Benthic foraminifera of the Maastrichtian sediments from the Malıboğazı (Kalecik, Ankara) and Irmak (Kırıkkale) areas in Türkiye

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Abstract. The investigation focuses on benthic foraminifera and their paleoecology, particularly on the Orbitoides genus in the Maastrichtian sediments from the northern and western Ankara City (Turkey). The hard and soft rock samples from two measured sections, namely as Malıboğazı (N Ankara) and Daryaka-Irmak (W Ankara, Kırıkkale) were evaluated. More than one hundred equatorial and axial sections of the Orbitoides genus were prepared. The benthic foraminifera of the Maastrichtian sediments are as follows: Dorothia sp., Marssonella sp., Lenticulina sp., Saracenaria sp., Oolina sp., Cibicides sp., Gavelinella sp., Orbitoides apiculatus, O. gruenbachensis, O. medius, Pseudomphalocyclus sp., Omphalocyclus macroporus, Lepidorbitoides sp., Sirtina sp., Sulcoperculina globosa, S. vermunti, Siderolites calcitrapoides, Laffitteina mengaudi, Laffitteina sp. In the Malıboğazı area, biometric data based on the internal and external parameters of the Orbitoides genus present reliable interpretations for paleoecological approaches of the Maastrichtian time. The calcareous siliciclastics comprise abundant Orbitoides apiculatus and O. gruenbachensis species. We have identified two ichnospecies as Maeandropolydora osmaneliensis and Curvichnus semorbis in the Orbitoides tests. It is thought that meandered microboring activity are related to parasitic life modes while cave shaped ones are associated with hermit type life modes. Orbitoides bearing siliciclastics overlie reefal sediments including biostromal limestones with rich rudist fauna, Thalassoniodes rich carbonates and massive, thick bedded limestones in the Malıboğazı area. In contrast, siliciclastics indicating open sea sediments outcrop widespready in the Irmak area. The obtained stratigraphical, sedimentological and paleontological data show that northern part of the Ankara was shallower than western part of the Ankara during the late Maastrichtian.

1. Introduction
Although there have been many stratigraphical and paleontological investigations around the Irmak (Kırıkkale) and Malıboğazı areas (Ankara, Central Anatolia) [1-7], benthic foraminiferal comparison of Maastrichtian sediments between the Malıboğazı and Irmak areas (figure 1), biometrical and paleoecological data on the Orbitoides genus are lack of data. Maastrichtian aged smaller benthic foraminifers’ studies in Turkey are rare.
However, there are many investigations on *Orbitoides* genus systematic, biostratigraphy, reproduction, paleobiogeography, paleoecology and microboring activities in various localities in Turkey [8-11]. The study presents data on biometry of the *Orbitoides* and microboring activity from the Malıboğazı area, 64 km northwest of the Ankara City. It also deals with a comparison on benthic foraminifera between two investigated areas. The aims of the study are to bring out differences and similarities of benthic fauna between two areas and to present biometrical data on the *Orbitoides* genus and its paleoecology. For these purposes, two measured sections were realised. Thirty four hard rock thin sections, four washing samples and one hundred and eight equatorial thin sections of *Orbitoides* genus were evaluated.

External (diameter, thickness and shape of the test) and internal parameters (embryo size \(Li+li\), embryo shape \(li/Li\), embryo wall thickness \(te\)) were measured and photographed under the research microscope in the Ankara University Palaeontology laboratory. Microboring and abnormal views in the *Orbitoides* tests were also observed.

2. **Geological setting and measured sections**

In the Irmak area, igneous rocks occur at the basement known as Kılıçlar Group [1, 7]. It comprises various geological units from bottom to top as follows: Ophiolits, radiolarites, Kocatepe limestone, Hisarköy Formation and Karadağ Formation. The upper Cretaceous sediments are Ilıcapınar Formation and Bölüldağ Formations (figure 2A). The Ilıcapınar Formation mainly consists of rhythmic fine to medium grained siliciclastics. The medium to grained sized siliciclastics of the Bölüldağ Formation is at the top of the Maastrichtian sediments. The Dizilişalar Formation overlies unconformably the Maastrichtian sediments. Maastrichtian sediments of Ilıcapınar and Bölüldağ Formations at Darkaya Mevkii near to Irmak Village (Kirikkale) were measured at the following coordinates: 36 S 536635.00E, 4416851.00N to 536554.00E, 4416946.00N.

In the Malıboğazı area, ophiolits and volcanics are seen at the basement (figure 2B). The Maastrichtian sediments, Malı Formation starts with basal conglomerates and reefal carbonates, unit 1.
Figure 2. Geological maps of the studied areas. A. Irmak area (modified from Yılmazel [7]), B. Malıboğazi area (modified from Okan et al. [4].
It continuous with abundant *Thalassonoides* bearing clayey carbonates, unit 2 [4] and massive to thick bedded limestones, unit 3. Towards the upper part of the section, siliciclastics, unit 4 include rich *Orbitoides* fossils (figure 3). Deltaic sediments of the Dizilıtaşlar Formation, Palaeogene in age overlies unconformably the Mali Formation. In this area, the Maasrichian siliciclastics was measured. The section is located at 2 km northwest of Tilkıköy Village, 36T, 542740.67 E, 4452246.16 N.

