ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

SYSTEMATICS AND BIOSTRATIGRAPHIC IMPLICATIONS OF MICROMAMMALS (RODENTIA) FROM SELECTED PLIOCENE-QUATERNARY BASINS ALONG THE NORTH ANATOLIAN FAULT ZONE

PhD. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

KUZEY ANADOLU FAY ZONU'NDAKİ BAZI PLİYOSEN-KUVATERNER YAŞLI HAVZALARDAN ELDE EDİLEN KÜÇÜK MEMELİLERİN (RODENTIA) SİSTEMATİK VE BİYOSTRATİGRAFİK ÇIKARIMLARI

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TEMMUZ 2023

Ozan ERDAL, a Ph.D. student of İTU Graduate School 60110022, successfully defended the thesis entitled "SYSTEMATICS AND BIOSTRATIGRAPHIC IMPLICATIONS OF MICROMAMMALS (RODENTIA) FROM SELECTED PLIOCENE-QUATERNARY BASINS ALONG THE NORTH ANATOLIAN FAULT ZONE", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To Maya,

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Ozan ERDAL
(M.Sc. of Palaeontology)

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ABBREVIATIONS

a : Anteroconid complex length
A/L : Relative length of the anteroconid complex
AC : Anterior cap
ACC : Anteroconid complex
AL : Anterior lobe
As : Anterosinus
Asd : Anterosinuid
Asl : Anterosinulus
B/W : Relative width of the dentine field restriction b
b : Width of isthmus between BRA3 and LRA4
BRA : Buccal re-entrant angle
BSA : Buccal salient angle
C/W : Relative width of the dentine field restriction c
C : Accessory cuspids
c : Width of isthmus between LRA3 and BRA3
D/W : Relative width of the dentine field restriction d
d : Width of isthmus between LRA5 and BRA4
dext : Dexter
Ds : Distosinus
e : Width of T6-T7 complex
Esd : Entosinuid
Hsld : Hyposinulid
Hsd/L : Relative height of the linea sinuosa based on Hsd (=ep)
Hsd : Hyposinuid
Hys : Hyposinus
L : Length
LRA : Lingual re-entrant angle
LSA : Lingual salient angle
m1–3 : Lower first molar–lower third molar
M1–3 : Upper first molar–upper third molar
Mes : Metasinus
Misd : Mimosinuid (Sinuid of Mimomys-ridge)
MN : Mammal Neogene
MNQ : Mammal Neogene–Quaternary
MP : Mammal Paleogene
Msd : Metasinuid
p : Posterior complex length
Pas : Parasinus
Pasd : Parasinuid
PC : Posterior cap
PL : Posterior lobe
Pmsd : Prismosinuid (Sinuid of Prismokante)

Prs : Protosinus
Prsd : Protosinuid
SDQ : Values for enamel thickness differentiation quotient (‘Schmelzband Differenzierungs Quotient’ in German)
sin : Sinister
T : Triangles
W : Width
WP : Width of posterior cap complex

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SYSTEMATICS AND BIOSTRATIGRAPHIC IMPLICATIONS OF MICROMAMMALS (RODENTIA) FROM SELECTED PLIOCENE-QUATERNARY BASINS ALONG THE NORTH ANATOLIAN FAULT ZONE

SUMMARY

Anatolia plays an important role as a bridge between Africa, Europe and Asia for the evolutionary course of vertebrates. It is potentially rich in fossil bearing deposits which would greatly serve to contribute the understanding of vertebrate evolution. However, paleontological research conducted in Turkey is mainly focused on Paleogene and Miocene deposits. Although it is obvious that any studies of mammalian paleontology dealing with any interval of Cenozoic in Anatolia is worthful because of its potential, one must point out that Quaternary mammalian fauna is still not well known when compared to European equivalent. In this manner, it is not difficult to estimate how micromammalian paleontology is less dealt.

The introduction of the present thesis deals with some general definitions and fields of application of micromammals besides a brief summary of all conducted or ongoing studies on the Quaternary micromammalian fauna in Anatolia. One of the main motivations of this study is to underline the potential contribution of micromammal paleontology to Quaternary research in Turkey.

On the following sections, a detailed study is provided on rodent remains which were collected from diverse localities in three adjacent basins on the North Anatolian Fault Zone (NAFZ), the depositional ages of which are estimated spanning from the Pliocene to the late Pleistocene. I investigated small mammal faunas of these basins by means of systematic paleontology, biochronology with proper stratigraphic positions, and studied their inference on paleoclimate and paleoenvironment of the localities.

The North Anatolian Fault Zone (NAFZ) forms the boundary between the Anatolian and Eurasian plates and hosts many tectonic basins. The chronology of the NAFZ basin deposits is established mostly by pollen and partly by mammalian fauna studies. Nonetheless, the formation history of these basins starting in the Late Miocene to the Pleistocene and actively continuing today is still incompletely known because biochronological data are still scarce.

The previous studies on the Tosya Basin by many authors and on its several aspects revealed detailed information on the structure of the basin (Barka and Hancock, 1984; Şengör et al, 1985; Andrieux et al, 1995; Dhont et al, 1998). The earliest deposition within the basin, the Devrez Formation, is claimed to date of Early-Middle Miocene but no fossil findings are discovered so far. According to Ünay and de Bruijn (1998), the only paleontological work on the area despite the lack of stratigraphic position nor systematic description, an Early Pliocene age (late Ruscinian-MN15) is suggested based on micromammal fauna from one locality at Ortalıca Village. In the same study, they proposed Early Pleistocene (MN17) age for a locality at Karasapaca Village to the West of Ortalıca, based on micromammal remains. Unfortunately, stratigraphic positions of these localities are uncertain.

In the present study, the occurrence of *Mimomys* cf. *polonicus* at the Sapaca locality points out the early late Villanyian (MN16b) age for the locality which is older than previously studied locality Karasapaca by Ünay and de Bruijn (1998), situated at the north-eastern to the Sapaca village. At the Ortalıca locality, the co-occurence of *Pliomys destinatus*, *Apodemus atavus* and *Mesocricetus primitivus* within their stratigraphic position, supports rather the transition from MN15 (late Ruscinian) to early Villanyian (MN16a), slightly younger than age proposed by Ünay and de Bruijn (1998). On the other hand, the newly discovered Kumkapı locality, at the SW of Ortalıca and Sapaca-Karasapaca, surprisingly indicates a much younger age, late Toringian with remains of *Microtus* (*M.*) *arvalis* and *Mus* cf. *macedonicus* which provide a profile well younger than the Umurlu locality findings from the Niksar Basin.

Finally, the finding in this basin reveals a more or less continuous deposition, where the faunal succession from the Early Pliocene (MN15) toward the Late Pleistocene follows the opening of the basin in a NE–SW direction, in almost 4 Ma. Indeed, the surprising young age of Kumkapı deposits is subjected to further geological studies in the near future.

The abundance of *Pliomys* and *Apodemus* species in Ortalıca, in overall, points out rather forested, wooded and humid environment rather than grassland. (Sen, 1977; Suata-Alpaslan, 2010; Hoek Ostende et al. 2015b; Popov, 2018). However, the presence of *Mesocricetus* remains together with *Pliomys* and *Apodemus* would indicate that for a while between MN15b–MN16a (Pliocene), there have been cooler climatic conditions occurred, which resulted in steppe environment (Sen, 1977; Hoek Ostende et al. 2015a; Popov, 2018) may be with sparse forested area for the food sources. Sapaca locality which is younger than Ortalıca but much older than the Kumkapı localities yielded only *Mimomys* species, which are generally reported from relatively warm and arid, open steppe environment (e.g. Rabeder, 1981; Montuire et al, 1994; Popov, 2017). Finally, the Kumkapı locality with the presence of recent species of *Microtus* and *Mus*, is not much different from the present climate and environmental condition of the studied area such as mixture of open environment with meadows and grasslands with warm climate, as pointed out in previous studies (e.g. Montuire et al, 1994; Çolak et al, 2016; Erdal et al, 2018, 2019).

The Suluova Basin is a prominent member of a wide transtensional Amasya Shear zone, located at the central part of the North Anatolian Shear Zone. Analysis of detailed stratigraphic sections, faulting data and mammal paleontology reveals that the Suluova Basin has started to evolve as a closed half-graben along the NE-SW trending, SW dipping basin bounding fault zone with normal slip at early Quaternary. Within this tectonic environment, the sedimentary assemblages were various facies of a river dominated alluvial fan network. As faults propagated westwards, the basin deepened and a fresh water lake started to develop at the basin depocenter. The initiation of E-W trending southern tectonic boundary of the basin caused further extension. Each basin boundary fault zones witnessed clockwise rotation in time.

Marking an increasing water income, the Suluova Basin has evolved into a vast fresh water lake during the Middle Pleistocene (~1.7–0.8 Ma) acting as a refugia for a potential rich faunal assemblage of large and small land mammals. Thus far, micro- and macromammal remains studied from several localities in the basin comprise *Kalymnomys* sp. and *Sivatherium* sp. from late Villanyian of Kurnaz; *Microtus*

(*Allophaiomys*) aff. *nutiensis*, *Mimomys* aff. *pliocaenicus* and *Apodemus* cf. *dominans* from late Villanyian–early Biharian of Kerimoğlu; *Mesocricetus* aff. *arameus* from early Biharian of Kızıleğrek, and *Mesocricetus* cf. *brandti* and *Arvicola* cf. *mosbachensis* from early Toringian of Yolpınar, in addition to some fragments of *Equus* sp.

The faunal association from five localities would allow to make some assumptions concerning the past environment. For instance, the paleoenvironment of *Sivatherium* is reported as grasslands and well-watered landscape with much warmer temperature for the early part of Early Pleistocene (MN17–MNQ18); *Kalymnomys* on the other hand, is not well known but based on actual relatives (e.g., *Lagurus lagurus*) it is thought that should be rather dry steppe environments (Alçiçek et al, 2017, p.242). The floodplain deposits at the Kurnaz locality would support the former hypothesis in addition to environmental changes with the presence of a paleolake at the younger Kerimoğlu locality which would point out rather warmer climate. The Kerimoğlu locality, as it is important for the formation of a paleolake which is also supported by the remains of unidentified fossil fish teeth, represents an environment surrounded with deciduous woodland and bushy vegetation covers with streams and marsh-like areas by the presence of a large vole *Mimomys* aff. *pliocaenicus* and *Apodemus* cf. *dominans*. (Siori and Sala 2007; Hoek Ostende et al, 2015a; Erdal et al, 2018; Sen et al, 2018). The macromammal remains at Kamışlı has been previously reported by Sickenberg and Tobien (1971, p.60–61) where faunal elements including *Equus* sp. point out steppe environment crossed by forest along the water courses and lakes. The presence of *Mesocricetus* spp. at Kızıleğrek and Yolpınar localities would indicate somewhat dry, semi-arid steppes covered by sparse vegetation (Krystufek and Vohralik 2009). Note that Anatolia is playing an important role for the evolution of the hamster *Mesocricetus* during the Middle Pleistocene, which is favoured by alternating dry periods and spreading lakes causing steppe-corridors for hamsters' dispersals and adaptations (Neumann et al, 2017). On the other hand, the water vole *Arvicola* findings together with *Mesocricetus* as at the Niksar Basin, demonstrate rather a mixture of steppe-like environments with water streams for that youngest locality to the east of the Suluova Basin.

A new micromammalian faunal assemblage from four horizons at the Umurlu locality (Niksar Basin, Tokat-Turkey) has been investigated; it improves our knowledge about the chronology of this basin infill. According to the stratigraphic range of the recorded species (*Mesocricetus* cf. *brandti*, *Cricetulus migratorius*, *Arvicola* cf. *mosbachensis*, *Microtus arvalis*, *M.* (*Terricola*) *subterraneus*, *Clethrionomys* cf. *glareolus*, *Apodemus flavicollis*, *Nannospalax* cf. *xanthodon*) the age of the deposit is constrained between early Middle Pleistocene and Late Pleistocene (i.e., 480–130 ka).

The fossil assemblage indicates a mixture of open environments with meadows and grasslands associated with forested and bushy vegetation covers. This fauna and the implied environment are typical for an interglacial period, most probably within the interval of MIS 12–5. The studied rodent assemblage with elements of several paleobiogeographic affinities shows once more the key position of Anatolia as a bridge between the Old World continents. It improves our knowledge on Quaternary micromammals of Anatolia, which is still poorly documented, and provides a well-constrained age of the investigated localities.

KUZEY ANADOLU FAY ZONU'NDAKİ BAZI PLİYOSEN-KUVATERNER YAŞLI HAVZALARDAN ELDE EDİLEN KÜÇÜK MEMELİLERİN (RODENTIA) SİSTEMATİK VE BİYOSTRATİGRAFİK ÇIKARIMLARI

ÖZET

Anadolu, omurgalıların evrimsel seyrinde Afrika, Avrupa ve Asya arasında bir köprü görevi görmektedir. Omurgalı evriminin anlaşılmasına büyük ölçüde katkıda bulunacak fosil yatakları açısından oldukça zengindir. Ancak Türkiye'de yürütülen paleontolojik araştırmalar, ağırlıklı olarak Paleojen ve Miyosen jeolojik zaman dilimlerine odaklanmaktadır. Oysaki Anadolu'da, Senozoyik zamanı hedefleyen bir memeli paleontolojisi çalışmasının değerli olduğu açık olsa da, Kuvaterner memeli faunasının Avrupa eşdeğeri ile karşılaştırıldığında hala iyi bilinmediğini belirtmek gerekir. Bu çalışmalara bakıldığında, hele mikromemeli paleontolojisinin daha da az ele alındığı görülmektedir.

Bu tezin giriş kısmında, öncelikle Anadolu'da Kuvaterner mikromemeli faunası üzerine yapılan veya devam eden tüm çalışmaların kısa bir özetini verdikten sonra, mikromemeli paleontolojisinin Türkiye'deki Kuvaterner araştırmalarına potansiyel katkısının altını çizer.

Sonraki bölümlerde, çökelme yaşlarının Pliyosen'den geç Pleistosen'e kadar uzandığı tahmin edilen Kuzey Anadolu Fay Zonu (KAFZ) üzerindeki üç bitişik havzadaki çeşitli lokalitelerden toplanan kemirgen fosil buluntuları detaylıca incelenmiştir. Bu havzaların küçük memeli faunalarını sistematik paleontoloji, biyokronoloji ve uygun stratigrafik konumlarla araştırdıktan sonra, lokalitelerin paleoiklim ve paleoçevrelerine ilişkin çıkarımları da iredelenmiştir.

Bu tezde de uygulandığı gibi, mikromemeli fosil kalıntılarını toplamak için, daha önceki arazi çalışmalarından bilinmiyorsa, fasiyeslerinde yüzlek vermiş gastropod kabuğu görülen killi uygun seviyeler tespit edilir. İlgili lokasyonlardaki her seviyeden en 20 kilogramlık birkaç çuval numune alınır ve 24 saat açık havada, güneş altında kuruması beklenir. Bu işlemden sonra tüm kurumuş killi numuneler suda çözülür. Bu killi çözeltiyi en iyi şekilde ve homojen olarak elde etmek için, ki kil yoğunluğuna göre bu işlemler zor olabilir, ekstra bir kimyasal işlem uygulanmalıdır. Bu durumlarda tercihen %1020 oranında seyreltilmiş hidrojen peroksit eklenir. Homojen bir çamur elde edildikten sonra, tüm çökeltiler 0,5 mm ila 8 mm gözenek boyutuna sahip eleklerden sırayla geçirilir. Elek üzerinde kalan ve yüksek oranda kilden arınmış malzeme, kuruması için 24 saat daha güneş ışığına bırakılır. Yıkanmış ve kurutulmuş numune binoküler makroskop altında tasnif edilir; tüm memeli veya gastropod kalıntıları numunenin geri kalanından ayrılır. Özellikle ve tercihen azı dişlerinin oklüzal (çiğneme) yüzeyi, diş morfolojisinin daha iyi gözlemlenmesi ve tanımlamasının daha iyi yapılabilmesi için, ince bir iğne ile diş arası çimentolarından (cement) hassas bir şekilde temizlenir. Nihayet, azı dişleri de ilgili araçlar ve yazılımlarla fotoğraflanır ve ölçülür. Son olarak, hepsi literatürden veya koleksiyondan alınan örneklerle karşılaştırılır. Nihayetinde de örnekler, tanımlama, karşlaştırma (sistematik paleontoloji) ve tür tayini işleleri yapıldıktan

sonra civar lokalitelerde bulunmuş türlerin bilinen yaşlarına göre biyokronolojik ve mümkün olan durumlarda paleoklimatik veya paleçevresel çıkarımlarda bulunulur (Saraç, 2003, 2012).

Kuzey Anadolu Fay Zonu (KAFZ), Anadolu ve Avrasya levhaları arasındaki sınırı oluşturmakta ve birçok tektonik havzaya ev sahipliği yapmaktadır. KAFZ havza çökellerinin kronolojisi, çoğunlukla polen ve kısmen de memeli faunası çalışmaları ile oluşturulmuştur. Bununla birlikte, bu havzaların Geç Miyosen'den Pleyistosen'e kadar olan ve günümüzde aktif olarak devam eden oluşum tarihi, biyokronolojik veriler hala yetersiz olduğu için hala tam olarak bilinmemektedir.

Çalışma kapsamındaki 3 havzadan biri olan Tosya Havzası hakkında birçok yazar tarafından ve çeşitli yönleriyle önceki çalışmalar havzanın yapısı hakkında ayrıntılı bilgiler ortaya koymuştur (Barka ve Hancock, 1984; Şengör ve diğerleri, 1985; Andrieux ve diğerleri, 1995; Dhont ve diğerleri, 1998). Havzadaki en erken çökeller Devrez Formasyonu'nun ErkenOrta Miyosen'e tarihlendiğini iddia etmektedir. Ancak şu ana kadar Miyosenden herhangi bir fosil bulgusuna rastlanmamıştır. Ünay ve de Bruijn'in (1998) bölgede yaptığı, stratigrafik konum ve sistematik tanımlama vermemiş olmalarına rağmen tek paleontolojik çalışmadır; Ortalıca Köyü'ndeki bir lokaliteden içeriğinde *Mimomys gracilis, Dolomys* sp., *Pliomys* sp., *Apodemus dominans, Mesocricetus* cf. *primitivus, Pliopetaurista* cf. *pliocaenica, Blackia* sp., *Dryomys tosyaensis, Glirulus* sp., *Myomimusoides* sp gibi mikromemeli faunasına dayalı olarak Erken Pliyosen yaşı (geç Rusciniyen-MN15) önerilmiştir. Aynı çalışmada, Ortalıca batısındaki Karasapaca Köyü'ndeki bir yerleşim yerinde bulunan lokalite için mikromemeli kalıntılara dayanarak Erken Pleistosen (MN17) yaşı önermişlerdir, fakat bu bulguların stratigrafik konumları belirsizdir.

Bu çalışmada, Sapaca köyünün yakınlarındaki Sapaca lokalitesinden *Mimomys* cf. *polonicus* türünün bulunması, bu köyün KuzeyDoğusunda yer alan ve ilk Ünay ve de Bruijn (1998) tarafından incelenen Karasapaca mevkiinden daha yaşlı olduğunu gösteren erken geç Villaniyen (MN16b) yaşını işaret etmektedir. Ortalıca mevkiinde, stratigrafik konumlarında *Pliomys destinatus, Apodemus atavus* ve *Mesocricetus primitivus*'un bir arada bulunması, daha çok Ünay ve de Bruijn (1998) tarafından önerilen yaştan biraz daha genç olan MN15'ten (geç Rusiniyen) erken Villaniyen'e (MN16a) geçişi desteklemektedir. Öte yandan, Ortalıca ve Sapaca-Karasapaca'nın güney batısında yeni keşfedilen Kumkapı lokalitesi *Microtus* (*M.*) *arvalis* ve *Mus* cf. *macedonicus* kalıntılarıyla birlikte şaşırtıcı bir şekilde çok daha genç bir yaş olan Geç Toringiyen'i gösterir ki, bu çalışmanın son havzası olan Niksar'daki Umurlu lokalitesi buluntularının yaşına oldukça yakındır.

Son olarak, bu havzadaki buluntular esas alındığında, Erken Pliyosen'den (MN15) Geç Pleyistosene doğru faunal istifin, havzanın yaklaşık 4 My'da KD-GB yönünde açılmasını takip ettiği, aşağı yukarı sürekli bir çökelmeyi ortaya koymaktadır. Gerçekten de, Kumkapı lokalitesinin şaşırtıcı genç yaşı, yakın gelecekte daha fazla jeolojik araştırma gerektirse de, şimdiki öngörülere göre Geç Miyosen'den Orta Pleyistosen'e kadar bir boşluk olduğu tahmin edilmektedir.

Ortalıca'da genel olarak *Pliomys* ve *Apodemus* türlerinin bolluğu çayır alanlarından çok ormanlık, ağaçlık ve nemli bir paleoçevresel ortamı işaret etmektedir (Şen, 1977; Suata-Alpaslan, 2010; Hoek Ostende vd. 2015b; Popov, 2018). Ancak *Mesocricetus* kalıntılarının bulunması, MN15b–MN16a (Pliyosen) arasında bir süre daha soğuk iklim koşullarının oluştuğunu ve bunun sonucunda da yer yer bozkır koridorlarının oluştuğunu gösterir (Sen, 1977; Hoek Ostende vd. 2015a; Popov, 2018). Ortalıca'dan daha genç ama Kumkapı lokalitesinden çok daha eski olan Sapaca lokalitesinde

genellikle nispeten sıcak ve kurak, açık bozkır ortamında rapor edilen *Mimomys* türü bulunmuştur (örn. Rabeder, 1981; Montuire ve diğerleri, 1994; Popov, 2017). Son olarak, *Microtus* ve *Mus* cinslerine ait güncel türlerin varlığı ile Kumkapı mevkii, daha önceki çalışmalarda da belirtildiği gibi, açık alan ve çayırların ılıman iklim kontrolünde geliştiği, günümüz iklim ve çevre koşullarından çok farklı olmadığı çıkarımı yapılmıştır. (örn. Montuire ve diğerleri, 1994; Çolak ve diğerleri, 2016; Erdal ve diğerleri, 2018, 2019).

Çalışma konusunun ikinci havzası olan Suluova Havzası, Kuzey Anadolu Fay Zonu'nun orta kesiminde yer alan geniş bir transtansiyonlu Amasya Makaslama Zonu'nun önde gelen bir üyesidir. Detaylı stratigrafik kesitlerin analizi, faylanma verileri ve memeli paleontolojisi, Suluova Havzası'nın erken Kuvaterner'de KD-GB yönlü, GB eğimli havzayı sınırlayan normal atımlı fay zonu boyunca kapalı bir yarı-graben olarak gelişmeye başladığını ortaya koymaktadır. Bu tektonik ortam içinde, tortul katmanlar, nehir egemen bir alüvyon yelpazesi ağının çeşitli fasiyesleri olarak gözükmektedir. Faylar batıya doğru ilerledikçe havza derinleşti ve havza depomerkezinde bir tatlı su gölü gelişmeye başladı. Havzanın güney tektonik sınırının DB gidişli olarak başlaması daha fazla genişlemeye neden olmuştur. Her bir havza sınırı fay zonu zaman içinde saat yönünde dönüşüne tanık olmuştur.

Suluova Havzası, Orta Pleistosen'de (~1,7–0,8 My) büyük ve küçük kara memelileri için bir sığınak görevi gören geniş bir tatlı su gölüne dönüşmüştür. Şimdiye kadar, havzadaki çeşitli lokalitelerden incelenen mikro ve makromemeli buluntular, geç Villaniyen yaşındaki Kurnaz lokalitesinden *Kalymnomys* sp. ve *Sivatherium* sp.; geç Villaniyenerken Bihariyen yaşlı Kerimoğlu lokalitesinden *Microtus* (*Allophaiomys*) aff. *nutiensis, Mimomys* aff. *pliocaenicus* and *Apodemus* cf. *dominans*; erken Bihariyen yaşındaki Kızıleğrek lokalitesinden *Mesocricetus* aff. *Arameus*; ve erken Toringiyen yaşlı Yolpınar lokalitesinden de *Mesocricetus* cf. *brandti* ve *Arvicola* cf. *mosbachensis* kalıntıları, *Equus* sp.'a ek olarak tanımlanmıştır.

Suluova Havza'sında da beş lokaliteden tanımlanan faunal topluluklar baz alınarak, geçmiş çevre ve iklim ile ilgili bazı varsayımlarda bulunmak mümkündür. Örneğin, *Sivatherium*'un paleoçevresi, Erken Pleistosen'in (MN17–MNQ18) erken kısmı için çok daha yüksek sıcaklığa sahip otlaklar ve sulak alanlar olarak rapor edilmiştir; *Kalymnomys* ise çok iyi bilinmemekle birlikte güncel akrabaları ile kıyaslandığında (örn. *Lagurus laurus*) daha çok kurak alanları işaret etmektedir. Kerimoğlu lokalitesi, tanımlanamayan balık dişi kalıntılarının da desteklediği bir paleogöl oluşumunda önemli olduğu için, yaprak döken ağaçlıklarla çevrili bir ortamı ve iri tarla faresi *Mimomys* aff. *pliocaenicus* ve orman faresi *Apodemus* cf. *dominans* türlerinin varlığı ile akarsular ve bataklık benzeri alanlarla kaplı çalılık bitki örtüsünü temsil eder (Siori ve Sala 2007; Hoek Ostende ve diğerleri, 2015a; Erdal ve diğerleri, 2018; Sen ve diğerleri, 2018). Kamışlı'daki makromemeli kalıntılar daha önce Sickenberg ve Tobien (1971, s.60–61) tarafından *Equus* sp. dahil faunal elementlerin bulunduğu rapora göre ortam akarsularla örgülü ve *Mesocricetus* türlerinin varlığı ile de göller boyunca ormanların geçtiği bozkır ortamını gösterir. Kızıleğrek ve Yolpınar lokalitelerinde seyrek bitki örtüsüyle kaplı biraz kuru, yarı kurak stepleri işaret eder (Krystufek ve Vohralik 2009). Anadolu'nun Orta Pleistosen boyunca *Mesocricetus*'un evriminde önemli bir rol oynadığına dikkat edilirse, aralıklı kurak dönemler, hamsterlerin dağılımları ve adaptasyonları için bozkır koridorları varlığının altını çizerler (Neumann ve diğerleri, 2017). Öte yandan, Niksar Havzası'nda olduğu gibi *Mesocricetus* ile birlikte *Arvicola* buluntuları, Suluova

Havzası'nın doğusundaki en genç yerleşim yeri için daha çok bozkır benzeri ortamların su akıntıları ile karışımını göstermektedir.

Bu çalışmadaki son havza olan Niksar Havzası'ndaki Umurlu lokalitesinde (Tokat) dört killi siltli fasiyesten zengin ve yeni bir mikromemeli fauna topluluğu incelenmiş, havza dolgusunun kronolojisi hakkındaki bilgimizi genişletmiştir. Kaydedilen türler *Mesocricetus* cf. *brandti*, *Cricetulus migratorius*, *Arvicola* cf. *mosbachensis*, *Microtus arvalis*, *M.* (*Terricola*) *subterraneus*, *Clethrionomys* cf. *glareolus*, *Apodemus flavicollis*, *Nannospalaxdon* cf. *xanthodon* olup, biyokronolojik yaşlara göre bu çökelin yaşını Orta Pleyistosen'in erken dönemleri ile Geç Pleistosen (480-130 bin yıl) arasında ortaya koymaktadır. Bu fosil faunası, ormanlık ve çalılık bitki örtüsü ile etrafında çayır ve otlaklarla açık alanların bir mozayiğini gösterir. Bu fauna ve ima edilen çevre, büyük olasılıkla MIS 12–5 aralığı içinde, buzullar arası bir dönem için tipiktir.

Bu çalışma ile tüm kemirgen fosil bulguları ve onların tahmin edilen paleobiyocoğrafik çıkarımları sayesinde, Anadolu'nun Eski Dünya kıtaları arasında bir köprü olarak kilit konumunu bir kez daha gösterilmeye çalışılmıştır. Bu çalışma sayesinde, Anadolu'nun Kuvaterner mikromemelileri hakkında az olan literatürümüze bir nebze katkı sağlamış ve üç havzenin jeolojik yaşını sağlamlaştırmıştır.

1. INTRODUCTION

This thesis deals with many rodent remains collected from the Pliocene-Pleistocene deposits of three basins (Niksar, Suluova and Tosya) throughout the North Anatolian Fault Zones (NAFZ). (Figure 1.1).

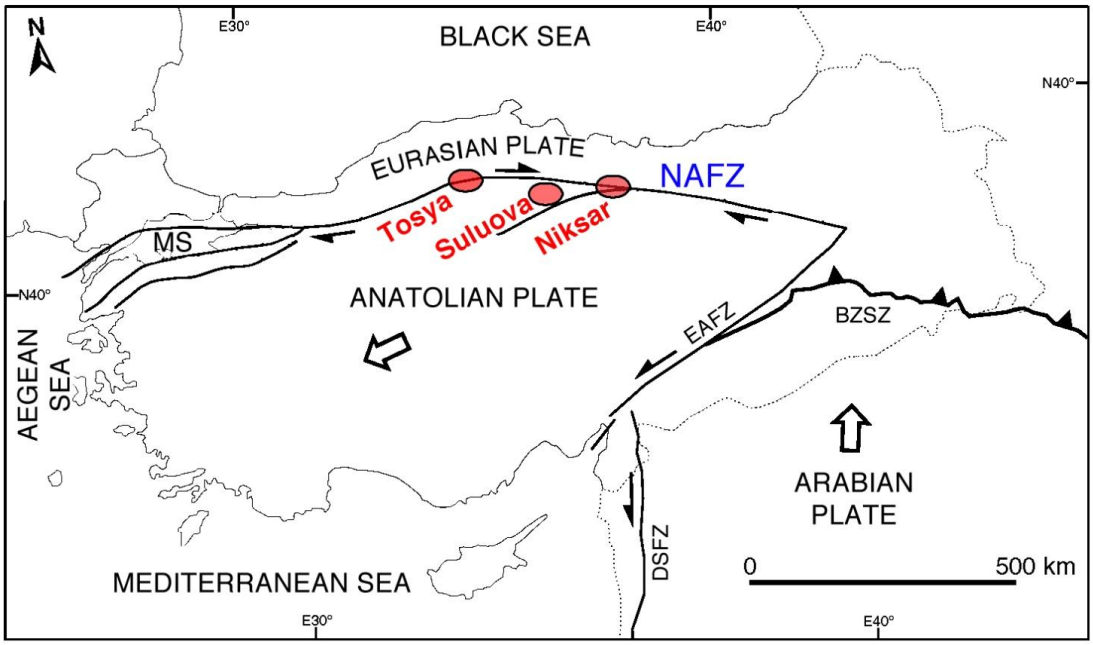


Figure 1.1 : Tectonic outline of Turkey and locations of studied pull-apart basins along the North Anatolian Fault Zones. MS, Marmara Sea; NAFZ, North Anatolian Fault Zones; EAFZ, East Anatolian Fault Zones; BZSZ, Bitlis-Zagros Suture Zone; DSFZ, Dead Sea Fault Zone (modified after Gürbüz, 2010).

The aim of the thesis is to describe small mammal fossils from the investigated basins, to discuss on aspects of systematic, to provide taxonomical revision and finally to infer biostratigraphic ages based on paleontological data as well as possible faunal successions in the studied basins. This study also provides biostratigraphic correlation between the sedimentary successions of these basins, paleoenvironmental and paleoclimatic assumptions if possible, and finally, the importance of micromammalian studies in Turkey in the past and the contribution of the present study.

The main reason of studying rodents, such as mouse, rat, vole, mole rat and hamsters, is that they are an efficient biostratigraphic tool. They are not migrating as larger mammals but undergo adaptive radiation in relatively restricted area during the large scale seasonal changes. On the other hand, they have a very short lifespan but reproduce very fast and thus they provide more distinct evolutionary features which allow to improve results based on comparative anatomy upon fossils. Especially some voles (e.g. Arvicolinae) display very distinctive and explicit-exclusive character traits which allow identifying species in high accuracy as much as possible. In addition, they can provide a great deal of information about the paleoenvironment in which they lived as well as about their paleobiogeography. Studying that group has some advantages. Some species have very precise habitat requirements which can lead paleoclimatical assumptions. Finally, they are efficiently used in land mammal biozones in Europe which facilitates great scale correlations, having relatively accurate assumptions on the age of the sediment layers bearing such remains.

Rodents represent the largest order of extant mammals, encompassing 2277 extant species (Wilson and Reader, 2005) or approximately 42% of worldwide mammalian biodiversity (Figure 1.2). They are also abundant in the fossil records considering their first origination in Early Paleocene (Li and Ting, 1993) or Late Paleocene (Hartenberger, 1998; McKenna and Bell, 1997). Therefore, with a large amount of sampling (detailed in the material and methods) it can be acquired information in order to contribute to a better knowledge of their evolution, dispersals, relationships with other members of the order from different localities in Turkey and elsewhere, possible local climatic fluctuations and, as cited above, in biostratigraphic aspect.

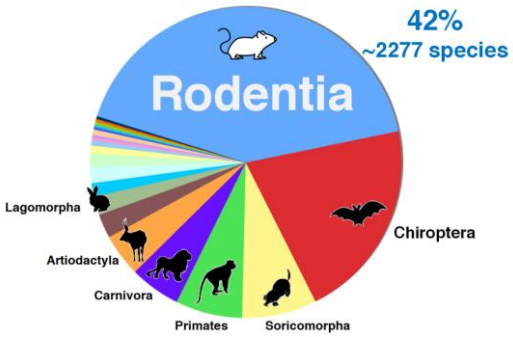


Figure 1.2 : The abundance of rodents by means of biodiversity among the extant mammal orders (after Carleton and Musser, 2005).

Since 1960, the geology and lithostratigraphy of basins formed along the North Anatolian Fault Zones (NAFZ) are explored by MTA geologists and academic researchers in variable details. However, the age and details of depositional environments are, in most case, not accurately constrained due to scarce biochronological data, mostly provided by pollen and some mammalian faunas. These basins have great potential for the discovery of late Cenozoic mammals, and thus it would allow refining chronology of their infill and their evolutionary history, as one of the scope of this very study.

1.1 Problematic of the Study

The NAFZ basins explored in the context of the present study host many paleontological and geological data which would shed light on rodent systematics in Turkey and the local evolution of NAFZ. Although those basins are studied in different aspects, the lack of efficient small mammal studies causes also the lack of solid relation between sedimentary environments, biostratigraphy and biochronology between these basins. According to Şengör et al. (2005) it prevents suggesting neither further models nor comments on the evolution of NAFZ.

