages. However, there are considerable reworking species marked by parenthesis in the Haymana region. The early to middle Eocene Çayraz Formation yields the middle to late Paleocene Ranikothalia nuttalli (sample KM11, Text-figure 5B), Lockhartia conditi (in sample KM29, Text-figure 5B), and L. haimei (in sample KM29, Text-figure 5B) as reworking species. Nummulites planulatus (in sample 921011-14, Text-figure 5B) occur in association with middle Eocene Assilina exponens and A. spira from the top Çayraz Formation, and is naturally reworked. Assilina exponens and A. spira has partial been washed from the top Çayraz Formation and transported into the lower Çayraz Formation (in samples KM11, 921011-10, 921011-11, and 021011-12; Text-figure 5B). Assilina dandotica of the late Paleocene to early Eocene species (Schaub 1981) is found from the lower Çaldaği Formation (sample KM2; Text-figure 5A) and Ilgînlikdere Formation (sample KM23; Text-figure 5B), and partial reworked. The early to middle Paleocene Daviesina danieli is reworking into the early to middle Eocene Çayraz Formation (in samples KM29, KM11, 921011-10, 921011-11, and KM43; Text-figure 5B), but is omitted to avoid the further confusion. The Campanian Planorbulinella dordoniensis is found from samples KM47, 35, 9 and E1044 (Beyobasi Formation; Text-figure 5B) and KM 2 and 33 (Çaldaği Formation, Text-figure 5A) as reworked species. As such, in the Haymana region, the geological problems created by the depositional environments and tectonic movements have occurred the extensive reworking species in the Beyobasi, Çaldaği, Ilgînlikdere, and Çayraz Formations.
stuartiformis, Abathomphalus mayaroensis, Rugoglobigerina spp., Pseudotextularia elegans and Racemiguembelina fructcosa (Text-figures 11A, 11B). This planktonic foraminiferal fauna indicates the Zone KS31 or Abathomphalus mayaroensis zone (Sliter, 1989; Caron, 1985). Asterisk species are reworked. Further, the upper Hisalköy Formation (samples 930 to 933) yields Anomalinaoides rubiginosus, *Cuvillerina soezertii, *C. spp., *Lepidorbitoides spp., Mississippina binkhorsti, *Orbitoides tissoti, Planorbulina cretae, *Sirtina orbitoidiformis, Chrysalidina spp., Pseudoquintasella spp., Valvulina spp., Hoeglundina elegans, and Lenticulina spp. (Text-figure 10B). Asterisk species are reworked. The present fauna is very poor in the low diversity, but is assigned to the faunal Assemblage 6. Also, samples 934 and 935 yields the planktonic foraminifera, Subbotina spp., Parasubbotina pseudobulloides, *P. trinidadiensis and Morozovella spp. (Text-figure 11B), and the planktonic foraminifera indicate the zone P2 due to similar fauna with the Akveren Formation (samples 602 to 604) in Kayabogazi, Günüuk (section 6) (Text-figures 11A, 11B). The upper Hisarköy Formation (samples 936 and 937) yields only planktonic foraminifera, Subbotina triloculinoides, Parasubbotina trinidadiensis, Morozovella spp., M. aqua, M. spp., Acanarina spp., Globanomalina chapmani (Part) and *G. compressa (Text-figure 11B). This fauna indicates the Zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). Then, the present assemblage is tentatively assigned to the faunal Assemblage 7, which is found in the Akveren Formation (sample 204) carring planktonic foraminifera in the Kizderbent, Yalakdere, Karanmurlu (section 2) (text-figure 11A). The top Hisarköy Formation (composed of alternation of cocoa colored shaly limestone and gray colored shale, sometimes with intercalation of pebble conglomerate; samples 938, 989 and 921015) yields Anomalinaoides rubiginosus, Kathina selveri, Miscellanea globularis, M. primitiva, Mississippina binkhorsti, Planorbulina cretae, Rotalia spp., Chrysalidina spp., Coskinon rajkei, Pseudolituonella spp., Valvulina spp., Hoeglundina elegans, Ildalina sinjarica, Lenticulina spp. and Dentalina spp. (Text-figure 10B). This fauna is assigned to the Assemblage 8 due to common occurrences of Kathina selveri, Miscellanea globularis, M. primitiva and Idalina sinjarica. Also, samples 938, 939 and 921015 yields the planktonic foraminifera, *Globusconus ex gr. G. daubjergensis, Subbotina triloculinoides, S. spp., *Parasubbotina pseudobulloides, *P. trinidadiensis, Morozovella velascoensis (Cushman), M. aqua, M. spp., Acanarina spp., Globanomalina chapmani (Part), G. pseudomenardii, G. spp., Igorina pusilla, *Heterohelix spp. and *Abathomphalus mayaroensis (Text-figure 11B). Asterisk species are reworked. The present planktonic foraminiferal fauna indicates the Zone P4 of the Selandian age (Bolli 1969; Berggren and Van

PLATE 1

1-5. Chaldagia haymanensis Matsumaru, n. gen., n. sp. Locality: KM20, Çaldağ, Haymana region. 1-5. ×50.
   1 Equatorial sections of megalospheric form, Holotype, Saitama Univ. Coll. No. 201201-1.
3-5 Centered oblique sections of megalospheric form.
6-12. Scandonea samnitica De Castro
   6 Equatorial section of megalospheric form. Locality: 6, KM20, Haymana region. ×20.
   7 Subequatorial sections of microspheric form. Locality: KM32, Haymana region.
   8 Subequatorial sections of megalospheric form. Locality: KM2, Haymana region. ×20.
   9 Transverse sections of three specimens, which are cut each uniserial chambers. Locality: KM46, Haymana region. ×20.
12 Oblique sections of two specimens. Locality: KM2, Haymana region. ×20.
Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). Sirel (1973) regarded the Hisarköy Formation to be the Maastrichtian - Danian age, which was overlain by the Thanetian Akgüney Formation. Özcan and Özkan Altner (1999) regarded the Akgüney Formation to be Danian age, although they don’t show any positive data. The author surveyed the Cide section twice in 1992 and 1995, and regarded the Hisarköy Formation to be the Flysh type strata, which was composed of the alternation of gray to light gray colored (sometimes orange colored in weathering) massive or banded limestone, compressed pebble bearing sandy limestone, oolite bearing limestone, greenish gray to cocoa colored calcareous shales and mudstones and pebble conglomerate. The age of the Hisarköy Formation was assigned to the Maastrichtian to Selandian based on the larger and planktonic foraminifera as stated above (Text-figures 11A-11B). The K-T boundary layers of the Hisarköy Formation are placed at near and at right angles to the corner between the north – south uphill road from Cide Town to Sinop City and east-west road parallel along the Black Sea toward eastern Sinop City, and put on the limestone between the gray colored muddy limestone (sample 929) and cocoa colored banded sandy limestone (sample 930). Along the descent down road from the boundary to Cide Town, the alternation of shaley-muddy limestone and medium grained sandstone of the Hisarköy Formation is developed, and samples 936 to 921915 were collected from the Hisarköy Formation. Sample 938 is placed at the transmission of electricity pole beside the road. Samples 938 to 921915 are collected from the top Hisarköy Formation, which is bounded by the fault with the folding Akgüney Formation (composed of the alternation of gray colored mudstone and limestone). The Hisarköy Formation (samples 901 to 921015) in the Cide section is correlated well with the Mahadeo Formation (samples W-73 to W-14) to Langpar Formation (samples W-15 to W-52) in the main Um Sohrungkew River section and partial Mawsmai section, 5 km NW from the Um Sohrungkew River section, both of Meghalaya, NE India (Pandey 1981, fig. 1; Pandey 1990, fig. 1), based on bentonic and planktonic foraminifera. The K-T Ir bearing goethite layers didn’t found in the upper Hisarköy Formation (samples 929 to 930) in the Cide section. The upper Hisarköy Formation (samples 930 to 933) of the Zones P0-1 of planktonic foraminiferal zones above the K-T boundary is, equatorial chambers radially. Locality: 909, Cide, Black sea region. ×20.

8-9. Lepidorbitoides pembergeri Papp


9 Equatorial section of megalospheric form, showing ill-balanced biserial nepionic arrangement of unrolling long primary (helicolepidine) spiral starting along protoconch and unrolling short primary spiral in opposite direction starting along deuteroconch. Locality: W-2 (Özcan and Altiner 1992, fig. 1), Haymana region. ×80.

10-11. Lepidorbitoides campaniensis Van Gorsel

10 Equatorial section of megalospheric form. Locality: W-2 (Özcan and Altiner 1992, fig. 1), Haymana region. ×80.

11 Centered oblique section of megalospheric form. Both forms showing biserial peri-embryonic arrangement of nepionic spirals, long primary nepionic spiral along protoconch and short primary nepionic spiral along deuteroconch. Locality: W-2 (Özcan and Altiner 1992, fig. 1), Haymana region. ×80.

12. Lepidorbitoides bisambergensis (Jaeger). Equatorial section of megalospheric form showing a quadriserial nepionic arrangement, without any accessory auxiliary chambers on deuteroconch. Locality: W-2 (Özcan and Altiner 1992, fig. 1), Haymana region. ×80.

PLATE 2

1-3. Pseudosiderolites vidali (Douvillé)

1 Subaxial section of microspheric form. Locality: 1. 913 and 3. 924, Cide, and 2. 801, Devrekanı, all of Black Sea region. ×20.

2 Oblique section of megalospheric form in center, associated with Cuvillierina soezeri (Sirel) in left and right. Locality: 1. 913 and 3. 924, Cide, and 2. 801, Devrekanı, all of Black Sea region. ×20.

3 Subequatorial section of megalospheric form. Locality: 1. 913 and 3. 924, Cide, and 2. 801, Devrekanı, all of Black Sea region. ×20.

4-5. Helicorbitoides voigti Van Gorsel

4 Centered oblique sections of megalospheric form, showing a few arcuate secondary equatorial chambers between first and second whors of primary nepionic spiral. ×50.

5 Transverse section of microspheric form. Locality: sample loc. 734, Bole, Black Sea region (Sirel 1995, fig. 1; Text-fig. 1). ×20.

6-7. Helicorbitoides longispiralis (Papp and Küpper)

6 Centered oblique sections of microspheric form (6) and showing probably two more whors of primary spiral, and later continuing arcuate equatorial chambers radially. Locality: 734, Siyamogle, Black Sea Region. ×20.