Figure 4 shows lithological and faunal contents of the siliciclastics in the measured sections from the Irmak and MaliBoğazi areas.

![Figure 3. Google Earth (A), field views (B-F) a schematic geological cross section of the Mali Formation (G-H).](image)

**Figure 3.** Google Earth (A), field views (B-F) a schematic geological cross section of the Mali Formation (G-H).

Cr. volcanics. Crₑ. Mali Fm. carbonates, Cr₂. Mali Fm. siliciclastics, Pₐ. Dizilıtaşlar Fm., Q₂. Quaternary slope deposits, Qₐ. alluvium, f. fault, r. rudist, t. *Thalassonoides*, o. *Orbitoides* bearing siliciclastics, stars show sample numbers.

### 3. Results and discussions

#### 3.1. Benthic foraminifera

In the Irmak area, the following fauna was determined within medium sized siliciclastics of the Iliçapınar Formation (figure 4A): *Orbitoides* cf. *medium*, *Orbitoides* sp., *Laffitteina* sp., *Siderolites* sp., and *Sulcoperculina globosa*, textularid, nodosarid and rotalid. Other smaller benthic and planktic foraminifera are as follows: *Ci bicides* sp., *Dorothyia* sp., *Gavelinella* sp., *Globotruncanæa* sp., *Rugoglobigerina* sp., *Lenticulina* sp., *Oolina* sp., *Saracenaria* sp. The Bölükdağ Formation contain *Orbitoides* cf. *medium*, *Orbitoides gruenbachensis*, *Orbitoides* sp., *Omphalocyclus macroporus*, *Pseudophalocyclus* sp., *Siderolites calcitraptoroides*, *Siderolites* sp., *Sulcoperculina* sp., *Laffitteina mengaudi*, rotalid, miliolid, texturalid. Table 1 correlates two studied areas based on similarities and differences of the Maasrichtian aged geological units.
3.2. Orbitoides Quantitative data

In the Malıboğazı area, the Mali Formation include Lepidorbitoides sp., Orbitoides apiculatus, Orbitoides medius, Orbitoides gruenbachensis, Orbitoides sp., Sirtina sp., Siderolites calcitrapoides, Sulcoperculina globosa, Sulcoperculina vermunti, rotalid, textulariid, nodosarid, echinoid, algae (figure 4B).

Orbitoides data are related to morphometric measurements based on external and internal parameters as indicated below. Four levels (sample numbers as ML4, ML5, ML6 and ML 7) were evaluated. These parameters within more than 20 individuals from each level were measured.

Test diameter (d): More than 108 individuals, population diameter changes from 4 to 10 mm. Mean value is between 6-8 mm. Figure 5A shows the diameter histogram and their maximum, minimum and mean value of each sample. Microspheric individuals are very rare. Macrospheric individual are predominant. Calcitic test of Orbitoides are seen clearly within medium grained sandstones.

Test thickness (t): Population thickness is between 2 and 3 mm. Figure 5B indicates thickness measurements in each level.

Test shape (t/d): If the test shape value approaches to 0, it indicates flattened individuals. If it reaches to 1, it is circular in shape. Our specimens values changes between 0, 2 and 0.3 (figure 5C).
Table 1. Similarities and differences of the Maastrichtian aged sediments from the studied areas