For instance, the deformation zones of NAF (*sensu stricto* NAF Zones-NAFZ) host many basins ranging in age from Middle-Late Miocene to Pleistocene (Irrlitz, 1972; Barka, 1985; Koçyiğit, 1989; Kazancı, 1993; Andrieux et al, 1995; Barka et al, 2000; Ünay and de Bruijn, 1998; Ünay et al, 2001; Şengör et al, 2005; Tarı, 2007; Erturaç, 2010). However, there are relatively few studies concerning sedimentology and age control, both conducted together (*e.g*. NAF basins: Ünay et al, 2001; Erturaç, 2010; Erturaç and Tüysüz, 2012; Çankırı Basin: Kaymakçı, 2000; Karadenizli, 2011).

Although the initiation of these basins is not well determined, it is mainly accepted as Late Miocene, based on palinological data from lacustrine sediments (Irrlitz, 1972). Recent palynology studies in the Suluova (Amasya) Basin point out to Middle Miocene (Kayseri and Akgün, 2008). Nevertheless, none of any mammal paleontological data support the Miocene age for those basins (Saraç, 2003). In addition and unfortunately, the stratigraphic position of Plio-Pleistocene fossil

vertebrate assemblages already published from those basins are unclear (Ünay and de Bruijn, 1998; Saraç, 2003).

The previous studies on the stratigraphy and chronology of sedimentary deposits in the Niksar Basin (cf. Irrlitz, 1972; Barka, 1985; Aktimur et al, 1992; Ünay and de Bruijn, 1998; Barka et al, 2000; Suata-Alpaslan, 2003) provide many information concerning the Neotectonic evolution of the basin with many controversies. The depositional units of the Niksar Basin are displayed as limited outcrops around Kelkit Stream and formed by river deposits and alluvial fans at the edge of the basin. In a recent study, some molars of *Microtus arvalis* discovered around the Umurlu Village suggest a middle Pleistocene age which constrains the evolution time of Niksar Basin (Erturaç and Tüysüz, 2012).

Concerning the Tosya Basin, many authors revealed detailed information of the structure of the basin (e.g. Barka and Hancock, 1984; Şengör et al, 1985; Andrieux et al, 1995; Dhont et al, 1998) but only one paleontological study covering many basins suggested an "early-middle" Pliocene (i.e. late Ruscinian-MN15) for one locality bearing molluscs in the greenish lacustrine clay deposits at Ortalıca Village in the Tosya Basin (on the Tosya-Merzifon road) based on micromammal fauna (e.g. *Mimomys gracilis, Dolomys* sp., *Pliomys*, sp., *Apodemus dominans*, *Mesocricetus* cf. *primitivus*, *Pliopetaurista* cf. *pliocaenica*, *Blackia* sp., *Dryomys tosyaensis*, *Glirulus* sp., *Myomimus* cf. *eliomyoides, Ochotonoides ortalicensis*). In the same study, they suggested early Pleistocene (MN17) age for a locality at Karasapaca Village based on another micromammal fauna (*Mimomys* cf. *pliocaenicus, Myomimus* sp., *Soricidae* gen. et sp. indet). Unfortunately, stratigraphic positions of these localities are uncertain.

In overall, most of the studies dealing with small mammals paleontology in Turkey are regarded as just "biochronological tool" by geologists to give a relative age to the sedimentary deposits rather than a paleontological work, especially before 2012 (see Chapter 1.3) in the exception of great work of Sen (1977) on Pliocene rodents of the Çalta locality (Ankara). For instance, Ünay et al. (1995) dated the northern part of the Büyük Menderes Graben as latest Pliocene–Early Pleistocene referring to arvicolids; Ünay et al. (2001) suggested an age of latest Pliocene for the earliest deposits of the Adapazarı pull-apart basins based on an index taxon *Kalymnomys* cf. *major*, compared to those of Greece and Israel; in a similar approach, Suata-Alpaslan

et al. (2010) sorted a biozonation of micromammals and dated the İğdeli deposits (Gemerek, Sivas) as Early Pliocene and the former author, proposed early Middle Pleistocene age for the Gölbaşı locality (Adıyaman) (Suata-Alpaslan, 2011a). Unfortunately it is strange that Suata-Alpaslan (2011a) appears to have reused some fossil illustrations as well as their measurements and descriptions from her other publication on Üçağızlı Cave (Suata-Alpaslan, 2011b). However, this discussion is not within the scope of this study and some small mammal findings from the Gölbaşı Locality are removed and not mentioned in this thesis.

Indeed, rodents are very important, and sometimes the only possible faunal element for inferring such relative geological ages on the study area as seen in a fauna of karstique fissure south of Seydişehir which is dated to Middle Pleistocene by co-occurrence of *Mimomys* and *Arvicola* (Sen et al, 1991; Montuire et al, 1994). On the other hand, the work of Sarica (2000) is a good example to demonstrate the contribution of micromammalian studies to the stratigraphy of the Büyük Menderes and Gediz grabens as well as to the systematic paleontology of small mammals in Anatolia. Note that none of these studies cited above, except a few (e.g. Ünay and de Bruijn, 1998; Erturaç, 2010), are carried on the selected basins of NAFZ which constitute the scope of the present thesis. Its aim is to provide a detailed systematic paleontology in order to contribute to small mammal paleontology database for ?Pliocene–Quaternary of Anatolia, to provide relative ages constrains for the stratigraphic context of the studied areas and assumptions on the paleoenvironmental and/or paleoclimatic context of deposits.

On the other hand, the Quaternary period, which includes Pleistocene–Holocene epochs (2.58 Ma–present), is now considered all around the world, a separate scientific field that incorporates numerous disciplines and interdisciplinary studies (e.g. geology, geomorphology, archeology, palynology, biology, paleoclimatology, glaciology, molecular phylogeny, paleontology, etc.). Overall, that period provides a great amount of information regarding the interaction of biotic and abiotic factors in our recent past and allows making future predictions.

Nevertheless, studies conducted on Quaternary deposits of Anatolia by means of paleontology are very scarce compared to European equivalents (Saraç, 2003, 2012). The importance of Quaternary period, which had a significant impact upon the human evolution, was unfortunately overlooked in Turkey roughly until the 1970s

except by geomorphologists (Kazancı, 2012). The studies carried through in Turkey up to present, have mostly focused on middle-late Paleogene (i.e. Eocene–Oligocene) and Neogene (i.e. Miocene–Pliocene). Studies on Quaternary mammals have also begun in the last two decades with the discovery and examination of newly found fossil bearing sites. However, regardless of such importance of Quaternary and paleontology in Turkey, paleontological studies conducted on Quaternary faunas of Anatolia and especially on small mammals are unfortunately very scarce (i.e. 15 publications since 1970, Erdal, 2017).

In paleontological context, this thesis aims to fulfil the relatively poor knowledge on Quaternary small mammal palaeontology of Anatolia and some basins formed along the NAF, (1) by studying abundant fossil material from Middle–Late Pleistocene layers of Niksar Basin, (2) by evaluating previously mentioned fossils in the thesis of Erturaç (2010) collected from Pleistocene Suluova Basin in addition to recent material; (3) by providing a revised systematic and biostratigraphic approaches upon a previous study on Pliocene deposits of Tosya Basin which was initiated by Ünay and de Bruijn (1998). Consequences of the present study can give access to some assumptions on the constraining age of basin initiation supported by biochronological information, understanding the stratigraphic successions in these basins, and paleoclimatical changes from Pliocene upward.

Beside the contribution of systematic paleontology on small mammals in Turkey for Quaternary deposits, this thesis aim also to provide relative geological ages in order to enhance the hypothesis of when these adjacent basins are opened and how they evolved. For instance, ages suggested in previous studies such as MN17–15 or ~2 Ma for the Tosya Basin (Ünay and de Bruijn, 1998), 2.5–0.7 Ma for the Suluova Basin (Sickenberg and Tobien, 1971; Saraç, 2003; Erturaç, 2010; Albayrak and Lister, 2011) and 0.7–0.6 Ma for the Niksar Basin (Erturaç and Tüysüz, 2012) are slightly changed. (Figure 1.3).

The specific problematic of each three basins are detailed separately in Chapters 2 and 4.

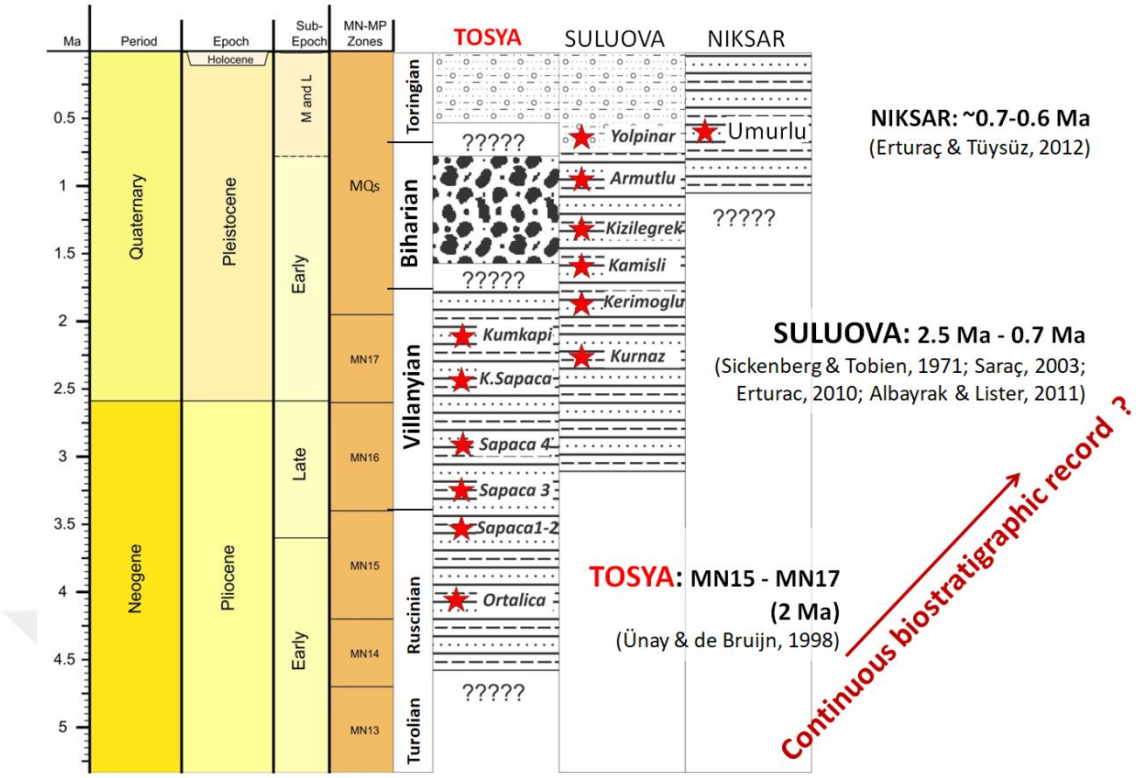


Figure 1.3 : Hypothetized and generalized columnar stratigraphic section of the three adjascent basins in this study, based on previous studies.

1.2 Small Mammals and Their Importance for Quaternary Studies

The term small mammal is used for convenience when referring to mammal species that are too small to be easily recognized in nature and it is essentially of no taxonomic value (Hillson, 2005). This group includes rodents (Rodentia: mice, squirrels, moles, beavers, hamsters, porcupines, etc.), hares and rabbits (Lagomorpha), "insectivorous" mammals (e.g. Soricidae, Scadentia) and bats (Chiroptera). The lack of taxonomic validity of this term is that there is no direct phyletic relationship between the aforementioned taxa, in other words, they do not constitute a monophyletic group in cladistic analyses (except Rodentia and Lagomorpha; see Glires). On the other hand, the fossil gathering methods for small mammals are generally the same (screen-washing and sorting out of the sediment; see Chapter 3) and they can be appear together under a binocular microscope. In short, this term provides an ease of use to a degree.

The most important group among the small mammals mentioned above is undoubtedly the rodents. According to paleontological data, they emerged during the Late Paleocene (e.g. Ischyromyidae or Paramyidae; Hartenberger, 1998) or

according to molecular studies in Early Paleocene (e.g. Wu et al, 2012). Today, they account for 42% of all living mammal species with around 30 families and the estimated number of species exceeds 2277 (Carleton and Musser, 2005). On the other hand, if the fossil records are taken into consideration, it is known that the present number of species cannot compete with the past, and therefore it is a fossil-rich group (Chaline and Mein, 1979; Fejfar et al, 2011; Vianey-Liaud and Marivaux, 2016).

In addition to species richness, the presence of rodents in all continents except Antarctica, and their adaptation to almost all habitats including human dwellings apart from their own natural habitats (e.g. trees, subterranean, deserts, steppes or forest areas, wetlands etc.) demonstrate their evolutionary success. This success was made possible by their generally fast reproduction rate and efficient adaptive radiation and especially the tooth-jaw morphology specific to this group (Figure 1.4).

Rodents as small mammals are found in more specific habitats, do not migrate seasonally and reproduce rapidly contrary to large mammals. Therefore, they can react/adapt to climatic and environmental changes relatively in shorter time, they are abundant in the Quaternary fossil records, their families and genera are still represented by extant species. All these features of rodents enhance the quality of fossil identification and consequently provide a positive feedback to assumptions mentioned above (Renfrew and Bahn, 2012; Royer et al, 2013; Kolfschoten, 2013; Rook et al, 2013). In particular, the studies conducted by Krystufek and Vohralik (2001, 2005, 2009) on Turkey's extant rodents provide important inferences about the past habitats of fossil rodents, their dispersal regions, and even nutrition, reproduction and lifestyles.

The Quaternary is distinguished by climatic oscillations following each other with high amplitudes and frequencies, and by cold periods which are relatively more intense. These cycles during the last 2.58 Ma, naturally affected the dispersion, speciation and migration of plant and animal communities over time, also caused extinction of some lineages and affected their geographical distribution (Kolfschoten, 2013; Escudé et al, 2013 and references therein). As to Anatolia, which is located between Africa, Europe and Asia, forms a bridge between these continents allowing dispersal events of both large and small mammals (Ünay, 1996; Sen 2013; Albayrak 2017; Erdal et al, 2016). On the other hand, it acted as glacial refugia for certain

species during cold periods due to climatic changes throughout the Quaternary. It also serves as a corridor for a number of species that exhibit adaptive radiation (e.g. mole-rats, arvicolines, Anatolian sousliks; Gür, 2013; Tougard, 2017). Moreover, according to certain authors (Chaline, 1987), these areas are considered as the triggers of new speciation. For such reasons, Anatolia, as it is today, contains much important paleontological data for the evolution of extant species.

Fossil records of land mammals show that many mammal species living today emerged at the Late Pliocene and Quaternary, especially in Europe and Asia. The adaptation, dispersion and even endemicity of these mammals are driven parallel to the continuously changing Quaternary environmental conditions. For instance a major faunal turnover including that of rodents is observed when two distinct fauna collection from Middle-Late Miocene and Quaternary are compared (Lister, 2004). In paleontological studies fossil rodents have many outcome such as mechanisms and origins of complex evolutionary change (e.g. Chaline et al, 1999; Fejfar et al, 2011), biostratigraphy (e.g. Sala and Masini, 2007), and relative dating with biozones (biochronology; e.g. Mein, 1975; Fejfar et al, 1997; Maul and Markova, 2007), assumptions on paleoclimate and paleoenvironment in ecological manner (e.g. Escudé et al, 2013; Popov et al, 2014; Bennasar et al, 2016; Lopez-Garcia et al, 2017) or taphonomic studies (e.g. Jenkins, 2012). Research on these subjects surely contributes to the Quaternary science.

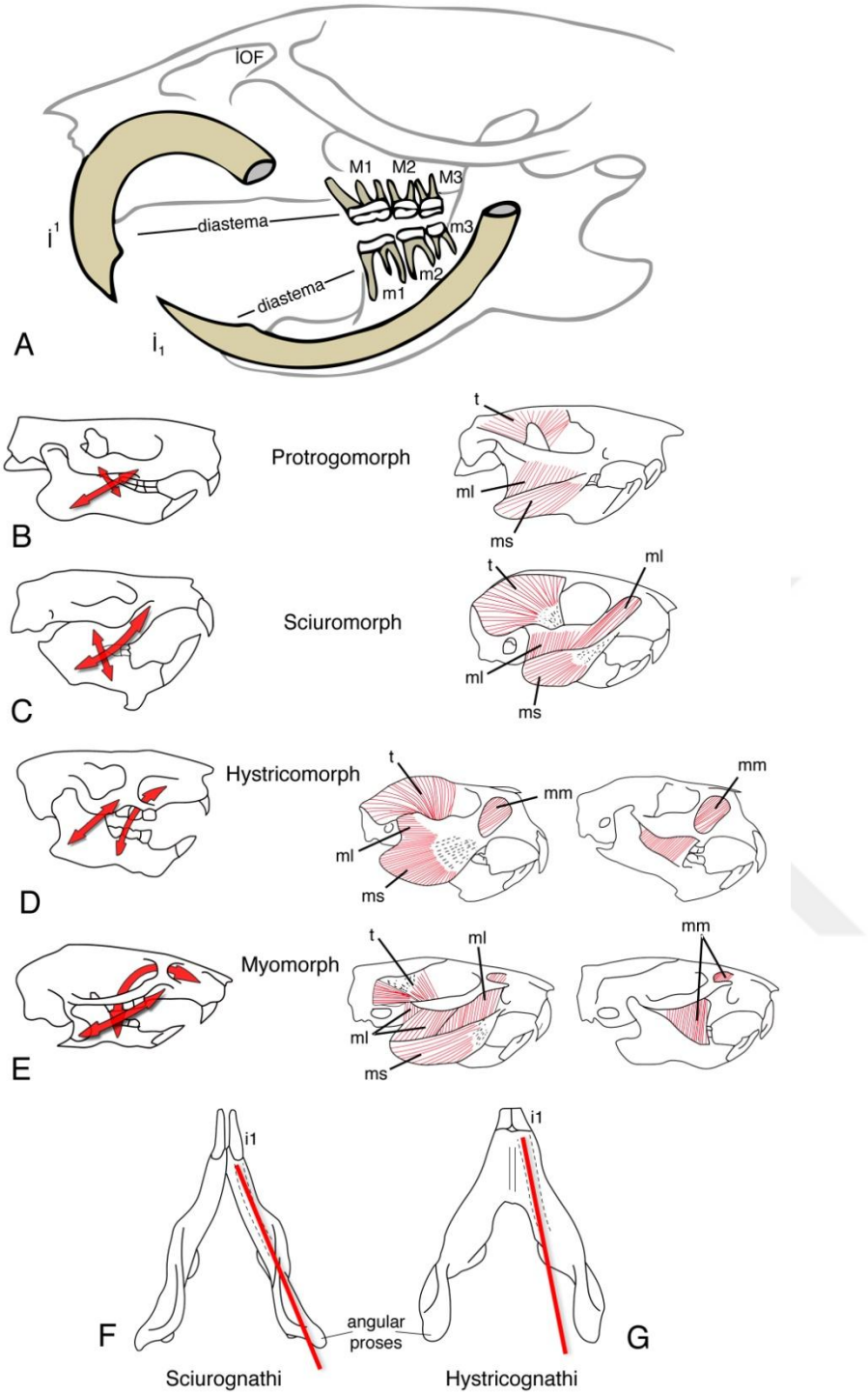


Figure 1.4 : (A) Some morphological features of rodents displayed in lateral view of generalized skull, mandible and teeth (modified after Hillson, 2005), (B–E) four types of zygomasseteric muscle system and (F–G) two mandibular morphology based on the plan of incisor-angular process which are both used for suprafamilial classification (modified after Carroll, 1988 and Benton, 2015). İ and i, upper and lower incisors; M1–M3 and m1–m3, upper and lower molar series; İOF, infraorbital foramen; t, masseter temporalis; ml, masseter lateralis; ms, masseter superfcialis; mm, masseter medialis.

1.2.1 Morphological features and general classification of small mammals

One of the most common characteristics of all rodents is their incisor teeth in the upper and lower jaws which are suitable for continuous gnawing just because they continue growing by lack of roots, as they are worn. These teeth may take a chisel shape as the anterior hard and thick enamel layer is worn much later than dentine during gnawing, thus it is highly functional against hard materials such as wood, nuts, seeds or fruit shells.

There is a gap called diastema between the incisors and the cheek teeth on the right and left of the lower and upper jaws. In other words, canine and premolars are completely lost in most species, although some of them preserve one premolar or two premolars in each half jaw such as squirrels (Figure 1.4.A). Rodents developed specific molars morphology adapted to different food types. In addition, the cranio-mandibular muscles responsible of jaw movements display a zygomasseteric muscle system grouped into four types, in regard to their connection type and to the differentiation of the fossa in front of the eye (infraorbital foramen, IOF). These four types of structures are used to roughly divide rodents into four groups (Figure 1.4.B–E). Besides, rodents can also be classified into two groups as Sciurognathi and Hystricognathi, depending on their jaw structure (Figure 1.4.F–G; see Wolff and Shermann 2007, table 2.2).

Jaw muscle systems are named and grouped as following; (1) “protrogomorpha” as seen in today's mountain beaver (*Aplodontia rufa*) is characteristic in fossil forms from the Eocene–Oligocene which have a relatively more primitive structure, (2) “hystricomorpha” which contains porcupines and guinea pigs, (3) “sciuromorpha” seen in rodents such as squirrels and beavers and (4) “myomorpha” specific to groups such as field voles, house mice and hamsters. The main distinctive feature is the connection of the muscles *masseter temporalis*, *masseter medialis*, *masseter lateralis*, *masseter superficialis*, and the location and structure of the infraorbital foramen (Figure 1.4.B–E). In particular, the medial masseter muscle is increasingly attached further away to the nasal bone in the last three groups (Wood, 1965; Carroll, 1988; Hautier et al, 2008; Benton, 2015). Originally introduced by Brandt (1855), these four groups were studied by some authors and used as suborder level of classification: Anomaluromorpha – “scaly-tailed flying squirrels-like rodents”, Castorimorpha – “beavers-like rodents”, Sciuromorpha – “squirrels-like rodents”,

Hystricomorpha – “porcupines-like rodents” and Myomorpha “mouse-like rodents”, respectively (Musser and Carleton, 2005).

On the other hand, Tullberg (1899) proposed a bifurcated suborder classification (Sciurognathi and Hystricognathi) according to the morphological structure of the mandible mentioned above (i.e. relative position of the angular process relative to the plane of the incisors). While the angular process in the sciurognath jaw structure is in the same plane with incisors (Figure 1.4.F), it occurs more to the side in the hystricognath rodents (Figure 1.4.G). Although the validity of this classification remains controversial, the only taxon with Hystricognath lower jaw morphology is the hystricomorphs (Musser and Carleton, 2005) and all extant rodent species represented in Turkey, to date over 60 according to Krystufek and Vohralik (2001), are included in the Sciurognathi suborder (see also Krystufek and Vohralik, 2005).

The high diversification of rodent families and species involved small differences in their cranio-mandibular morphology, for some taxa even in molar morphology (e.g. Murinae) throughout their gradual evolution following the gradually changing environmental pressures on their ecological and nutritional needs; it is yet resulted in an important evolutionary successes.

Morphological features observed in the cranio-mandibular structure, in jaw muscles connections and in teeth are possibly occurred independently in rodent taxa several times, which lead to a mosaic evolution (Hautier et al, 2011). As a result, phylogenetic studies conducted in living rodent groups show that these classifications above family levels are not very trustworthy. As a solution, it is suggested that the fossils should be elaborated by morphometric studies (Hautier et al, 2008, 2011 and references therein).

It is of course not easy to perform systematic studies on such a “large” group of mammals that have achieved this much evolutionary success, whether at species, family or suborder levels. However, although there are often minor differences in practice, the accumulation of knowledge over one century on the skeletal and dental morphology of extant and fossil rodents allowed global recognition of major groups, and thus provided a relatively stable systematics. In this manner, the work of Musser and Carleton (2005) is considered as a widely accepted key-reference in rodent systematics. In the systematic studies, the extant species can be evaluated both in

molecular and morphological aspects, while fossil species can only be examined on a morphological basis.

As to reveal phyletic relationships, the observed molecular and / or morphological characters are used in phylogenetic analyses. These analyses may give different results depending on selected species, characters, geological time, fossil abundance and samples as well as molecular samples (Erdal, 2017, figure 2).

In this thesis, the taxonomic levels proposed by Musser and Carleton (2005) are followed; as one of consequences, the subfamily Arvicolinae is grouped under the family Cricetidae rather than Arvicolidae.

1.2.2 Teeth

In a paleontological study, all of the observed and informative features on fossil material are essential to obtain a detailed morphological description which allows a systematic study at the lowest degree (i.e. genus or species). Although, it is emphasized in the previous section that cranial and jaw morphologies are used for higher rank in classification, analyses performed on teeth are still very useful in small mammal paleontology. Teeth, and in particular molars, show very great morphological differences between families as a result of evolution, especially among rodents (Figure 1.5). Some information like genus/species identification, individual age, feeding type, predation occurrence, diseases etc. can be inferred from teeth. Since teeth are the hardest element of the skeletal components with enamel tissue in the outermost layer of the tooth, which contains 96% bioapatite, they are highly resistant to taphonomic processes and therefore, it is more likely that they appear in fossil material with the highest chance of reaching to the present. Hence, teeth are the most common and precious specimens in the fossil records (Saraç, 2003; Clementz, 2012).

It is known that teeth play an important role in nutrition and that they adapt their feeding abilities on the vegetation that changes under climatic and environmental affects. As a consequence, changing vegetation plays a major role on herbivorous mammal adaptation, either by migration or by evolving molar morphologies parallel to evolved vegetation. The latter fits to rodents, most of which are herbivorous, having different tooth morphologies emerged by following different habitat-

vegetation preferences all along the lineages from which they are evolved (Figure 1.5). Morphological differences, especially observed on the occlusal side of the teeth, are gradually increased from the interspecific level towards higher taxonomic levels, such as genera, subfamilies, or families. However, as some specimens having slight variations can be attributed to different species although they may be synonyms, some others are classified as the same species due to identification difficulties because of these interspecific variations. On the other hand, teeth are subjected to wear during the lifetime of an individual. The degree of wear is proportional to the individual age. Therefore it is critical to select fossil specimens, if available, less damaged and less worn. The anatomical properties of teeth are described using the accepted nomenclature and terminologies although there are some slight variations (e.g. Mein and Freudenthal, 1971; Meulen, 1974; Pasquier 1974; Rabeder, 1981; Rekovets and Nadachowski, 1995; Sarica and Sen, 2003; Hordijk and de Bruijn, 2009; García-Alix et al, 2009; Lazzari et al, 2010). Some of the main properties are the shape of the occlusal surface; forms, connection, length and directions of valleys and ridges (e.g. lophs, cusps, secondary cusps, crests, etc.); enamel thicknesses; measurable features such as width-length-height; some proportional ratios; the number and structure of roots.

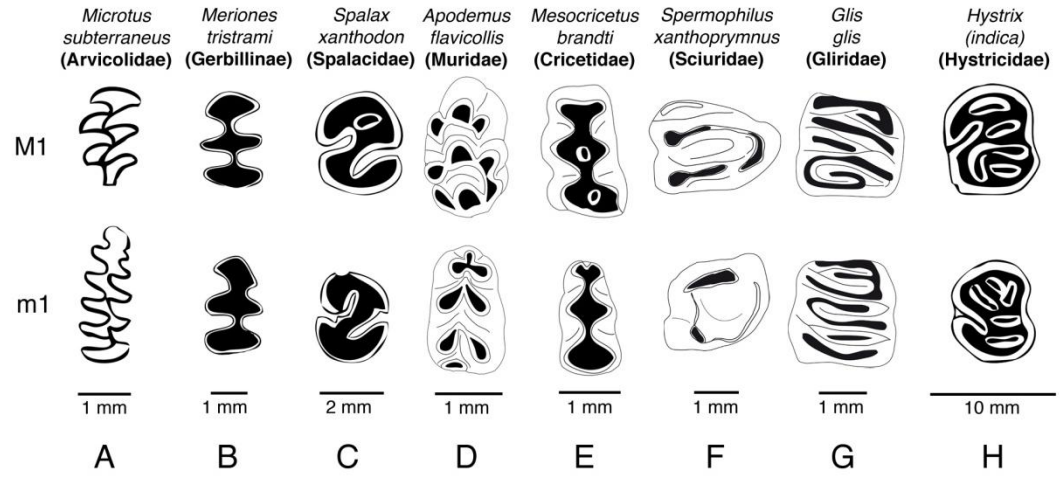


Figure 1.5 : The representative upper and lower first molars of some extant species and relevant families from Anatolia (modified after Krystufek and Vohralik, 2005, 2009). Myodonta: (A) common pine vole, (B) Tristram's jird, (C) Anatolian mole rat, (D) Yellow-necked wood mouse, (E) Turkish hamster; Sciuroidea: (F) Anatolian ground squirrel, (G) Common dormouse; Ctenohystrica: (H) Indian porcupine.

The species richest group of rodents is Myomorpha (=Myodonta) with sciurognath jaw structure, including all Muridae and closely related taxa. This family, which emerged in the early Eocene, has been strikingly diversified since the Miocene. The superfamily Muroidea within Myodonta constitutes the two richest families of all rodents: Muridae and Cricetidae as both constitute the most abundant fossil material of this thesis.

One of the most important taxon from the family Cricetidae is the arvicolines (Subfamily Arvicolinae), in other words, field voles (Figures 1.5 and 1.6). This group, which has undergone a significant continuous morphological evolution from the Early Pliocene to Pleistocene and during the Holocene, deserves a special attention among the rodents with its biostratigraphic significance. Some researchers, such as Meulen (1973), Maul (1996), Fejfar et al. (2011), advocate grouping arvicolines in a family rank, Arvicolidae, due to their rich specific diversity, instead of a subfamily Arvicolinae within Muridae (Krystufek and Vohralik, 2005) or Cricetidae (Carleton and Musser, 2005; for other examples see Krystufek and Vohralik, 2005, table. 30). Whether family or subfamily, arvicolines offer a diversity of more than 100 species, especially in the Northern Hemisphere. Their geographic radiation throughout the Quaternary provides key data to constrain age of depositional environments and their correlations. The teeth that have undergone the most significant modifications in this group are the first anterior molar (m1) in the lower row and the third posterior molar (M3) in the upper row. Therefore, they are considered as the most informative molars by means of biostratigraphy and taxonomy. One of the most striking examples of intensive studies focused almost exclusively on these two molars belongs to Rekovets and Nadachowski (1995) for the Pleistocene arvicolines of Ukraine.

1.2.3 Evolving characters and biozones

The age constrain of layers in the basins involved in this thesis is based on identification of fossil specimens after an anatomical comparison, supported by the morphological observations and many measurements, with previously known fossil material. This aims to identify the genus and species, which therefore, using its evolutionary stage in its lineage, would allow to deduce a time interval (i.e. its age or its biozone). These biozones are built by previous studies through distinct evolving

characters in time of before mentioned special group, the arvicolines or their first/last appearance in the fossil records (Figure 1.6). Therefore it is important to provide general information concerning the evolution of arvicolines.

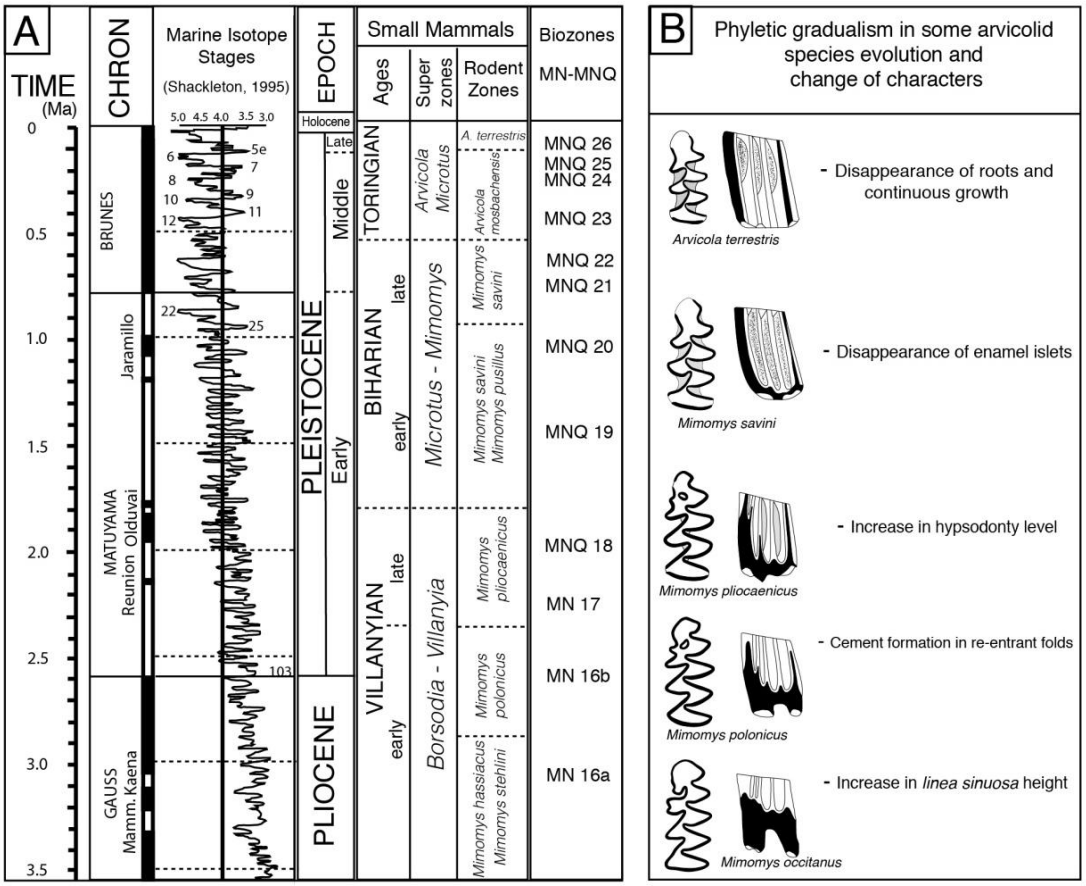


Figure 1.6 : A combined chart concerning the second half of Pliocene and Quaternary which involves (A) geological timescale, polarity chrons, marine isotope stages, epochs and ages after micromammalian biozones (adapted from Masini and Sala, 2007 and Popov, 2017); (B) Phyletic gradualism in Mimomys–Arvicola lineage displaying some gradually changed characters observed on m1 (adapted from Neraudeau et al, 1995 and Chaline et al, 1999).