7 megalospheric form, showing probably two more whors of primary spiral, and later continuing arcuate...
however, correlated with the basal Salvipinari Formation (sample 504), which overlies the K-T Ir layers (0.24 ppb by Arakawa et al. 2003) of the top Tarakl Formation in Medetli (section 5) as stated above (Matsumaru et al. 1996, 1997; Arakawa et al. 2003, 2007; Text-figure 7). The K-T Ir boundary layers of the top Tarakl Formation below the Salvipinari Formation is correlated well with the K-T iridium layers (12 ppb by Bhandari et al. 1998, 1994; 4.1 ppb by Murali et al. 1990) of the top Mahadeo Formation, Um Sohryngkew River section, Meghalaya, NE India, based on the chemistratigraphy (Ir and siderophiles). The upper Mahadeo Formation (samples W-3 to W-7 and J85-25) below the Ir bearing K-T limonite layers in the Um Sohryngkew River section, Meghalaya, NE India indicate the terminal Maastrichtian Globotruncanita stuartiformis Zone without Abathomphalus mayaroensis (Pandey 1981, p. 57; 1990, fig. 1c), and also the topmost Mahadeo Formation (about 1m thick; samples S10 to S30) right below the K-T Ir layers indicate the terminal Maastrichtian calcareous nanofossil Micula prinsii zone (Garg and Jain 1995; Kar et al. 2006, fig. 2; Anthonissen and Ogg 2012, p. 1119). In there, the top Mahadeo Formation (samples J85-32), 1.5 m above the K-T Ir layers yields Parvulalglobigerina eugubina (sample J85-32), 1.5 m above the K-T Ir layers in the top Mahadeo Formation, Um Sohryngkew River section, Meghalaya, NE India indicate the terminal Maastrichtian Globotruncanita stuartiformis Zone without Abathomphalus mayaroensis (Pandey 1981, p. 57; 1990, fig. 1c), and also the topmost Mahadeo Formation (about 1m thick; samples S10 to S30) right below the K-T Ir layers indicate the terminal Maastrichtian calcareous nanofossil Micula prinsii zone (Garg and Jain 1995; Kar et al. 2006, fig. 2; Anthonissen and Ogg 2012, p. 1119). In there, the top Mahadeo Formation (samples J85-32), 1.5 m above the K-T Ir layers yields Parvulalglobigerina eugubina (Pandey 1990, figs. 1c, 2h) of the Zones P1 to P3 of planktonic foraminiferal zones in Turkey (Text-figure 13; Plate 8, figures 11-12). Navarella joaguini don’t seem to survive into the Globotruncanita stuartiformis zone in the top Mahadeo Formation (Pandey 1981, p. 57). Also, the Langpar Formation (samples W23 to W35), about 25 to 38 m above the K-T Ir layers yielded Anomalinoideas rubiginosus (Pandey 1990, fig. 1a). This species is known in the Assemblages 2 to 8 and Zones KS 28 to P 5 of planktonic foraminiferal zones in Turkey (Text-figure 13; Plate 10, figures 2-3).

10. Kokaksu Section, Zongludak (Text-figures 1, 7). The lower Akveren Formation (sample 1001) yields Minouxia spp. and planktonic foraminifera, Globigerinelloides spp., Heterohelix spp., Contusotruncanita contusa, C. fornicata, Globotruncanita arca, G. lineianna, G. spp., Globotruncanita stuarti, G. stuartiformis, Rugoglobigerina rugosa, R. spp., Lepidorbitoides minor (Schlumberger). Equatorial section of megalospheric form, showing 8 nepionic spirals of chamber arrangement due to having two accessory auxiliary chambers on deuteroconch. Locality: 909, Cide, Black Sea region. ×50. Scale is 1000 micron.

2-3. Lepidorbitoides socialis (Leymerie)

2 Equatorial sections of megalospheric form, showing multi-nepionic spirals, and having more than five accessory auxiliary chambers on deuteroconch. Locality: KM3, Haymana region. ×30. Scale is 1000 micron.

3 Equatorial sections of megalospheric form, showing multi-nepionic spirals, and having more than five accessory auxiliary chambers on deuteroconch. Locality: 928, Cide, Black Sea region. ×30. Scale is 1000 micron.

4-8. Pseudorbitoides trechmanni Douvillé


5 Equatorial sections of microspheric form, associated with Orbitoides spp. showing small spiral of primary chambers and equatorial chambers subdivided by pseudorbitoid layer of radial elements. Locality: 902, Black Sea region. ×50.

6 Tangential section. Locality: W-3 (Ozcan and Altiner 1992, fig. 1), Haymana region. ×70.

7 Axial sections of megalospheric form (7 left), microspheric form (7 right). Locality: 908, Black Sea region. ×20.

8 microspheric form carrying radial elements (center), associated with Orbitoides spp. (left) and Contusotruncanita contusa (Cushman) (right). Locality: 903, Cide, Black Sea region. ×30.

9-10, 12 center and right. Conorbitoides cristalensis Brönnimann

9 Axial section. Locality: 912, Black Sea region. ×110.

10 Transverse section. 910, Cide, Black Sea region. ×40.

12center Transverse section. 910, Cide, Black Sea region.

12 right Equatorial section of microspheric form, associated with Sirtina orbitoidiformis Brönnimann and Wirz (12 left) and Globotruncanita aegyptiaca Nakkady (12 right lower). Locality: 910, Cide, Black Sea region. ×20.


### PLATE 4

1-4. *Sirtina orbitoidiformis* Brönnimann and Wirz


2. Transverse section of microscopic form. Locality: 926, Cide, Black Sea region. ×50.

3. Oblique section. 104, Tavşantepe, Black Sea region. ×50.


5-7. *Sulcoperculina dickersoni* (Palmer)

5. Axial section of microscopic form. Locality: 908, Black Sea region. ×60.


8-11. *Sulcorbitoides pardoi* Brönnimann


10. Transverse section. Locality: E1033.5, East Erif, Haymana region. ×20

11. Equatorial section of microscopic form. Locality: 926, Cide, Black sea region. ×60.

The planktonic foraminiferal fauna indicates the Zone P4 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995).


13. Yeşilçay Section, Agva (Text-figures 1, 7). The lower Akveren Formation (samples 1301 and 1302) yields Anomalinaoides rubiginosus and Navarella joaguini (Text-figure 10B). This fauna is assigned to the Assemblage 3 due to occurrences of Navarella joaguini. Also, both samples yield Globotruncanita spp. (Text-figure 11B). The upper Akveren Formation (samples 1303 and 1304) yields Anomalinaoides rubiginosus (Text-figure 10B), and also yield the planktonic foraminifera, Subbotina spp., Morozovella spp. and Globanomalina compressa (Text-figures 10B, 11B). The planktonic foraminiferan fauna indicates the Zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995). The present fauna will be assigned to the Assemblage 7, because the Zone P3 is found in the

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**PLATE 5**

1-2. *Sivasella monolateralis* Sirel and Gündüz

1 Transverse section of microspheric form, showing lack of lamellar wall on the dorsal side toward the periphery. Locality: W-1 (Ozcan and Altiner 1992, fig. 1), Haymana region. ×100.

2 Vertical section of megalospheric form, showing no lamellar wall on the dorsal side of the test, although *Sivasella* carry the thick lamellar wall on the dorsal side of the test. Locality: W-1 (Ozcan and Altiner 1992, fig. 1), Haymana region. ×80.

3-5. *Planorbulina create* (Marsson)

3 Vertical section. Locality: KM47, Çaldağ, Haymana Region.

4 Centered oblique section of megalospheric form. Embryonic chambers are followed by spirally arranged nepionic chambers. Locality: E1033, East Erif, Haymana region.

5 Centered oblique section of megalospheric form. Embryonic chambers are followed by spirally arranged nepionic chambers. Locality: 935, Cide, Black Sea region. ×50.

6-8. *Planorbulinella dordontiensis* Hofker


10 Centered oblique section of megalospheric form, showing the value of Van Hinte (1966)’s Li + li embry diameter of 256 micron. Large coarse spines of *Siderolites calcitrapoides* can be seen (lower right). Locality: 902, Cide, Black Sea region. ×10.

11 Centered oblique section of megalospheric form, showing the value of Van Hinte (1966)’s Li + li embry diameter of 422 micron. Locality: 903, Cide, Black Sea region. ×20.

Akveren Formation (samples 1008 to 1014) carrying Assemblage 7 in the Kokaksu, Zonguldak (section 10).

**Spot sample 734** (Sirel 1995) (Text-figure 1). The author visited the type locality of *Helicorbitoides boluensis* Sirel 1995, which is described from samples at Mendenler village (present Sabunlar köyü/village), 9.5 km north of Dirgine town, NE Bolu on September 11 and 12, 1999 with Dr. Kemar Erdoğan, M.T.A. We couldn’t, however, find the *Helicorbitoides*-bearing limestone (sample no. 734) of the Turonian - Campanian Buldandere Formation. The author was, however, given a few samples for study from Dr. Ercument Sirel, who analysed samples from M.T.A.collection. The limestone sample 734 yields *Helicorbitoides voigti* Van Gorse, *H. longispiralis*, *Orbitoides medio*, *O. tissoti* and *Pseudosiderolites vidali* (Text-figure 10B) together with *Globotruncanita stuartiformis* (Text-figure 11B).

Sirel (1995) established *Helicorbitoides boluensis* based on the characters of wide primary whorls and many secondary equatorial chambers. But *H. voigti* and *H. longispiralis* are presented in sample 734 as stated above (Plate 2, figures 4-5; Plate 2, figure 6). Further, *Helicorbitoides longispiralis* (Plate 2, figure 7) was found at the first time from the lower Hisalköy Formation (sample 909) in the Cide section, although it has been reworked (Text-figure 10A). The stratigraphic relationship between the Buldandere Formation in Bolu and the Hisalköy Formation in the Cide section is obscure. According to Van Gorse (1975), the descendant of *Helicorbitoides longispiralis* is *Lepidorbitoides pembergeri* Papp from the upper Campanian beds. *Lepidorbitoides pembergeri* (Plate 2, figures 8-9) was found at the first time in this study from samples W-1 and W-2 of the Campanian Haymana Formation together with *Lepidorbitoides campaniensis* and *L. bisambergensis* (Text-figures 4, 5B; Plate 2, figures 10-11; Plate 2, figure 12). As such, the evolutionary trend in the *Helicorbitoides – Lepidorbitoides* lineage from *Helicorbitoides voigti* through *Helicorbitoides longispiralis* and *Lepidorbitoides pembergeri* to *L. campaniensis* and *L. bisambergensis* during the late Campanian to early Maastrichtian will have to be existed. It needs the further study from many samples of the Unit C, Haymana Formation in Haymana, Hisarköy Formation in Cide and Buldandere Formation in Bolu.

**FAUNAL ASSEMBLAGE ZONATIONS AND THEIR GEOLOGICAL AGES**

11 larger foraminiferal assemblage zonations have been recognized from the biostratigraphical occurrences of larger benthonic foraminiferal species, associated with planktonic foraminifera from the best selected sections and samples in the Haymana and Black Sea regions. From 73 samples in the Haymana region, 101 species with one new species belonging to 57 genera with one new genus of larger and benthonic species were identified (Text-figures 5A, 5B). From 105 samples in the Black Sea region, 62 species belonging to 47 genera of larger

**PLATE 6**

1-2. *Orbitoides media* (d’Archiac)  
1 Equatorial section of megalospheric form (Van Hinte’s Li +li embryo diameter = 572 micron). Locality: 1. KM3, East Erif, Haymana region. ×30. Scale is 1000 micron.  
2 Centered oblique section of megalospheric form (Van Hinte’s Li +li embryo diameter = 582 micron). Locality: 906, Cide, Black Sea region. ×20. Scale is 1000 micron.

3-5. *Orbitoides megaliformis* Papp and Küpper  
3 Centered oblique section of megalospheric form (Li + li embryo diameter = 565 micron). Locality: 806, Devrekani, Black Sea Region. ×20. Scale is 1000 micron.  
4 Centered oblique section of megalospheric form (Li + li embryo diameter = 691 micron). Locality: 902 Cide, Devrekani, Black Sea Region. ×20. Scale is 1000 micron.  
5 Equatorial section of megalospheric form (Li + li embryo diameter = 687 micron). Locality: KM3, East Erif, Haymana region. ×30. Scale is 1000 micron.