| Formation name          | Irmak Area                                      | Malıboğazi Area                      |
|-------------------------|-------------------------------------------------|--------------------------------------|
| **Outcrops lithology**  | Ilıcapınar Formation and Bölükdağ Formation     | Malt Formation                       |
|                         | Ilıcapınar Formation deposits outcrop widely.   | Malt Formation is seen within a restricted area. It comprises the following units: (1) biostromal limestones, (2) limestones with abundant *Thalassonooides* isp. (3) thick bedded to massive limestones, (4) siliciclastics. |
|                         | Ilıcapınar Formation deposits outcrop widely.   | Malt Formation is seen within a restricted area. It comprises the following units: (1) biostromal limestones, (2) limestones with abundant *Thalassonooides* isp. (3) thick bedded to massive limestones, (4) siliciclastics. |
| **Thickness**           | Ilıcapınar Formation more than 500m, Bölükdağ | Maximum 150m                          |
|                         | Formation 50-100m                                |                                      |
| **Contacts**            | Underlying units: Kılıçlar Group                 | Underlying units: Volcanics          |
|                         | Overlying unit: Dizilitaşlar Formation           | Overlying unit: Diziliştar Formation  |
| **Fauna contents**     | *Orbitoides medius, O. gruenbachensis, O.       | *Lepidorbitoides sp., Orbitoides apiculatus, O. medius, O. gruenbachensis, Orbitoides*  |
|                         | *apiculatus, Orbitoides sp., Omphalocyclus cf.   | *sp., Sirtina sp.* Siderolites calcitrapoides, *Siderolites* calcitrapoides, *Sulcoperculina globosa, Sulcoperculina* sp., *Laffitteina meagadi, Laffitteina* sp., In fine clastics: *Marssonella* sp., *Dorotheia* sp., *Lenticula*? sp., *Oolina* sp., *Saracenaria* sp., *Cibicides* sp., *Gavelinella* sp., *Globotruncana arca, Globotruncana* sp., *Rugoglobigerina* sp., Rotalid, rudist, echinoid, crinoid, coral, bryozoae?, algae |
|                         | *macroporus, Pseudomphalocyclus* sp., *Siderolites* calcitrapoides, *Sulcoperculina* globosa, *Sulcoperculina* sp., *Laffitteina meagadi, Laffitteina* sp., In fine clastics: *Marssonella* sp., *Dorotheia* sp., *Lenticula*? sp., *Oolina* sp., *Saracenaria* sp., *Cibicides* sp., *Gavelinella* sp., *Globotruncana arca, Globotruncana* sp., *Rugoglobigerina* sp., Rotalid, rudist, echinoid, crinoid, coral, bryozoae?, algae |
| **Age**                 | Ilıcapınar Formation: Early to middle Maastrich. | Malt Formation: Maastrichtian         |
|                         | Bölükdağ Formation: Maastrichtian.              |                                      |
| **Environment**         | Turbiditic and open marine paleoenvironment at the base, shallow marine environment at the top. | Biostromal paleoenvironment at the base, very shallow marine paleoenvironment with trace fossils, shallow marine and fore reef paleoenvironment with *Orbitoides* fossils. |

![Figure 5. Orbitoides external parameter histograms and their maximum, minimum and mean values in the each sample. A. diameter histogram (d, mm), B. thickness measurement (t, mm), C. test shape (t/d), x axis shows number of individuals, y axis shows measurement values, min. Minimum, max. Maximum, ort. mean values.](image-url)
Embryo size (Li+li): It is a significant internal parameter for species identifications of the Orbitoides genus [12, 13]. Based on the quantitative data of Li+li, Gorsel [12] classify the species as follows: 400-500 µ Orbitoides tissoti; 500-600 µ Orbitoides medius; 600-750 µ Orbitoides megaliformis; 750-1000 µ Orbitoides apiculatus gruenbachensis and bigger than 1000 µ Orbitoides apiculatus. In our specimens, in the Orbitoides population Li+li value changes between 470 µ and 1678 µ. Mean value is 1077 µ. (figure 6A). So this means that O. gruenbachensis and O. apiculatus are predominant species. Biostratigraphically predominance of these species shows Late Maastrichtian age.

Embryo shape (li/Li): li/Li value is from 0, 56 to 1. Mean value is 0, 89 (figure 6B). This means that embryo is more or less globular in shape. The embryo includes two inner chamberlets known as protoconch and large deuteroconch.

Embryo wall thickness (te): It is calculated from the equation of ((Lo+lo) - (Li+li))/4. It changes between 4 µ and 100 µ. Mean value is 58 µ (figure 6C). If these values are correlated to early Maastrichtian species of Orbitoides, it is seen that wall thickness of O. gruenbachensis and O. gruenbachensis is thicker.

Microboring: While the Orbitoides specimens of Malboğazı include more microborings, it is unseen in the specimens of the Irmak area. Identified ichnospecies are Maeandropolydora osmaneliensis and Curvichnus semorbis (figure 7).

Figure 6. Orbitoides internal parameter histograms and their maximum, minimum and mean values in the each sample. A. Embryo size histogram (Li+li, mm), B. embryo shape measurement (li/Li, mm), C. wall thickness (te, mm), x axis shows number of individuals, y axis shows measurement values, min. Minimum, max. Maximum, ort. mean values.
Figure 7. Orbitoides views from the Malıboğazı area. 1-4a. Abnormal external test views of Orbitoides, 4b. Equatorial section, 5a-b. Orbitoides external and equatorial views, 6-11. ichnospecies within the Orbitoides tests, 6-7. Curvichnus semorbis isp. 8-11. Maeandropolydora osmaneliensis isp., 12a-b. Reproduction view within an axial section, 13. Microborings within an axial section, 14. Microspheric individual (B form), 15-18. Various embryo views of macrospheric individuals (A forms) including various filling materials, scale on 1-11 shows 1mm, others 0.5mm.
4. Conclusions

Maastrichtian sediments outcropping around Irmak Village (Kırıkkale) and Malıboğazı (Kalecik) include various fauna contents and sediments [14]. *Orbitoides* bearing siliciclastics are seen at the top of the Maastrichtian in the Malıboğazı area. Measurements of *Orbitoides* parameters show that *O. gruenbachensis* and *O. apiculatus* are predominant species in the late Maastrichtian. The obtained stratigraphical, sedimentological and paleontological data show that northern part of the Ankara was shallower than western part of the Ankara during the late Maastrichtian (figure 8).

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