The first change observed in the evolution of arvicolines is the gradual increase of the crown height in molars; in other words, brachydont molars (tooth occlusal length ≥ crown height) change over time towards hypsodonty (crown height ≥ tooth occlusal length) (Figure 1.6.B). Since this continuous elongation is not at the same rate as the enamel, enamel free areas start forming on both molar occlusal surface and the lateral sides. Those results in variations / undulations throughout the boundary line between enamel layer and dentine field called *linea sinuosa* in lateral sides of the molar. Another prominently variable feature is the structure and number of the indentations and protrusions; re-entrant and salient folds forming a kind of

angle in occlusal view. In addition, two enamel dependant characters also are extensively used; the enamel islets generally found on occlusal surface of m1 and M3 of primitive species and the ratio of *Mimomys*-folds presence in the population. Both enamel dependant characters tend to decrease during the Late Pliocene and eventually to disappear (Lozano-Fernandez et al, 2013).

As well, molar roots disappeared completely in many groups and it allowed many species to develop molars with continuous growing (hypselodont) during the second half of Middle Pleistocene. The formation of crown cement was observed in the re-entrant folds in many arvicoline lineages, and in some, the chewing surfaces have become more complex with the addition of new triangular structures, and thus further elongated mesio-distally. The thickness of tooth enamel displays variations in time. For instance, the thickness in the lower teeth does not show much differentiation in various parts of the tooth, as seen in early taxa such as Pliocene *Mimomys*, which is a fossil genus; while this differentiation is very prominent in extant *Microtus* species (Rabeder, 1981; Carls and Rabeder, 1988). In general, the dominant species of the Pliocene rodent fauna have rooted teeth with relatively shorter crowns (e.g. *Mimomys polonicus*). In many groups of Pleistocene arvicolines, the teeth began to lose their roots, gradually became hypsodont and finally appear nowadays with the other morphological changes mentioned above (e.g. complexity of occlusal surface, mesio-distal elongation, appearance of cement etc.). The leading factor causing these changes is the increasing colder climate. The fact that an increasing colder climate during Pliocene–Pleistocene with increasing drought has a direct impact on vegetation, and consequently on feeding habits depending on more abrasive nutrients, which explain the evolving characters against tooth wear in aforementioned rodents. Although the changes here are seen as a part of a phyletic gradualism, the evolution of this group does not occur simultaneously in different lineages and regions. The evolutionary history of this group is still debated, hence reflecting the importance of arvicolines for Quaternary research (see Koenigswald and Kolfschoten 1996; Fejfar et al, 1997, 2011; Chaline et al, 1999; Maul et al, 2000, 2014; Maul and Markova, 2007; Kalthoff et al, 2007; Bogicevic et al, 2012, 2017; Lozano-Fernandez et al, 2013; Kolfschoten, 2013; Rook et al, 2013; Rekovets et al, 2014a and references therein).

Concerning the evolution of certain species of arvicolines and their first/last occurrence in geological time, especially in Eurasia, the *Mimomys savini–Arvicola mosbachensis–Arvicola terrestris* lineage documents the transition between the Middle and Late Pleistocene. *M. savini*, a fossil species with rooted molars is replaced by *A. terrestris* with rootless and continuously growing teeth. *A. mosbachensis*, also a fossil species emerged in the Middle Pleistocene, provides both temporal and morphological link between *Mimomys* and *A. terrestris*, either by exhibiting incomplete root structures in some populations (e.g. Maul et al, 2000), and by displaying negative enamel thickening. Although the co-occurrence of *Arvicola* and *Mimomys* species is considered a rare condition in the late Early Pleistocene (late Biharian) European fauna (Sen et al, 1991), they have been found together in the Emirkaya-2 locality (Seydişehir) which constitutes a kind of example of transitional fauna in Anatolia (Sen et al, 1991; Montuire et al, 1994). The lineage forming the biozones of the later stages of Early Pleistocene is *Microtus* (*Allophaiomys*)–*Microtus* (*Microtus*), already lacking roots. Besides changes in tooth enamel thickness, the genus *Microtus* over time is represented by new species with more complex tooth occlusal morphologies, as well as with wide geographical dispersion (e.g. *M.* (*Stenocranius*) *hintoni*, *M.* (*Stenocranius*) *gregaloides*, *M.* (*Stenocranius*) *gregalis*, *M.* (*Terricola*) *arvalidens* and *subterraneus*, *M.* (*Microtus*) *arvalis*; Maul and Markova, 2007 and references therein). The most important lineage in Pliocene–Early Pleistocene is *Mimomys occitanus-Mimomys hajnackensis-Mimomys polonicus-Mimomys pliocaenicus* (Figure 1.6; e.g. Maul and Markova, 2007; Fejfar et al, 2011).

The extensive geographical distribution of lineages mentioned above throughout the Quaternary, their relative abundance in the fossil records, and their rapid evolution, allow them to be the key fossil groups for land biostratigraphy. The Quaternary is divided into many biostratigraphic units by criteria such as the presence (first appearance), absence (extinction), coexistence, and abundance (dominance) of certain taxa in a particular geological time interval. An outcome of these information provided to use land mammal ages technique (mammal age; *sensu* Fejfar and Heinrich, 1990) for relative dating and to provide correlation. As similar ages used for large land mammals biostratigraphy (e.g. Villafranchian, Galerian), as to small mammals, Kretzoi (1965) proposed three basic age ranges which are later developed

for Early and Middle Pleistocene and widely used in the Quaternary. These are Villanyian, Biharian and Toringian (Figure 1.6.A). Note that the Pleistocene lower boundary was moved back from 1.8 Ma to 2.58 Ma (Gibbard and Head, 2009a, b; Gibbard et al, 2010) and therefore, somewhat a late part of the Villanyian, is consequently included in the Quaternary. Those three ages are also considered as three separate super zones and each are constrained with different assemblage zones of rodent lineages mentioned before (See Figure 1.6.A, "Small Mammals" and Figure 1.6.B). In the Villanyian fauna, the *Mimomys* species appear to be predominant, the *Microtus* species are absent or very few. As for the Biharian, *Microtus-Mimomys* species generally appear together. During Toringian, *Mimomys* is replaced by the *Arvicola* species. The largest and most severe rodent faunal turnover occurs between the Villanyian and Biharian, with the emergence of *Microtus* (*Allophaiomys*) species that have lost their roots. While this event was formerly dated as the beginning of the Olduvai geomagnetic chron, it also seemed to indirectly support the Pliocene–Pleistocene boundary at 1.8 Ma. However, Tesakov (1998), based on his findings in the Tegelen fauna, suggested that this faunal change coincided with a time interval much earlier than the Olduvai reversal (2.1–2.2 Ma). Nevertheless, dating the boundary between early Biharian–late Biharian before the Jaramillo reversal, where lineages of the *Microtus* (*Allophaiomys*) species gone extinct, a general consensus has been established. The Biharian–Toringian transition (~0.5 Ma) is marked by replacement of *Mimomys savini* by *Arvicola*. However, Maul and Markova (2007) state that the *Mimomys* species survived in Eastern Europe for a longer period of time compared to in Western Europe (Fejfar and Heinrich, 1990; Kolfschoten, 1992, 2013; Maul, 1996; Koenigswald and Kolfschoten, 1996; Fejfar et al, 1997, 2011; Chaline et al, 1999; Maul and Markova, 2007; Sala and Masini, 2007; Popov, 2017).

In addition to mammalian ages, superzones and rodent zones, another system has been developed in Europe which is widely used in the relative dating of the Paleogene, Neogene and the Quaternary. The Paleogene is divided into 30 zones (Mammal Paleogene, MP1–30; Schmidt-Kittler et al, 1987) and the Neogene into 17 zones (Mammal Neogene, MN1–17; Mein, 1975, 1989; de Bruijn et al, 1992), based on the genus or species of both large and small land mammals, and also by considering their first appearance in the fossil records as well as their assemblage or

abundance zones. Finally, the Quaternary has been divided into 9 zones (Guérin, 1989) as MNQ18–26 succeeding from MN17, which corresponds to the late Villanyian, although different suggestions have been proposed by certain studies (e.g. Cordy, 1982). As a result of moving recently the lower limit of the Quaternary back to 2.58 Ma, part of MN17 is henceforth part of the Quaternary. For a brief history of these zones, see Guérin (1989) (see Figure 1.6.A, France MN–MNQ).

Following the same idea of these zones, a new zonation of land mammals for Anatolian Neogene Period has been proposed after some genus and species of Muroidea and Dipodoidea superfamilies. Based on the Anatolian-European species comparison, zones between MP30–MN17 are correlated to 16 zones as A–P starting from the Late Oligocene (Chattian or Arvernian) to the end of Pliocene (Ünay et al, 2003, table 1). It should be noted here that the Anatolian "P" zone, which corresponds to MN17, should be included in the Early Pleistocene, in other words, into Quaternary (e.g. Hoek Ostende et al, 2015a). Nevertheless, the zonation of Ünay et al. (2003) is not referred in that thesis.

1.3 Previous Studies on Small Mammals in Turkey

Although veritable studies in paleontological domain started much later in Turkey compared to European countries (e.g. Kiessling et al, 2010; Servais et al, 2012), the current situation does not show a pleasing picture according to statistical work of Nazik and Özer (2013). Possible reasons of this state are presented by Sen (2016) in detail, taking into account all the historical developments.

1.3.1 Small mammal paleontology studies between 1975–2012

The first detailed and coherent study on findings of small mammals in Turkey, is a doctoral thesis conducted at the National Museum of Natural History in France (Muséum National d'Histoire Naturelle-MNHN, Paris) (Sen, 1977). In his study, he carried out systematic, phylogenetic, biogeographic and paleoecological examinations of nine rodents and one rabbit species obtained from a very rich fauna in both vertebrates ("reptiles", birds, amphibians and mammals) and some invertebrates (e.g. gastropods) at the Pliocene Çalta locality (late Ruscinian, MN15)

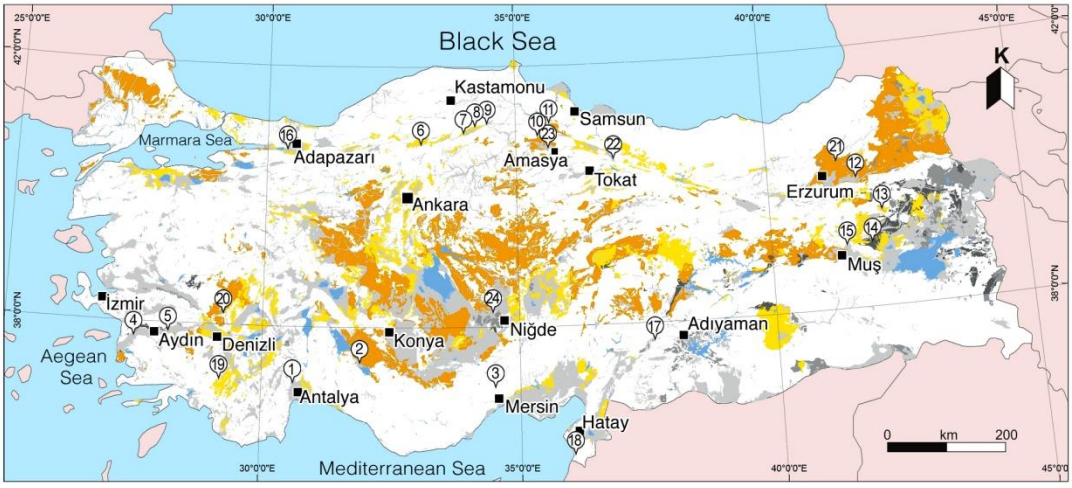
which is situated approximately 60 km north-west of Ankara (Sen, 1977; Sen et al, 1998; see also Sen, 2003).

Despite that more than fifty percent of land covered with Neogene and Quaternary sediment environments in Anatolia (Sen, 2003), and that there are more than 400 mammalian fossil localities discovered between 1950 and 2012 (Saraç, 2003, 2012), many of them have only been reported preliminary faunal lists without any description of material (see in particular Sickenberg et al, 1975). On the other hand, the highest numbers of known localities are from the Miocene (i.e. Late Miocene with 176, Middle Miocene with 63 and Early Miocene with 47 localities). Although the time interval of the Pliocene was shortened and partially included into Quaternary, there are 70 discovered and studied localities from the "shortened" Pliocene. As to Quaternary, it is still and relatively poor by means of discovered and excavated localities (Saraç, 2012; Erdal, 2017).

Quaternary paleontology studies in Turkey began with Sickenberg et al. (1975) and 11 of 19 publications concern small mammals among 37 reported fossil sites (Saraç, 2003), (Figures 1.7.1–17, Storch, 1988; Sen et al, 1991; Hír, 1992, 1993a; Montuire et al, 1994; Ünay et al, 1995; Ünay and de Bruijn, 1998; Ünay and Göktaş, 1999; Ünay et al, 2001; Suata-Alpaslan, 2011a, b).

Following the chronologic order of studies, the first one involves the work of Sen et al. (1991) from karstic fissure fillings at the Pleistocene Emirkaya-2 locality (Figure 1.7.2) south of Seydişehir. In addition to the remains of amphibians, "reptiles" and birds, 28 mammal species of which 16 are rodents and they are detailed in systematic and paleoecological approaches later by Montuire et al. (1994). The most important aspect of the studies in this locality is the coexistence of *Mimomys savini* and *Arvicola mosbachensis* (= *cantiana*), rarely found in the late Biharian rodent fauna in Europe. In other words, the coexistence of these two species indicates the late Biharian–early Toringian boundary.

On the other hand, Hír (1992, 1993a, b) studied the Holocene sub-fossils (e.g. *Mesocricetus, Cricetulus, Allocricetus,* etc.) in a cave at 3000 meters altitude north of Karagöl in the Bolkar Mountains (Mersin) and provided important morphometric and morphological data for this period. (Figure 1.7.3).



1- Karain-B
2- Emirkaya-2
3- "Karagöl" mağarası
4- Kemalpaşa Mahallesi 1-2, Havutçulu, Moralı, Kürttepe, Bozköy, Burçaktepe
5- Şevketin Dağı
6- Sivricek
7- Kumkapı
8- Karasapaca, Sapaca
9- Ortalıca
10- Hamamayağı
11- Yenice 1-2
12- Pekecik
13- Kaşkaldak
14- Ziyaret
15- Çataklı
16- Değirmendere, Çaybaşı, Kumbaşı
17- Gölbaşı
18- Üçağızlı Mağarası
19- Bıçakçı
20- Gökpınar
21- Yayladağ
22- Umurlu
23- Kurnaz, Kerimoğlu, Kızıleğrek, Yolpınar
24- Tepecik-Çiftlik

References of localities: (1) Storch, 1988; (2) Sen et al, 1991; Montuire et al, 1994; (3) Hir, 1992, 1993a; (4) Ünay et al, 1995; Ünay and de Bruijn, 1998; Ünay and Göktaş, 1999; (5) Ünay et al, 1995; Ünay and de Bruijn, 1998; (6) Ünay and de Bruijn, 1998; (7) Erdal et al, in prep.; (8) Ünay and de Bruijn, 1998; Erdal et al, in prep.; (9) Ünay and de Bruijn, 1998; Erdal et al, in prep.; (10–15) Ünay and de Bruijn, 1998; (16) Ünay et al, 2001; (17) Suata-Alpaslan, 2011a; (18) Suata-Alpaslan, 2011b; (19) Hoek Ostende et al, 2015a; (20) Erten et al, 2015; Erten, 2017a,b; (21) Vasilyan et al, 2014; (22) Erdal et al, 2018; (23) Erturaç, 2010; Erturaç et al, 2019.; (24) Erdal et al 2019.

Figure 1.7 : Dispersal of late Neogene–Quaternary deposits on the Geological Map of Turkey at 1:500,000 scale and location spots concerning 37 localities where 20 studies (completed or ongoing) are conducted for micromammalian paleontology of Quaternary in Anatolia (modified after Erdal, 2017).

Ünay et al. (1995) suggested four biochronological ages (i.e. late Villanyian, late Villanyian–early Biharian, late Biharian–early Toringian and Toringian) for the northern part of the Büyük Menderes graben (North-East of Söke, Aydın and near Nazilli), based on the evolutionary phyletic succession and the presence/absence of arvicoline *Microtus* (*Allophaiomys*) species collected from several localities in the graben (Figure 1.7.4–5). Later, Ünay and Göktaş (1999) examined the sediments in the western part of Söke and revealed their findings with a generalized stratigraphic section comprising a part of the previous study with a few new localities (Burçaktepe, Biharian–present; Figure 1.7.4).

In addition to the revision of Büyük Menderes graben fauna, Ünay and de Bruijn (1998) studied some rodent faunas from many localities at Tosya, Çerkeş and Havza basins situated on the North Anatolian Fault Zone, and Pasinler and Muş basins in the east (Figure 1.7.4–15). In fact, as the authors have pointed out, this study should be considered as a "discovery/preview", since very few samples have been taken and

examined from many localities. Fossil materials and species, although not many in number, are promising in terms of richness of the localities. Nevertheless, the specific species examined give an idea of the age of the relevant localities and, to a lesser extent, the paleoecological environment.

In these studies (except Ünay and Göktaş, 1999) unfortunately, the main deficiency is that the layers where the fossils were obtained are not shown in a stratigraphic section. Therefore, it is quite difficult to situate the fossil bearing horizon in the stratigraphy of the basin, to evaluate the correlation of localities close to each other, to determine the opening and deposition times of the basins or interpreting faunal succession. In the lack of stratigraphic information, for instance, it is difficult to correlate the strata of Yenice-1 (MN16), Hamamayağı (Biharian) and Yenice-2 (Toringian) localities all in the Havza Basin (Samsun) since the closest localities of Yenice display hence a two million years of gap between MN16–Toringian (Ünay and de Bruijn, 1998). However, the authors complain about the intense tectonic activities in this basin which cause a difficulty for understanding the superposition of the localities. Another important point is that in these articles, MN17 or late Villanyian is included in the Pliocene period, at the time they are written. For this reason, to interpret the study of Ünay and de Bruijn (1998) in the light of current information, 8 of the 22 localities of MN17 must be included in the Quaternary (e.g. Havutçulu, Bozköy, Şevket'in Dağı, Hamamayağı etc.).

Ünay et al. (2001) studied micromammal fossils from Değirmendere and Çaybaşı localities in the Karapürçek Formation and from Kumbaşı locality in the northern branch of the NAF in Adapazarı pull-apart basin. The richest faunal group in all three localities consists of arvicolids, with a new species identified from this group as *Tibericola sakaryaensis* (= *Microtus* (*Allophaiomys*) *sensu* Agusti, 1991) (Figure 1.7.16). They proposed a late Villanyian–early Biharian (Early Pleistocene) age for Değirmendere and Kumbaşı localities, and late early Biharian for the younger Çaybaşı locality based on comparison of their fossil assemblage with European specimens. Interestingly, since the late Villanyian was a part of the Late Pliocene at that time, they declared the formation of the Adapazarı Basin as Late Pliocene and supported this with other studies (e.g. Toker and Şengüler, 1995; Emre et al, 1998). Nevertheless, the age of these localities must be Early Pleistocene, indicating that the deposition in this basin started in Early Pleistocene or slightly earlier. As a result, it

may be useful to update and improve this study, either in the light of new locality or new fossil findings, or by revising the material somehow stored in a collection.

In a study of Suata-Alpaslan (2011a) at Gölbaşı near Adıyaman (Figure 1.7.17) six genera and four species of three rodent families are identified but it has to be revised and clarified, due to some confusion as mentioned in the problematic of the study (see section 1.1). As to age of the locality, she proposed late Biharian–early Toringian (ca. 0.6–0.5 Ma) based on findings of *Mimomys–Arvicola* transition since "rooted" and "rootless" molars were found together in arvicolid specimens, similar to fauna of Emirkaya-2.

Suata-Alpaslan (2011b) also investigated the Üçağızlı Cave (Figure 1.7.18) in the southwest of Hatay, which yielded small mammal fauna obtained from Epipaleolithic and Upper Paleolithic layers (41–17 ka). The Late Pleistocene rodents in this cave indicates that there is no morphological difference, at least within the eastern Mediterranean populations, when the rodent fauna in equivalent layers of the Karain-B cave 30 km northwest of Antalya (Storch, 1988) and actual specimens at the Hatay region are concerned.

1.3.2 Small mammal paleontology studies after 2012

Since the list of Quaternary mammal localities provided by Saraç (2012), new ones have been added to the list and it is important to sum the state of the art on paleontology in Turkey. For instance, the rich rodent fossil remains from the Bıçakçı locality (Figure 1.7.19) in the Neogene–Quaternary Çameli Basin (South of Denizli) are one of these (Hoek Ostende et al, 2015b). In addition to the paleoecological deductions, this study has made valuable contributions to the literature of Anatolian small mammals, especially in terms of systematic paleontology.

In another study at the Denizli Basin, Erten et al. (2015) described rodent fossils from seven new localities, ranging in age mostly between MN6–MN9 (Middle Miocene) and one from Early Pleistocene (MNQ18–19; late Villanyian–early Biharian). A new fossil species of *Mus* (*Mus denizliensis*) as the first fossil discovery of the extant genus in Anatolia was identified from the Gökpınar locality (Figure 1.7.20). Following studies at the same locality emerged a new genus and species of Muridae (*Extrarius orhuni* Erten, 2017a) and a new species of the genus *Spalax*

(mole-rats; *Spalax denizliensis* Erten, 2017b). Though what makes *Extrarius* intriguing here is that there is no material yet to reveal the origin of this genus or its evolutionary relationship with possible relative groups (Erten, 2017a). The discovery of new *Spalax* at Gökpınar locality on the other hand, is important for three reasons: (1) the Spalacidae family is accepted by many authors as monophyletic taxon despite their confusing molar morphology (Ünay, 1996; Sarica and Sen, 2003; Sen and Sarica, 2011), (2) that is the younger fossil specimen of the *Spalax* genus in Anatolia, compared to *S. odessanus* as known the youngest fossil species known so far, from the Pliocene (MN15) of Ukraine and Greece (Topachevski, 1969; de Bruijn, 1984); (3) the evolution of this family started in Anatolia during the Early Miocene and therefore, further examination of Anatolian spalacids is suitable to enhance interesting results in terms of stratigraphy and elucidation of ambient conditions. Consequently, as the author pointed out, *S. denizliensis* being the youngest and the first fossil of its genus from Anatolia, it may be useful to better understand the phylogeny, evolution and adaptation of this family in later studies.

An Early Pleistocene locality in the Pasinler Basin (Erzurum) (Figure 1.7.21), yielded not only rodents, but also gastropods, bivalves, amphibians, bony fishes (Teleostei) and "reptiles" (Vasilyan et al, 2014). The only small mammal fossil found in this locality, *Microtus* (*Allophaiomys*) cf. *pliocaenicus* provided an age of 1.5–1 Ma (early Biharian) for the basin. This study is important also for paleoclimatical and paleoecological assumptions.

The examples resumed above with locations shown on the map (Figure 1.7), point out that old and new studies on Quaternary small mammals are mostly focused in Western, Northern and Eastern Anatolia regions. Along the North Anatolian Fault (NAF), which is very important in terms of active tectonic and geological aspects, time interval for basin formations under the control of this fault is not fully enlighten. However, stratigraphy, sedimentology and palynology studies in the region provided valuable information about the chronology and Neotectonic evolution of these basins, and the age of initial basin opening is generally accepted as Late Miocene (e.g. Irrlitz, 1972; Barka, 1985; Aktimur et al, 1992; Barka, 1985). Nonetheless, studies involving small mammalian paleontology are limited (Ünay and de Bruijn, 1998; Ünay et al, 2001; Erturaç, 2010; Erturaç and Tüysüz, 2012; Erdal et al, 2018; Erturaç et al, 2019).

This thesis on small mammals is being carried out with the aim of discovering new localities as well as acquiring new materials in three basins developed along the NAFZ in order to enhance the biostratigraphic knowledge and also to train small mammal paleontology specialists, which are currently very few in Turkey. These basins involving Quaternary sediment packages are as follows: Niksar (Tokat; Erdal et al, 2018), Suluova (Amasya; Erturaç et al, 2019) and Tosya (Kastamonu; Erdal et al, *in prep.*) (Figure 1.7.7–9, 22–23).

In addition, the rodent fauna gathered for the first time from the Tepecik-Çiftlik Neolithic archaeological excavation (Niğde province) since 2000 was studied by the author during the preparation of this thesis (Figure 1.7.24; Erdal et al, 2019).

Although it is decided to do not include this study in the present thesis, because the locality is not on NAFZ, the thesis author used this unique opportunity to increase our knowledge on the Holocene rodents from Central Anatolia. The Neolithic Tepecik-Çiftlik excavation site is one of the oldest mound-shaped human settlements in Anatolia (Figure 1.7.24; Erdal et al, 2019). This mound extends from the Late Neolithic to the Roman-Byzantine period according to the layers that contain the remains of five different civilizations. Levels from which rodent fauna were obtained dates back to ca. B.C. 6650–5900. (Bıçakçı et al, 2012, 2017). In this excavation so far, *Microtus* (field vole), *Arvicola* (water vole), *Mus* (house mice), *Spermophilus* (ground squirrel), *Mesocricetus* (hamster) and *Spalax* (mole-rat) species have been identified by abundant jaws and molars specimens. Paleoecological deductions were obtained by comparing them with the current fauna of Central Anatolia. The taphonomy of these groups was addressed as much as possible according to the trench units and levels in the excavation area. Considering the common habitat characteristics of the species, a dry steppe environment dominated by sparse vegetation or perennial short meadows is observed. On the other hand, the presence of *Arvicola* indicates that there may also be rivers or swamp like environments.

2. GEOLOGICAL SETTINGS OF STUDIED BASINS

The dextral strike-slip North Anatolian Fault (NAF), which forms the northern boundary of the Anatolian Plate, extends roughly parallel to the Black Sea coast for approximately 1500 km from Karlıova at East toward Greece at West. It forms a wide arc geometry between 26° and 40° East longitudes, within a deformation zone of varying width. The suture zones developed in the Tethys evolution of Anatolia and the deformation zone of the NAF overlap to a large extent. Secondary faults associated with the NAF and terrestrial basins developed parallel to them are defined as the North Anatolian Fault Zone (NAFZ), and it is defined as a zone extending from 100 meters to 120 km wide (Şengör et al, 2005; Erturaç et al, 2019).

The NAF is a prominent structure of a zone of deformation called the North Anatolian Shear Zone (NASZ; Şengör et al, 2005), which lies along the boundary between the Eurasian plate and the Anatolian microplate. Its dextral slip accommodates the counter clockwise rotation and westward escape due to the collision between the Arabian and Anatolian plates (Şengör, 1979; Reilinger et al, 2006). NASZ hosts many tectonic basins, which vary in size and origin, where their depositional history holds the key to the evolution of the NASZ (cf. Barka, 1985; Şengör et al, 2005).

Within this deformation zone, a tectonic corridor has developed with composite depression areas filled with Neogene and Quaternary sediments and occasional uplifts as a result of jumps, bends and bifurcations of the NAF line over time. There are 16 basins of varying sizes along the line from Erzincan to the Gulf of Izmit (Figure 2.1; Ketin, 1948; Şengör, 1979; Şengör, 1980; Barka, 1992; Şengör et al, 2005; Erturaç, 2010).

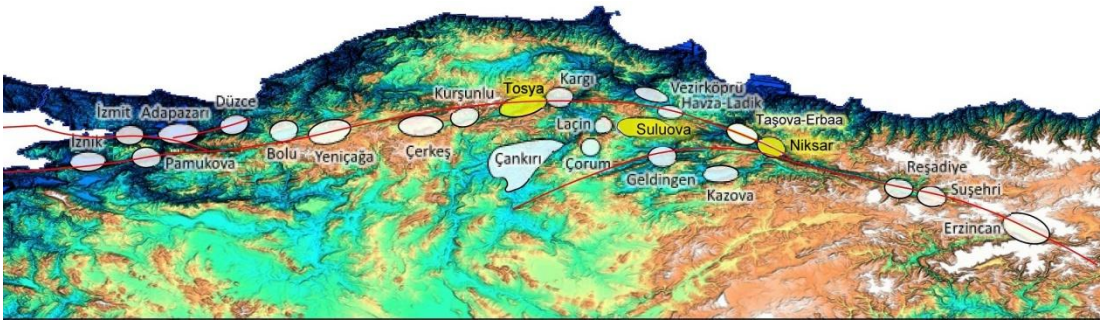


Figure 2.1 : Basins formed along the NAF and NAFZ including three studied basins coloured in yellow, Tosya, Suluova and Niksar as the scope of this thesis (modified after Erturaç, 2010).

Studies conducted within the scope of this corridor suggest that the oldest basins are Middle–Upper Miocene (ca. 12-5.5 Ma), while the youngest basins are younger than the Pleistocene (ca. 2.59 Ma) (Irrlitz, 1972; Barka, 1985; Koçyiğit, 1990; Kazancı, 1993; Andrieux et al, 1995; Barka et al, 2000; Ünay and de Bruijn, 1998; Ünay et al, 2001; Şengör et al, 2005; Tarı, 2007; Erturaç, 2010; Sarp et al, 2013). However, there are relatively few studies concerning sedimentology and age control, both conducted together (*e.g.* NAF Basins: Ünay et al, 2001; Erturaç, 2010; Erturaç and Tüysüz, 2012; Çankırı Basin: Kaymakçı, 2000; Karadenizli, 2011). Especially paleontological studies conducted on Pliocene and Pleistocene deposits are very scarce (Saraç, 2003, 2012).

Even the initiation of those basins is not well determined; it is supposed and mainly accepted as Late Miocene, based on palinological data from lacustrine sediments (Irrlitz, 1972). Besides, recent palynology studies on the Suluova (Amasya) and Havza (Samsun) basins, point out Middle Miocene (Kayseri and Akgün, 2008) which refers to post collisional intra-mountain closed basin formation. Nevertheless, none of any paleontological material supports the Miocene age for those basins (Saraç, 2003) and unfortunately, the stratigraphic position of Plio-Pleistocene fossil vertebrate assemblages from those basins are unclear (Ünay and de Bruijn, 1998; Saraç, 2003).

The Niksar Basin is an important depression generated on NAFZ and situated at East. The previous studies such as those on stratigraphy and chronology of sedimentary deposits enlarged the knowledge on neotectonic evolution (Irrlitz, 1972; Barka, 1985; Aktimur et al, 1992; Ünay and de Bruijn, 1998; Barka et al, 2000; Suata-Alpaslan, 2003). However, many controversies exist upon those sedimentary

deposits. The depositional units of Niksar are displayed as limited outcrops around Kelkit Stream and formed by river deposits and alluvial fans at the edge of the basin. In a recent study, some molars of *Microtus arvalis* (Arvicolinae, Rodentia) are discovered around the Umurlu Village, which suggest a middle Pleistocene age which constrains the evolution time of Niksar Basin (Erturaç and Tüysüz, 2012).

The works on the Tosya Basin by many authors and on several aspects revealed detailed information of the structure of the basin (Barka and Hancock, 1984; Şengör et al, 1985; Andrieux et al, 1995; Dhont et al, 1998). The earliest deposition within the basin, the Devrez Formation, is claimed to be of Early-Middle Miocene but no fossil findings are discovered so far. However, in the only detailed paleontological work of Ünay and de Bruijn (1998) on the area, it is suggested "early–middle Pliocene" (late Ruscinian-MN15) for one locality bearing molluscs in greenish lacustrine clay deposits at Ortalıca Village (on Tosya-Merzifon road) based on micromammal fauna. Unfortunately, stratigraphic positions of those localities are uncertain.

2.1 Tosya Basin

In previous studies, all Neogene units deposited in the Tosya Basin were defined as Lower and Upper Pontus formations under the Pontus Group (Irrlitz, 1972; Barka, 1985). Among these formations, which are separated from each other by angular unconformity, Upper Miocene (Tortonian) ages are suggested for the Lower Pontus Formation and Lower Pliocene-Pleistocene ages for the Upper Pontus Formation (Irrlitz, 1972; Barka, 1985, 1992; Andrieux et al, 1995; Dhont et al, 1998). However, in the latest mammalian paleontology studies (Ünay and de Bruijn, 1998; Saraç, 2003), no evidence of Miocene age could be obtained in these basins. In these studies, the basement ages of the basin fillings were determined as Lower Pliocene (ca. 4 Ma; Late Ruscinian; MN15) and a continuous deposition up to the Middle Pleistocene at the top was indicated.

There are important studies on the geology, sediment stratigraphy (Barka, 1985, 1992; Andrieux et al, 1995) and evolution (Dhont et al, 1998) of this basin, which is located in the south of the current NAF active branch (1943 earthquake surface rupture). Today, the basin flowing into Kızılırmak by Devrez Stream is approximately 30 km in length and 10 km in width (Figure 2.2). At the bottom of the

basin stratigraphy is the Devrez formation, which is defined as an intercalation of volcanogenic clastic units and clayey marl. The apparent thickness of the unit, which is exposed on the edge of Devrez Stream in the southeast of Tosya district, is 90 meters. There are no fossil finds in this highly deformed unit, but since it is unconformably overlain by the Lower Pontus Formation, its age is defined as Early-Middle Miocene (Barka, 1985).

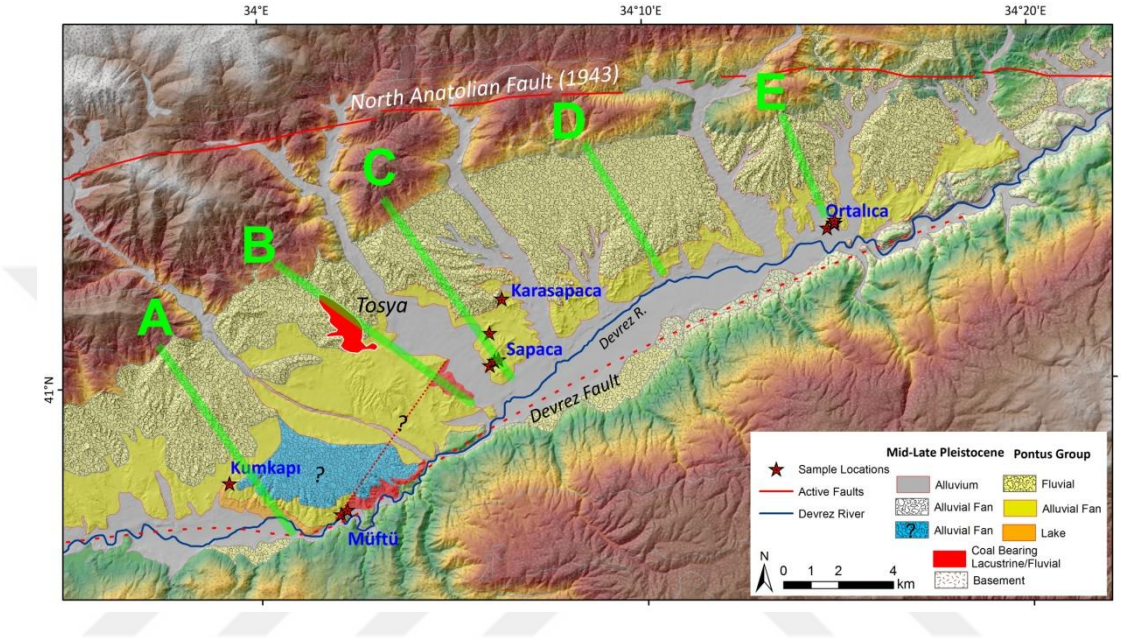


Figure 2.2 : Topographic map of Tosya Basin with different depositional environments. A–E display cross-section for measured stratigraphic sections; stars indicate localities from which small mammal material are collected (compiled from Barka, 1985; Andrieux et al, 1995; MTA).