6-8. *Orbitoides gruenbachensis* Papp  
6 Equatorial section of megalospheric form (Li + li embryo diameter = 936 micron). Locality: 928, Cide, Black Sea region. ×20. Scale is 1000 micron.  
7 Equatorial section of megalospheric form (Li + li embryo diameter = 880 micron). Locality: KM3, East Erif, Haymana region. ×20. Scale is 1000 micron.  
8 Equatorial section of megalospheric form (Li + li embryo diameter = 821 micron). Locality: KM3, East Erif, Haymana region. ×30. Scale is 1000 micron.  

9-11. *Orbitoides apiculata* Schlumberger  
9 Equatorial sections of megalospheric form (Li + li embryo diameter = 1161 micron). Locality: 928, Cide, Black Sea region. ×30. Scale is 1000 micron.  
10 Equatorial sections of megalospheric form (Li + li embryo diameter = 1560 micron). Locality: 928, Cide, Black Sea region. ×30. Scale is 1000 micron.  
11 Equatorial sections of megalospheric form (Li + li embryo diameter = 1113 micron). Locality: KM3, East Erif, Haymana region. ×30. Scale is 1000 micron.

12. *Orbitoides spp.* Equatorial section of microspheric form, showing proloculus, early biserial nepionic spirals of chamber arrangement and later arcuate median chambers. Locality: KM3, East Erif, Haymana region. ×30. Scale is 1000 micron.
and important benthonic foraminiferal species were identified (Text-figures 10A, 10B). As such, the total 114 species (49 common species) with one new species belonging to 66 genera (38 common genera) with one new genus of larger and benthonic foraminifera were identified. These taxa have been found from total 178 samples (73 samples in the Haymana region; 105 samples in the Black Sea region) in total 19 sections (7 sections in the Haymana region; 12 sections in the Black Sea region). The biostratigraphic synthesized occurrence of age-diagnostic larger and benthonic foraminifera (89 species with 8 reworked species) is shown in Text-figure 13. From 32 samples in the Haymana region, 30 species belonging to 23 genera of the planktonic foraminiferal species, associated with larger foraminifera were identified (Text-figures 6A, 6B). From 67 samples in the Black Sea region, 52 species belonging to 23 genera of the planktonic foraminiferal species, associated with larger and benthonic foraminifera were identified (Text-figures 11A, 11B). The Letter Stages (Matsumaru 2011) from the middle Paleocene (Selandian) and middle Eocene (Lutetian) and planktonic foraminiferal zones from the late Cretaceous to Paleogene sedimentary sequences in the Haymana and Black Sea regions, but a stricter definition of the larger foraminiferal assemblage zones couldn’t be thoroughly defined the boundaries in the type sections, due to limited samples, clarification of species by diagenesis and problems of re-worked-transported species. The last problems are very important to note, because it is made from more complicated geology created by various depositional environments and tectonic events in both regions. The result of the present study indicates, nevertheless, that the larger foraminifera from 12 formations (Beyobasi, Haymana, Kakarca, Hisalköy, Çaldag, Yeşilyurt, İlginlikdere, Çayraz, Yaghane, Salvipinarı, Halidiye and Akveren Formations) can be grouped into the following eleven assemblage zones in upward sequences:


The seven defining species of this assemblage (Assemblage 1) occur in a composite fauna derived from samples W1 and W2 of the thick-bedded turbiditic sandstone (ÖZgan and ÖZgan Altiner 1997’s unit C) intercalated in shales/marls of the Haymana Formation along the route of and around Haymana, Turkey (Text-figures 2, 4, 5B). The Assemblage 1 is defined by the occurrence of above seven species. The other species that occur in

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**PLATE 7**

1-2. *Omhpalocyclus macroporus* (Lamarck)
   1 Vertical section of megalospheric form. Locality: 1. 915, Cide, Black Sea Region. ×20.
   2 Equatorial section of megalospheric form. Locality: 804, Devrekânı, Black Sea region. ×50.


6-10. *Cavillierina soezerii* (Sirel)
   6 Centered oblique section of megalospheric form. Locality: 6. 925, Black Sea Region. ×50.
   7 Centered oblique section of microspheric form. Locality: 802, Black Sea Region. ×20.
   8 Vertical section of microspheric form. Locality: 908, Cide, Black Sea Region. ×20.
   9 Oblique sections of specimen, showing ornamentation of chevronlike ridges in the periphery of test. *Globotruncanita stuartiformis* (Dalbietz) (left upper) and *Sirtina orbitoidiformis* Brönniman and Wirz (left) can be seen. Locality: KM48, West Erif, Haymana region. ×20.
   10 Oblique sections of specimen, showing ornamentation of honeycomb in the periphery. Locality: 801, Devrekânı, Black Sea region. ×20.
Assemblage 1 are Lepidorbitoides pembergeri, Planorbulina cretaceae. Pseudorbitoides trechimanni, Simplobrrites papyraceus, Sirtina orbitoidiformis, Sivasella monolateralis, Sulcoperculina dickersoni, Minouxia spp., Pseudolitonella spp., Textularia spp., and Pseudedomia hamaoui (Text-figure 5B). The Campanian species Lepidorbitoides pembergeri and Pseudorbitoides trechimanni are reworked from the lower Campanian horizons due to the turbidity current. The Assemblage 1 is correlated with the upper Campanian CVIa to CVIII benthiotic foraminiferan zones in the Charentes and Dordogne, France (Bignot and Neumann 1991) based on common occurrences of above seven species. Also, the Assemblage 1 may partial be correlated with the fauna in the upper Bulandere Formation (sample 734), Bolu (Sirel 1995) due to common occurrences of Orbitoides tissoti, O. media and Pseudosiderolites vidali (Text-figure 10B). Further, it can be correlated with the planktonic foraminiferal zones, Zone KS27 or Globotruncanita calcarae zone (Sliter 1989; Caron 1985) due to the occurrence of Globotruncanita stuartiformis, but not the presence of G. calcarae (Text-figures 6B, 11B). Pseudorbitoides trechimanni has been found from the Beyobasi Formation (sample KM3) (Matsumaru 1997), which is known as reworked species in the Assemblage 3. The Beyobasi Formation (samples KM3 to KM25) in the east Erif section, Haymana contains planktonic foraminiferal species of Globotruncanita cf. subspinosa as reworked species (Text-figure 6A). Also, the Çaldag Formation (sample KM8) in the Bahacek section contains Globotruncanita elevata as reworked species (Text-figure 6B). As such, these species of G. stuartiformis, G. cf. subspinosa and G. elevata may sound the Zone KS27 in the lower Haymana Formation.

Geological age: Late Campanian.


The six defined species of the assemblage occur in a composite fauna derived from two type samples 902 and 906 of the variations in environment of the lower Hisalkoy Formation in the Cide section, Black Sea region. This assemblage (Assemblage 2) is defined by the occurrence of above six defined species (Text-figure 10A). The Assemblage 2 is known from the other samples as follows: sample KM9 of the Beyobasi Formation in the east Erif section (Text-figures 3, 5A), sample N1 of the top sandstone (Unit C) of the Haymana Formation (Text-figures 4, 5A) and samples 202 to 203 of the Kakarca Formation in the Kizderbant, Yalakdere, Karamursel (section 2) (Text-figures 7, 10A) and samples 901 to 907 of the lower Hisalkoy Formation (section 9) (Text-figures 7, 10A). The following species characterize this assemblage: Anomalinoideas rubiginosus, Cavillierina sozneri, Lepidorbitoides spp., Mississippina binkhorsti, Planorbulinella dordoniensis, Planorbulina cretacea, Pseudorbitoides trechimanni, Rotalia spp., Siderolites calcitrapoides, Simplobrrites papyraceus, Sirtina orbitoidiformis, Sulcoperculina dickersoni, Siderolites pardoii, Chrysalidina spp., Textularia spp., Pseudedomia spp. and Pseudolitonella spp. (Text-figures 5A, 10A). The Unit C (sample N1) of the Haymana Formation yields the planktonic foraminifera Heterohelix spp. and Globotruncanita stuartiformis, which indicates from the top Zone KS24 to lower Zone KS31 (Sliter 1989; Caron 1985). If the Assemblage 1 is assigned to the zone KS27, the Assemblage 2 may at least be assigned to the zone KS28. Also, the Kakarca Formation (sample 201) and lower Hisarkoy Formation (samples 901 to 907) yield the planktonic foraminifera Heterohelix spp., Globotruncanita aegyptiaca, G.

Geological age: Late Campanian.

PLATE 8

1. Idalina antiqua Munier-Chalmas and Schlumberger. Equatorial section of microspheric form. Locality: KM35, Çaldag, Haymana region. x60.

2-4. Idalina sinjarica Grimsdale
   3 Equatorial section of microspheric form. KM26, Çaldag, Haymana region. x20.

   5 Equatorial section of megalospheric form.
   6 Oblique section.


9-10. Loftusia ketini Meric. Locality: KM34, Çaldag, Haymana region. x30. Scale is 1000 micron.
   9 Transverse section.
   10 Equatorial section.

11-12. Navarella joaguini Ciry and Rat
   11 Subaxial section of specimen, associated with Omphaloclycus macroporus (Lamarck) (lower). Locality: 915, Cide, Black Sea region. x10,
arca, G. falsostuarti, G. lineana, G. spp., Globotruncanita conica, G. stuarti, G. stuartiformis, Globotruncanella citae, Ruggoglobigerina spp., Gansserina gansseri and Pseudo-textularia elegans (Text-figures 11A). They indicate the Zone KS30 or Gansserina gansseri zone (Sliter 1989; Caron 1985).

As such, the Assemblage 2 may totally indicate the Zones KS28 to KS30.

Geological age: Early Maastrichtian.


The eight species above occur in a composite fauna derived from two type samples that represent various environmental conditions, and this assemblage is defined by the biostratigraphic occurrence of the above eight species. The first is sample KM47, Beyobasi Formation in the Çaldaş section, west Haymana, which yields Lepidorbitoides minor, L. socialis, Orbitoides apiculata, Omphalocyclus macroporus, Siderolites calcitrapoides, Sirtina orbitoidiformis and Navarella joaguini (Text-figure 5A). The second section, KM25 of the Beyobasi Formation in the east Erif section, Haymana yields Lepidorbitoides spp., which seems to be L. socialis, Orbitoides apiculata, Siderolites calcitrapoides, Sirtina orbitoidiformis, and Nummofalotia cretacea (Text-figure 5A). Assemblage 3 is also known the Beyobasi Formation (samples KM34, KM35 and KM41) in the Çaldaş section (Text-figure 5A); Beyobasi Formation (samples KM3, E1044 to E1034) in the east Erif section (Text-figure 5A); and Hisalköy Formation (samples 908 to 915) in Cide (section 9) (Text-figure 10A). In addition, the Akveren Formation (samples 1220 to 1227) in Avdal, Agva (section 12) and Akveren Formation (samples 1301 and 1302) in Yeşilcay, Agva (section 13) yield Navarella joaguini, but other diagnostic species are obscure due to the environment of deeper facies (Text-figure 10B). The other species in the Assemblage 3 are Anomalinoidea rubiginosus, Cypeorbidis mammillatus, Conorbitoides cristalensis, Cuvillierina soezieri, C. spp., Planorbolina cretae, Hellenocyclus beotica, Kathina sp. A, Mississippiina binkhorsti, Orbitoides gueorguianensis, O. media, O. megaliformis, O. tissoti, Rotalia trochiformis, R. spp., Pseudomphalocyclus blumenthali, Pseudosiderolites vidali, Simplorbites papyraceus, Saltopectina dickersoni, Lofusia ketini, Chrysalidina spp., Pseudollitounella spp., Textularia spp., Idalina antique, Keramosphaerina spp., Pseudodimoria hamaoui, Heliocribitoides longispiralis, Pseudorbitoides trechimanni and Planorbulinella dordoniensis (Test-figures 5A, 10A). The last three species are wored. The Hisalköy Formation (samples 908 to 915) yields the planktonic foraminifera Heterohelix spp., Guembelitria cretacea, Globotruncanita aegyptiaca, G. arca, G. falsostuarti, G. lineana, G. spp., Globotruncanita conica, G. stuarti, G. stuartiformis, Globotruncanella citae, Abathomphalus mayaroensis and Racemiguembalina fructicosa (Text-figure 11A). These species indicate the Zone KS31 or Abathomphalus mayaroensis zone (Sliter 1989; Caron 1985).

Geological age: Late Maastrichtian.

Assemblage 4: Orbitoides apiculata – Omphalocyclus macroporus – Lepidorbitoides socialis – Siderolites calcitrapoides – Planorbulina cretae (Marsson) – Sirtina orbitoidiformis –

PLATE 9


2–4. Pseudolituonella spp.
   2 Axial section of megalospheric form, type 1, Orbitoides spp. can be seen. Locality: 2. KM47, Haymana region. ×50.
   4(L) Centered oblique section of megalospheric form (type 2). Locality: KM2, Haymana region. ×20.


10–12. Laffitteina bibensis Marie
   10 Tangential section. Locality: KM5, Haymana region. ×20.
   11 Axial section of megalospheric form. Locality: E1033, Haymana region. ×50.
**Hellenocyclina beotica Reichel – Mississippina binkhorsti (Reuss).**

The eight species of the assemblage occur in a composite fauna derived from three type samples that represent the variations in environmental conditions in different regions. The first is sample KM40 of the Beyoabsi Formation in the west Erif section, which yields Hellenocyclina beotica, Omphalocyclus macroporus, Orbitoides apiculata, Siderolites calctrapoides and Sirtina orbitoidiformis (Text-figure 5A). The second sample, 921 of the Hisalköy Formation in the Cide (section 9) yields Hellenocyclina beotica, Mississippina binkhorsti, Planorbulina cretaea, Siderolites calctrapoides and Sirtina orbitoidiformis (Text-figure 10B). The third sample, 926 of the Hisalköy Formation in the Cide yields Lepidorbitoides socialis, Omphalocyclus macroporus, Siderolites calctrapoides and Sirtina orbitoidiformis (Text-figure 10B). The third sample, 926 of the Hisalköy Formation in the Cide yields Lepidorbitoides socialis, Omphalocyclus macroporus, Siderolites calctrapoides and Sirtina orbitoidiformis (Text-figure 10B). The Assemblage 4 is known the Beyoabsi Formation (samples KM48 and KM49) in the west Erif section (Text-figures 3, 5A); Haymana Formation (samples Y2, Y1, N2 and S1) in Haymana (Text-figures 4, 5B); Akveren Formation (samples 810 to 806) in the Devrekan, Kastamonu (section 8) (Text-figures 1, 7, 10A); and Hisalköy Formation (samples 916 to 929) in Cide (section 9) (Text-figures 1, 7, 10A-10B). The other species in the Assemblage 4 are Anomalinoidea rubinogosus, Conorbitoides cristalesisis, Cuvillerina soezzieri, C. spp., Lepidorbitoides minor, L. spp., Orbitoides guenbacherisis, O. media, O. megalorormis, O. tissoti, Rotalia spp., Pseudosiderolites vidali, Simplorbites papyraceus, Sulcoperculina dickersoni, Broeckinella arabica, Loftusia spp., Pseudochrysalidina spp., Hoeglundina elegans, Keramosphaerina spp., Sivasella monolateralis, Chrysalidina spp., Loftusia ketini, Pseudolituonella spp., Textularia spp., Ophithalmium spp., Lenticulina spp., Dentalina spp., Scandonea samnitica De Castro and Pseudorbitoides trechmanni (Text-figures 5A, 5B, 10A, 10B). The last species is reworked. The planktonic foraminifera of samples S1, 920 and 928 in the Assemblage 4 are Heterohelix spp., Globotruncana esnehensis, G. falsostuerti, G. inaeiana, G. spp., Globotruncana stuartii, G. stuartiformis, Abathomphalus mayeroensis, Pseudotextularia elegans and Racemguiembelina fructiosa (Text-figures 6B, 11A, 11B). These species indicate the Zone KS31 or Abathomphalus mayeroensis zone (Slier 1989; Caron 1985). The stratigraphic horizons carrying the Assemblage 4 is correlated with the Maastrichtian Md lithostratigraphic horizons of NW Europe, due to common occurrences of Planorbulina cretaea, Hellenocyclina beotica, Siderolites calctrapoides, Orbitoides apiculata and Omphalocyclus macroporus (Bignot and Neumann 1991, table 4).

**Geological age:** Late Maastrichtian.

**Assemblage 5: Planorbulina cretae – Mississippina binkhorstii - Anomalinoidea rubinogosus (Cushman) – Hoeglundina elegans (d’Orbiguy).**

The above four species of the assemblage occur in a composite fauna derived from two type samples 930 and 931 that represent variations in the depositional environment of the Hisalköy Formation in Cide (section 9), Black Sea region (Text-figure 10B). The Assemblage 5 is defined by the biostratigraphic occurrence of the above four species, which have been known from the Maastrichtian in Turkey, and additional new species don’t exist.

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**PLATE 10**


2-3. *Anomalioidea rubinogosus* (Cushman)

2 Equatorial section of megalospheric form. Locality: 931, Black Sea region. ×50.

3 Axial section of megalospheric form. Locality: 920, Black Sea region. ×50.

4. *Kathina* sp. A. Axial section of megalospheric form, and this form is characterized by having low trochospiral coil; calcareous wall, lamellar, and finely perforate; vertical canals between umbilical pillars; and umbilical cavities, respectively. Locality: KM34, Caldag, Haymana region. ×30.


5 Axial section of microspheric form, associated with infant form of *Ranikothalia nutallii* Davies (upper).

6 Tangential section.


8-9. 10 right. *Daviesina danieli* Smout

8 Axial section of megalospheric form. Locality: 908, Cide, Black Sea region. ×50.

9 Oblique section of microspheric form. Locality: 9, KM5, Haymana region. ×50.


10(L) *Pseudochrysalidina* sp. Locality: KM21, East Erif, Haymana region. ×50.


in the present assemblage. The first sample 930 yields Mississippina binkhorsti, Planorbulina cretae and Hoeglundina elegans. The second sample 931 yields Anomalainoides rubiginosus and Planorbulina cretae. The other species in the Assemblage 1 are *Cuvillierina soezerii, *C. spp., *Lepidorbitoides spp., *Orbitoides tissoti, *Sirtina orbitoidiformis, Chrysalidina spp., Pseudolimitedella spp., Valvulina spp., and Lenticulina spp. (Text-figure 10B). Asterisk five species are re-worked. The Assemblage 5 is known the Hisalköy Formation (samples 930 to 933) in the Cide section, and samples 930 to 933 stated above yield the planktonic foraminifera, *Globocousa* ex gr. G. daubjergensis?, Parvularglobobinigera ex gr. P. eugubina, Eoglobigerina ex gr. E. fringa, Subbotina spp., Parasubbotina pseudoholoides, Morozovella spp., *Globigerinelloides spp., *Heterohelix spp., *Contusotruncana contusa, *Globotruncana falsostuari, *G. linneiana, *G. spp., *Globotruncanita stuartii, *Abathomphalus mayaroensis, *Rugoglobigerina rugosa and *R. spp. (Text-figure 11B). Asterisk ten species are reworked. These species indicate the Zones P0-1 (Blow 1969; Berggren and Van Couvering 1974; Smith 1982; Toumarkine and Luterbacher 1985; Canudo et al. 1991; Berggren et al. 1995; Molina et al. 1996; Anthonissen and Ogg 2012). According to Bignot and Neumann (1991, table 4), the larger brnthonic foraminiferal fauna of *Planorbulina cretae*, Rotalia trochidiformis, Fallotia cf. colomi (Silvestri) and Laffiteinea mengaudi (Astre) (= L. bicornis) from the Danian, NW Europe is correlated with the nannofossil zones from the Zone NP 1 to a part of Zone NP4 by Martini and Müller (1986). Drobne et al. (1988) described the fauna of *Bolkarina* sp., Periloculina cf. slovenica Drobne, *Pseudochrysalidina* sp., Scandonea sp., Protoelphidium sp., Rotaliids and miliolid-alveolinid type form from the Danian Unit 1 and Unit 2 beds (samples DV-4/5 to 24 and DV-44/8 to 38) in the Dolenja Vas section, Slovenia. Afterward, Drobne et al. (1996) described the fauna of *Protoelphidium* sp., *Pseudochrysalidina* sp. and *Scandonea* sp. from the Paleocene (Danian) limestone units in the Dolenja Vas, which was called the Shallow Benthic Zones SB1 (= SBZ 1) by Serra-Kiel et al. in press. On that occasion, they neglected *Bolkarina* sp. (Drobne et al. 1988, p.157, pl. 25, figs. 1-2) from samples DV-5/4647 and DV5/6964, which should naturally be included into the SB1 zone (Serra-Kiel et al. 1998). *Bolkarina* sp. is known to be a junior synonym of *Orbitosiphon tibetica* (Douville) from Meghalaya, NE India (Matsumaru and Sarma 2010, p. 551), and *O. tibetica* is well known to occur the Selandian-Thanetian Lakadong Limestone, Meghalaya, and Tertiary a1 of Letter Stages, correlated with the Zones P4 to P5 of planktonic foraminiferal zones in the Philippines (Matsumaru 2011, text-figure 3). Also, Drobne et al. (1996) described carbon and oxygen isotope data and high value of Hg content in addition to Chrons Ch29R for the entire carbonate sequence of the K-T boundary layers at the Dolenja Vas. However, they (Drobne et al. 1996, p. 174) couldn’t show the enrichment data of iridium in the K-T layers (brec- cia interval), although they described enrichment of Ir. Serra-Kiel et al. (1998) described 20 Shallow Benthic Zones (SBZ) for the Paleogene based on the compiled stratigraphic

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**PLATE 11**

1-2. *Miscellanea globularis* Rahaghi

1 Equatorial sections of megalospheric form. Locality: KM10, Çaldağ, Haymana region. ×40. Scale is 1000 micron.

2 Axial section of megalospheric form. Locality: KM13, Çayraz, Haymana region. ×40. Scale is 1000 micron.


3 Axial section of megalospheric form. ×60.

4 Equatorial section of microspheric form, associated with *Pseudochrysalidina* spp. (left). ×50.

5. *Pseudolacazina donatae* (Drobne). Axial section of megalospheric form (left), and equatorial section of megalospheric form (right), associated with *Miscellanea globularis* Rahaghi (right corner). Locality: KM10, Çaldağ, Haymana region. ×20.