The Lower Pontus Formation in the Tosya Basin consists of gypsum marl, clay and fine sandy lacustrine units at the lower levels. The age of the Lower Pontus Formation was defined as Upper Miocene (Tortonian) by ostracod and pollen analyzes (Irrlitz, 1972). There is no current study on the age of the unit. With the dominance of the fluvial facies towards the upper levels of the unit, the grain size becomes coarser and is overlain by the Upper Pontus Formation conformably and transitively (Barka, 1985). It is predicted that it was deposited in the Early Pliocene-Pleistocene age range with ostracods and pollens collected from the Upper Pontus Formation, which mostly precipitated in a river and occasionally in a shallow lake environment (Barka, 1985). The thickness of the measurable sediment fill of the basin was defined as 300 meters. We studied sampled from localities at Tosya Basin as shown in Figure 2.3 and Figure 2.4.

2.1.1 Sampled localities and their facies

Following figures (Figure 2.3 and 2.4) display some facies at Ortalıca, Sapaca and Kumkapı localities where we collected fossil material.

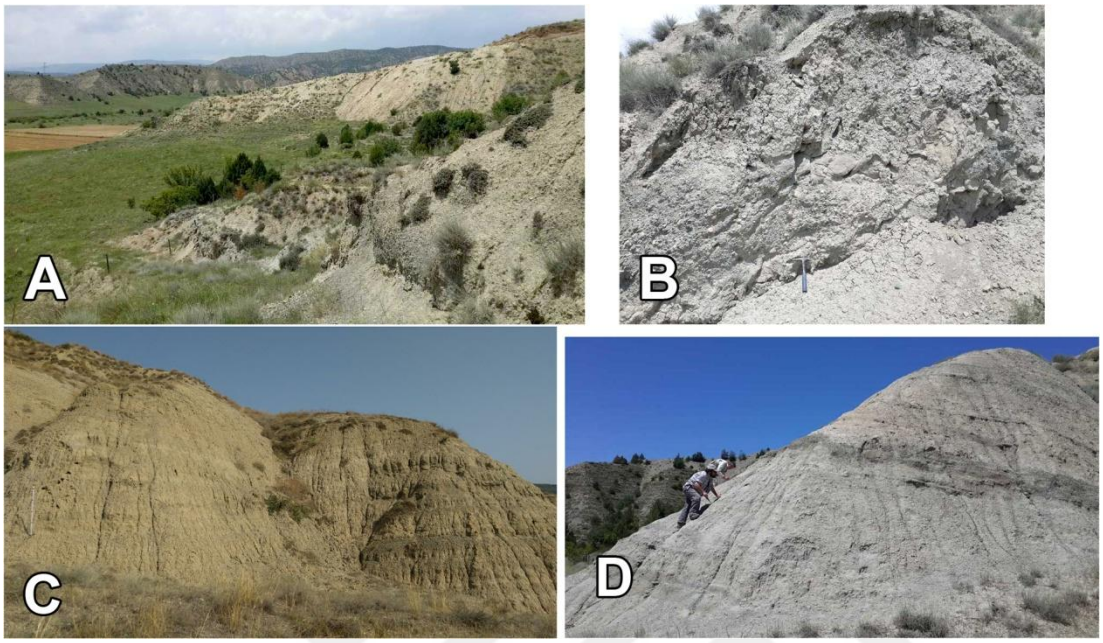


Figure 2.3 : Field picture of facies of Ortalıca-1 (A–B) and Ortalıca-2 (C–D), which are visited to sample for the mammal fossils. A- Distal fan facies of first stage of alluval fan formation at the east of the Tosya Basin near Ortalıca Town; B- Grey silty and clayey layers of distal fan facies possibly limited lacustrine environment; C- Intercalation of silt/fine sand and coarse sand/pebble layers, distal fan facies of first stage of alluvial fan development; D- Clay rich siltly layers of distal fan with intercalation of coarse sand and pebble layers showing erosional contact.

2.1.2 Measured stratigraphic section (MSS) of Ortalıca-2 locality

All the sections in Figure 2.2 (i.e. A–E) will be discussed in detail in a geological study in preparation (Erturaç et al, *in prep*). However, in the scope of this thesis, the Ortalıca locality which has been known from a previous study with its rich fossil fauna (Ünay and de Bruijn, 1998) has an important place. This study, as not being focused only on that locality but on localities from many basins in Turkey, did not either provide a precise locality of the sampling area, nor a measured stratigraphic section.

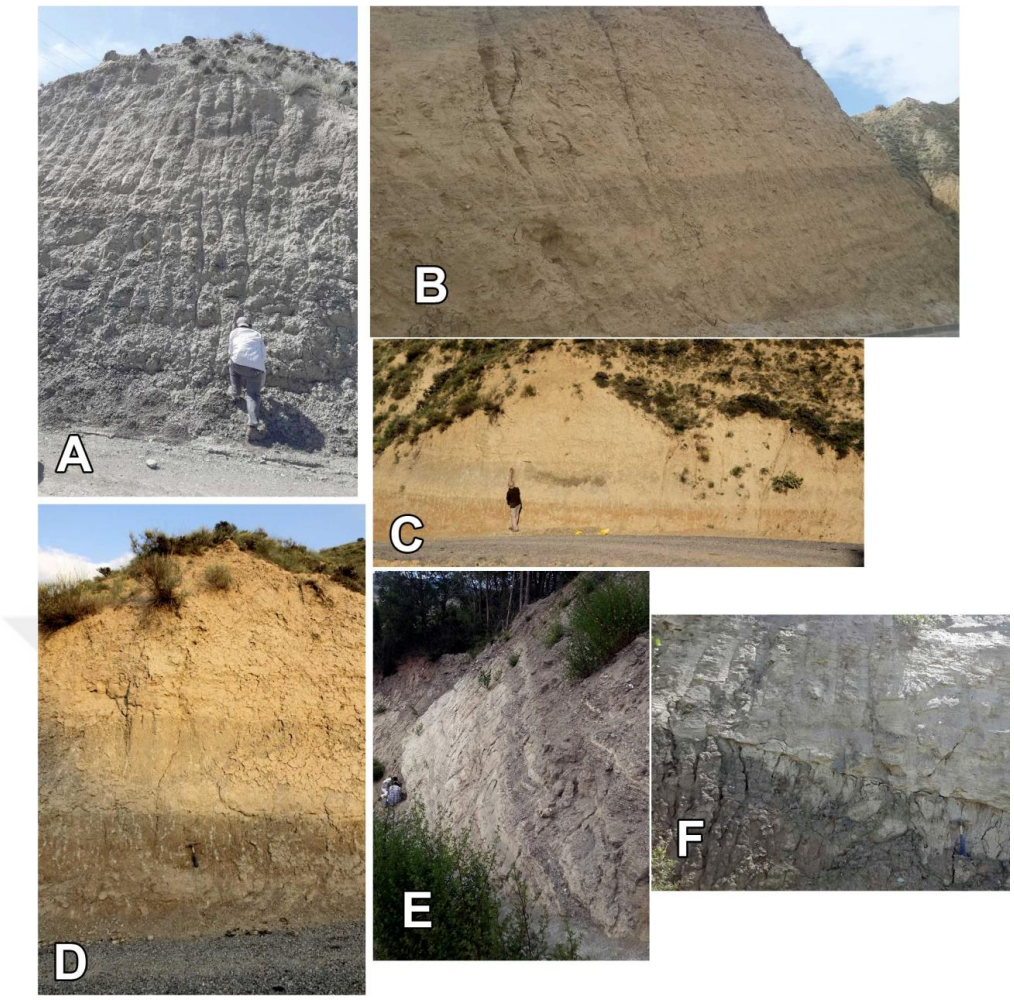


Figure 2.4 : Field picture of facies of Sapaca-1 (A), Sapaca-2 (B), Sapaca-3 (C–D) and Kumkapı (E–F) which are visited to sample for the mammal fossils. A- Clay-silt layers with fine pebble sand lenses; B- Thick horizontal bedding of silty fine sand layers of distal alluvial fan, possible lacustrine environment formed at the edge of the closed Tosya Basin; C- Thick horizontal bedding of silty fine sand layers of distal fans, possible lacustrine environment formed at the edge of the closed Tosya Basin; D- Thick horizontal bedding of silty fine sand and clay rich layers of distal first stage fan, possible lacustrine environment formed at the edge of the closed Tosya Basin; E- Southward tilted lacustrine deposits overlain by second stage alluvial fan and Devrez river deposits; F- Southward tilted clay rich lacustrine layers.

The columnar view here above give altitude above sea level elevation of depositional facies in the A–C and E sections as appeared in Figure 2.2, and they include localities studied in the scope of this thesis (Kumkapı, Sapaca, Karasapaca, Ortalıca) (Figure 2.3 and 2.4 and the MSS of Ortalıca locality in Figure 2.7).

The Tosya Basin compromises 3 distinct stages of alluvial fan development initiated at MN15 (late Pliocene). The opening of the basin is controlled by a fault located to the north of the basin by the formation and slip resolved on the Oğuz Fault. The thickness of the basin sediments decreases to the west indicating that the fault/basin

evolved from the east to the west. The basin sediments show distinct sedimentary facies of proximal, medial and distal alluvial fans with thick layers of coarse angular blocks and clasts intercalated with coarse pebble and sandy layers and at the southern part of the basin mostly distal facies are observable with clayey-silty layers with sand/pebble channels and lenses. The thickness of these fine grained facies increase significantly at the centre of the basin (Sapaca-Karasapaca) indicating limited lacustrine deposition within a closed tectonic basin. The visible thickness of the first stage alluvial fan deposits are over 300 meters.

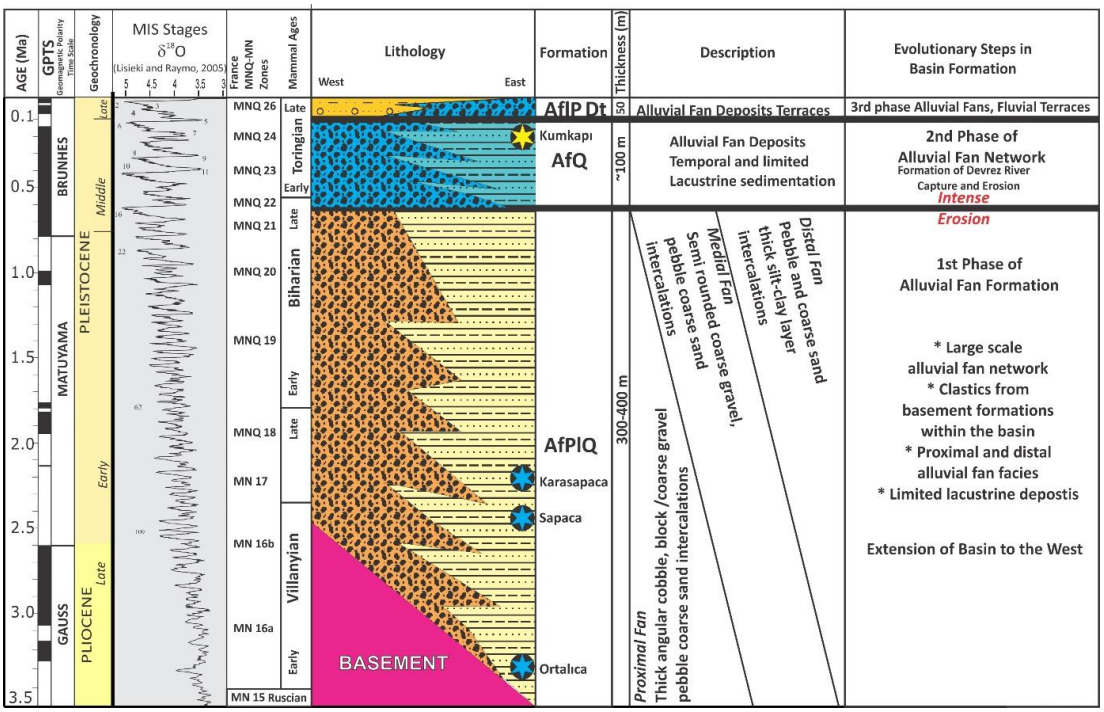


Figure 2.5 : Joint generalized columnar stratigraphic section of the Tosya Basin. Note the location of Ortalıca MSS.

The second stage of alluvial fan development started at Early Toringian / Middle Pleistocene when intense erosion took place at the basin where all rivers feeding the alluvial fans deeply entrenched the sediments of the first stage deposition. This event indicates that the basin is captured, possibly by Kızılırmak River, to the open drainage (Black Sea) and the formation of Devrez River and also the Devrez Fault. The Kumkapı alluvial fan developed after this period still preserving its original form. The Kumkapı locality constrains the age of alluvial fan, Middle-Late Toringian (pre-late Pleistocene). At this section alluvial fan deposits overlay limited lacustrine deposits, possibly formed by semi-damming of the parts of the basin with alluvial sediments. The visible thickness of the second phase deposits is 75 meters.

Near the Müftü locality (Figure 2.6), the second stage fan deposits are cut by Devrez Fault and aligned with coal bearing Early Miocene deposits (lower Pontus formation?). Durak et al. (*submitted*) have recorded a rich pollen assemblage from the fine-grained sediments with lignite and gypsum-bearing deposits of the Aspiras Basin. This pollen assemblage consists mainly of altitudinal plants such i.e. *Cathaya*, *Picea*, *Abies*, *Cedrus*, *Tsuga*, *Keteeleria*, along with minor quantities of mixed mesophytic taxa *Betula*, *Engelhardia, Ilex Castanae,* Mastixiaceae etc. Also they have recognized biostratigraphical markers such as *Dicolpopollis kockelii*, *Caryapollenites simplex* and *Intratriporopollenites instructus*, and suggested an early Miocene age which has been confirmed by the presence of some ostrocods such as *Pseudocandona praecox* and *Potamocypris gracilis*. A similar pollen flora is obtained from the exposures situated southern side of the Devrez creek, especially in the amounts of conifers and mixed masophyitc forest elements. Micopaleontological (palynomorphs and ostracods) data indicate a lacustrine setting surrounded by a forested area from swampy condition (i.e. low-lying area) to upland environment.

The recent sedimentation within the basin is represented by young (third phase) alluvial fans to the north and south of the Devrez River and the terraces of the Devrez River (Huber-Ferrari et al, 2021).

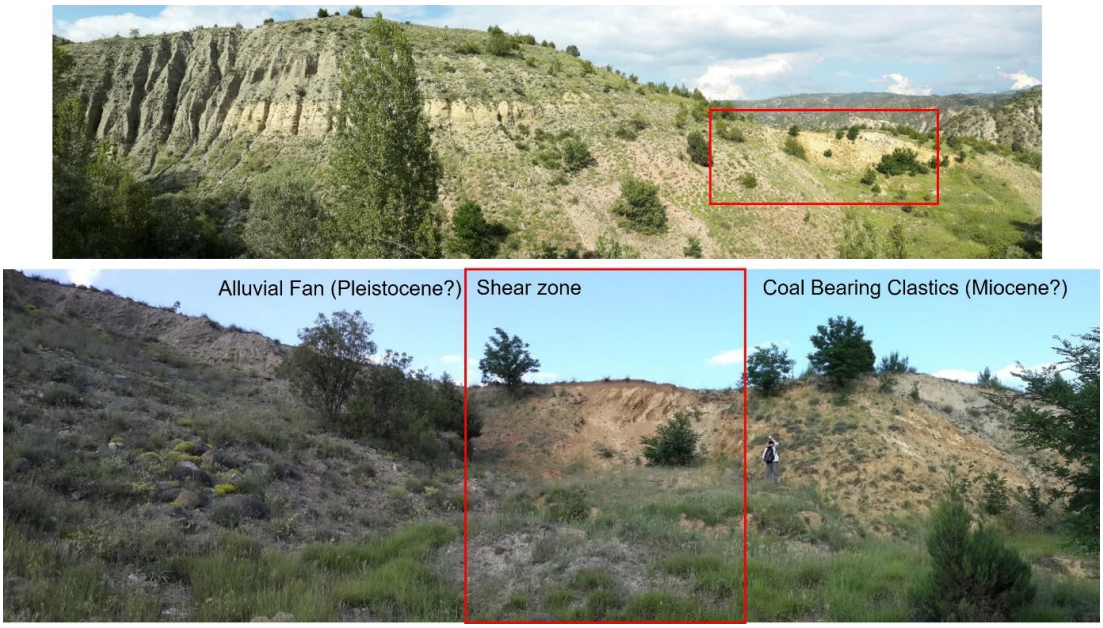


Figure 2.6 : Faulted contact (Devrez Fault) between the pre-late Pleistocene alluvial fan deposits (second stage) and early Miocene clastics.

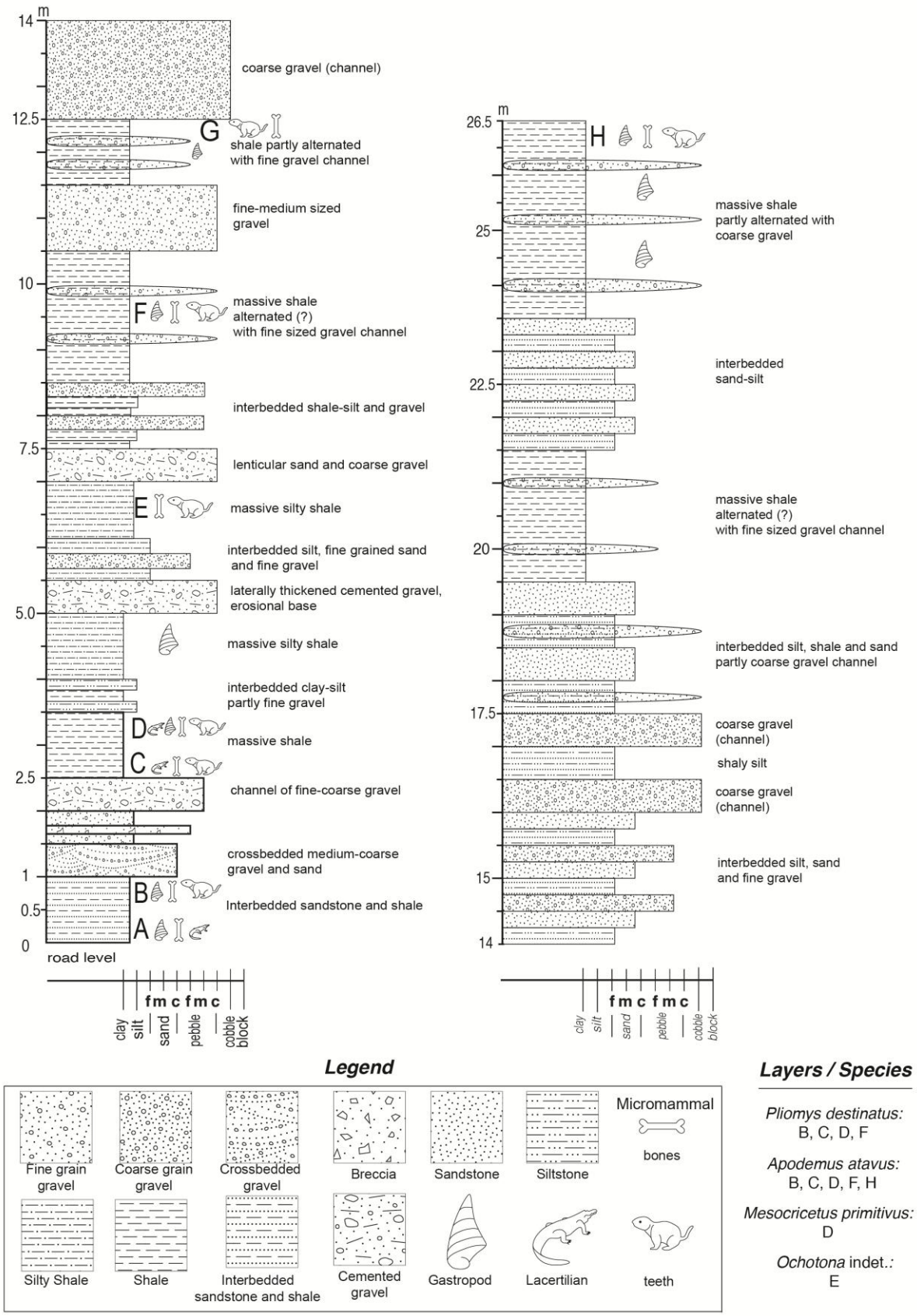


Figure 2.7 : Measured stratigraphic section of Ortalıca-2 locality. (481 m amsl X:604957 Y:4545115 UTM36). For details of faunal assemblage, see Chapter 4.1.

2.2 Suluova Basin

The Suluova Basin is an apparent depression located in North Central Anatolia, within the Central Pontides. The shape of the basin resembles a deformed E-W oriented right trapezoid that covers an area of 560 km^2. The activity of Suluova Fault offset the trapezoid for 10 km and caused 7 km further extension by forming a new pull-apart basin of 60 km^2 at SE corner of the Suluova Basin (Figure 2.8).

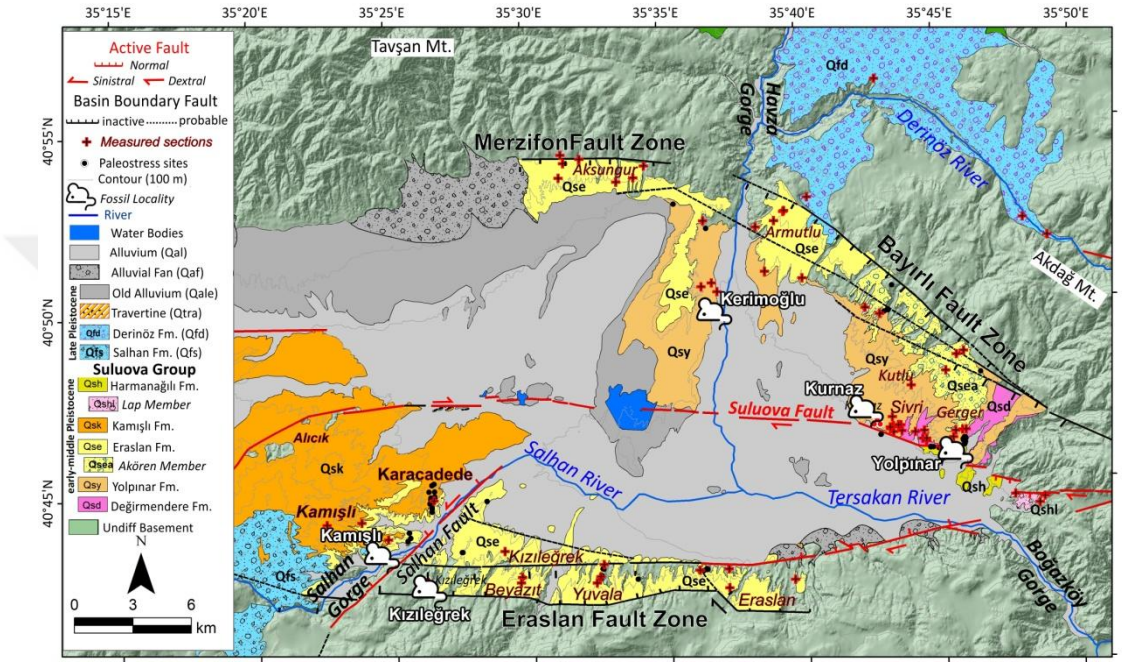


Figure 2.8 : Geological map of Suluova Basin with fossil bearing localities (modified after Erturaç et al, 2019)

The basement rocks of the basin belong to the Tokat Massif of the eastern Sakarya Zone (Şengör and Yılmaz, 1981; Yılmaz et al, 1997, Okay and Tüysüz; 1999). The pre-Neogene rocks of the basin mainly consist of Early Eocene limestones of the Çekerek Formation (Tçek) to the south and coal bearing clastics of the Çeltek Formation (Tçel) at northeast. The Middle Eocene volcanics of the Merzifon Group (Tmer; Keskin et al, 2008) can be observed at a wide region surrounding the western half of the Suluova Basin. The Triassic age Yeşilırmak Metamorphics (TRy, Tüysüz, 1996) expose to the south, early Cretaceous micritic limestones of Soğukçam Formation (Csog, Tüysüz, 1996) and late Cretaceous volcanics/volcanoclastics of Lokman Formation (Clok, Gülmez and Genç, 2015) expose at the NE and ENE part of the basin respectively. From all these formations derive clastics to the basin fill during the Quaternary.

The sedimentary fill of the Suluova Basin is classified into seven formations by using lithology, depositional environment, sediment source, fossil content and finally the fault segment which controlled the sedimentation. These formations form the Suluova Group (Erturaç, 2010; Rojay and Koçyiğit, 2012), which deposited during throughout the Quaternary (Erturaç et al, 2019).

2.2.1 Kurnaz and Kerimoğlu localities

Two fossil bearing sites, Kurnaz and Kerimoğlu are within the Yolpınar Formation ((Figure 2.8); Erturaç et al, 2019). According to the same authors, the Kurnaz section (Figure 2.9) constitutes a thick clay deposit rich in organic material and represents a swamp environment. It is overlain by fine grained channel deposits and silty coarse sand deposits. In this section, macro- and micromammal remains yielded the first age constraint for the basin stratigraphy. Close to the basin depocenter, in the Kerimoğlu section (Figure 2.9), an intercalation of fine-grained sediments with well-developed cross stratification and mollusc remains indicating a low energy environment of swamps and also providing clues of the development of a freshwater lake were observed (Erturaç et al, 2019, fig. 7D). The Kerimoğlu section has also a layer with abundant micromammal and fish remains, providing information on both age and environment of this unit. This section continues for at least 100 m or more as the Eraslan Formation. The Kurnaz and Kerimoğlu sections reveal distal parts of a wide alluvial fan network, increase of water input to the closed basin, and introduction of a freshwater lake (Erturaç et al, 2019).

The Kurnaz fossil bearing layer is situated at the bottom of the Kurnaz section at 510 m above mean sea level (amsl) and formed of clay and overlained by silty clay and coarse sand alteration (Erturaç et al, 2019).

As to the Kerimoğlu fossil locality (Figure 2.10), it is in the Kerimoğlu section and is situated at 560–565 m amsl and between altering pebble with sand and fine matrix-silty clay layers, and plastic clay (Erturaç et al, 2019).

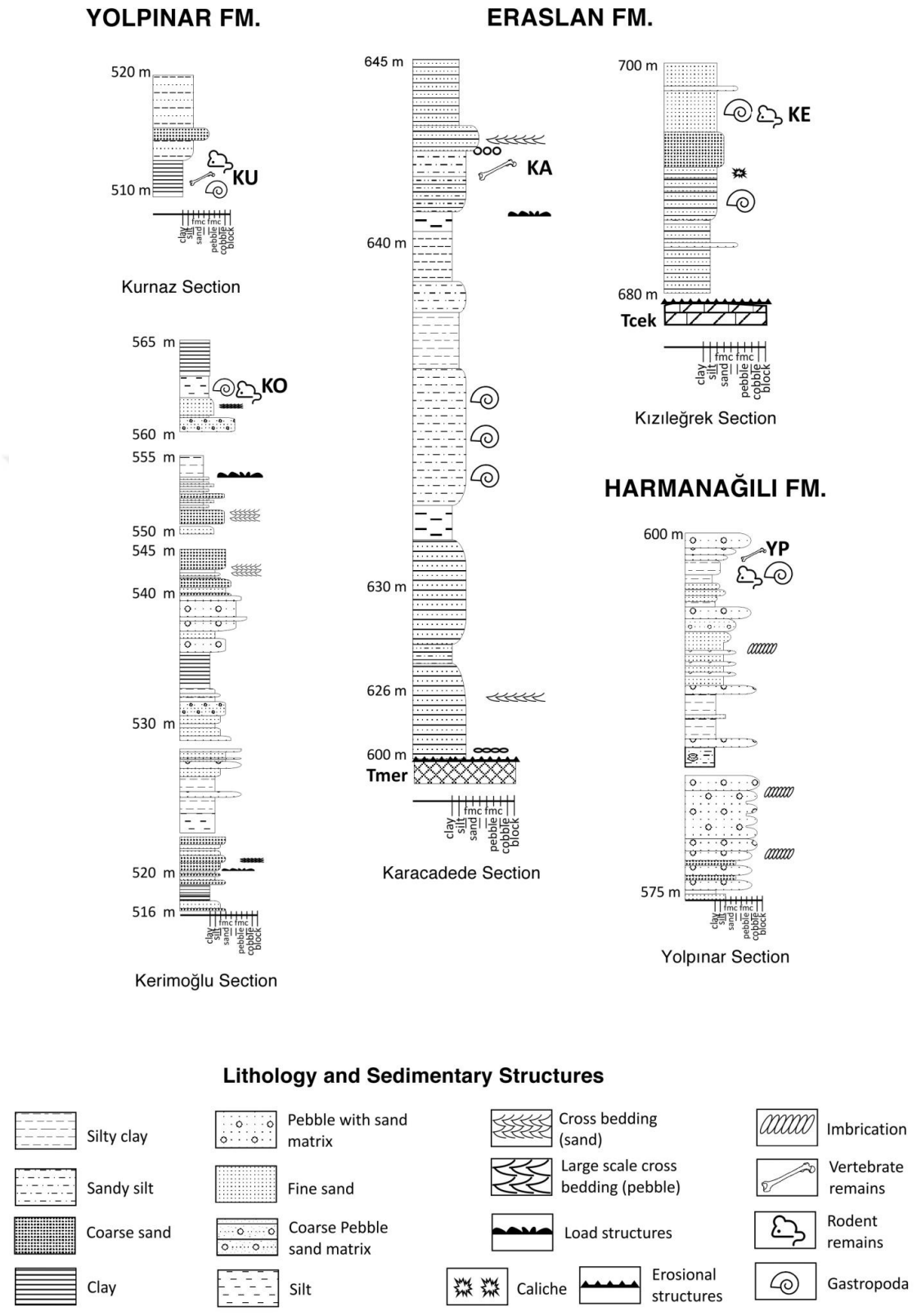


Figure 2.9 : KU, Kurnaz; KO, Kerimoğlu; KA, Kamışlı; KE, Kerimoğlu; YP, Yolpınar; Tmer, Middle Eocene volcanics of the Merzifon Group; Tcek, Eocene Çekerek Formation (modified after Erturaç et al, 2019).

Figure 2.10 : Fossil locality of Kerimoğlu. A, panoramic view; B, closer view to the right part of the layer in A.

2.2.2 Kızıleğrek and Kamışlı localities

The two fossil bearing localities in the SW part of the Suluova Basin, the Kızıleğrek and the Kamışlı localities (Figure 2.11), are included in the uppermost part of the Suluova lacustrine succession within the Eraslan Formation (Figure 2.8; Erturaç et al, 2019).

According to MSS of the Kızıleğrek section, it starts with an apparent unconformity over the Eocene limestones and ranges up between 680–700 m amsl (Figure 2.9). Whereas the Kızıleğrek section is a succession of lithified sand and altering fine to laminated fine sand with a coarse sand, the 50 m thick Karacadede section, which includes the Kamışlı fossil locality near to 640 m amsl, exhibits fine-grained sand and silty sand beds showing cross-bedding and bearing mollusk and macro- and micromammal remains (Figure 2.9; Erturaç et al, 2019).

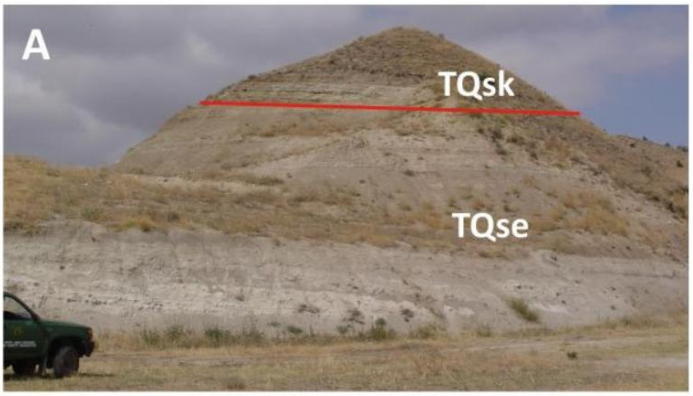


Figure 2.11 : Karacadede section in the Eraslan Formation holding the Kamışlı fossil locality. Fossiliferous layer is situated just below the red line separating the Kamışlı Fm (TQsk) from the Eraslan Fm (TQse) (from Erturaç, 2010, p. 87)

2.2.3 Yolpınar locality

The Yolpınar locality (Figure 2.12) is situated at the easternmost portion of the basin, within the Harmanağılı Formation at the North of the active depocenter of the Suluova Basin (Figure 2.8). This formation and the fossil locality are separated by the Suluova Fault from the older Yolpınar and Değirmendere formations, and the basement rocks. This unit comprises intercalation of rounded coarse- to medium-grained pebbles and sand bars with horizontal silt to fine sand deposits (Figure 2.9). This sequence, with the maturity of the coarse-grained clasts and channel and sand bar structures, indicates continuous fluvial deposition from braided to meandering river environments. Up in the section, a mollusk-bearing silty clay bed yielded an ?*Equus* molar (Figure 2.12.A) and some rodents (Figure 2.12.B), providing the youngest age of sedimentation in the Suluova Basin at Yolpınar locality (Erturaç et al, 2019).