6 Equatorial section of microspheric form, associated with *Pseudolacazina donatae* (Drobne) (upper, lower and right) and *Idalina sinjarica* Grimsdale (left corner, left and right lower).

7 Transverse section of specimen, associated with *Orbitosiphon tibetica* (Douville) (right).


10-11. *Coskinon rajkae* Hottinger and Drobne

10 Oblique section of specimen, showing coiled apex. Locality: 1008, Black Sea region. ×100.

11 Subaxial section. Locality: 1012, Kokakus, Black Sea region. ×50.

distribution of larger foraminiferal taxa. The SBZ1 (Danian) is defined by two taxa of *Laffitteina bibensis* and *Bangiana hanseni*, which is Drobné et al.’s *Protoelphidium* sp., based on reference sections and key-localities from northern Spain (Campos, Lizarraga); southern France (Belbeze); Slovenia (Dolenja Vas); and Turkey (Calda, Erif, Bahceci, Dundarli, and Gölköy). Fleury et al. (1985) described the genus *Laffitteina* to be the Maastrichtian. As results of this study, the Assemblage 5 may partial be correlated with the Danian larger foraminiferal fauna of NW Europe (Bignot and Neumann 1991), although *Laffitteina bibensis* occurred the beds above the K-T boundary layers in Turkey (Text-figure 13).

Geological age: Early Paleocene (Danian).


The above six species of the assemblage occur in a fauna derived from the type sample (KM5) of the Çaldağ Formation in the east Erif section, Haymana region (Text-figure 5A). This assemblage (Assemblage 6) is defined by the biostratigraphic occurrence of the above five species. The common species is *Anomalinoideas rubiginosus*, *Cavillerina* spp., *Daviesina danieli*, *D. langhami*, *Dictyokathina simplex*, *Kathina major*, *K. selveri*, *Miscellanea* spp., *Operculina heberti*, *Planorbulina cretae*, *Rotalia trochidiformis*, *R*. spp., *Chrysalidina* spp., *Pseudochwyalina* spp., *Pseudolituonella* spp., *Textularia* spp., *Miliolina* spp., *Chrysalidina* spp., *Valvulina* spp., *Hellenocyclina beotica*, *Lepidorbitoides* spp., *Omphalocyclus macroporus*, *Orbitoides apiculatus*, *O*. *gruenbachensis*, *O*. megafoformis, *O*. *tissoti*, *Planorbulinella dordoniensis*, *Siderolites calcitrakeoides*, *Simplorbits papyraceus*, *Sirtina orbitoidiformis*, *Sulcoperculia dickersoni*, *Sulcorbitoides parodi*, *Keramosphaerina* spp., *Nummofaltia cretae*, *Ophthalmidium* spp., *Monorchamotis apenninica*, *Minouxia* spp., and *Pseudedomia hamaoui* (Text-figures 5A, 10A, 10B). Asterisk 19 species are reworked. The Assemblage 6 is seen in the basal Çaldağ Formation (sample KM32) in the Çaldağ section, west Haymana; basal Çaldağ Formation (samples E1033.5 to KM33; KM3, type material) in the east Erif section, NW Haymana; Yağhane Formation (samples 302 and 303) in Yağhane, Derbent, İzink (section 3); Yağhane Formation (samples 403 and 405) in Güneytepe, Yenisehir, İzink (section 4); Salvipinari Formation (sample 505) in Medetli, Gölpazari (section 5); Halidiye Formation (samples 601 to 606) in Kayabogazı, Göynük (section 6); Akveren Formation (samples 807 to 810) in Devrekani, Kastamonu (section 8); Hisalkoy Formation (samples 934 and 935) in Cide (section 9); Akveren Formation (sample 1007) in Kokaksu, Zongludak (section 10) and Akveren Formation (samples 1228 to 1235) in Avdal, Ağva (section 12). Further, the Assemblage 6 contains the planktonic foraminifera such as *Subbotina triloculinae*, *Parsabotina pseudobulloidei*, *P. trinidadensis Paramurica* ex gr. *P.* inconstans, and *P.* ex gr. *P. uncinata* in samples E1033.5, E1034.5, E1034.6.

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**PLATE 12**


4. Axial section of megalospheric form.

5-6. *Discocyclina archiachi* (Schlumberger)

5. Equatorial section of megalospheric form, showing *Discocyclina archiachi* type nepionic–equatorial chamber growth pattern of annuli. Locality: 921013-1, Polatli, Haymana region. ×20


11. Equatorial section of deformed megalospheric form.

12. Subaxial section of megalospheric form.
PLATE 13

   1  Equatorial section of megalospheric form.
   2  Axial section of megalospheric form.


8-9. Nummulites globulus Leymerie. Scale is 1000 micron.
   8  External view. Locality: KM23, Çayraz, Haymana region. ×5.

   10 External view of microspheric form.
   11 Internal form of microspheric form.

Assemblage 8: Kathina selveri – K. major Smout - Discocyclina seunesi Douville – Miscellanea globularis – M. primitiva – Ranikothalia nuttalli (Davies) – Pseudolacazina donatae (Drobne).

The seven species defining of this assemblage are found in the composite fauna of three co-type samples that represent the variations in environmental conditions in different regions. The first, sample KM26 of the Ilginlikdere Formation in the Çaldağ section, west Haymana yields Miscellanea globularis, M. primitiva, Pseudolacazina donatae and others (Text-figure 5A).

The second sample, KM13 of the Yesilyurt Formation in Çayraz section, north Haymana yields Kathina major, K. selveri, Miscellanea globularis, M. primitiva and others (Text-figure 5B). The third sample, 702 of the Akveren Formation in Siyamoglu, Mengen (section 7) yields Discocyclina seunesi, Miscellanea primitiva, Ranikothalia nuttalli and others (Text-figure 10A). The assemblage is assigned to the Assemblage 8. In addition to the above type samples, the Assemblage 8 is known the Ilginlikdere Formation (samples KM24 to KM17) in the Çaldağ section; Ilginlikdere Formation (sample 921013-1) in the Polatlı (Kirkkavak) section, western Haymana; Yesilyurt Formation (samples KM19 and KM13) in Çayraz section; Yaghane Formation (samples 101 to 104) in Tavşantepe, Gebze (section 1); Halidiye Formation (samples 607 and 608) in Kayabogazi, Göynük (section 6); Akveren Formation (samples 701 and 702) in Siyamoglu, Mengen (section 7); Hisalköy Formation (samples 938 to 921915) in Cide (section 9); and Akveren Formation (samples 1015 and 1016) in Kokaksu, Zonguldak (section 10). From these samples, they include the following species in the Assemblage 8: Anomalinooides rubiginosus, Asterocyclina stella, A. spp., Coskinon rajkai, Dictyokathina simplex, Discocyclina archiaci (Schlumberger), D. spp., Orbitocythere ramaraoi, Planorbulina cretae, Kathina selveri, K. spp., Miscellanea spp., Mississippiina binkhorsti, Orbitosiphon tibetica, Rotalia trochidiformis, Sistanites iranica. Chrysalidina spp., Pseudochrysalidina spp., Pseudolititsonella spp., Valvulina spp., Hoeglundina elegans, Textularia spp., Valvulina spp., Idalina sinjarica, Rotalia trochidiformis, R. spp., Miliolina spp., Lenticulina spp., Peneroplis spp., Scandonea sammitica, Sirtina orbitoidiformis, Sivasella monolateralis, *Subco-perculina dickersoni* and *Ophthalmondium* spp. (Text-figures 5A, 5B, 10A, 10B).

The Assemblage 8 contains the planktonic foraminifera such as Morozovella angulata, M. aequa, M. velascoensis, Acarinina mekkannai, Globanomalina chapmani, G. compressa, G. pseudomenardii and Igorina pusilla in samples KM4, KM10 and KM26 of the Ilginlikdere Formation; samples KM19, KM27 and KM13 of the Yesilyurt Formation; samples 101 and 102 of the Yaghane Formation; samples 938, 939 and 921015 of the Hisalköy Formation; and samples 1015 and 1016 of the Akveren Formation. These species partially indicate Zone P4 (Blow 1969; Berggren and Van Couvering 1974; Toumarkine and Luterbacher 1985; Berggren et al. 1995).

The Assemblage 8 is correlated with both the Idalina sinjarica – Miscellanea primitiva – Kathina selveri – Lockhartia diversa Smout Assemblage (Assemblage 1) and Aberisphaera gambonica Wan – Daviesina khatiyahi Smout – Lockhartia haimei (Davies) – Miscellanea miscella – Ranikothalia nutallti Assemblage (Assemblage 2) in the middle Paleocene (Selandian) to late Paleocene (Thanetian) Lakadong Limestone, Meghalaya, NE India (Matsumaru and Sarma 2010) (Text-figure 12). Also, the Assemblage 8 is correlated with the Daviesina danieli – Kathina selveri – Orbitocythere ramaraoi – Lockhartia haimei – Miscellanea miscella – Ranikothalia nutallti – Alveolina vredenburgi Davies Assemblage (Assemblage 2) of the middle Paleocene (Selandian) - late Paleocene (Thanetian) lower Masungit Limestone, Maybangan Formation, Luzon Island; lower Sula Formation, Cagraray Island; and Talutunan-Tumicob Formation, Marinduque Island, all of the

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**PLATE 14**

1-2. Nummulites partschi de la Harpe..  
1 1 External view. Locality: KM1, Çayraz, Haymana region. ×5.  
2 Internal view. Locality: KM29, Çayraz, Haymana region. ×5.  
4 Internal view of megalospheric form, ×6.  
5 Internal view of microspheric form, ×5.  
6-8. Nummulites laevigatus (Bruguier). Scale is 1000 micron.  
7 Equatorial section of microspheric form. Locality: 921011-10, KM11, Çayraz, Haymana region. ×30.  
8 Equatorial section of megalospheric form. Locality: KM11, Haymana region. ×30.  
9-10. Nummulites lehneri Schaub. Scale is 1000 micron.  
10 Equatorial section of microspheric form. Locality: KM1, Çayraz, Haymana region. ×30.  
11-12. Assilina dandotica Davies. Scale is 1000 micron.  
11 External view. Locality: KM23 (= 921011-5a), Çayraz, Haymana region. ×5.  
12 Axial section. Locality: KM23 (= 921011-5a), Çayraz, Haymana region. ×30.
Tertiary a1 of the Letter Stages in the Philippines (Matsumaru 2011) (Text-figure 12).

Geological age: Middle Paleocene (Selandian) – Late Paleocene (Thanetian).