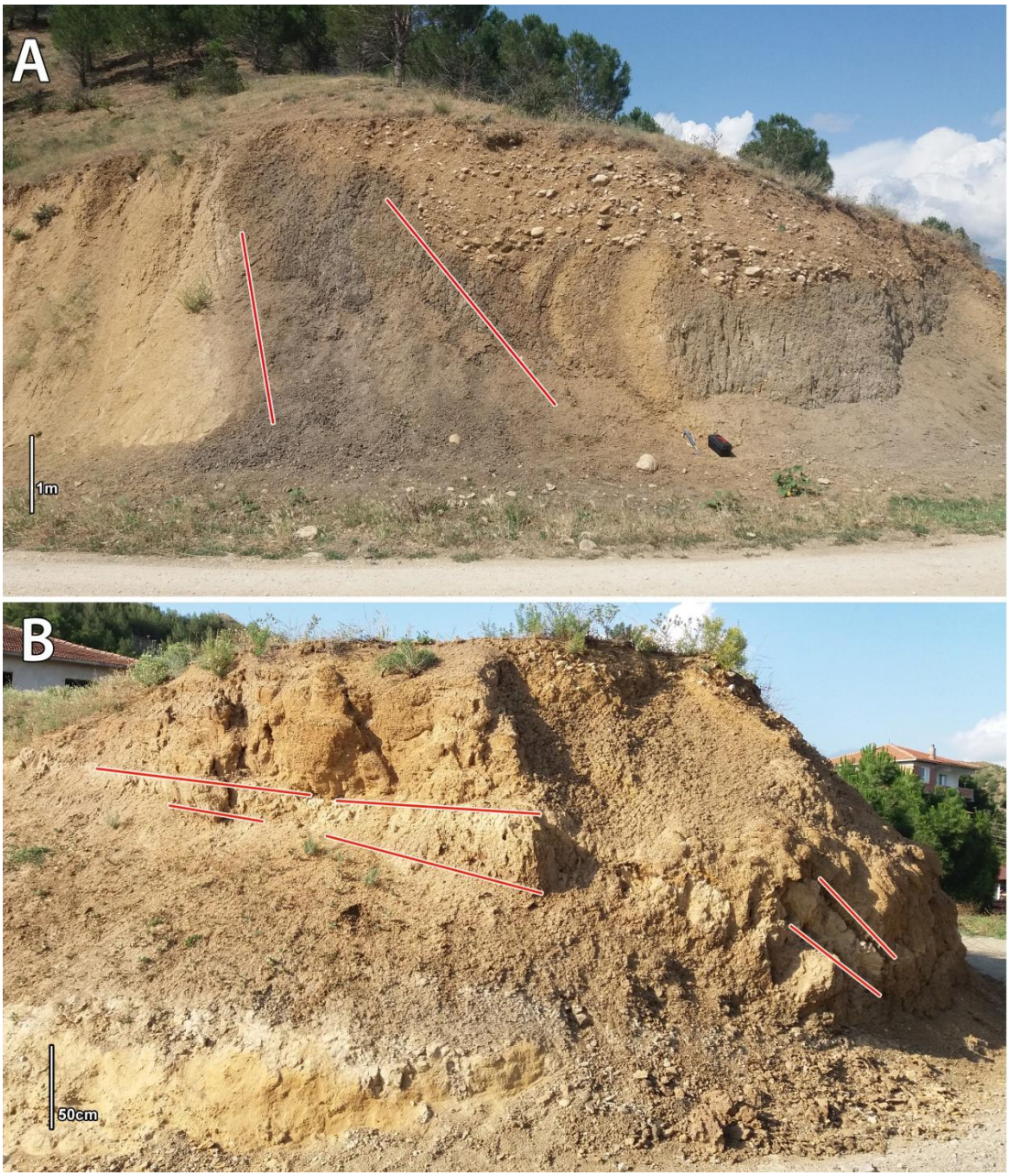


Figure 2.12 : The silty clayish layer bearing the fossil localities in this study. A, layer delivered fragmentary tibia of *Equus* sp., B, micromammal delivered layer.

2.3 Niksar Basin

In a narrow nucleation zone located around the town of Niksar (40°30’ N, 37° E), a major secondary synthetic fault (splay) bifurcates from the main strand of the North Anatolian Fault Zone. Trans-pressional in nature, the Ezinepazar Fault strikes approximately E-W for some ~100 km to the west (Barka and Kadinsky-Cade, 1988; Erturaç and Tüysüz, 2012) and partly ruptured during the 1939 earthquake (surface

magnitude (Ms): 7.9). The separation between the Ezinepazar Fault and the main strand of NAF, which ruptured in a successive event in 1942 (Ms: 7.0), gives way to the formation of the Niksar Basin, which is one of the focus of this study.

The Niksar Basin is a lazy Z- shaped, sigmoidal pull-apart basin (Mann et al, 1983; Hempton and Dunne, 1984; Aktimur et al, 1992; Tatar, 1993; Gürbüz and Gürer, 2009). The formation of the basin is controlled by ~8 km right-handed dilatational step-over in between the two non-parallel master faults of NAF (Yoshioka, 1996; Figure 2.13). The topography of the Quaternary plain (270–300 m amsl) is ~1 km lower than the surrounding mountain peaks and drained by Kelkit River to the Black Sea. The basin fill is characterized by active and inactive braided river, marsh and alluvial fan deposits, which is estimated to be over 600 m in thickness (Hempton and Dunne, 1984; Tatar 1993). Barka et al (2000) discussed the geological evolution of the Niksar Basin and constrained its age to 1-0.7 Ma by correlating the width of the basin (15 km) with the modern slip rate of the fault zone (~15-20 mm/year; Zabcı et al, 2015). At the ENE margin of the basin, young Pliocene–Quaternary volcanic rocks expose along pairs of steep strike-slip faults, parallel to the deformation zone, which have been dated by K-Ar method and the ages range between 568 ± 3 ka to 461 ± 7 ka (Tatar et al, 2007). Erturaç and Tüysüz (2012) suggested a maximum age about 0.6–0.7 Ma (early Toringian) for the formation of the Umurlu Plain based on the presence of *Microtus* aff. *arvalis*.

The Umurlu Plain is small, E–W elongated, rhomboidal shaped and isolated as a piedmont basin (2 km in length, 1 km in width) in between high mountains (1400 m to the south and 600 m to the north). It is filled with a network of alluvial fans. The plain is adjacent to the Niksar Basin (~4 km west) and formed within a dilatational step-over between the Kelkit and Ezinepazar segments of the 1939 earthquake rupture (Figure 2.13.B). The basement rocks are Permian–Triassic metamorphics (phyllite and marble blocks) of the Turhal Group (Aktimur et al, 1992).

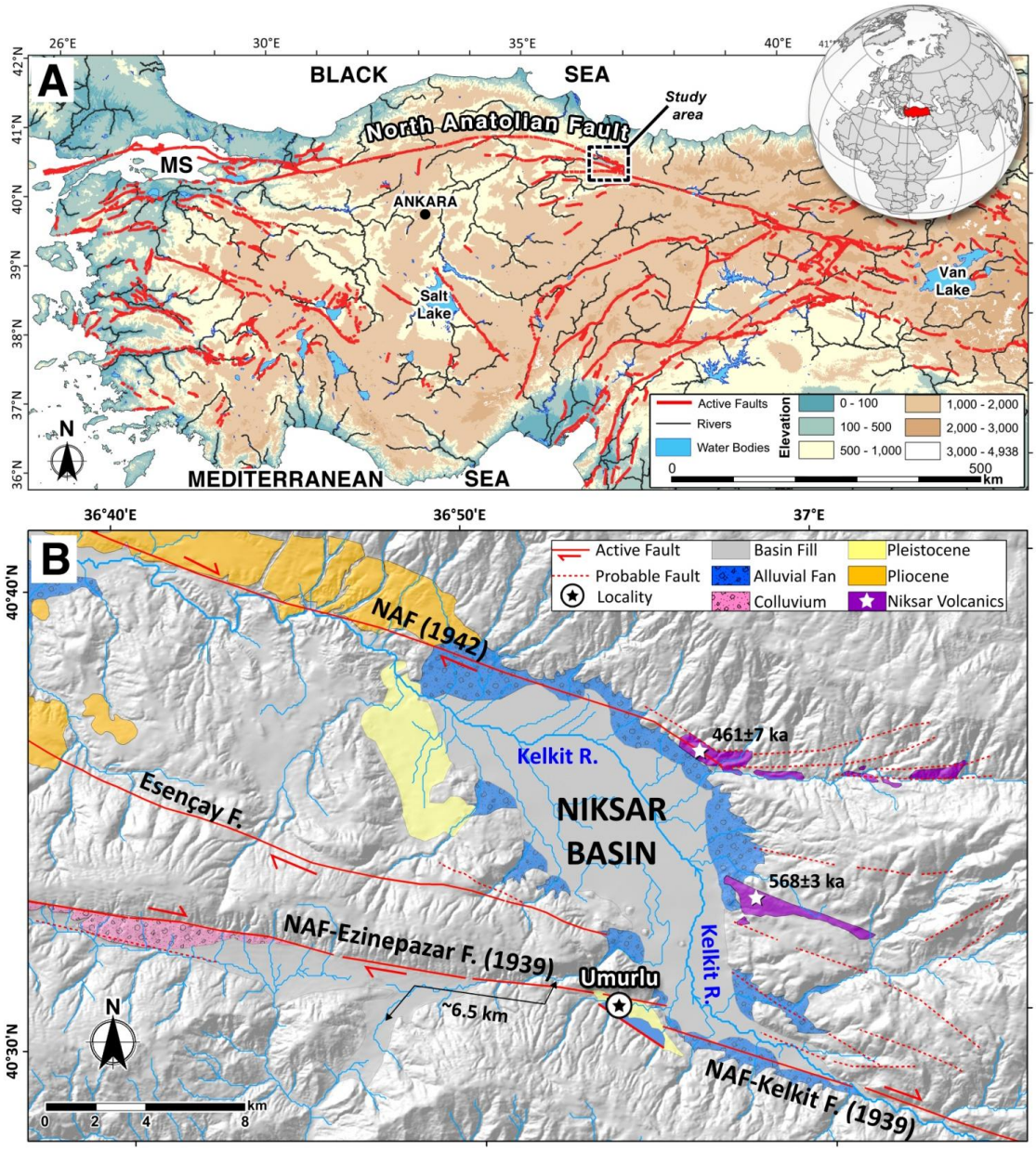


Figure 2.13 : Maps displaying the location of Niksar Basin along the North Anatolian Fault and the Umurlu locality: A, Physiography and active fault map of Northern Anatolia (faults compiled from Emre et al, 2013; elevations are in meter); B, Quaternary geology of the Niksar Basin, units and faults draped over hill shaded topography (compiled from Tatar et al, 2007 and Erturaç and Tüysüz, 2012; numbers between brackets indicate the date of earthquake rupture). Abbreviations: F, fault, MS, Marmara Sea, NAF, North Anatolian Fault, R, river. (from Erdal et al, 2018).

2.3.1 Umurlu locality

The Umurlu site consists of a single isolated section (40.51° N, 36.88° E and 435 m amsl) which is exposed within an abandoned sand quarry located on the westernmost tip of the plain. The section is 4 m in height and ~15 m in width. It is composed of highly sheared fluvial clastics of polygenic origin, including clasts of different lithologies, and overlain unconformably by alluvial fan deposits which are not faulted and dominated by metamorphic rock clasts (Figure 2.14).

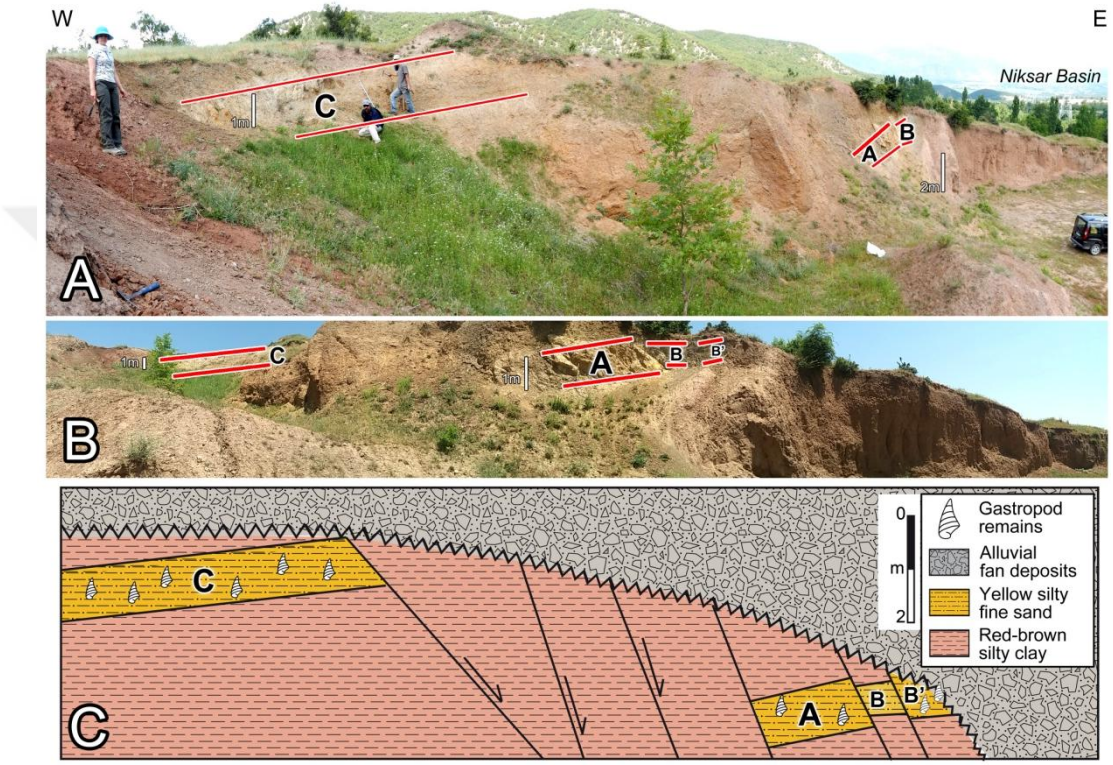


Figure 2.14 : A and B, The panoramic pictures of the Umurlu locality; C, the simplified interpretation of the section. The fossil bearing layers A, B, B' and C are one meter thick each, and consist of bright yellowish-orange fine silty sands (layers A and C) and greyish silts (layer B). All layers contain abundant terrestrial gastropod remains. A dark brown silty clay layer with sparse gastropod remains is distinguished as B'. A, B and B' are in faulted contact whereas the layer C is located ~2 m above these layers (Erdal et al, 2018).

Although sheared, tilted and offset, all these layers were possibly deposited approximately at the same time period. Based on the facies and clast lithology, it is interpreted that these fluvial deposits are a part of the Niksar Basin and deposited by the Kelkit River. The long-term dextral offset (~6.5 km, Erturaç and Tüysüz, 2012; Figure 2.13.B) of the Ezinepazar Fault probably shifted this unit to its current position where it is preserved within the younger alluvial fan dominated piedmont plain.

3. MATERIAL AND METHODS

Since this thesis deals with paleontological aspect of the overall of the study, only fossil gathering and processing procedures are mentioned in this chapter. For geological aspect, it has been already studied in details for the Suluova and Niksar basins by Erturaç (2010), Erturaç and Tüysüz (2012), Erdal et al. (2018), Erturaç et al. (2019).

As to Tosya Basin, in the scope of this thesis and in cooperation with Dr. Korhan Erturaç, the extent of Neogene–Quaternary deposits, basement rocks and some lithostratigraphic units are mapped. Also, we surveyed measured stratigraphic sections (MSS) and made correlations between various outcrops of Neogene-Quaternary deposits in order to establish a detailed stratigraphy of the sedimentary series of the basin. In addition, studies of the the lithology, grain size, sedimentary structures, cementations, fossil content completed the fieldwork. The upper and lower limits of sections are measured via GPS and controlled after 1/25.000 topographic map. MSS is illustrated and discriminated according to different facies aspect. In this regard, correlation and depositional environment of units in these basins is again, preliminarily determined.

As a reminder, the study on Tosya Basin is partly mentionned in this thesis but two publications are in preparation (Erturaç et al, *in prep*; Erdal et al, *in prep*).

3.1 Small Mammal Fossils Gathering from Sedimentary Deposits

Although small mammal bearing localities have been known before this study *grosso modo*, except deposits on the Suluova Basin, it had to be rediscovered. Fossiliferous strata are chosen according to specific facies features within the prospection of the area. Layers to be sampled for small mammal study had to be exposed to drainage and erosion, to be not laminated or bioturbated and to display some gastropod

remains as a clue of terrestrial fossil remain trace, all within a distinct stratigraphic position.

In order to perform a "pre-analysis" of the sediments chosen for finding small mammalian fossils, a few sacs of 20–30 kg from each locality are carefully filled and are exposed to the sunlight on a straight ground at least for 48 hours to dry out the sample. (Figure 3.1.A). Before screen-washing, those sediments are shared in plastic basins preferably near a stream, lake or river, and filled with water in the aim to dissolve clay which constitutes generally the major part of the sample. If needed, few drops of hydrogen peroxide or acetic acid (in carbonated sediments) are added to accelerate the dissolution process. Once the dissolved sample is more or less homogenous, it is screen-washed on metal sieves of different mesh size (e.g. 0.5, 1 and 8 mm^2). The washed sample which is trapped on the mesh is supposed to spread on large canvas by avoiding any mixture with other samples already washed separately. Those samples are again, exposed to the sunlight for 48 hours (Figure 3.1.B).

Washed dry samples are sorted-out under binocular microscopes (Leica EZ4 HD and SOIF SZM45). All fossil remains are separated by tweezers carefully and stored separately (Figure 3.1.C). In case of detection of at least 4-5 recognazible and informative fossil specimens (i.e. preferably teeth) from a 20 kg of sac, the number of sampling in weight is increased when possible, from the locality concerned. The amount of sample to screen wash depends on the richness of the fossil bearing strata, dissolution condition, the amount of material that appears after screen washing and of course, the biostratigraphic or paleontological importance of the facies.

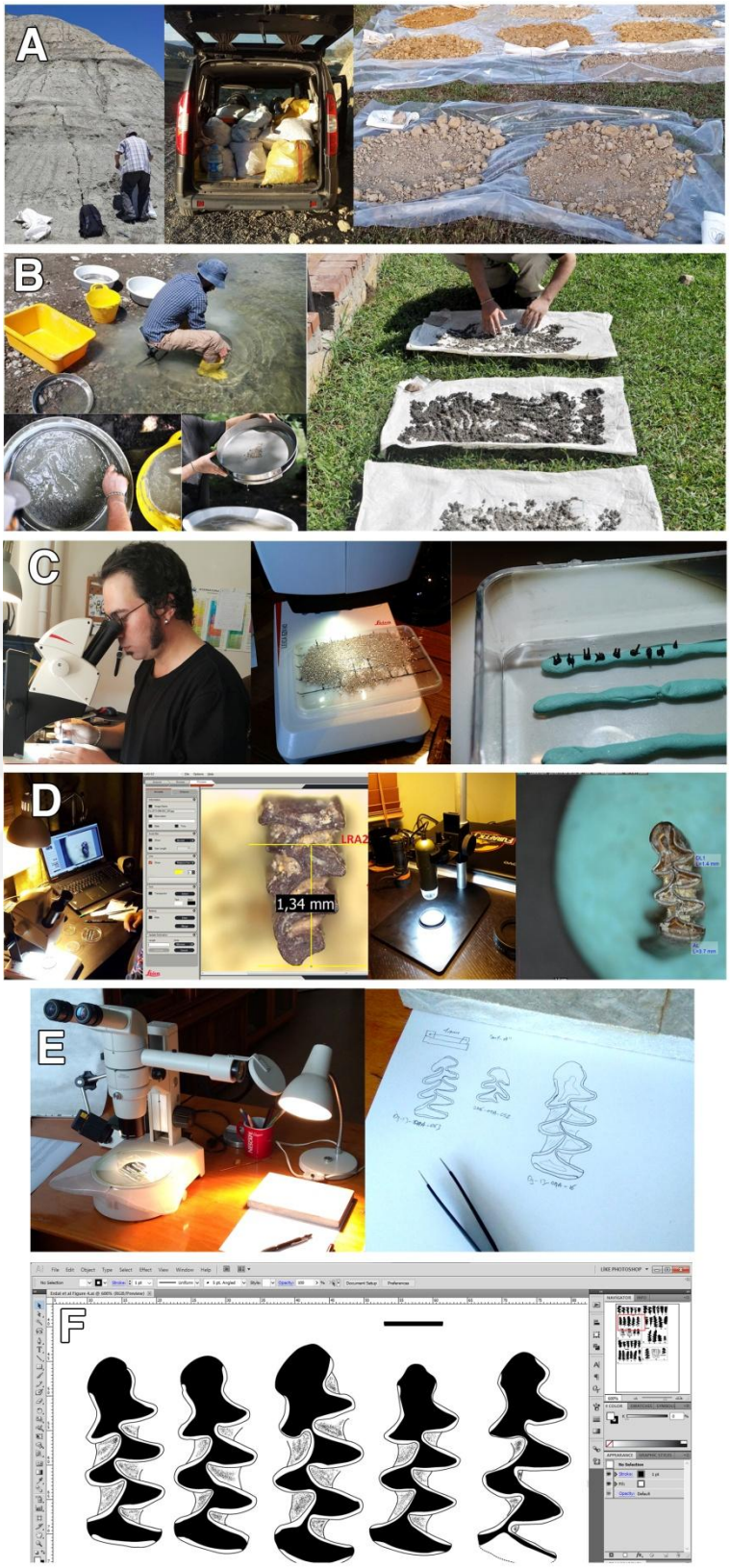


Figure 3.1 : Methods applied in this thesis. A- sampling and drying the sediment; B- Wet screen-washing and drying washed sample; C- Sorting out fossil specimens and ranging under binocular microscope; D- photographing and measuring; E- Drawing sketches with *camera lucida*; F- Enhancing sketches on digital platform.

3.2 Field Campaigns, Localities and Sampled Material

In 2013, four localities from the Suluova Basin (Kamışlı, Yolpınar, Kurnaz and Kerimoğlu) are visited and 13 sacks of sediment (~360 kg) are collected. In the same year, from one locality (Umurlu) in the Niksar Basin eight sacks of sediments (~200 kg) are collected.

In 2014, 9 localities in the Tosya Basin are visited and 52 sacks (~1300 kg) are collected; these localities are SapacaKarasapaca Section (known as Tos24-38-39-40-41 during the campaign field), Kumkapı (Tos33), Ortalıca-1 (Tos28A–B) and Ortalıca-2 (Tos29).

In 2016, based on the results of previous campaign, only small mammal rich fossil localities are revisited. Among them, Kumkapı, Ortalıca-1 and Ortalıca-2 are kept same as the locality names but all Sapaca-Karasapaca section localities are named separately as the following; Sapaca-1 (Tos38), Sapaca-2 (Tos39), Sapaca-3 (Tos24). We collected from each locality around 25 sacks, but seven of them are damaged by villagers at night, so it is ~450 kg at maximum. Therefore, there are six locality yielded fossil remains examined in this study, among nine in total.

The Yolpınar and Kerimoğlu localities in the Suluova Basin are revisited and 23 sacks are collected (~575 kg). Finally, the Umurlu locality in the Niksar Basin was also excavated with 17 sacks (~510 kg).

All these samples are screen-washed mainly during the field campaign, if not, at the ITU laboratories. For details concerning the localities of the Tosya Basin, see Chapter 4.1; of the Suluova Basin see Chapter 4.2 and of the Niksar Basin Chapter 4.3.

Following screen-washing and sorting of the material, all obtained specimens by numbers of teeth are given in Table 3.1. Some molars are already on fragmentary mandible or maxillary.

Note that some specimens are damaged and thus obscured the genus/species identification although they are also counted. Besides, remains of ochotonids and soricids are also collected; they will be subject of another study, to be published later. All fossil material is stored at the Gebze Technical University.

Table 3.1 : Number of teeth specimen gathered in this study.

	Basin			
Group of specimen	Tosya	Suluova	Niksar	**Total (Group)**
Arvicolinae	48	22	221	291
Murinae	33	1	57	91
Cricetinae	11	2	2	15
Sciuridae	2	-	-	2
Gliridae	7	-	-	7
Spalacidae	-	-	1	1
Ochotonidae	85	-	-	85
Soricidae	28	-	44	72
Bovidae	2	-	-	2
Equidae	-	2	-	2
Giraffidae	-	2	-	2
incisors	~23	~3	>100	126
Total (Basin)	239	32	425	696

The Niksar Basin has one locality with the highest number of specimens whereas the specific richness is lower than in other localities. The Suluova Basin is relatively poor in fossil material of small mammals; both in number of specimen and of species. As to Tosya, it has the most diverse fossil groups. Almost the half of the specimens represents ochotonids and soricids which will be evaluated separately in a future study.

3.3 Evaluation of the Material

The most frequently found specimen as for the majority of mammals are the teeth, generally molars in case of rodents, which is the most robust part of the body by having 98% of bioapatite (Ca_2PO_4) and with a minimum porous structure.

Molars are measured with the software provided by Leica EZ4 HD and Dino-Lite USB microscope ((Figure 3.1.D), large specimens such as mandibles and limb bones with Vernier calliper, all in a precision of 0.01 mm. SEM photographs are taken in the laboratories of Metallurgical and Materials Engineering Department of ITU, at MNHN and larger specimens photographs are done by thesis author using Canon 600D DSLR. Drawings are made by *camera lucida* (Figure 3.1.E) and thereafter enhanced by Macromedia Flash Professional v.8 and Adobe Illustrator CS5 (Figure

3.1.F). Bivariate plots are provided via PAST v3.15 software (Paleontological Statistic; Hammer et al, 2001).

The nomenclature and measurement methods for arvicolids (Figure 3.2 and 3.3) are after Meulen (1974), Carls and Rabeder (1988), Rekovets and Nadachowski (1995), Abbassi et al. (1998), Hordijk and de Bruijn (2009), for cricetines (Figure 3.4), after Mein and Freudenthal (1971); for spalacines (Figure 3.5), adapted after Sarica and Sen (2003); for murines (Figure 3.6) the combined terminology is after Pasquier (1974), García-Alix et al. (2009) and Lazzari et al. (2010); for giraffid after Gentry et al. (1999).

Abbreviations used for teeth and measurement nomenclature are shown as M/m for upper/lower molars respectively, followed by a number for its position in molar series (i.e., anterior to posterior, 1–3); dext, dexter and sin. sinister; a, anteroconid complex length; AC, anterior cap; ACC, anteroconid complex; AL, anterior lobe; A/L, the relative length of the anteroconid complex; b, width of isthmus between BRA3 and LRA4; BRA, buccal re-entrant angle, BSA, buccal salient angle; B/W, C/W and D/W, relative width of the dentine field restriction (of b, c and d, respectively); C, accessory cuspids, c, width of isthmus between LRA3 and BRA3, d, width of isthmus between LRA5 and BRA4, e, width of T6-T7 complex; Hsd, hyposinuid; Hsd/L, relative height of the linea sinuosa based on Hsd (=ep); L, length; LRA, lingual re-entrant angle, LSA, lingual salient angle; p, posterior complex length; PC, posterior cap; PL, posterior lobe; SDQ, values for enamel thickness differentiation quotient (‘Schmelzband Differenzierungs Quotient’ in German); T, triangles; W, width; WP, width of posterior cap complex; T, triangles; for linea sinuosa of upper molars: As, Anterosinus; Asl, Anterosinulus; Ds, Distosinus; Hys, Hyposinus; Mes, Metasinus; Pas, Parasinus; Prs, Protosinus and of lower molars: Asd, Anterosinuid; Esd, Entosinuid; Hsd, Hyposinuid; Hlsd, Hyposinulid; Misd, Mimosinuid (Sinuid of Mimomys-ridge); Msd, Metasinuid; Pasd, Parasinuid; Pmsd, Prismosinuid (Sinuid of Prismokante); Prsd, Protosinuid.

Note that “negative enamel thickness” used in arvicoline terminology stands for m1 molar type of which triangles leading edge are thinner than trailing edge (e.g. T5 in Figure 3.2.C) whereas in “positive enamel thickness” it is the opposite. For upper molars, it is the contrary to lower ones.

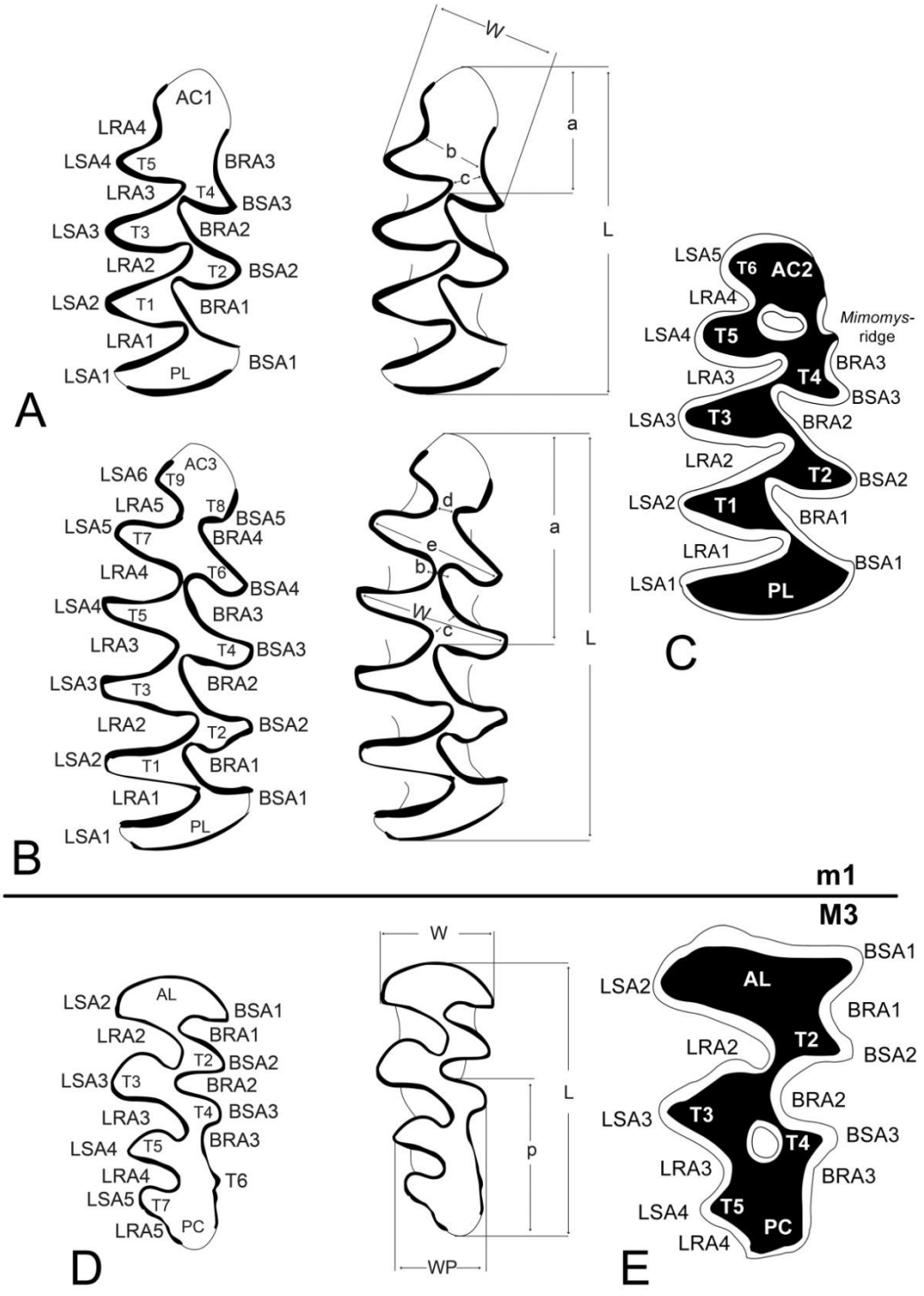


Figure 3.2 : Nomenclature and distances of measurements used for arvicolines in this thesis. A, *Arvicola* type of lower first molar (m1) bearing an anterior cap 1 (AC1); B, *Microtus* type of m1with AC3; C, *Mimomys* type m1 bearing an anterior cap 2 (AC2) with same measurement method as figured in A; D, *Microtus* type upper third molar (M3); E, *Mimomys* type M3.

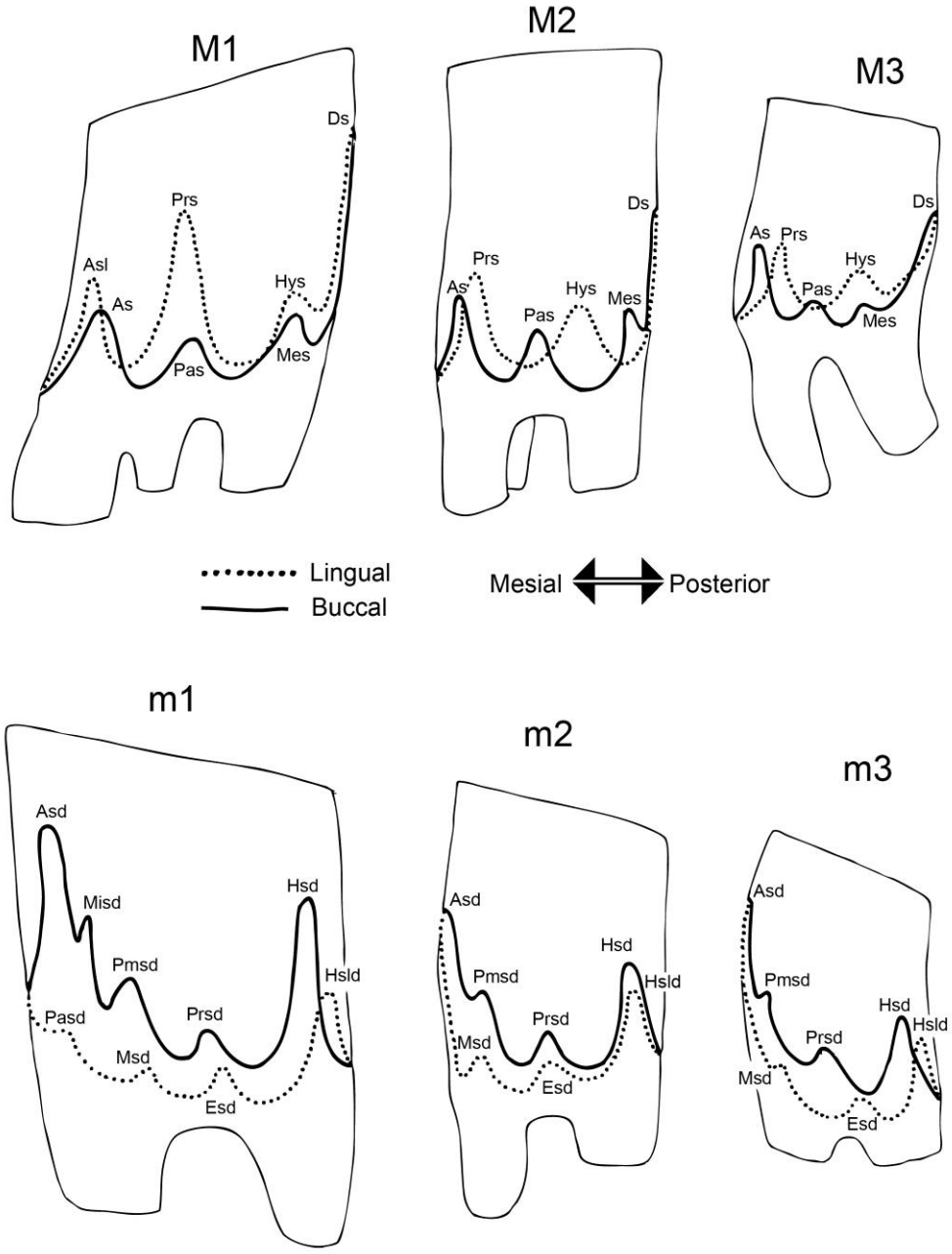


Figure 3.3 : Terminology used for *linea sinuosa* (modified after Carls and Rabeder 1988). Upper Molars: As, Anterosinus; Asl, Anterosinulus; Ds, Distosinus; Hys, Hyposinus; Mes, Metasinus; Pas, Parasinus; Prs, Protosinus. Lower Molars: Asd, Anterosinuid; Esd, Entosinuid; Hsd, Hyposinuid; Hlsd, Hyposinulid; Misd, Mimosinuid (Sinuid of Mimomys-ridge); Msd, Metasinuid; Pasd, Parasinuid; Pmsd, Prismosinuid (Sinuid of Prismokante); Prsd, Protosinuid.