The nine defining species of this assemblage occur in a composite fauna derived from three type samples (KM23, KM42 and KM29) of the Ilginlikudere Formation in the Çaıraz section, north Haymana. The first sample KM23 yields *Assilina dandotica, A. leymerie, A. placenta, A. pustulosa, Nummulites deserti, N. globulus and Operculina canalifera* d’Archiac (Text-figure 5B). The second sample KM42 yields *Assilina pustulosa, Nummulites atacticus, N. deserti* and *Operculina canalifera* (Text-figure 5B). The third sample KM29 yields *Assilina leymerie, A. placenta, *Daviesina danieli, Discocyclina archiaci, D. spp.,* Lockhartia conditi, *L. haimei, Nummulites atacticus, N. globulus, N. irregularis* Deshayes, *N. partschi* de la Harpe, *Operculina canalifera, Alveolina canavarti, A. oblonga, A. spp., and Orbitolites complanata* (Text-figure 5B). Asterisk species are reworked. The present assemblage is assigned to the Assemblage 9, and is also known in the Eskipolatli Formation (sample 921013-2) in the Polatlı (Kırkkavak) section, western Haymana, and Ilginlikudere Formation (samples 921011-4 and 921011-7) in the Çaıraz section. The other species in the Assemblage 9 is *Alveolina vredenburgii* Davies (Text-figure 5A). Samples KM23 yields planktonic foraminifera such as *Acarinina* spp. and *Subbotina* spp. (Text-figure 5B), but is obscure for planktonic foraminiferan zones. The Assemblage 9 is correlated with the *Alveolina oblonga – A. schwageri* Checchia-Rispoli – *Assilina laxispira* de la Harpe – *A. placenta* Assemblage 3-1 in the lower Umlatdoh Limestone, Meghalaya, NE India (Matsumaru and Sarma 2010) (Text-figure 12). Also, the Assemblage 9 is correlated with the *Alveolina subpyrenaica* Leymerie – *Nummulites atacticus – N. burdigalensis* (de la Harpe) – *N. globulus – N. millecaput* Boubée – *Operortolitites douvillei* Nuttall Assemblage 3 in the upper Masungit Limestone, Maybangan Formation, Luzon, which indicative of the Tertiary a2 of the Letter Stages in the Philippines (Matsumaru 2011) (Text-figure 12).

Geological age: Early Eocene (Ypresian).


The above six species that define this assemblage are found in the type sample KM11 (= 921011-8) of the Çaıraz Formation in the Çaıraz section, north Haymana. The present assemblage is assigned to the Assemblage 10, and is also known the Çaıraz Formation (samples KM11 to 921011-12) in the Çaıraz section (Text-figure 3). The other species in the Assemblage 10 are *Assilina exponens Sowerby, A. mediana Pavlove, *A. spira* (De Roissy), *A. spp.,* Daviesina danieli, Discocyclina archiaci, *D. seunesi, D. trabayaensis* Neumann, *D. spp., Eorupertia boninensis* (Yabe and Hanzawa), *Miscellanea spp., Nummulites atacticus, N. distans* Deshayes, *N. globulus, N. irregularis, N. partschi* de la Harpe, *Operculina canalifera, Alveolina canavarti, A. oblonga, A. spp., and Orbitolites complanata* (Text-figure 5B). Asterisk nine species are reworked and re-deposited as allotochtonous species. Sample 921011-11 yields *Subbotina* spp., but don’t indicate the planktonic foraminiferal zones (Text-figure 6B). The Assemblage 10 is partial correlated with the *Nummulites atacticus – N. globulus* Assemblage (Assemblage 3-2) in the upper Umlatdoh Limestone and *Alveolina elliptica nuttalli – Nummulites beaumonti – N. gizehensis – N. perforatus – Orbitolites complanatus* Assemblage (Assemblage 4-1) in the lower Prang Limestone, both of Meghalaya, NE In-

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**PLATE 15**


1  External view.

2  Center oblique section of megaspheric form.

3  Axial section of megaspheric form.

4-5. *Assilina leymieriei* d’Archiac and Haime. Locality: KM23, Çaıraz, Haymana region. Scale is 1000 micron.

4  External view. ×3,

5  Axial section. ×10.


6  External view. ×3.

7  Equatorial section of microspheric form. ×30.


8  External view.

9  Equatorial section of microspheric form.


10  External view. ×3.

11  megalospheric form. ×30.

12  Equatorial section of microspheric form.

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dia due to common occurrences of Assilina laxispira, Nummulites atacicus, N. globulus, N. gizehensis and Orbitolites complanatus (Matsumaru and Sarma 2010) (Text-figure 12). Also, the Assemblage 10 is partial correlated with the Assemblage 3 in the upper Masungit Limestone, Maybangain Formation, Luzon Island, that indicates the Tertiary a2 of Letter Stage in the Philippines, based on common occurrences of Nummulites atacicus, N. globulus and N. distans (Matsumaru 2011) (Text-figure 12).

Geological age: Early Eocene (Ypresian) – Middle Eocene (Lutetian).

Assemblage 11: Assilina exponens (Sowerby) – A. spira (De Roissy).

The above two species that define this assemblage are found together in the type sample 921011-14 of the upper Çayraz Formation in the Çayraz section, north Haymana (Text-figure 3). The present assemblage is assigned to the Assemblage 11, and is also known in sample KM43 of the upper Çayraz Formation in the Çayraz section. The occurrence species from sample KM43 is as the following: Assilina cuvillieri, A. medanica, A. tenuimarginata, *Daviesina danieli, Discocyclina spp., *Nummulites atacicus, *N. planulatus (Lamarck), Nummulites laevigatus, N. lehneri, *Operculina heberti, *Alveolina canavarii, Alveolina spp., *Keramosphaerina spp., and Orbitolites complanatus (Text-figure 5B). Asterisk species are reworked. Further, sample KM43 of the top Çayraz Formation in the Çayraz section, north Haymana yields the planktonic foraminifera Acarinina spp., but don’t indicate the planktonic foraminiferal zones (Text-figure 6B). The Assemblage 11 is partially correlated with the Nummulites acutus (Sowerby) - Nummulites beaumonti d’Archiac and Haine – N. gizehensis (Forskal) – N. millecaput Bouée - N. perforatus (Montfort) Assemblage 4-2 in the middle Prang Formation, Meghalaya, NE India, due to common occurrences of Orbitolites complanatus (Matsumaru and Sarma 2010) (Text-figure 12).

The Assemblage 11 is correlated with the Nummulites gizehensis – N. perforatus – N. ptukhiani Kacharava – N. striatus (Bruguiere) – Assilina exponens Assemblage 4 in the Formation III, Caraballo Group, Luzon Island; Taltunan-Tumicob Formation, Marinduque Island; and limestone sample 578 of the Koban Group, Mindanao Island, based on common occurrences of Assilina exponens. The latter assemblage (Assemblage 4) is assigned to the Tertiary a3 of Letter Satges in the Philippines (Matsumaru 2011) (Text-figure 12).

Geological age: Middle Eocene (Lutetian).

SYSTEMATIC DESCRIPTION

Family Miliolidae Ehrenberg 1839

Chaldagia Matsumaru, n. gen.

Name: This genus is named after the Çaldağı Village, Haymana Town, about 50 km SW Ankara, Turkey, where the material for study was collected.

Type species: Chaldagia haymanensis Matsumaru, n. gen., n. sp.

Diagnosis: Test is lituiform or French horn in outline of the megalospheric form and flabelliform in outline of microspheric form. Surface of both forms is rather smooth, but exist slightly suture depression, and sides are flattened with blunt periphery. Megalospheric form has the embryo consisting of spherical to subspherical proloculus and second small arcuate chamber, and sometimes enrolled tube immediately following proloculus connecting second arcuate chamber in the embryo. Early stage in the megalospheric form is enrolled, more or less inclined to planispiral planes of arcuate to angular chambers, 7 chambers in a first whorl and 13 chambers in the second whorls, enlarging rapidly as added, and sutures are straight and radial in the coiling whors and slightly depressed. Later stage is forming uncoiled and inflated or flared reniform shaped chambers as added. In the microspheric form, the early stage is strepto-

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**PLATE 16**


3-5. **Assilina spira** (De Roissy). Locality: 921011-14, Çayraz, Haymana region. 3. ×1, 4-5. ×30. Scale is 1000 micron.

4. Equatorial section of megalospheric form

5. Equatorial section of microspheric form


7-8. Equatorial sections of megalospheric form.


10. External view.

11. Equatorial section of microspheric form.

12. Transverse section.
The wall is calcareous, porcelaneous, imperforate and commonly including light colored calcite grains in the outer side of thick wall. The aperture consists of numerous pores as sievelike in septa of spiral chambers and terminal wall of adult chambers in rectilinear and flabelliform arrangement.

Remarks: *Chaldagia* resembles *Scandonea* De Castro 1971 from the upper Cretaceous of Apennines, Italy, in having spirally coiled early stage and successive uncoiled later stage and cribrate aperture. However, *Chaldagia* is different from

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**PLATE 17**

1 *Globotruncanita elevata* (Brotzen). Axial section, showing very low trochospiral test, spiral side slightly convex, but slightly concave in the last whorl and umbilical side strongly convex with wide and deep umbilicus; a kind of carina on top of chambers except in the last chamber. Locality: KM8, Bahçecek, Haymana region. ×100.

2 Upper specimen: *Globotruncanita stuartiformis* (Dalbiez). Axial section, showing low trochospiral test, spiral side slightly convex of central part and umbilical side convex with very wide and deep umbilicus; beaded keel in periphery.

2 Lower specimen: *Contusotruncanina fornicata* (Plummer). Axial section, showing low trochospiral test, biconvex, two keels present in axial periphery. Locality: 201, Kızderbent, Black Sea region. ×50.

3 *Globotruncanita* cf. *subspinosa* (Passagno). Axial section, showing very low trochospiral test, spiral side flat, but slightly convex in central part and umbilical side convex with wide and shallow umbilicus; somewhat compressed. Locality: KM8, Bahçecek, Haymana region. ×100.

4 Upper specimen: *Globutruncanita linneiana* (d’Orbigny). Axial section, showing box-like shape, very low trochospiral test, spiral side almost flat to slightly convex and umbilical side almost flat with wide and shallow umbilicus; two spaced keels in periphery.

4 Lower specimen: *Globotruncanita stuartii* (De Lapparent). Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with wide and deep umbilicus; beaded keel in periphery. Locality: 907, Cide, Black Sea region. ×50.

5(L) *Globotruncanita stuartii* (De Lapparent). Axial section, the same as orientation with 4 lower.

5(R) *Contusotruncanina contusa* (Cushman). Axial section, showing conical shape and high trochospiral test, spiral side strongly convex and umbilical side slightly flat with wide and deep umbilicus; narrow double keels in periphery. Locality: 921, Cide, Black Sea region. ×30.

6 *Contusotruncanina formicata* (Plummer). Axial section, the same as orientation with 2 lower. Locality: 928, Cide, Black Sea region. ×30.

7 *Globotruncanita arca* (Cushman). Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with wide and fairly deep umbilicus; periumbilical rim well marked; two widely separate keels in periphery. Locality: 1001, Kokaksu, Black Sea region. ×120.

8 *Globotruncanita falsostuarti* Sigal. Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with wide and fairly deep umbilicus; two narrow separate keels in periphery. Locality: 908, Cide, Black Sea region. ×100.

9 *Globotruncanita aegyptiaca* Nakady. Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with fairly wide and deep umbilicus; two narrow keels in periphery. Locality: 914, Cide, Black Sea region. ×100.

10(L) *Contusotruncanina formicata* (Plummer) Axial section, the same as orientation with 2 lower.

10(R) *Globotruncanita arca* (Cushman). Two specimens. Axial sections, the same as orientation with 7. Locality: 1001, Kokaksu, Black Sea region. ×50.

11 *Globotruncanita conica* (White). Oblique section, showing conical shape, high trochospiral test, spiral side strongly convex and umbilical side almost flat to concave with wide and deep umbilicus; one keel in periphery. Locality: 201, Kızderbent, Black Sea region. ×50.