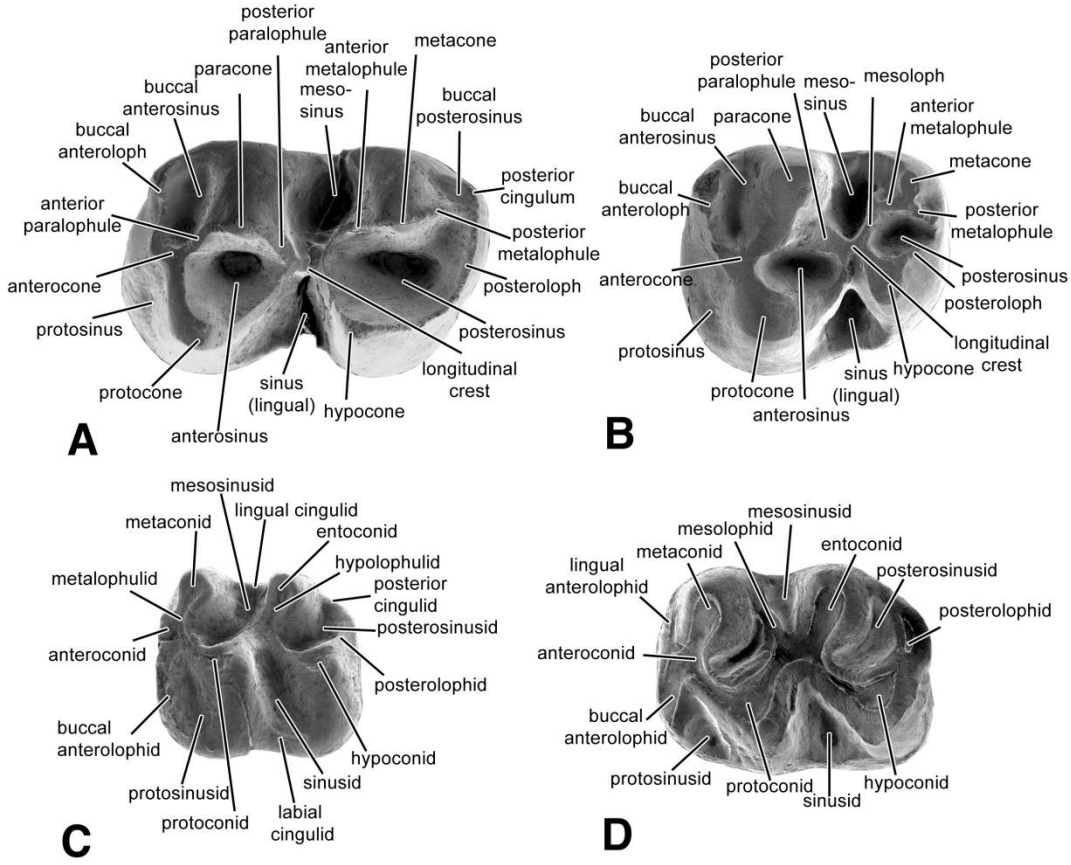


Figure 3.4 : Nomenclature used for cricetines in this thesis. A–B, upper and D, lower molars for *Mesocricetus* spp.; C lower molar for *Cricetulus* spp., according to the material and molar type studied in this thesis.

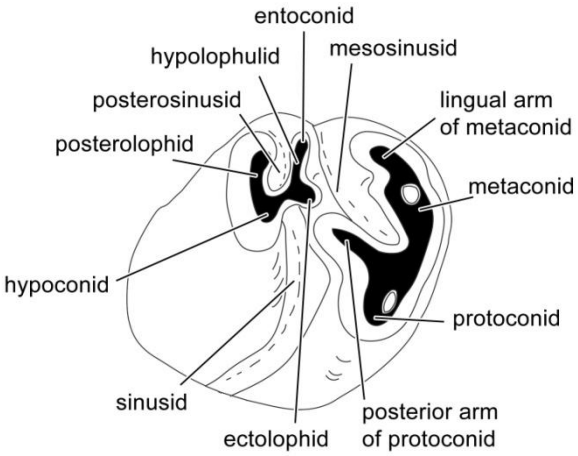


Figure 3.5 : Nomenclature of a spalacid m3, described in this thesis.

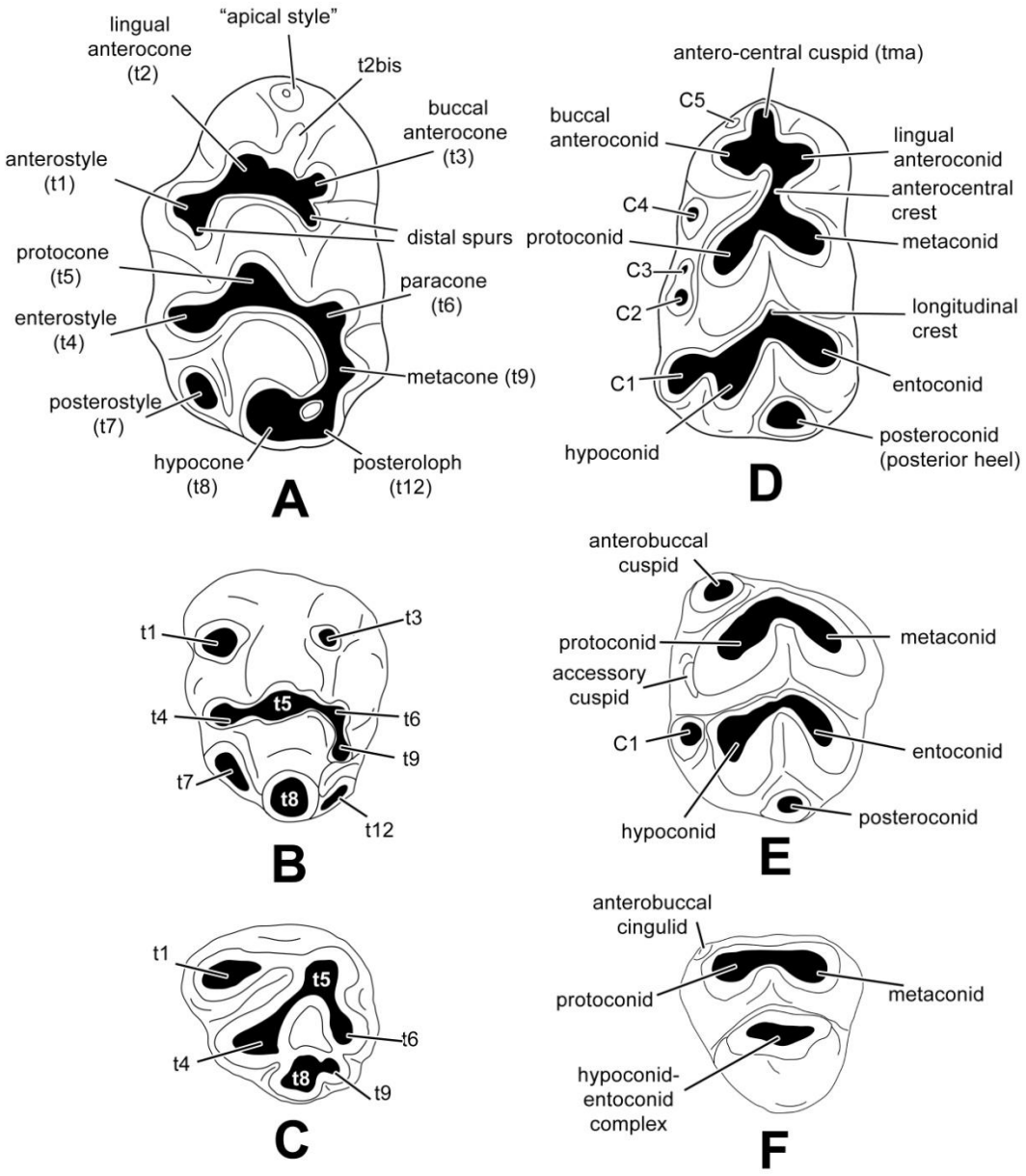


Figure 3.6 : Murine nomenclature used in this thesis. A–C, upper M1–M3 and D–F, lower m1–m3, respectively.

4. SYSTEMATIC PALEONTOLOGY

Anatolia, by means of paleobiogeography of small and large sized mammals, is considered as a bridge between Europe, Asia and Africa-Arabia since the Paleogene, as mentioned by many paleontologists (i.e., Ünay, 1996; Sen, 2013; Erdal et al, 2016; Métais et al, 2016; Albayrak, 2017).

In Quaternary, this area has not experienced extensive loss of species contrary to more northern latitudes of Eurasia due to the moderate climatic oscillations, and thus Anatolia provided a refuge for many immigrant mammalian groups (e.g., Neumann et al, 2017).

Despite the importance of Quaternary and its paleontology for Turkey, as mentioned in Chapters 1.1 and 1.3, paleontological studies on Quaternary faunas of Turkey and especially on small mammals are scarce (i.e. 15 publications since 1970; Erdal, 2017).

However the potential of Anatolia for that time interval is great as shown by some recent studies (i.e., Hoek Ostende et al, 2015a, b; Erten, 2017; Erdal 2017; Erdal et al, 2018; Erturaç et al, 2019). The first studies are those of Sen et al. (1991) and Montuire et al. (1994) for a Middle Pleistocene fauna of Emirkaya-2; of Ünay et al. (1995) from the latest Pliocene-early Pleistocene of Büyük Menderes Graben; of Suata-Alpaslan (2011a, b) from the Middle Pleistocene of Gölbaşı (Adıyaman) and Üçağızlı Cave (Hatay). Concerning the Quaternary deposits along the North Anatolian Fault Zone there are works of Ünay and de Bruijn (1998), Ünay et al. (2001) and Vasilyan et al. (2014) and finally this thesis with publications (Erdal et al, 2018; Erturaç et al, 2019; Erdal et al, in prep.).

In order to enhance the knowledge on small mammal paleontology of Pliocene–Quaternary deposits on NAFZ, this section of this thesis focuses on systematic studies of fossil specimen gathered from three adjacent basins (Tosya, Suluova and Niksar; Figures 1.1 and 2.1), and 9 localities (see Chapter 2). Besides, some

previously discovered and mentioned micro- and macro-mammal specimens also are evaluated (Erturaç, 2010).

Following the identification and systematic studies of fossil material, biochronologic ages are inferred for related deposits to constrain the formation, opening or evolving of the relevant basins. Although the geological ages of these basins have been partly known from previous geochronological studies, the present study provides solid bases for the age of sedimentary series and/or refines the previously suggested correlations. On the other hand, it is also aimed to test whether there is a continuous faunal succession from Pliocene to Quaternary in these basins or not, parallel to eventual climatic and paleoenvironmental changes (see also Chapter 5).

This present section deals with the following basins:

(1) Localities visited in the Tosya Basin have been known from the work of Ünay and de Bruijn (1998) whereas the stratigraphic positions of neither fossil bearing layers, nor biostratigraphy were unclear. With a recently discovered locality (Kumkapı, see Chapter 2.1), some revision on systematic paleontology as well as age constrain of the basin with a biochronology, are provided in this thesis.

(2) The Suluova Basin is explored and studied in extensive detail on geology by Erturaç (2010). During his studies, some mammal localities were discovered and preliminarily studied. In the scope of this thesis, these localities are re-visited in order to increase the fossil material and also to re-evaluate the macro- micro-mammal remains previously collected by Erturaç (2010). The systematic paleontology in this section hence contributed to Quaternary paleontology and also provided age constrain for the basin evolution besides a "proof" of a proto-lake formed in the Suluova Basin by fish teeth remains (see Chapter 2.2).

(3) A new rodent fauna of early Toringian (Middle Pleistocene) age is presented from the locality Umurlu in the Niksar pull-apart Basin (see Chapter 2.3). It contributes to the paleontological data of Quaternary micromammals in Turkey and enhances the age constrain for the initiation and long-term geological slip rate of the Ezinepazar Fault as well as the minimum age of the Niksar Basin. It provided paleoenvironmental insights, and initiated studies now in progress on small mammals from the adjacent NAFZ basins such as the Suluova (Amasya) and Tosya (Kastamonu) basins.

4.1 Tosya Basin

As mentioned in Chapter 3.2, there are 10 distinct localities sampled during the 2014 and 2016 field works but only Kumkapı, Sapaca 1 and Sapaca 2 as well as Ortalıca 1 and Ortalıca 2 localities are yielded identifiable and significant micromammal fossil remains, as shown in Figure 4.1.

In addition, it is attempted a measured stratigraphic section (MSS) for Ortalıca-2 locality as shown in Figure 2.6, in Chapter 2.1.2 where the layer A is yielded only some lacertilian, gastropods and fish remains;. The remain of *Apodemus* is found in all layers except E and G; *Pliomys* is present in B–D and in F, *Mesocricetus* is found only at the layer D. On the other hand, layer E yielded and premolar of *Ochotona* (Sevket Sen pers. comm.) and G only an incisor of lagomorphs.

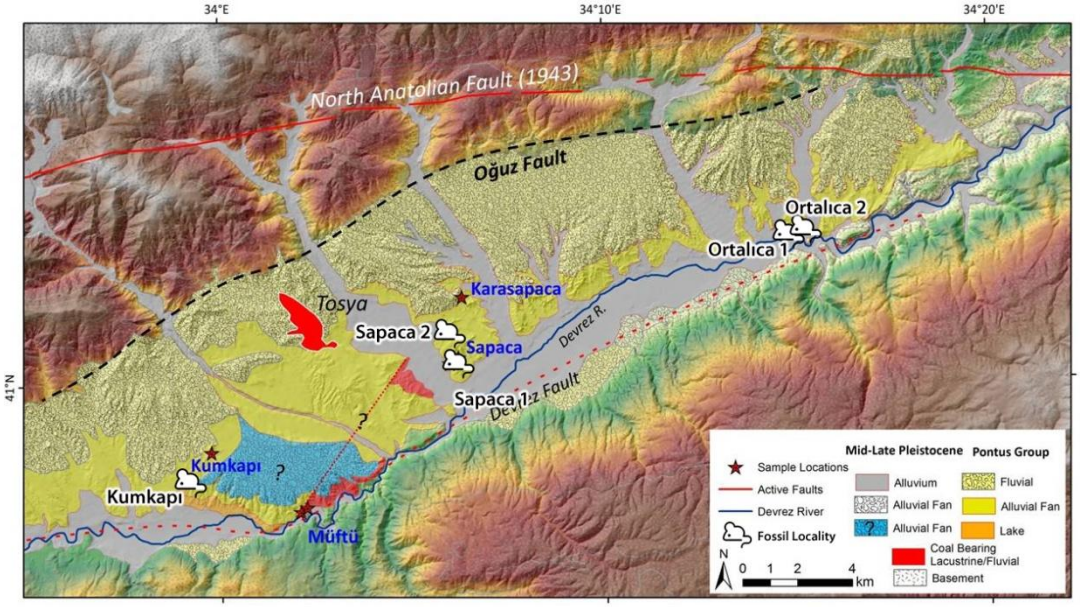


Figure 4.1 : Simplified topographic map of Tosya Basin with different depositional environments and fossil localities. (compiled from Barka, 1985; Andrieux et al, 1995; MTA).

4.1.1 Fossil remains from Ortalıca 1-2 localities

4.1.1.1 *Mesocricetus primitivus*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Cricetinae Fischer, 1817

Genus: *Mesocricetus* Nehring, 1898

Mesocricetus primitivus de Bruijn, Dawson and Mein, 1970

Figure 4.2

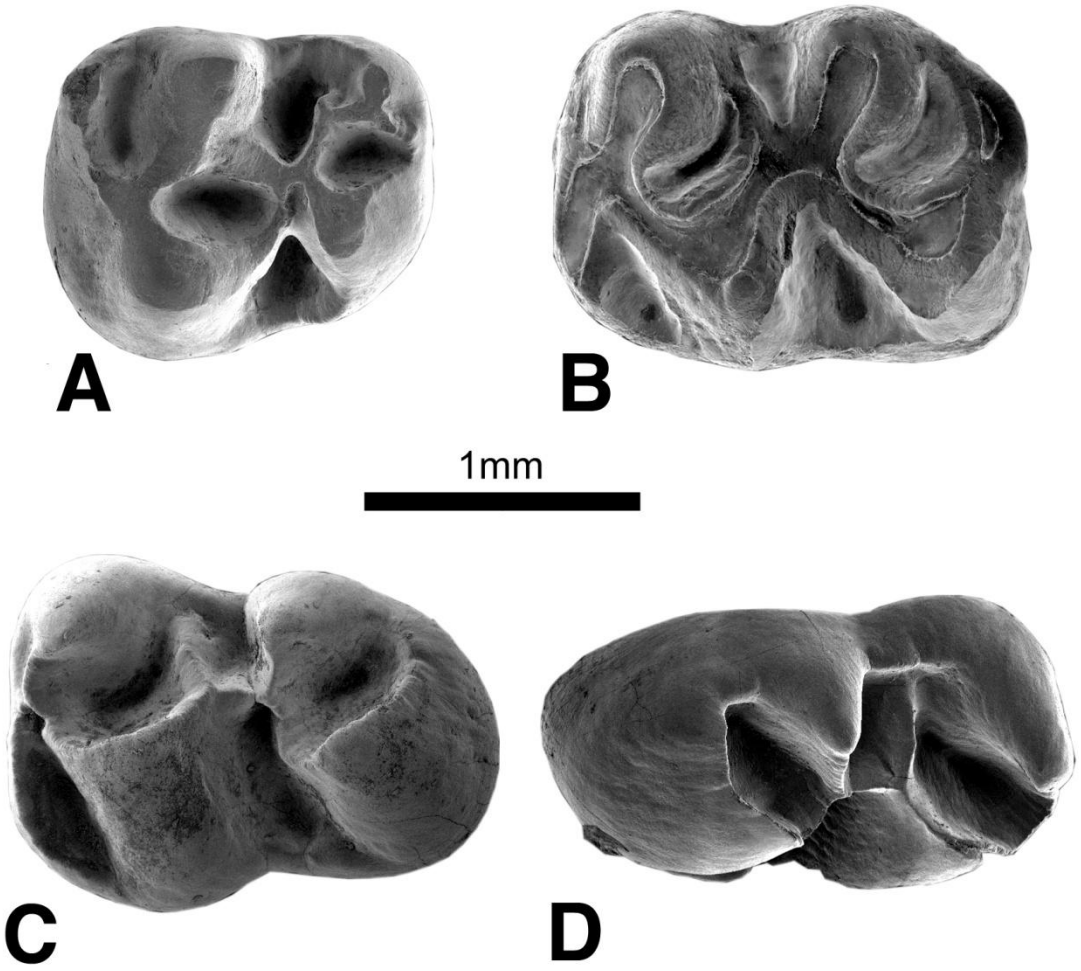


Figure 4.2 : *Mesocricetus primitivus* molars from Ortalıca locality. A, M3s (ORT-62); B, m2d (ORT-63); C, m3s (ORT-64) and D, m3d (ORT-65).

Material: 1 M3s (ORT-62), 1 m2s (ORT-63), 1 m3s (ORT-64), 1 m3d (ORT-65).

Localities: Ortalıca-1 (3 specimens: ORT-62, 64–65) and Ortalıca-2 (1 specimens: ORT-63).

Measurements in mm: Table 4.1

Description: The M3 as the only found upper molar from Ortalıca is (Figure 4.2.A) short rather than elongate and subrectangular in outline. Anterior part is wider than posterior. The buccal anteroloph is well developed and oriented straightforward to anterobuccal side of the molar, leaving anterosinus open. The lingual anteroloph is lost, therefore the protosinus. The buccal tubercles are slightly situated posterior to the lingual tubercles. The paracone is almost equal in size as protocone but the metacone is much smaller than hypocone. The low posterior paralophule and posterior protolophule are connected to the short longitudinal crest, and they enclose on the middle of molar, together with the protocone and paracone, the inner part of the mesosinus, which is oval-shaped. The posterior spur of paracone is absent. The mesosinus and (lingual) sinus are deep, symmetrical and they have same volume. The connection between the posterior paralophule, posterior protolophule, longitudinal crest, mesoloph and anterior arm of hypocone form the letter "X". The prominent and strong mesoloph is oriented slightly backwards to join the horizontal anterior metalophule. The posterior metalophule is much shorter, and descend to the base of the crown to join the extremely reduced posterior cingulum. Between the metacone and hypocone, there is a short and narrow posterosinus, which is delimited by metalophule, mesoloph, hypocone and posteroloph and it is open on the posterior side. There are two anterior one posterior roots.

Table 4.1 : Measurements in mm of *Mesocricetus primitivus* from Ortalıca. (*) estimated value.

Taxon	Molar	Length	Width
Mesocricetus primitivus	M3 s	1.45	1.26
	m2 d	1.67	1.23
	m3 s	1.78	1.3
	m3 d	1.73*	-

The m2 is subrectangular in outline equally wider in anterior and posterior parts (Figure 4.2.B). The lingual conids are situated posterior to buccal conids and they are curved slightly backwards. The buccal anterolophid is prominent while the lingual anterolophid is thin and low. The protoconid and buccal anterolophid delimits a wide

protosinusid. The mesolophid is protruding from the end of the posterior branch of protoconid, directed lingually but curving slightly towards the base of the metaconid where they are connected. Hence, the mesosinusid is divided in two parts. The posterosinusid is wide and deep, and enclosed on the posterior side of the molar by a widened posterolophid which is curved low toward the entoconid. The cingulum encounters the buccal and posterior margins of the tooth. There are two roots.

The two m3 are identical in morphology but the less worn one (Figure 4.2.D) is missing the protoconid and some anterobuccal part. In addition, the angle of pictures is not the same, which would be confusing. The anterior side is wider than posterior part. The buccal cuspids are shifted posteriorly as in m2. As in m2, the lingual anterolophid is weaker and reduced almost into a ridge-cingulid structure. The buccal anterolophid is robust and joins the base of the protoconid, thus enclosing the protosinusid. The mesolophid is oblique and straight rather than curved, descending to the base of the metaconid and ends near the lingual cingulid without a connection with metaconid base (*contra* m2); consequently, the mesosinusid is interrupted as in m2. The posterolophid is well developed, joins the base of the entoconid to enclose the posterosinusid. There is no posterior cingulid. Roots are not preserved.

Comparison and discussion: The medium sized hamster M3, m2 and m3 from Ortalıca are greater in size than *Cricetulus migratorius* found in Turkey from the early Pliocene İğdeli (Sivas, Suata-Alpaslan et al, 2010), Middle Pleistocene of Emirkaya-2 (only M3 and m2; Seydişehir, Montuire et al, 1994) and the latest Villanyian Bıçakçı localities (Çameli Basin, Hoek Ostende et al, 2015b) as also shown in Figures 4.3 and 4.4. On the other hand, the Ortalıca cricetine m3 is far smaller than *Cricetus cricetus* found from the Middle Pleistocene Emirkaya-2 locality (Montuire et al, 1994) as the only representative of the species in fossil form since the recent forms are not grounding in Anatolia, according to Krystufek and Vohralik (2009). However, one m2 of *Cricetus* sp. was also reported from the Bıçakçı locality of which the size are still greater than Ortalıca specimen (L=2.05, W=1.61 mm; Hoek Ostende et al, 2015b). In order to reinforce the comparison with the cricetine M3 and m2 from Ortalıca, selected *C. cricetus* from the Early Pleistocene Futjovka Cave (North Bulgaria, Popov, 2017) is equally greater in size than Turkish specimens. *Allocricetus* is very close to *Cricetulus* for some authors that

they can be classified under *Cricetulus* genus (e.g. Hoek Ostende et al, 2015b and references therein). *Allocricetus* sp. indet. from the Çankırı Basin is slightly smaller than Ortalıca species (Sen et al, 2018) whereas *A. bursae* (Popov, 1994, 2000, 2017) is in overall smaller in size than but closer in morphology to the Turkish specimens.

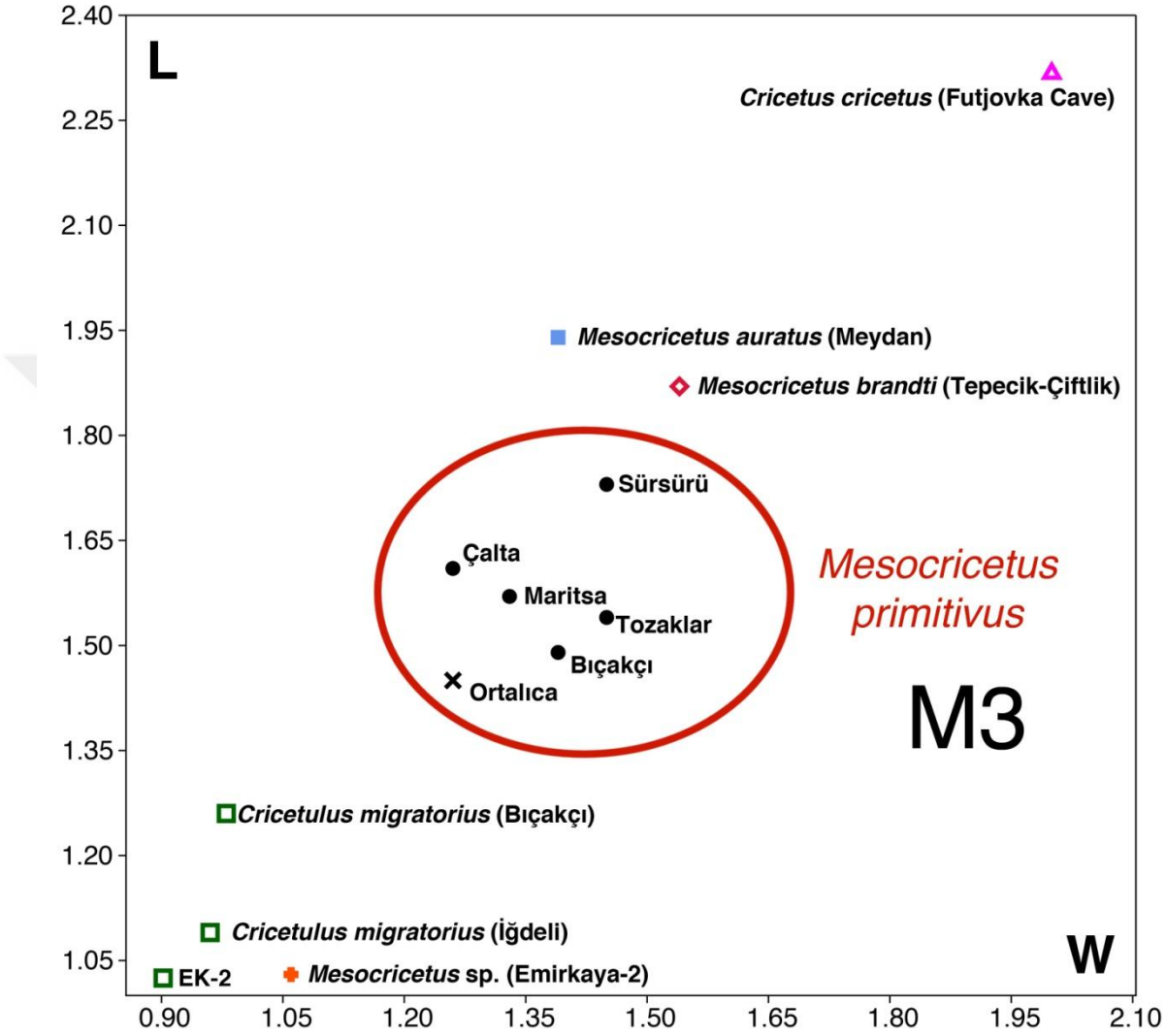


Figure 4.3 : Scatter diagram of upper third molar mean values in mm of Pliocene–Recent *Mesocricetus* spp., *Cricetulus migratorius* and *Cricetus cricetus* from diverse localities. L, length; W, width; EK-2, Emirkaya-2 locality for *Cricetulus migratorius*.

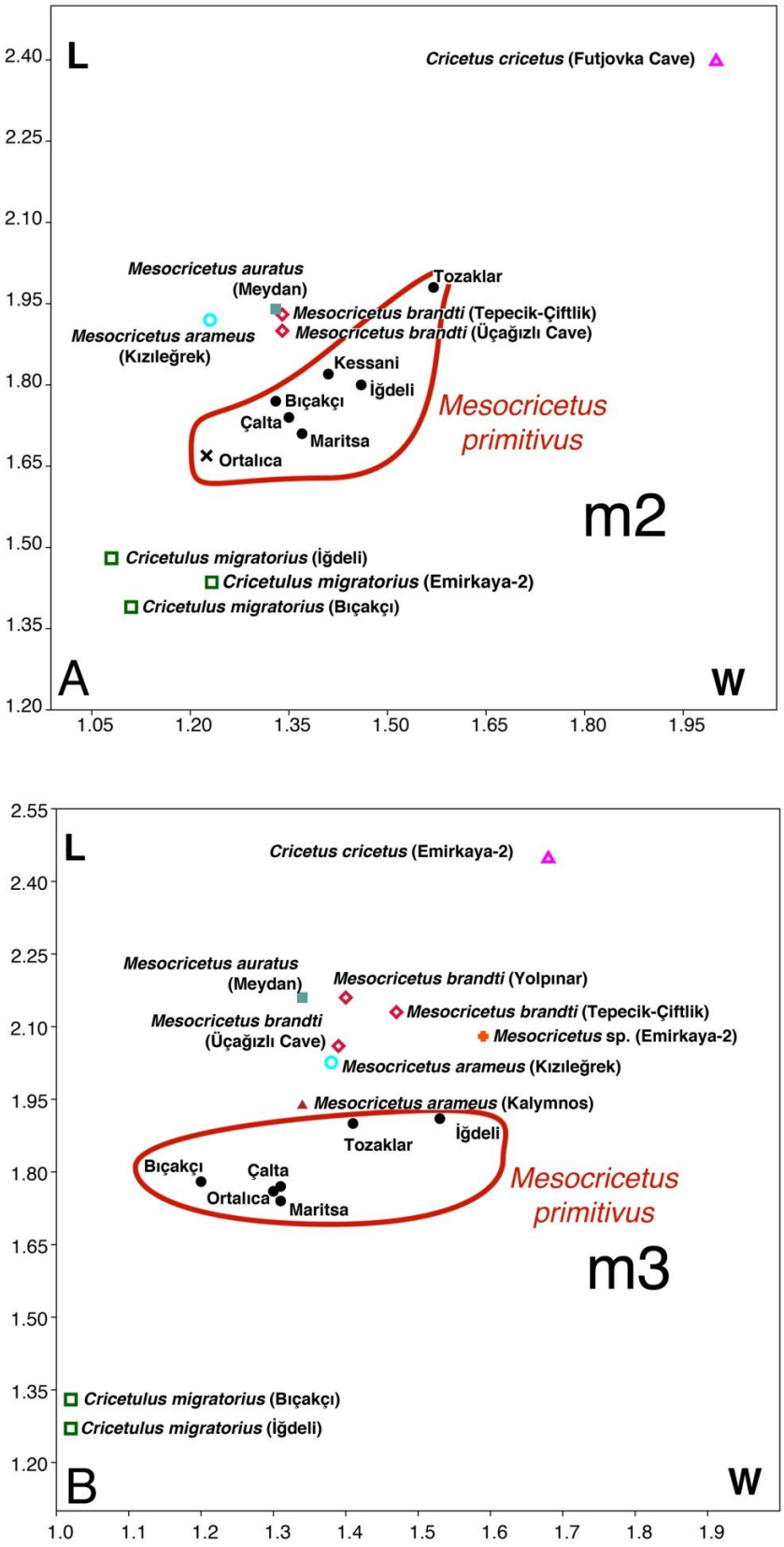


Figure 4.4 : Scatter diagram of lower second and third molar mean values in mm of Pliocene–Recent *Mesocricetus* spp., *Cricetulus migratorius* and *Cricetus cricetus* from diverse localities. L, length; W, width; EK-2, Emirkaya-2 locality for *Cricetulus migratorius*.

The hamster from Ortalıca better fits with *Mesocricetus* since there is a mesoloph and mesolophid on M2 and m2–m3, respectively, *contra* all metrically compared specimens above. However, the Ortalıca *Mesocricetus* molars are greater in length and width than the M3 of *Mesocricetus* sp. from Emirkaya-2 (Montuire et al, 1994, fig. 18) (Figure 4.3) and morphologically, shorter and narrower. The Emirkaya m2 is narrower than the one from Ortalıca and has a more prominent lingual anterolophid, as seen in Figure 4.3. The m3 of *Mesocricetus* sp. from Emirkaya-2, on the other hand, is greater in size than the Ortalıca hamster and it differs in having stronger lingual anterolophid and much oblique mesolophid (Figure 4.4.B).

The Ortalıca cricetine is also compared to the Holocene subfossil of *Mesocricetus auratus* from Meydan locality (near Madenköy, Niğde; Hír, 1992), to *M. brandti* from the Holocene archaeological site Tepecik-Çiftlik (Niğde; Erdal et al, 2019), to *M. brandti* from the early Toringian Üçağızlı Cave (Hatay; Suata-Alpaslan, 2011b) and *M. arameus* from the early Biharian Kızıleğrek (Suluova Basin, Erturaç et al, 2019), to *M. arameus* from the Early Pleistocene Kalymnos (Greece, Kuss and Storch, 1978). All of these *Mesocricetus* spp. have m2 and m3 greater in length from the Ortalıca hamster (Figures 4.3 and 4.4).