12 *Gansserina gansseri* (Bolli). Axial section, showing very low trochospiral test, spiral side flat and umbilical side strongly convex with wide and deep umbilicus; one beaded keel in periphery. Locality: 1001, Kokaksu, Black Sea region. ×100.
Scandonea in having French horn shaped megalospheric form with depressed sutures in the coiling stage, flabelliform shaped microspheric form with streptospiral coiling in the early stage, and both megalospheric and microspheric forms, always small proloculus. Chaldagia may resemble Kolchidina Morozova 1967 from the lower Paleocene (Danian) of USA and USSR (Loeblich and Tappan 1988, p. 78) in having enrolled early chambers and uncoiled later chambers, but is different from Kolchidina in having cribrate aperture and wall component of calcareous and porcellaneous.

Chaldagia haymanensis Matsumaru, n. gen., n. sp.

Plate 1, figures 1-5

Material and type specimen: Specimens of limestone thin section KM20 in the Çaldağ Formation in the Çaldağ section, Haymana region (Text-figure 3). Holotype is megalospheric specimen in the equatorial section, Saitama University Coll. no. 201201-1 (Plate 1, figure 1). Paratype is microspheric specimen in the equatorial section, Saitama University Coll. no. 20201-2 (Plate 1, figure 2).

Description: Test is small and litiform, French horn to flabelliform shaped. Megalospheric form is 0.60 to 0.96 mm in diameter and 0.58 to 0.87 mm in width in the equatorial section and probably 0.52 mm in thickness in the oblique section; and the form ratio of diameter to thickness is 1.15 to 1.84. Microspheric form is 0.80 mm in diameter and 0.75 mm in width. Spherical to subspherical proloculus and first 7 chambers in a whorl in megalospheric form are measuring internal diameter $36 \times 32$, $40 \times 40$, $56 \times 64$, $64 \times 56$, $48 \times 36$, $60 \times 48$ and $80 \times 80$ micron and its wall vary 8 to 12 micron thick. Enrolled tube of about a half whorl following proloculus and second arcuate chamber can be seen (Plate 1, figure 1). Spherical proloculus of later biserial, regularly globular chambers spread excessively forming open cone.

PLATE 18

1 Globotruncanita conica (White). Axial section, the similar as orientation with figure 11 of Plate 17. Locality: 1225, Avdal, Black Sea region. ×50.

2 Globotruncanella citae (Bolli). Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with fairly wide and shallow, one keel in periphery. Locality: 914, Cide, Black Sea region. ×100.

3 Abathomphalus mayaroensis (Bolli). Axial section, showing thin box-like shape, very low trochospiral test, spiral side almost flat and umbilical side slightly flat to concave with fairly wide and shallow umbilicus; two beaded keels in periphery. Locality: 908, Cide, Black Sea region. ×50.

4 Rugoglobigerina rugosa (Plummer). Axial section, showing low trochospiral test, biconvex, spiral side almost flat and umbilical side convex with wide and fairly deep umbilicus; surface of chambers on periphery rugose with pustules. Locality: 1003, Kokaksu, Black Sea region. ×100.

5 Globotruncanca esnehensis Nakkady. Axial section, showing low trochospiral test, biconvex, spiral side convex and umbilical side convex with wide and deep umbilicus; double keels in periphery. Locality: 1225, Avdal, Black Sea region. ×50.

6 Pseudotextularia elegans (Rzehak). Axial section, showing subtringular shape, broader test in apertural side; chambers biserially arranged and inflated; sutures depressed and zigzag between chambers. Locality: 907, Cide, Black Sea region. ×50.

7(L) Racemiguembelina fructicosa (Egger). Axial section, showing subconical test, early stage planispiral and
Subbotina triloculinoides (ex gr. Plummer)

Parvulargoglobigerina (ex gr. Premoli Silva)

Eoglobigerina

Globoconusa

forms. The wall is calcareous, porcellaneous and imperforate, measuring 32 to 56 micron thick and 30 to 38 micron thick in both megalospheric and microspheric forms.

Associated fauna: Anomalinoideas rubiginosus (Cushman), Miscellanea globularis Rahaghi, M. primitiva Rahaghi, Planorbula cretae (Marsson), *Subcoperculina dickersoni* (Palmer), Chrysalidina spp., *Pseudolituonella* spp., Textularia spp., *Idalina sinjarica* Grimsdale, *Opthalmidium* spp., and *Scandonea samnitica* De Castro (Text-figure 5A). Asterisk species are reworked.

Stratigraphic horizon: Çalda Formation.

Geological age: Middle Paleocene (Selandian).

Family MILIOLIDAE Ehrenberg 1839

Scandonea samnitica De Castro 1971

Plate 1, figures 6-12

Scandonea samnitica De Castro 1971, p. 5-6, 16-65, pl. 1, figs. 1-9; pl. 2, figs. 1-8; pl. 3, figs. 1-6; pl. 4, figs. 1-9; pl. 5, figs. 1-9; pl. 6, figs. 1-6; pl. 7, figs. 1-5; pl. 8, figs. 1-7; pl. 9, figs. 1-5; pl. 10, figs. 1-5; pl. 11, figs. 1-6; pl. 12, figs. 1-8; pl. 13, figs. 1-9; figs. 1-10, 12-15, tabs. 1-6. – Bignot 1972, p. 206, 262, pl. 4, fig. 4 lower (but not Scandonea sp.); pl.

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**PLATE 19**

1-2. *Globoconusa* ex gr. *G. daubjergensis* (Brönnimann)

1 Equatorial section. “Subbotina” spp. or “Parasubbotina” spp. (left) “Globigerina” spp. (right). Locality: 1013, Kokaksu, Black Sea region. ×60.

2 Oblique section showing general shape of high spiral test and can be seen. Locality: KM19, Çayraz, Haymana region. ×90.

3. *Eoglobigerina* ex gr. *E. fringa* (Subbotina)

Equatorial section, showing trochospiral test; globular to subglobular chambers, 4 chambers in the last whorl; tightly coiled and sutures, curved. Locality: 933, Cide, Black Sea region. ×90.

4-5. *Parvulargoglobigerina* ex gr. *P. eugubina* (Luterbacher and Premoli Silva)

Equatorial sections of both forms, showing low trochospiral test; subglobular chambers, 6 chambers in the last whorl and gradually increasing in size; tightly coiled and sutures depressed. Locality: 4. 933, Cide and 5. 1229, Avdal, both of Black Sea region. ×100.

6-7. *Subbotina triloculinoides* (Plummer)

6 Slightly axial section, showing spiral side flat to slightly convex and umbilical side convex with central depression. Locality: 936, Cide, Black Sea region. ×100.

7 Tangential section, showing globular to subglobular chambers, slightly coiled and 3 1/2 chambers in the last whorl. Locality: 6. 936, Cide, Black Sea region. Locality: KM19, Çayraz, Haymana region. ×100.

8-9. *Parasubbotina pseudobulloides* (Plummer)

8 Axial section, showing low trochospiral. Locality: KM19, Çayraz, Haymana region. ×100.

9 Equatorial section, showing globular to subglobular chambers, inflated and 5 chambers in the last whorl. Locality: 1228, Avdal, Black Sea region. ×100.

10. *Parasubbotina trinidadensis* (Bolli)

Axial section, showing very low trochospiral test, biconvex, spiral side flat or slightly convex and umbilical side convex with umbilicus fairly wide and deep. Locality: KM19, Çayraz, Haymana region. ×100.

11. *Praemurica* ex gr. *P. inconstans* (Subbotina)

Equatorial section, showing globular to subglobular chambers, 5 chambers in the last whorl and spirals, tightly coiled. Locality: 1228, Avdal, Black Sea region. ×100.

12. *Praemurica* ex gr. *P. uncinata* (Bolli)

Subequatorial section, showing angular-conical shape of early chambers in the last whorl and later chambers subangular, sutures, strongly backwardly curved. Locality: 1228, Avdal, Black Sea region. ×100.
PLATE 20

1. *Praemurica* ex gr. *P. uncinata* (Bolli)
   Axial section, showing very low trochospiral test, biconvex; spiral side flat to slightly convex and umbilical side convex with open umbilicus. Locality: 604, Kayabogazi, Black Sea region. ×90.

2. *Morozovella angulata* (White)
   Axial section, showing very low trochospiral test, spiral side almost flat and umbilical side strongly convex with open umbilicus. Locality: KM19, Çayraz, Haymana region. ×100.

3-4. *Globanomalina pseudomenardii* (Bolli)
   3 Equatorial section, showing trochospiral test, equatorial periphery slightly lobulate, acute with a keel. Locality: KM10, Çaldaş, Haymana region. ×50.
   4 Axial section, showing very low trochospiral test, compressed; and umbilicus narrow and fairly shallow. Locality: 939, Cide, Black Sea region. ×100.

5. *Morozovella velascoensis* (Cushman)
   Transverse section, showing very low trochospiral test, spiral side almost flat and umbilical side strongly convex; axial periphery with peripheral keel, and ornamented with short knobs around umbilical area of last whorl. Locality: 101, Tavşantepe, Black Sea region. ×50.

6. *Morozovella aequa* (Cushman and Renz)
   Axial section, showing very low trochospiral, spiral side flat to slightly convex and umbilical side strongly convex with narrow and deep umbilicus. Locality: KM19, Çayraz, Haymana region. ×100.

7. *Acarinina mckannai* (White)
   Axial section, showing low trochospiral test, spiral side slightly convex and umbilical side strongly convex, inflated. “Subbotinii” spp. (7 right) can be seen. Locality: 101, Tavşantepe, Black Sea region. ×50.

8-9. *Globanomalina compressa* (Plummer)
   8 Equatorial section, showing trochospiral test, subglobular chambers, equatorial periphery lobulate, tightly coiled. Locality: 936, Cide. ×100
   9 Axial section, showing very low trochospiral, inflated and somewhat compressed, and umbilicus wide and deep. Locality: 1009, Kokaksu, Black Sea region. ×96.

10-11. *Globanomalina chapmani* (Parr)
   10 Equatorial section, showing trochospiral test, subglobular chambers, equatorial periphery subacute, and tightly coiled. Locality: 936, Cide. ×100
   11 Axial section, showing very low biconvex, umbilical side more convex than spiral side slightly flat to convex. Locality: 1016, Kokaksu, both of Black Sea region. ×100.

12. *Igorina pusilla* (Bolli)
   Axial section, showing low trochospiral test, biconvex and compressed, spiral side convex and umbilical side convex with narrow umbilicus, axial periphery acute to subacute. Locality: 1015, Kokaksu, Black Sea region. ×100.
Specimens of Figures 1-3, 5-6, 8-10, 13-14 and 15 are from Locality: 10. 1003, Kokaksu, Black Sea region; those of Figures 4, 7, 11-12 and 16 are from Locality: 10. 1001, Kokaksu, Black Sea region. Scale is 100 micron.

1-2. *Abathomphalus mayaroensis* (Bolli)
   1a Umbilical side, showing concave; 5 chambers, angular-truncate; sutures, depressed and radial; primary apertures, interiomarginal, covered by tegillum; and periphery with double keels. ×60.
   1b Spiral side, showing almost flat to slightly convex; spiral chambers, arranged about 3 whorls. ×60.
   2 Lateral side, showing axial periphery, with double keels. ×70. Scale is 100 micron.