Mesocricetus auratus and *M. brandti* (for their close relationship, see Erdal et al, 2018, p.82) differs from the Ortalıca hamster as already mentioned by Sen (1977, p.11) in having stronger ridges with rhomboidal pattern on upper molars, elongated m2 and m3 with stronger mesolophids but weak lingual anterolophids, much wider talonid, more posteriorly curved lingual cuspids, much prominent buccal anterolophid on m3 (e.g. Hír, 1992; Krystufek and Vohralik, 2009; Erturaç et al, 2019), in exception of the lack of lingual anteroloph on M3 and rather connected mesolophid on m2 which are probably minor but constant variations of *M. primitivus*, as discussed further in this section.

The cricetine of this study also differs from *Mesocricetus arameus* from Kalymnos (Kuss and Storch, 1978) and Kızıleğrek (Erturaç et al, 2019) in having wider protosinusid and weaker buccal anterolophid, less elongate and rather squarish m2, much narrower talonid and well-developed cingulids on m3.

Note that the all available material for Ortalıca hamster is rather grouped in the scatter diagram with the *Mesocricetus primitivus* species; it is smaller in general in

length or width for the M3 and m2 (Figure. 4.3 and Figure 4.4.A), but overlapping in m3 (Figure 4.4.B), especially with that of Çalta and Maritsa localities. According to the definition of *M. primitivus* from the type locality Maritsa (de Bruijn et al, 1970; see also Hoek Ostende et al, 2015b), the main characteristic is the well-developed mesolophid on m2 and m3 in addition to relatively strong lingual anteroloph (=lingual branch of anterior cingulum *sensu* de Bruijn et al, 1970) on M2 and M3. In this manner, the Ortalıca hamster differs only in lack of lingual anteroloph on M3, based on the available material and comparison with the figured specimens from Maritsa (de Bruijn et al, 1970, pl. 4.7–11). As to mesolophid, they are as well developed and elongate as Maritsa specimens. However, the mesolophid on m2 of Ortalıca cricetine is connected to the base of the metaconid as it is already mentioned in other studies (e.g. Suata-Alpaslan et al, 2010).

Surprisingly, all Pliocene *Mesocricetus* species are defined as whether "cf." *primitivus* from Anatolian localities such as Çalta (Sen, 1977), Ortalıca (only M2, Ünay and de Bruijn, 1998), İğdeli (Suata-Alpaslan et al, 2010) and from Greece (Kessani, Vasileiadou et al, 2003), or as "aff." *primitivus* from Sürsürü and Tozaklar (Ünay and de Bruijn, 1998), and from the latest Villanyian Bıçakçı (Hoek Ostende et al, 2015a). Note that Ünay and de Bruijn (1998) reported from Ortalıca only M2 which does not allow direct comparison with the material under study. The common reason to ascribe all of these Pliocene and one Early Pleistocene *Mesocricetus* remains as "cf." or "aff." *primitivus* in previous studies, is due to differential characters provided by de Bruijn et al. (1970) for the diagnosis of *M. primitivus*. It soon appeared that the dental features display many variations as found in subsequent fossil faunas; absence or weak development of lingual anteroloph on M2 and M3, the length or orientation of mesolophid (i.e. straight or curved toward metaconid) (Hoek Ostende et al, 2015a, p. 237) on m2 and m3, and so on. These characters are also valid for the Ortalıca material. The type material of *M. primitivus* from Maritsa (de Bruijn et al, 1970) is scarce; hence the lack of variation (Vasileiadou et al, 2003; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015a) while the material from Çalta (Sen, 1977) is relatively more abundant. Many intraspecific variations are underlined first by Sen (1977, p. 111) and also by the above mentioned authors. I suggest that they should be all considered as the possible variation within the species *M. primitivus* from the Pliocene–early Pleistocene, since

their size and dental morphology are reasonably close. In this regard, the hamster from Ortalıca is defined as *Mesocricetus primitivus* which represents the smallest specimen found so far, at least, until new fossil are gathered. Accepting these variations as intraspecific would avoid the stress to define a new species holding very few and variable morphological features differing from the type material. Also, it would be much suitable to accept new fossil findings having similar morphological features (i.e. occlusal morphology with minor variations and close sizes) as the species *M. primitivus*, rather than to confer or affiliate.

4.1.1.2 *Pliomys destinatus*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Arvicolinae Gray, 1821

Genus: *Pliomys* Méhely, 1914

Pliomys destinatus Tesakov, 2005

Figure 4.5

Material: 3 M1 (ORT-1–3), 6 M2 (ORT-4–9), 6 M3 (ORT-10–15), 3 m1 (ORT-16–18), 3 m2 (ORT-19–21), 7 m3 (ORT-22–28).

Localities: Ortalıca-1 (ORT-1–4, ORT-6–7, ORT-9–13, ORT-15–24, ORT-27–28) and Ortalıca-2 (ORT-5, 8, 14, 25–26). For stratigraphic positions see Figure 2.6 in Chapter 2.1.2.

Measurements in mm: Table 4.24.

Description: All molars are medium sized, brachydont with low but slightly undulating *linea sinuosa*, and without cementum in re-entrant angles.

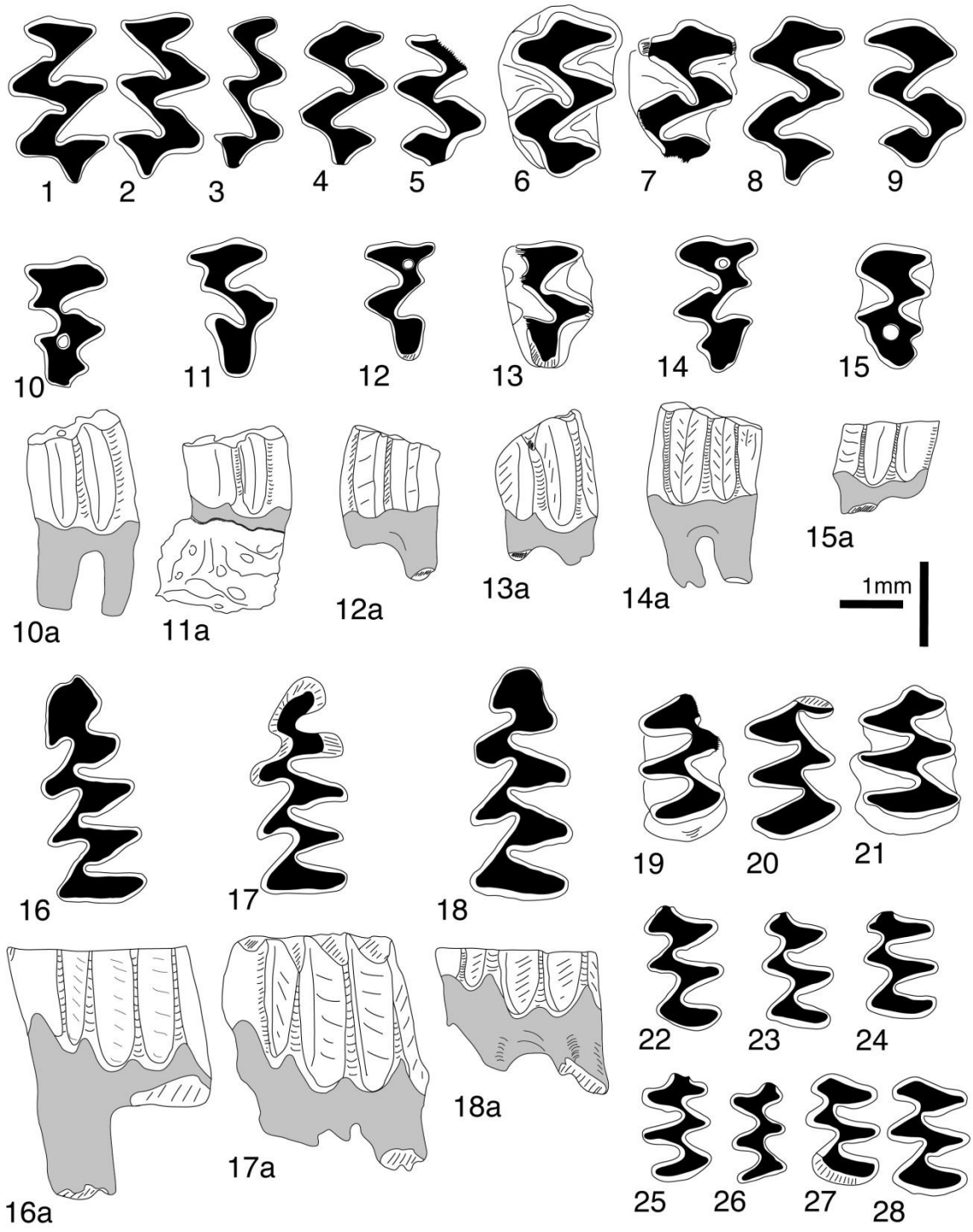


Figure 4.5 : Upper and lower molars of *Pliomys destinatus* from Ortalıca. 1–3: M1; 4–9: M2; 10–15: M3; 16–18: m1; 19–21: m2; 22–28: m3. “a” represents lingual view for M3, buccal view for m1. Vertical scale bar is for occlusal, lateral scale is for lateral views.

Only upper first and second molars have three roots, and others have two roots. Just one m1 (Figure 4.5.17a) display a labial rootlet. The enamel differentiation is not observed on any molars. The distosinus is generally greater in height than anterosinus as well as other *linea sinuosa* elements on upper molars; the anterosinuid has almost double height of hyposinuid on lower molars (Tables 4.23.).

Table 4.2 : Upper molars measurements of *Pliomys destinatus* in mm. (*) indicates estimated values.

	L			W			As			Ds			Asl		Prs		PA-index	
	N	Range	Mean	N	Range	Mean	N	Range	Mean	N	Range	Mean	N	Range	Mean	Range	Mean	Range	Mean
M1	3	1.91-2.09	2.03	3	0.86-1.22	1.09	3	0.25-0.47	0.34	3	0.82-0.93	0.87	3	0.27-0.34	0.3	0.36-0.49	0.42	0.48-0.62	0.55
M2	6	1.64*-2	1.84	6	1.06-1.29	1.19	6	0.27-0.39	0.31	6	0.42-0.73	0.51	5	-	-	0.21-0.41	0.33	0.42-0.53	0.45
M3	6	1.48-1.71	1.57	6	0.79-0.99	0.91	6	0.18-0.34	0.23	6	0.32-0.43	0.38	6	-	-	0.16-0.28	0.24	0.29-0.44	0.33

Table 4.3 : Lower molars measurements of *Pliomys destinatus* in mm. (*) indicates estimated values.

	L			W			Asd			Hsd		Hsld		HH-index	
	N	Range	Mean	N	Range	Mean	N	Range	Mean	N	Range	Mean	Range	Mean	Range	Mean
m1	3	2.65-2.74	2.71	3	1.08-1.15	1.11	3	0.99-1.11	0.96	3	0.51-0.72	0.64	0.23-0.49	0.34	0.59-0.85	0.73
m2	3	1.53-1.68*	1.59	3	0.98-1.11	1.06	2	0.51-0.54	0.53	3	0.19-0.46	0.36	0.21-0.42	0.31	0.28-0.62	0.48
m3	7	1.21-1.46	1.34	7	0.7-0.98	0.88	7	0.31-0.46	0.39	7	0.1-0.38	0.21	0.15-0.29	0.23	0.19-0.47	0.32

Table 4.4 : The m1 ratios of *Pliomys destinatus* and the WP of M3 in mm.

		A/L		B/W		C/W		L/W		WP	
	N	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
m1	3	39.93-51.7	47.21	16.51-32.4	22.1	6.11-8.26	7.24	2.38-2.53	2.45	-	-
M3	6	-	-	-	-	-	-	-	-	0.82-0.93	0.87

The anterior side of AL of M1s is flat. The AL is followed by closed T1–T4 although the dentine fields are more or less confluent; in relatively older specimens (e.g. Figure 4.5.1–2, crown heights are 1.79 and 1.85 mm, respectively) the confluence between T1–T2 and T3–T4 and PC is apparent, but in younger specimens (e.g. Figure 4.5.3, crown height=2.3 mm) the confluence is established between all of triangles and it is weaker on T4–PC. Triangles are symmetrical and they have similar

volume, as the LRAs and BRAs. The leading edge of T1 is quite parallel to the anterior side of BRA1. The posterior side of PC is sharp with deep LRA3 and BRA3.

The M2s have an AL followed by T2–T3 and a PC with T4. The dentine fields are much confluent in younger individuals (e.g. Figure 4.5.4 and Figure 4.5.8 with h=2.06 and 2.44 mm, respectively) than in older ones (e.g. Figure 4.5.5–7, 9 with h=1.39, 0.99, 1.08 and 1.41 mm, respectively). As in M1, the M2 has a strong LRA3 almost forming a right angle. Except one specimen (Figure 4.5.9), the anterolingual side of AL is depressed, like forming an additional re-entrant angle. The depression on the anterobuccal side is faint but still distinguishable.

The M3 has an anterior loop, broadly fused with T2 if the enamel islet is absent (Figure 4.5.10–11, 13, 15; h=1.92, 1.33, 1.77 and 0.99 mm, respectively). The least and most worn specimens (Figure 4.5.10, 15) bear an enamel islet on PC, but none of six M3s displays islets on AL and PC at the same time. It is apparent that the presence or absence of enamel islets is independent of wear level, at least, for present sample. For instance, while some M3 (Figure 4.5.10, 12, 14) have an islet despite their relatively high crown height (h= 1.92, 1.56 and 1.61 mm, respectively), it can be absent or present on others (Figure 4.5.11, 13, 15). However, it is evident that there is a strong relation with the enamel islet on PC and the deepness of BRA2. In other words, the two M3s having an enamel islet on the PC has shallower BRA2 contrary to others where the deep BRA2 fused with an islet somehow. The quantity of material is not sufficient to hypothesize further. The dentine field of T2 and T3 is separated except in two specimens (Figure 4.5.12, 15). The T3 is broadly confluent with PC only on specimens bearing an enamel islet on PC. The BRA1 is shallow in typical pliomyine-type. The BRA2 and BSA3 are well developed in all molars, BRA2 deeper on molars which lack enamel islet on their PC. BRA3 is weak (Figure 4.5.10), absent (Figure 4.5.11–14) or well developed (Figure 4.5.15). The PC is rather simple and slightly elongate. In two specimens out of 6, there is a formation of weak LSA4 with very shallow LRA4.

One m1 among three represents the oldest individual (Figure 4.5.18; h=1.15 mm) and one other the youngest (Figure 4.5.17; h=2.4 mm) which possibly undergone a post-mortem abrasion. As to third m1, it display an intermediate stage of wear Figure 4.5.16; h=1.94 mm). For instance, lingual triangles gain volume with wear as well as the anterior cap, LRA4 gets more and more shallow, and on advanced wear stage, it

almost disappears and AC shortens with fusion of T5. That evolution can be traced also on A/L ratio which decreases from around 51 to ~40 with stable length (Figure 4.5.2–3). On the other hand, measurements are almost identical except the A/L ratio (see Tables 4.24.4). Therefore, despite occlusal morphology which appears to be different at first sight, all of m1 material in this section belongs to the same species.

The m1s are constituted by posterior lobe and three triangles, followed by alternating T4–T5 as a part of anteroconid complex 2 (ACC2) and a broad, trapezoid to oval-shaped anterior cap (AC). On the tip of AC of one specimen, a faint notch is visible in occlusal and lateral view (Figure 4.5.16–16a). There is no *Mimomys*-ridge, nor an enamel islet. Therefore the morphotype is rather *Dolomys*-type with deep BRA3. BRAs are oriented forward while LRAs are more laterally. The BRA3 and LRA4 are reciprocally constricted to form the BSA4 and LSA5 but triangles T6–T7 are not formed. LSA5 is disappeared on worn specimen (Figure 4.5.18). The confluence of dentine fields is more or less established. The connection of T5 to AC is broad and T5 completely fuses with AC on advanced wear stage. T4–T5 are completely separated by deep LRA3. The buccal tip of T4 is blunt and lacks a groove for a potential *Mimomys*-ridge. The *linea sinuosa* is undulating with the highest anterosinuid, followed by prismosinuid, hyposinuid and as the lowest, protosinuid.

The m2s are formed by PL and four asymmetrical triangles; lingual ones are greater than buccal ones. PL is isolated, in other words, less confluent compared to the dentine field of T1–T2. BSA3 of one specimen is damaged but according to anteriorly oriented BRA2, the dentine field connection between T3–T4 is constricted, on the contrary of other two specimens where T3 is broadly confluent with T4 (Figure 4.5.20). On the complete specimen (Figure 4.5.21) there is a faint depression on the anterobuccal side which bifurcate slightly the anterosinuid.

The asymmetry of m3's triangles is apparent as on m2s but on the youngest individual (Figure 4.5.26; h=1.68) LRAs and BRAs have equal volume. On that latter specimen, all dentine fields are confluent but with increase of wear, couples of T1–T2 and T3–T4 are more or less isolated from another. On four specimens of m3, there is an anterolingually situated LRA3, much deep on least worn molar (Figure 4.5.26) and almost disappeared on the most worn specimens (Figure 4.5.24, 27; h=1.25 and 0.82 mm, respectively).

Comparison and discussion: The medium size, slightly undulating but low *linea sinuosa*, lack of cementum in re-entrant angles on all molars, short and simple PC as well as shallow BRA1 on M3 (="pliomyine" structure *sensu* Chaline et al, 1999), asymmetrical triangles, not fully specialized T4–T5 by confluence to be part of a wing within ACC2, broad, slightly rectangular shape of anterior cap on m1 allow to identify the genus of Ortalıca arvicoline as *Pliomys*.

Despite some morphological similarities at first sight with some *Dolomys* spp. (e.g. *D. adroveri*, *D. milleri* and *D. nehringi*), I exclude them from comparison with Ortalıca vole due to their much larger size and some difference on the anteroconid complex of m1 (i.e. less elongate and much rounded AC, more protruding tip of BRA3 which forms an enamel islet, presence of T6 and T7 in *Dolomys* spp.; presence of *Mimomys*-ridge on m1 of *D. nehringi* and *D. milleri*) (see, Kretzoi, 1955, p. 349; Sulimski, 1964; Rabeder, 1981; Minwer-Barakat et al, 2004; Popov, 2004; Hordijk and de Bruijn, 2009).

The *Pliomys* of this study differs from the *Mimomys gracilis* found and described by Ünay and de Bruijn (1998, p. 438) at the same locality differs in greater size of m1s and slightly smaller m3s, as well as lower *linea sinuosa* and hypsodonty.

Because of similar depth and undulation pattern of *linea sinuosa*, the Ortalıca vole is compared to *Dolomys occitanus* from the late Ruscinian (MN15b) of Muselievo (North Bulgaria; Popov, 2004), from the late Ruscinian of Sète (Southern France; =*Mimomys stehlini in* Thaler, 1955; Michaux, 1971) and from the late Ruscinian (MN15) Ericek locality in the Çameli Basin (=*Mimomys occitanus in* Hoek Ostende et al, 2015b). According to Hoek Ostende et al. (2015b), many *Mimomys occitanus* specimens are described erroneously as *M. stehlini* (*contra* Minwer-Barakat et al, 2008), probably following the species from Sète (Michaux, 1971). The systematic position and taxonomic disagreement is beyond of the scope of the present thesis, but for simplicity I follow Popov (2004) and Minwer-Barakat (2008) to recognize *Dolomys* instead of *Mimomys* for *occitanus* species (see also Maul, 1996; Hoek Ostende et al, 2015b).

The measurements of *Pliomys* from Ortalıca are situated at the lower limit of *D. occitanus* from Muselievo and Sète (also Nîmes, see Michaux, 1971) but far smaller

from that of Ericek locality (indirect measurement from the scale provided by Hoek Ostende et al, 2015b, fig.6). The most worn m1 from Ortalıca (Figure 4.5.18) is similar by means of ACC form to that from Muselievo (Popov, 2004, fig.33-D) but the Bulgarian specimens do not display such a variation as the loss or faint of LRA4. On the other hand, the Ortalıca *Pliomys* differs in having more anteriorly elongate anterior cap, wider and less anteriorly oriented BRA3, a blunt T4 but without a groove which give rise to a *Mimomys*-ridge in later wear stage on m1; flattened (*contra* undulated) leading edges of T2 and T3 as well as presence of depression on anterolingual side of AL on M2; narrower but elongate PC having rather rounded enamel islet (if present) than laterally elongate, much independent T3, deeper BRA2 and LRA3 on M3.

Length of m1 and of a juvenile M3 of *Dolomys* sp. illustrated by Ünay and de Bruijn (1998) from the same region Ortalıca (locality is uncertain), overlaps well with that of the present Ortalıca vole. These authors did not illustrate the lateral view of molars (Ünay and de Bruijn, 1998, fig.4.3–5) but they provided the height of M3 distosinus as 0.9 mm which is almost double of that *Pliomys* in the present study (*contra* 0.32–0.43 mm, Table.4.2). Also, *Dolomys* sp. in their study differs from the *Pliomys* m1 in having shorter AC, more symmetrical triangles, shallower BRA3, more protruding LSA5. In addition, one illustrated specimen (Ünay and de Bruijn, 1998, fig.4.5) has T4–T5 couple completely fused with AC. The juvenile M3 resembles rather to Arvicoline gen. et sp. indet. which is mentioned in the next section of this thesis (Figure 4.6.4).

One of the well known *Pliomys* species is *Pliomys hungaricus*, initially described by Kormos (1934) from the Csarnota-2 locality (Hungary) as *Dolomys*. However, Sulimski (1964, p. 207) drawn attention to the similarities between *Dolomys* and *Pliomys*, and questioned their systematic positions, especially that of *D. hungaricus*. On the other hand, several authors used different generic name for *hungaricus*, such as *Propliomys* (e.g. Radulescu and Samson, 1996; Popov, 2004; Hordijk and de Bruijn, 2009; Fejfar et al, 2011), *Pliomys* (e.g. de Bruijn and Meulen, 1975; Chaline et al, 1999; Tesakov et al, 2007), and *Dolomys* (e.g. Sulimski, 1964; Maul, 1996). That disagreement is probably caused by several papers of Kretzoi (1955a, 1955b, 1956, 1959) who used all of these generic names to describe very similar specimens (see Sulimski, 1964, p. 208). That discussion is far beyond the scope of the thesis but

for simplicity, I prefer to follow the suggestion of de Bruijn and Meulen (1975) that moved *Propliomys* and *Dolomys* into *Pliomys* for *hungaricus* species.

Pliomys of Ortalıca is compared to *Pliomys hungaricus* from the early Villanyian Csarnota-2 locality (Kormos, 1934; after illustration and differential description in de Bruijn and Meulen, 1975, p. 323, Pl.1.5–6; differential description by Tesakov, 2005, p. 132), from the early Villanyian (MN16a) Podari locality (Romania, Radulescu and Samson, 1996), from the Early Pliocene Notio 1 locality (Ptolemais Basin, Greece, Hordijk and de Bruijn, 2009), and from the Early Pliocene of Weze-1 (Poland, Sulimski, 1964). In overall, *P. hungaricus* molar size is slightly greater than the Ortalıca vole except the Greek *Pliomys*, of which they really overlap (Table 4.24.4; Hordijk and de Bruijn, 2009, tabl. 23–24).

The *linea sinuosa* of the Ortalıca *Pliomys* m1 is similar to that of *P. hungaricus*, likewise the hypsodonty level. However the undulation on M3s of Turkish specimen is lesser and dentine track is lower. Another similarity is the weak presence of labial rootlet on m1, although it is rare in these populations (e.g. de Bruijn and Meulen, 1975, pl.1.5b). On the other hand, *P. hungaricus* differs from the Ortalıca vole in having shorter anterior cap, much protruding LSA5 on moderately worn molars, presence of LSA6, LRA5 and variably BRA4 on younger specimens, presence of a trace of *Mimomys*-ridge or a groove on BSA3 and rarely enamel islet (e.g. Hordijk and de Bruijn, 2009, pl. 24-5a) on m1, three rooted M3 except "cf." species from Poland and North Bulgaria (Sulimski, 1964; Popov, 2004). It is worth mentioning that M3 of *P. hungaricus* (=*Propliomys*) from Notio-1 locality display such occlusal pattern variation that match well with the Ortalıca material, except the presence of two enamel islets at the same time as well as higher *linea sinuosa* (Hordijk and de Bruijn, 2009, Pl.24, 26).

From Ortalıca, Ünay and de Bruijn (1998) described also a fragmented m1 and five M3 of *Pliomys* sp. (Ünay and de Bruijn, 1998, fig. 4.6–8). According to the authors, the AC2 reminds the morphotype of *P. graecus* (cf. de Bruijn and Meulen, 1975, pl. 1.5a) with its complexity of ACC. It differs from the Ortalıca material *Pliomys* by the presence of BRA4 and LRA5, together forming somewhat a LSA6 on m1. As to two rooted M3s of *Pliomys* sp., they perfectly match with the present material in occlusal pattern but in lateral view, the distosinus appears to be much higher within a much undulating *linea sinuosa*.

Pliomys samsoni from the Middle Pleistocene Rotbav-Dealul Tiganilor locality (Romania) differs from the Ortalıca arvicoline by its smaller molar size, more hypsodont m1 with *Clethrionomys*-type anterior cap on m1, and by the absence of enamel islets on M3 of which the dentine fields are all broadly confluent (Radulescu et al, 1997).

The molar sizes of *Pliomys* from Ortalıca are slightly smaller or close to the lower limits of *P. graecus* from the early Villanyian localities Tourkobounia-1 (Greece, de Bruijn and Meulen, 1975) and from Yenice-1 localities (MN16, Samsun, Ünay and de Bruijn, 1998). The first lower molars of *P. graecus* differ from the Ortalıca vole in having higher *linea sinuosa* (e.g. hyposinusid is as high as anterosinuid), relatively more symmetrical triangles, narrower and somewhat anteriorly pointed anterior cap, much distinct T6–T7 with the variable shape of LRA5, deeper LRA4. The upper third molars of *P. graecus* differ by the disappearance of enamel islet at early stage of wear, more protruding T5, and slightly higher dentine track. According to illustrations by de Bruijn and Meulen (1975, pl. 2.4–7) for M1 and M2s, the occlusal morphology is very similar to that of Ortalıca arvicoline, especially for the "pinched" shape of PC with the presence of LRA3 and BRA3 on M1, and the notch on the anterolingual side of AL of M2. However, the dentine track is lower on the Ortalıca specimens and less undulated.

The Ortalıca *Pliomys* differs from the Early Pleistocene *P. episcopalis* by its greater size and lower dentine tracks as well as the absence of T6 on m1 (e.g. de Bruijn and Meulen, 1975; Cuenca-Bescos et al, 1999; Berto et al, 2020), and from the late Early–Middle Pleistocene (Maul and Markova, 2007) *P. coronensis* (=*lenki*, see Terzea, 1983 for priority of species name) by its small size, lower dentine tracks, absence of LRA5 and BRA4 and narrower AC (e.g. Chaline, 1970; Cuenca-Bescos et al, 2010; Lopez-Garcia et al, 2016; Berto et al, 2020).

One of the most detailed studies on *Pliomys* (i.e. providing many measurements and ratios of all molars, detailed occlusal and lateral drawings, comparisons) is that of Tesakov (2005) who describe a new species, *P. destinatus* from the Early Pliocene (MN15, late Ruscinian) Odessa Catacombs (Ukraine). In overall, measurements and morphological variations of upper and lower molars of *Pliomys destinatus* matches well with *Pliomys* from Ortalıca. For instance, measurements of length and width of all molars, as well as anterosinus, protosinus and PA-index for upper molars,

anterosinuid and A/L index for lower molars are within the range and mean values (cf. Table 4.24.4; Tesakov, 2005, tabl.1–6). On the other hand, the distosinus of the Ortalıca vole M1 is slightly greater by 0.3 mm but that difference decreases with M2 and M3. As for lower molars, the values of hyposinuid and hyposinulid of the Ortalıca arvicoline are greater in overall by 0.1–0.15. These differences, in my opinion, should be considered as minor and negligible since the abundance of the Ortalıca material is not equal to that of the Odessa Catacombs specimens, although the Ortalıca material is slightly more hypsodont, at least for m1 and M1. According to descriptions and illustrations for *P. destinatus* by Tesakov (2005, figs.1–8) there are very few differences. The M1s and M2s perfectly match accept the distosinus height as mentioned above but M3 of *P. destinatus* differs from the Ortalıca vole in having strongly reduced lingual rootlet (on 2 specimens out of 17), short living anterior enamel islet, and closing posterior enamel islet in older individuals (Tesakov, 2005, p. 129). In statistical approach, the presence of rootlet is negligible due to relative scarcity of the Ortalıca material. For the anterior enamel islet, *P. destinatus* bears it already on a M3 with a lower crown height while it is absent on other M3s with higher crown height (e.g. Tesakov, 2005, fig. 7.3–4 and 6) as seen on the Ortalıca *Pliomys* (e.g. Figure 4.5.10 and Figure 4.5.12). As to posterior enamel islet, the observation of Tesakov (2005) might be definitely (i.e. disappearance of posterior islet with age) true for his sample. It could be explained also that this enamel island disappear when BRA2 becomes deeper and fuses with that islet, which is true for both Turkish and Ukrainian samples. However it is strange that despite high occlusal similarities between one M3 of *P. destinatus* figured by Tesakov (2005, fig. 7.9), which lacks the posterior islet, and the Ortalıca arvicoline (Figure 4.5.15) with this islet, might prove that enamel vanishing can be independent of the evolution of BRA2, as a result of intraspecific morphological variation. Note that the above mentioned M3 from Ortalıca represents the oldest individual vole with height of 0.99 mm, while the Ukrainian vole M3 is around 0.70 mm. The m1 of *P. destinatus* differs from the Ortalica specimens in having a faint groove on the tip of BSA3, and a transformation of the tip of BRA3 into a “shelf”, equivalent to an enamel islet, *sensu* Tesakov (2015) although both of these characteristics are rare (Tesakov, 2005, fig. 1.10). There is no difference observed on the m2 and m3 between the two *Pliomys*.

In sum, the differences mentioned above between *Pliomys destinatus* from Odessa Catacombs and *Pliomys* from Ortalıca are rather insignificant for a solid discrimination, and therefore it is safe to identify the Ortalıca vole as *Pliomys destinatus*. However, it seems that the Turkish *P. destinatus* is slightly younger than the Ukrainian vole if the minor differences of *linea sinuosa* (<0.1–0.15 mm) are taken into account (i.e. increasing hypsodonty in time, see Neraudeau et al, 1995; Chaline et al, 1999).

4.1.1.3 Arvicolinae indet.

Subfamily: Arvicolinae Gray, 1821

Gen. *et* sp. indet.

Figure 4.6

Material: 3 M1 (ORT-29–31), 2 M3 (ORT-32–33), 2 fragmented m1 (ORT-34–35), 1 m2 (ORT-36).

Localities: Ortalıca-1 (ORT-29) and Ortalıca-2 (ORT-30–36). For stratigraphic positions see Figure 2.6 in Chapter 2.1.2.

Measurements in mm: Table 4.54.7.

Description: The three rooted, highly worn M1s (for height, see Table 4.5) are wide with more voluminous buccal triangles than lingual ones. BRAs are deeper than LRAs. The cementum is absent. Tips of salient angles are more or less rounded. The posterior part is rounded. There is a slight *Mimomys*-type enamel differentiation (i.e. negative enamel differentiation; trailing edge are thinner than leading edges of triangles). On the much worn specimen, LRA1 became a somewhat enamel islet.

One of two juvenile M3 has clearly two roots preserved, the posterior one is elongate. Both specimens underwent a post-mortem abrasion which affected the posterior cap. However, it is clear that in the younger one (Figure 4.6.4, h=2.37 mm), the posterior cap is isolated and much likely it should be attached to T4 afterwards with increasing wear level, as seen on the other specimen (Figure 4.6.5, h=1.91). The typical “pliomyine” structure is not fully formed since BRA1 is still deep. On both specimens, the dentine field of T3 and T4 is confluent and they are connected also to T2. Note that T3 and T4, or BSA3 and LSA3 are horizontally lined. One can hypothesize that the possible fusion of the tip of LSA4 into posterior wall of LSA3,

would cause a formation of a posterior enamel islet, which could explain why some M3 equipped with posterior islet lacks the LSA3, as seen in *P. destinatus* of Ortalıca (e.g. Figure 4.5.15).

There are also two m1 fragments completely different in occlusal pattern and I could not identify securely. The one with simple occlusal morphology on AC (Figure 4.6.6) has probably (i.e. with reference to m1 of *Pliomys destinatus* from Ortalıca) a non-confluent T4–T5, very deep LRA4, short and vertically not deep anterolingual re-entrant angle (LRA5). It is possible that two latter (i.e. LRA5 and LSA6) would be disappeared after some wear stage.

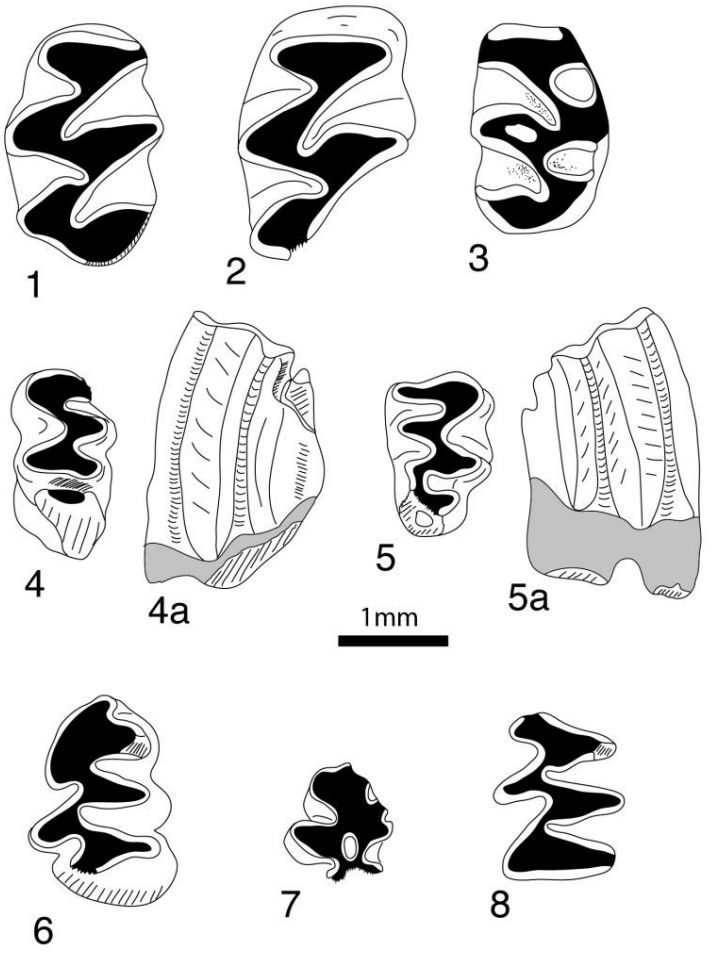


Figure 4.6 : Molars of arvicoline gen. et sp. indet. 1–3, M1; 4–5,M3; 6–7, m1; 8, m2.