3. *Abathomphalus intermedius* (Bolli)
   3a Umbilical side, showing concave; wide and inflated chambers, arranged 6 chambers in the last whorl. ×80.
   3b Lateral side, showing a single keel, occurred at ventral side of spiral chambers. ×80.
   3c Spiral side, showing chambers, arranged staircase-like imbricate. ×80.

4. *Contusotruncana contusa* (Cushman)
   4a Umbilical side, showing concave, wide and deep umbilicus; angular chambers, arranged in flattened in the last whorl. ×50.
   4b Spiral side, showing highly spiral chambers making up conic form. ×50. Scale is 100 micron.

5-6. *Globotruncanita stuarti* (de Lapparent)
   5a, 6a Umbilical sides of two forms, showing umbilicus wide and deep; and trapezoidal chambers arranged 6 chambers in the last whorl, slightly overlapping along the umbilical area, and increasing in size.
   5b Spiral side, showing sutures, slightly curved, raised and beaded.
   6b Lateral side, showing test, low trochospiral, biconvex, and equatorial periphery, with a single keel of raised sutures. 5, 6. ×40, 6. ×50. Scale is 100 micron.

7. *Globotruncanita stuartiformis* (Dalbize)
   7a Umbilical side, showing convex; and triangular chambers, arranged 7 chambers in the last whorl.
   7b Lateral side, showing biconvex, and peripheral keel, present.
   7c Spiral side, showing sutures, curved in the first whorl to straight and tangential in the last whorl. ×70.

8. *Globotruncanella citae* (Bolli)
   Umbilical side, showing distinctly concave; subglobular chambers arranged 4 chambers in the last whorl, increasing in size; and peripheral keel, present. ×80.

9. *Globotruncanella petaloidea* (Gondolfi)
   Umbilical side, showing concave; subglobular chambers arranged 4 chambers in the last whorl; and imperforate peripheral band, present. ×100.

10. *Globotruncanina falsostuarti* Sigal
    10a Umbilical side, showing umbilicus wide and fairly deep; subangular-truncate chambers arranged 7 chambers in the last whorl.
    10b Oblique side, showing very low trochospiral, spiral side slightly convex and umbilical side with central depression.
    10c Spiral side, showing sutures, curved, raised and beaded. ×40.

11. *Globotruncanina arca* (Cushman)
    11a Umbilical side, showing umbilicus, wide and fairly deep; angular-truncate chambers arranged 6 chambers in the last whorl; sutures, curved, depressed and beaded.
    11b Lateral side, showing test, low trochospiral; spiral side convex and umbilical side slightly convex with central depression.
    11c Spiral side, showing sutures, curved, raised and beaded. ×50. Scale is 100 micron.

12. *Rugiglobigerina rugosa* (Plummer)
    12a Lateral side, showing test, low trochospiral; spiral side, fairly flat and umbilical side, wide and deep.
    12b Spiral side, showing globular chambers with slightly rugose surface, 5 chambers in the last whorl, tightly coiled. ×70.

13. *Pseudotextularia elegans* (Rzehak)
    Oblique side, showing subtriangular test; globular chambers biserially arranged and inflated; and sutures, zigzag between chambers. ×100.

14. *Racemiguembelina fructicosa* (Egger)
    Lateral side, showing subconical test; globular chambers with costate surface, arranged biserial early stage and later becoming multiserial; and apertures, protected by ponticuli, arranged in the top side of test. ×50.

15. *Guembelitria cretacea* Cushman
    Lateral side, showing subconical test; and globular chambers with partial pore mounds, arranged triserial and inflated. ×100.

16. *Gansserina gansseri* (Bolli)
    16a Umbilical side, showing test, strongly convex; hemispherical chambers, arranged 6 chambers in the last whorl.
    16b Lateral side, showing plano-convex test, spiral side flat and umbilical side strongly convex; a single keel, present.
    16c Spiral side, showing chambers, staircase-like imbricate arrangement; sutures, curved, raised and beaded. ×50. Scale is 100 micron.
uniserial chambers are developed. The aperture is numerous pores and cribrate, and measuring 22 to 48 micron in inner diameter.

**Stratigraphic horizon:** Haymana, Çaldağ, Yağhane, and Ilginkildere Formations.

**Geological age:** Upper Cretaceous (Maastrichtian) to Middle Paleocene (Selandian).

Remarks: De Castro (1971) described perfectly *Scandonea samnitica*, n. gen., n. sp. from the Apennines, Italy, and this monospecies of *Scandonea* was known from the upper Cretaceous (Bignot 1972). Other authors have examined this species from the Anatoria (Haymana) in Turkey and Dinarides, eastern Adriatic coast, and this species was known until the lower Paleocene (Danian) (Męrc 1984; Drobne et al. 1988). Sirel (1999) established both genera *Haymanella* paleocenica, n. gen., n. sp. and *Kayascularia decastroi*, n. gen., n. sp. from

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**PLATE 22**

All specimens are from Locality: 10. 1006, Kokaksu, Black Sea region. Scale is 100 micron.

1-2. *Parvalargoglobigerina eugubina* (Luterbacher and Premoli Silva)

1a, 2a Umbilical sides of both forms, showing subglobular chambers, 5 chambers (1a) and 6 chambers (2a) in the last whorl; umbilicus, fairly open and shallow; and aperture, interiomarginal, and low arch.

1b, 2b Lateral sides of both forms, showing test, very low trochospiral, and laterally compressed.

1c, 2c Spiral sides of both forms, showing sutures, curved, slightly depressed. 1. ×200, 2. ×100. Scale is 100 micron.

3. *Eoglobigerina fringa* (Subbotina)

3a Umbilical side, showing globular to subglobular chambers, 4 chambers in the last whorl; umbilicus open and shallow; and aperture, interiomarginal and low arch.

3b Lateral side, showing test, low trochospiral, initial whorl somewhat convex and umbilical side slightly convex with central depression.

3c Spiral side, showing chambers, tightly coiled; and sutures, curved. ×200. Scale is 100 micron.

4. *Parasubbotina pseudobulloides* (Plummer)

4a Umbilical side, showing globular to subglobular chambers, inflated, 5 chambers in the last whorl; umbilicus fairly open and depressed.

4b Lateral side, showing test, low trochospiral, initial whorl somewhat flattened and umbilical side convex; and periphery rounded. 4c Spiral side, showing sutures, curved and depressed. ×100.

5-6. *Subbotina triloculinoides* (Plummer)

5a, 6a Umbilical sides of both forms, showing inflated globular to subglobular chambers, 3 1/2 chambers in the last whorl; and periphery broadly rounded.

5b Lateral side, showing test, biconvex; spiral side initial whorl slightly convex and umbilical side, convex with central depression.

5c Spiral side, showing chambers, tightly coiled. 6b. Oblique side, showing sutures, curved and depressed. 5. ×100, 6. ×90. Scale is 100 micron.

7. *Globanomalina pentagonalis* (Morozova)

7a Umbilical side, showing subglobular chambers, 5 chambers in the last whorl; umbilicus, wide and deep; and periphery bluntly rounded.

7b Lateral side, showing test, biconvex; spiral side initial whorl convex and umbilical side convex with central depression.

7c Spiral side, showing tightly coiled. ×100. Scale is 100 micron.

8. *Globanomalina compressa* (Plummer)

8a Umbilical side, showing globular to subglobular chambers, ovate, 5 chambers in the last whorl; umbilicus wide and open, slightly depressed.

8b Oblique side, showing very low trochospiral, and last chamber, depressed. ×80. Scale is 100 micron.

9. *Praemurica inconstans* (Subbotina)

9a Umbilical side, showing globular to subglobular chambers, 5 chambers in the last whorl; umbilicus fairly wide and depressed; and tightly coiled.

9b Oblique side, showing low trochospiral, and last chamber, depressed.

9c Spiral side, showing chambers in the last whorl, sutures slightly curved, radial and depressed. ×80. Scale is 100 micron.

10-11. *Parasubbotina trinidadensis* (Bolli)

10a, 11a Umbilical sides of both forms, showing globular to subglobular chambers, 5 chambers in the last whorl; umbilicus fairly wide and depressed; and aperture interiomarginal, bordered by lip.

10b, 11b Lateral sides of both forms, showing test, biconvex; spiral side slightly convex and umbilical side slightly convex with central depression; and periphery rounded.

10c, 11c Spiral sides of both forms, showing chambers in the last whorl, sutures, slightly curved, radial and depressed. ×100. Scale is 100 micron.
Haymana, Anatoria and others, Turkey, based on the features of aperture with tooth or single aperture, but not cribrate aperture of the *Scandonea*. However, holotype of *Kayseriella decastroi* has sieveplate or metamorphophore with cribrate aperture in 13th spiral chambers of the lower part of the test (Sirel 1999, pl. 1, fig. 6), and other form in the subaxial section shows metamorphophore in the proximal side of penultimate chamber (Sirel 1999, pl. 2, fig. 12). Also, his tooth, teeth and ribs caused by poor preservation of some forms are belonging to subepidermal partitions and trace of sieveplate or subepidermal network. The uniserial chamber in the horizontal section in *Haymanella paleocenica* (Sirel 1999, pl. 2) shows the same feature of subepidermal partitions in the uniserial chamber of *Scandonea samnitica*, but there exists between wide variation of *Scandonea samnitica*. The present three forms (Plate 1, figures 6-8) of *Scandonea samnitica* from the Çaldağ Formation are identical to Sirel’s *Haymanella paleocenica* due to short coiling, but the present two forms (Plate 1, figures 10-11) of *Scandonea samnitica* are identical to forms of *S. samnitica* (De Castro 1971, pl. 5, fig. 7; pl. 6, fig. 2). Also, *Scandonea samnitica* from the Çaldağ Lime-stone, Haymana (Meric 1984, pl. 1, figs. 1-6; pl. 2, figs. 1-6) are identical to *S. samnitica* (De Castro 1971, pl. 1-7, 11-12), although Sirel (1999, p. 128) denied Merci’s *Scandonea samnitica*. As results, *Haymanella paleocenica* Sirel and *Kayseriella decastroi* Sirel are in accordance with *Scandonea samnitica* De Castro.

CONCLUSION

The present study has been researched the larger benthonic foraminiferal assemblages in the Haymana and Black Sea regions, Turkey (Text-figures 1, 2) based on the accurate correlation of the biostratigraphical sequences of larger foraminifera with planktonic foraminiferal zones. This study introduced some element concentrations (patterns of iridium and other siderophile) and strontium values in K–T boundary layers by the author’s research group in order to confirm the mass extinction of biota (foraminifera). As it can be seen from Text-figures 5A, 5B, 6A, 6B, 10A, 10B, 11A and 11B, the total 11 larger foraminiferal assemblage zones for 13 divisions of the upper Campanian to Lutetian sedimentary rocks could be recognized at the first time in the Haymana and Black Sea regions, Turkey (Text-figures 12, 13). The correlation chart between larger foraminiferal assemblages in Turkey, those in Meghalaya, NE India (Matsumaru and Sarma 2010), and those of the Philippine Archipelago (Matsumaru 2011) is shown (Text-figure 12). Larger foraminiferal biostratigraphic research may, however, be required to improve more or less the present larger foraminiferal assemblage zones, due to analysis of abundant samples under the effects of sedimentation, diagenesis and local tectonic activity by identifying stratotypes for their exact boundaries.

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