Table 4.5 : Measurements of length, width and crown height of upper and lower molars of unidentified arvicoline from Ortalıca. For figure numbers in the table, see Figure 4.6.

Molar	Institution number	Figure No	Length	Width	h	WP (M3)
M1 s	ORT-29	1	2.27	1.56	1.09	-
M1 d	ORT-30	2	?	1.47	1.17	-
M1 d	ORT-31	3	1.96	1.23	0.33*	-
M3 s	ORT-32	4	1.52*	0.59*	2.37	0.74
M3 d	ORT-33	5	1.5*	0.81	1.91	0.743
m1 s	ORT-34	6	?	?	?	-
m1 d	ORT-35	7	?	?	?	-
m2 s	ORT-36	8	1.61	1.14	1.7	-

Table 4.6 : *Linea sinuosa* measurements of upper molars.

Molar	Institution number	Figure No	As	Ds	Prs	PA-index
M1 s	ORT-29	1	0.33	0.54	0.44	0.55
M1 d	ORT-30	2	0.37	-	0.38	0.530377
M1 d	ORT-31	3	0.25	0.38	-	-
M3 s	ORT-32	4	0.35*	0.92*	0.35*	0.49*
M3 d	ORT-33	5	0.21	0.57	0.27	0.342053

Table 4.7 : *Linea sinuosa* measurements of lower molars.

Molar	Institution number	Figure No	Asd	Hsd	Hsld	HH-index
m2 s	ORT-36	8	0.96	0.33	0.2	0.385876

For the other m1 with more complex AC, it is difficult to name salient and re-entrant angles because of missing part of the molar. However, there is a anteroposteriorly elongate oval-shaped enamel islet, with two lingual re-entrant angles allowing the formation of two lingual salient angles. On the anterobuccal sides, there are two enamel interruptions delimited by two faint re-entrant angles in addition to another one which is deeper at the level of enamel islet.

The m2 is hypsodont with a posterior lobe followed by barely confluent alternating T1–T3. T3 is confluent with T4. LSAs are much voluminous than BSAs. The enamel is much thicker than that of the m2 of *Pliomys destinatus* from Ortalıca.

Comparison and discussion: The M1s in this section are separated from and not evaluated within the other Ortalıca arvicoline specimens identified as *Pliomys destinatus* for their different length, width or height as well as *linea sinuosa* differences. The two juvenile M3s are excluded from *Pliomys* destinatus due to their higher hypsodonty and different morphology despite their advanced wear degree. For instance, the specimen in Figure 4.6.5 has a height of 1.91 mm just like *Pliomys destinatus* from Ortalıca (see Figure 4.6.10) but with completely mature and much worn morphology. The two m1s (Figure 4.6.6–7), of which only anterior part is preserved, avoid attribution to the same species securely. Finally, the m2 (Figure 4.6.8) is not counted as *P. destinatus* because of the extremely higher anterosinuid although the other enamel track heights are close to *P. destinatus*.

The M3 (Figure 4.6.4) is similar to that of *Dolomys* sp. illustrated by Ünay and de Bruijn (1998, fig. 4.4) from Ortalıca by its occlusal morphology as well as length, width and distosinus high, which perfectly match.

One of the fragmented m1 from Ortalıca with simple morphology of AC (Figure 4.6. 6) is similar to *Pliomys graecus* from Tourkobounia-1 locality (de Bruijn and Meulen, 1975, pl. 1.1a-b) by its anterolingual re-entrant angle, prominent ?T7, and prismosinuid in equal height with anterosinuid in buccal view, rather than *P. hungaricus* from Casrnota-2 illustrated by the same authors (de Bruijn and Meulen, 1975, pl. 1.5a-b) which has prismosinuid much lower.

The other m1 with complicated AC bearing an enamel islet (Figure 4.6.7) belongs most probably to a *Mimomys* species with relatively high anterosinuid (i.e. reaching the half of the crown height, measurements not possible).

Finally, the m2 (Figure 4.6.8) is different from that of *P. destinatus* of Ortalıca because of its extremely high anterosinuid (0.96 mm) despite its similar occlusal morphology and size.

Based on these different arvicoline remains, one can hypothesize that in Ortalıca, *P. destinatus* was not the only arvicoline, as found out by Ünay and de Bruijn (1998, p. 437, *Mimomys gracilis* and *Dolomys* sp.).

These specimens should be re-evaluated in future when new samples are collected and material is increased.

4.1.1.4 *Apodemus atavus*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Muridae Illiger, 1811

Subfamily: Murinae Illiger, 1811

Genus: *Apodemus* Kaup, 1829

Apodemus atavus Heller, 1936

Figure 4.7

Material: 7 M1 (ORT-37–43), 6 M2 (ORT-44–49), 2 M3 (ORT-50–51), 4 m1 (ORT-52–55), 3 m2 (ORT-56–58), 2 m3 (ORT-60–61).

Localities: Ortalıca-1 (14 specimens: ORT-37–41, 44–46, 50, 53, 56–58, 61) and Ortalıca-2 (10 specimens: ORT-42–43, 47–49, 51–52, 54–55, 60).

Measurements in mm: Table 4.8, Figure 4.8

Description: The medium sized molars from Ortalıca locality belong to the genus *Apodemus* as having a well-developed and distinct t7 on M1 and M2, prominent t3 on M2, distinct tma on m1 and buccal cingulids on m1 and m2.

On the upper first molars, the tubercle 1 (t1) is much voluminous than t3, projected transversally and situated posterior to t2 and t3. The t1 lacks a posterior spur and is not connected to t5 except in one specimen where the contact is low (Figure 4.7.7). The t1 can be separate from t5 (Figure 4.7.6), in contact (Figure 4.7.4) or fused (Figure 4.7.1–3, 5, 7), depending on occlusal abrasion.

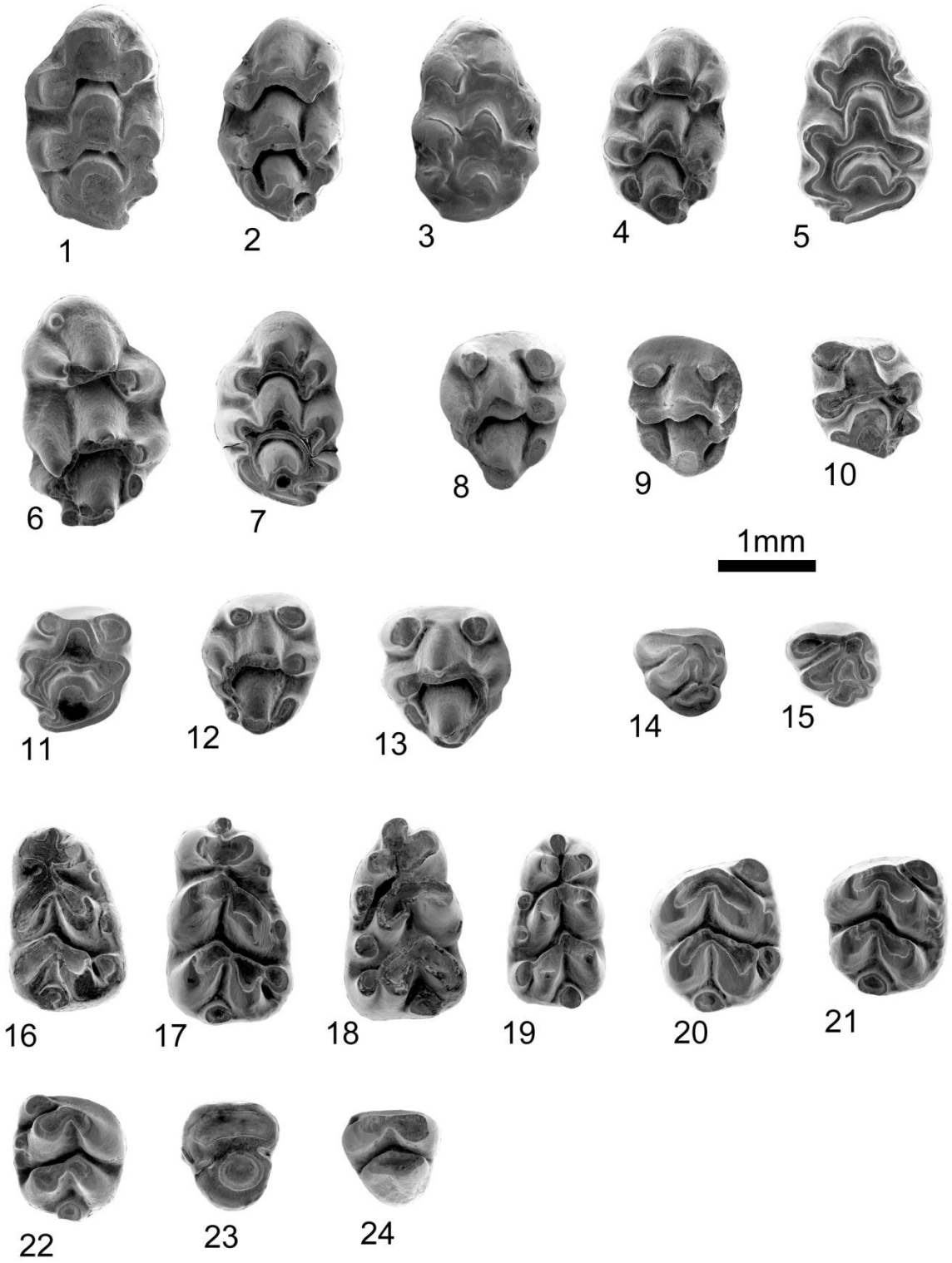


Figure 4.7 : *Apodemus atavus* molars from Ortalıca. 1–7, M1 (ORT-37–43); 8–13, M2 (ORT-44–49); 14–15 (ORT-50–51); 16–19, m1 (ORT-52–55); 20–22, m2 (ORT-56–58); 23–24, m3 (ORT-60–61).

The t2 is as robust as t5 and t8, and these medial tubercles are greater than the buccal and lingual ones. There are t1bis and t2bis on two different specimens (Figure 4.7.2, 5 and Figure 4.7.3, 7, respectively). Note that the specimen ORT-39, not well-expressed in Figure 4.7.3, has identical occlusal morphology to ORT-38 (Figure 4.7.2) except the direction of t12 which is more lateral on ORT-39 and not oriented towards t9 as in ORT-38. The t3 bears a prominent posterior spur which is not connected to t5. On one specimen (Figure 4.7.6) there is a rounded apical style (*sensu* Erdal et al, 2018) on the anterobuccal edge, at the base of t2. The ring between the tubercles t4-t5-t6-t9-t8-t7 is established at the dentine field level if worn (e.g. Figure 4.7.1, 5, 7), by contacts of tubercles (e.g. Figure 4.7.2, 4) or it is incomplete when the tooth is fresh (e.g. Figure 4.7.6). The relative position of t4 to t6 is also variable; slightly below or at the same line. The t7 is well developed, anterolingually oriented, isolated in less worn specimens or fused into t8. The t9 is situated low relative to t7 and is in contact with or fused to t8. The t12 is distinct and robust and in general, laterally elongate except in one specimen (Figure 4.7.2) where it is curved and in contact with t9, which results in closing of the posterobuccal valley. Three roots are observed on two specimens out of seven (Figure 4.7.1, 4).

On the upper second molars, t1 has roughly double size of t3, both are isolated from the t5 and they lack posterior spurs. The t4 is in contact with t5 at low level in the half of M2 material, and fused in the other half. On all M2s, the dentine field of t5 is continuous with that of t6. There is a contact between t6 and t9. In some specimens, the t9 is reduced and became much smaller than t4 though still prominent (e.g. Figure 4.7.8, 13) or is almost equivalent in size (e.g. Figure 4.7.9–12) but always connected to the base of t8. The ring t4-t5-t6-t9-t8-t7 is clear. The t7 is strong, elongated and encloses the valley surrounding the t8 in lingual side by reaching the t4 on 2 specimens out of 6 (e.g. Figure 4.7.11, 13). The t12 is lost in one specimen (Figure 4.7.8) which caused a wide recession on the posterobuccal edge of the molar, on another, it is reduced into a crest-like shape establishing the connection between t8 and t9 (Figure 4.7.13) and well developed on the rest of four M2s. There are four roots when preserved.

The subtriangular M3 has a transversally elongate drop-shaped t1 barely fused with t5 on the mesial edge. The t2 and t3 are absent. The t4 is oblique and straightforward to t5 on the anterobuccal corner. In one specimen (Figure 4.7.15) the t5 is strikingly individualized with the constriction of the anterolingual, anterobuccal and medial

Table 4.8 : Length and width measurements (in mm) of *Apodemus atavus* from Ortalıca locality.

		Length		Width	
Molars	N	range	Mean	range	Mean
M1	7	1.8-2.16	1.94	1.16-1.42	1.26
M2	6	1.13-1.51	1.28	1.06-1.23	1.15
M3	2	0.82-0.86	0.84	0.85-0.89	0.87
m1	4	1.78-2.03	1.89	0.96-1.18	1.11
m2	4	1.2-1.46	1.32	1.1-1.25	1.16
m3	2	0.9-1.1	1	0.96-0.98	0.97

valleys which isolate the t5 from t1, t4 and t6. The t4-t5-t6 complex reminds an inverse letter “L” with almost a right angle at the t5 level. The isolated posterior cusp is formed by t8 and t9 and is bilophed. The t8 is either separated from t4 by a valley or connected rather towards anterobuccally. The t9 is always in contact with t6. There is a depression on the posterior side of the molar, between t8 and t9, proving the bilophed complex of t8-t9.

The lower first molars are elongate, in subrectangular form and robust. The tma is present (anterocentral cuspid) in all m1s with a variable size and connections. In the half of these molars the tma is fused with the anteroconid complex. In general, the tma is smaller than buccal and lingual anteroconids except in one molar (Figure 4.7.18) where it has a comparable size to the complex. The anteroconid complex elements are transversally symmetrical and equal in size but in the specimen with larger tma, lingual anteroconid is shifted anteriorly and oriented rather oblique (Figure 4.7.18). As a consequence, that m1 has an anterior wall posterobuccally inclined. The anterocentral crest (=medial spur of protoconid-metaconid complex) is absent and on three out of four specimens protoconid-metaconid complex is in weak contact with the anteroconid complex. On the most worn specimen, however, that connection is apparent. The size of protoconid and metaconid is similar. The valley between lingual anteroconid and metaconid is narrower and shorter (in occlusal view) than its buccal equivalent (i.e. between buccal anteroconid and protoconid).

On three specimens, the entrance of the anterobuccal valley host a well developed accessory cuspid (=C4) but that cuspid is manifested by a bulge issued of the posterior wall of buccal anteroconid (Figure 4.7.17). The longitudinal crest is about to take shape in one specimen (Figure 4.7.19) but very caduceus. The accessory cuspid C0 is absent. The C1 is low, in comparable size with that of posteroconid, and isolated from or in contact with hypoconid. Except the C1, there are two other accessory cuspids which tend to decrease in size toward anterior part of the molar, on the contrary of one specimen where they all have similar size (Figure 4.7.18). There are two roots preserved.

The m2 has a large and oval shaped anterobuccal cuspid which is situated low to the protoconid. There is no longitudinal crest issued of hypoconid-entoconid complex and therefore, the medial valley is transversally open without interruption. On one specimen, the dentine field of hypoconid is not confluent with that of entoconid but in contact at the enamel level. The posteroconid is rather rounded and it has a similar size with that of anterobuccal cuspid. The C1 is present on one specimen (Figure 4.7.20), in low contact with the hypoconid. The other accessory cuspids are small but prominent (Figure 4.7.22) or not fully formed and present as a bud on the buccal cingulid. There are two roots.

One of two m3 is worn, as a consequence, the protoconid-metaconid complex is completely fused to form a subrectangular shape but the posterior cuspid complex became rounded, and the transversal valley is closed (Figure 4.7.23). On the other, the posterior cuspid complex is transversally elongate and anteroposteriorly narrow, isolated from the anterior complex. The latter is bilophed, and there is a low and faint cingulid bulge on the anterobuccal edge of protoconid reminding the relict of an anterobuccal cuspid (Figure 4.7.24). There are two roots.

Comparison and discussion: The mean values of M1 and m1 molar size of *Apodemus* from Ortalıca is far smaller than of *A. mystacinus*, *A. jeanteti* and *A. gorafensis* but close to lower limits of *A. gudrunae*, and is greater than *Apodemus witherbyi* (see Figure 4.8 and see Table A.1 for references, localities and ages of *Apodemus* spp. used in morphological and metric comparisons in this study).

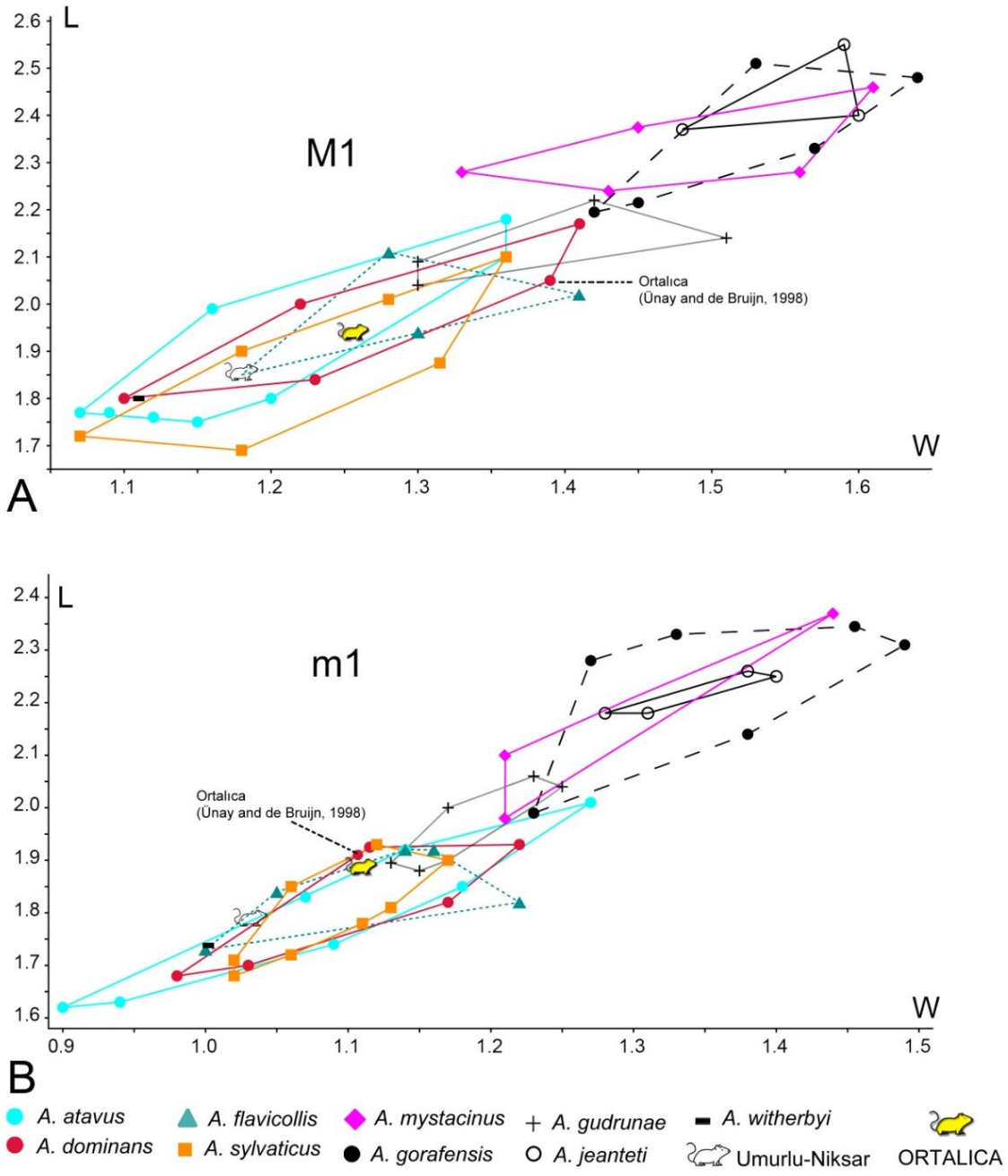


Figure 4.8 : Scatter diagram of selected *Apodemus* spp. by mean values in mm from different localities of (A) M1 and (B) m1. L, length; W, width; (modified after Erdal et al, 2018).

Apodemus gudrunae differs from Ortalıca wood mouse by the weaker connection between the t1 and t2, lack of posterior spur of t3 on M1, absence of connection between t6 and t9 on M2, isolated t1, isolated and distinct t8 and t9 (e.g. Colombero et al, 2014, fig.5-C) or t6 fused into posterior bilophed complex on M3 (e.g. Minwer-Barakat et al, 2009, fig. 3.3), the tma generally distinct and situated anteriorly from the anteroconid complex on m1, rather oval shaped posteroconid on m2, well-developed anterobuccal cuspid rather than a bulge of cingulid and prominent cuspid situated buccal to the entoconid-hypoconid complex on m3 (Weerd, 1976; Aguilar et al, 1982; Minwer-Barakat et al, 2009; Colombero et al, 2014).

Based on M1/m1 mean sizes, as shown on the scatter diagram (Figure 4.8), there are still four candidates to compare with Ortalıca wood mouse; *Apodemus atavus*, *A. dominans*, *A. flavicollis*, *A. sylvaticus* of which each clusters greatly overlap, although *A. atavus* displays the most extremes values for length and width. Mean values of *Apodemus* from Ortalıca pop up almost in the middle of clusters especially for M1 (Figure 4.8.A) whereas the m1 pushes the upper limits of length but it has a medium width (Figure 4.8.B).

The *Apodemus atavus* was first erected by Heller (1936) from the early Pliocene layers at Gundersheim (its type locality, Germany) based on a lower jaw fragment bearing m1 and m2 (Heller, 1936, p. 126; taf. X, fig.2). Later on, a much detailed description and comparisons as well as criticism on the synonymy of *A. atavus* with *A. dominans* are handled by Fejfar and Storch (1990). The type locality yielded abundant and homogenous specimens for *Apodemus atavus*, is correlated to MN15b and renamed Gundersheim-4 (Fejfar and Storch, 1990). Metrically, Ortalıca *Apodemus* is within the range of molars from Gundersheim-4 (Fejfar and Storch, 1990, tabl. 2). As to morphology, descriptions and figures provided by the authors (Fejfar and Storch, 1990, abb. 39–50, p. 146) allow me to consider Ortalıca wood mouse really close to *A. atavus*, based on similarities such as: t7 and t12 always well developed, t3 with posterior spur, connection between t6 and t9 as well as t1-t2 on M1; distinct t12 and t7, t9 generally strong but a little reduced on M2; anteroconid complex connected to metaconid-protoconid complex on m1, lack of longitudinal crest on m1 and m2. The only difference might be the number of roots of M2; 2/3 of the Gundersheim-4 M2 have three roots, 1/3 has four roots, whereas three rooted M2

is not observed at Ortalıca, although half of the material did not preserve roots (Table 4.9).

Table 4.9 : Number of roots on M1–M2 and m1–m2 of *Apodemus atavus* / *dominans* species.

Species	Locality	Age	Molar type	Number of roots (M1, m1)	Number of roots (M2, m2)	Study
A. atavus	Gundersheim-4	MN15b	M1	3	3 or 4[a]	Fejfar and Storch, 1990
A. atavus	Komanos 1 low (Greece)	Pliocene	M1	3	3	Hordijk and de Bruijn, 2009
A. atavus	Notio 1 (Greece)	Pliocene	M1	3	3	Hordijk and de Bruijn, 2009
A. dominans	Çalta (Turkey)	Pliocene	M1	3	-	Sen, 1977
A. atavus	**Ortalıca (Turkey)**	**MN15**	**M1**	3	4	**This study**
A. atavus	Monte la Mesa (Italy)	early Biharian	M1	3[b]	-	Marchetti et al, 2000
A. atavus	AGU-1C (Granada Basin)	Late Miocene–Pliocene	M1	3	3	Garcia-Alix et al, 2008
A. dominans	Muselievo (N Bulgaria)	late Ruscinian (MN15b)	M1	3	3 or 4[c]	Popov, 2004
A. dominans	Taşova (Turkey)	MN15	M1	3	-	Ünay and de Bruijn, 1998
A. dominans	Igdeli (Turkey)	MN14	M1	3	-	Suata Alp et al, 2010
A. cf. *dominans*	Yenice-1 (Turkey)	MN16	M1	4	-	Ünay and de Bruijn, 1998
A. atavus	Bıçakçı (Turkey)	latest Villanyian	M1	4	-	Ostende et al, 2015a
A. atavus	TCH-1B (Spain)	early MN15	m1	2	2	Minwer-Barakat et al, 2005
A. atavus	PUR-7 (Spain)	Late Miocene–Pliocene	m1	2	-	Garcia-Alix et al, 2008
A. atavus	**Ortalıca (Turkey)**	**MN15**	**m1**	2	2	**This study**
A. atavus	Monte la Mesa (Italy)	early Biharian	m1	2	-	Marchetti et al, 2000
A. aff. *atavus*	PUR-4 (Spain)	Late Miocene–Pliocene	m1	2	2	Garcia-Alix et al, 2008
A. atavus	Bıçakçı (Turkey)	latest Villanyian	m1	3	-	Ostende et al, 2015a
A. atavus	Saint-Vallier (France)	MN17	m1	3	-	Martin-Suarez and Mein, 2004

a- 2/3 of collection has three, 1/3 has four roots; b- 1 out of 159 M1 has four roots; c- 2 out of 8 M2

Apodemus dominans was first described by Kretzoi (1959) from Csarnota-2 (Hungary), correlated to MN15b, and the description as well as the material are enhanced by Weerd (1976) in comparison with specimens from three Ruscinian localities in the Teruel Basin (Spain, Weerd, 1976, p. 87). Measurements overlap with that of Ortalıca species although the maximum values of Turkish specimens are slightly greater (Table 4.8; Weerd, 1976, tabl. 20). By morphological aspect, *A. dominans* from Teruel matches well with the *A. atavus* from its type locality (see Fejfar and Storch 1990) and also with the Ortalıca specimens; the only exceptions are the lack of posterior spur on t3 on some M1s and absence of the tma (=antero-central cusp) in one m1 from Teruel, according to description provided by the author. These should be considered as minor variations and therefore, *Apodemus* from Ortalıca displays great similarities with *A. dominans* from Csarnota-2 and Teruel Basin, and also to *A. atavus* from Gundersheim-4 at the same level.

That great overlap, as well as general morphological similarities shared between *A. atavus-A. dominans* couple spanning from the Late Miocene (MN13; e.g. Vasileiadou et al, 2012; Colombero et al, 2014) to Early Pleistocene (e.g. Bruijn and Meulen, 1975; Marchetti et al, 2000; Hoek Ostende et al, 2015a) and younger species couple group *A. flavicollis – A. sylvaticus* from the Early Pleistocene (De Giuli and Torre, 1984) to recent (Pasquier, 1974; Krystufek and Vohralik, 2005) are questioned by many authors to underline the difficulties of species discrimination within the couples cited above (see Erdal et al, 2018, p. 94).

For instance, many authors accept *Apodemus dominans* and *Apodemus atavus* as two distinct species based on slight size differences despite the great morphological similarities (e.g. Storch and Dahlmann, 1995; Ünay and de Bruijn, 1998; Popov, 2004; Hordijk and de Bruijn, 2009; Suata-Alpaslan, 2010; Vasileiadou et al, 2012; Hoek Ostende et al, 2015a, b), while some authors support the junior synonymy of *A. dominans* to *A. atavus*, since the latter has the species name priority (e.g. Fejfar and Storch, 1990; Martín-Suárez and Mein, 2004; Minwer-Barakat et al, 2005; García-Alix et al, 2008; Colombero et al, 2014; Siori et al, 2014; Erdal et al, 2018).

Ortalıca wood mouse, which is situated within the overlapping cluster of *A. dominans* and *A. atavus* (means of L=1.94; W=1.26), share its spot for M1 with the closest values of species (with difference of 0.02 mm) *A. atavus* from "early" MN15 of Tollo de Chiclana-1B (Granada Basin, Minwer-Barakat et al, 2005), from the

early Biharian of Monte la Mesa (Marchetti et al, 2000), *A. dominans* from Pliocene of Çalta (Sen, 1977), *A.* cf. *dominans* from the MN13-14 of Kessani (Vasileiadou et al, 2012). On the other hand, *Apodemus atavus* from the latest Villanyian Bıçakçı locality is smaller (mean of L=1.89; Hoek Ostende et al, 2015a) and the M1 of *A. dominans* from Ortalıca as described by Ünay and de Bruijn (1998) is far greater than *Apodemus* of the present study (Figure 4.8.A; mean of L=2.05; Ünay and de Bruijn, 1998). Note that they are not added on the scatter diagram to avoid illegibility.

On the other hand, for mean values of m1 (L=1.89; W=1.11), *Apodemus dominans* from the late Pliocene Maritsa-1 (de Bruijn et al, 1970) exactly matches with the *Apodemus* of the present study and the other closest records within the deviation of 0.02 mm, such as *A. dominans* from the Early Pleistocene of Tourkobounia-1 (Bruijn and Meulen, 1975) and Mas Rambault 2 (MN17, Aguilar et al, 2002), *A. atavus* from the Early Pleistocene of Saint-Vallier, Drôme (MN17, Martin-Suarez and Mein, 2004) and of TOJ1 - Granada Basin (Garcia-Alix et al, 2009). *Apodemus dominans* previously described from Ortalıca is slightly greater in length but within the range of the specimens of the present study (mean L=1.92; Ünay and de Bruijn, 1998), *A. dominans* from Çalta is below the lower limits by 0.03 mm difference (L=1.75, Sen, 1977) and *A. atavus* from Bıçakçı is very close to mean values (L=1.83; Hoek Ostende et al, 2015a).

All these metrics comparisons demonstrate again that discrimination as *A. dominans* or *A. atavus* after slight differences but overall greatly overlapping measurements, despite extremely similar morphological aspects, is not reliable because of ignoring the intraspecific variation. Therefore, I follow Martín Suárez and Mein (2004), Siori et al. (2014) and Erdal et al. (2018, and references therein) to consider all *A. dominans* under the specific name *atavus*.

In morphological aspect, the *Apodemus* from Ortalıca fits overall well with the description and illustrations, if provided, of *A. dominans* or *A. atavus* from previous studies in Turkey (e.g. Sen, 1977; Ünay and de Bruijn, 1998; Suata-Alpaslan, 2009; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015a, b; Sen et al, 2018) and in Europe (e.g. Pasquier, 1974; Bruijn and Meulen, 1975; Marchetti et al, 2000; Minwer-Barakat et al, 2005; Garcia-Alix et al, 2008; Hordijk and de Bruijn, 2009; Colombero et al, 2014). However there are minor morphological intraspecific

variations that I compiled from some studies mentioned above as well as from Erdal et al (2018, p.94) which are not specific only to Ortalıca *Apodemus.* These variations constitute a well-developed or crest-like t12, position of t1 relative to t3 (less frequently horizontally lined or more frequently slightly backward), presence of posterior spur on t1, presence of t1bis and t2bis on M1, presence of connection between t4 and t7 and reduction of t12 on M2, fusion of t6 with bilophed posterior complex on M3, numbers of accessory cuspids on lower molars, presence of anterocentral crest issued from metaconid and its connection to lingual anteroconid, weak presence or absence of longitudinal crest issued of hypoconid-entoconid complex on m1, development of longitudinal crest and presence of c1 on m2, manifestation of the anterobuccal cuspid and shape of posterior cuspid on m3. These above mentioned variations can be observable if not all and independently whether the species is *A. dominans* or *A. atavus*.

On the other hand, Hordijk and de Bruijn (2009) state that the identification of two small to medium sized *Apodemus* species from the Ruscinian and Villanyian localities is problematic since these specimens shares primitive characteristics of M1 and M2 such as three roots, well-developed t12, and presence of c1 on m1 and m2. All of these features listed by authors must constitute intraspecific variations as mentioned above. Indeed, the number of roots also displays variations.

In many records the number of roots is not provided because of their poor preservation. Comparisons between the remains referred to *Apodemus atavus* or *A. dominans*, of which M1/m1 and/or M2/m2 roots are preserved from many localities and different ages (Table 4.9), seems to support the statement of Hordijk and de Bruijn (2009): i.e. three rooted on M1 and M2 conserved primitive state. In addition, *A. atavus* from the latest Villanyian Bıçakçı and *A.* cf. *dominans* from the MN16 Yenice-1 localities with four roots may represent more evolved forms in having four roots contrary to Italian *A. atavus* from the early Biharian of Monte La Mesa with interestingly three roots (Marchetti et al, 2000; Table 4.9). That evolutionary trend of increase of root number from 3 to 4 on upper molars and from 2 to 3 in lower molars for Pliocene–Pleistocene species might be true, again with the exception of Italian *A. atavus*. However, the variation of the number of roots on M2 seems to be more uninformative since roots are less preserved and therefore more data is needed. Nevertheless, the presence of four rooted M2 although in minority (i.e. two out of

eight specimens) in the assemblage of *A. atavus* (=*Sylvaemus dominans*) from the late Early Pliocene Muselievo (MN15b, late Ruscinian) would point out to a transition in increasing of root number (i.e. from 3 to 4) in such population (Popov, 2004; Table 4.9).

These overlapping metric and slight morphological variations are not surprising when considering the presence of *A. atavus* even in China (Cai and Qui, 1993 *in* Minwer-Barakat et al, 2005) which indicate the wide range dispersal of the *A. atavus* all along the Palearctic, in addition to the time interval from Late Miocene to Early Pleistocene with their relatively conservative plesiomorphic morphology (Minwer-Barakat et al, 2005). Besides, it is true that small samples of a species from a locality bear many similarities with other closely related species on one hand; large samples are rather heterogeneous involving many species, on the other, as stated by Vasileiadou et al. (2012).

According to almost perfect match with description of *Apodemus dominans*/*atavus* from Çalta (Sen, 1977), İğdeli (Suata-Alpaslan et al, 2010), Moncucco-7 (MN13; Colombero et al, 2014), Tourkobounia-1 (de Bruijn and Meulen, 1975), as well as greatly overlapping molar size despite some minor morphological variations, after my comparisons with other studies and the priority of species name *atavus*, the wood mouse from Ortalıca in this study is ascribed to *Apodemus atavus*.

Apodemus atavus from Ortalıca has larger molars than of *A. flavicollis* from the Toringian of Umurlu locality (Niksar Basin, Erdal et al, 2018 and Chapter 4.3). On the other hand, the mean size of M1 is comparable (i.e. with difference of 0.02 mm) to *A. flavicollis* from the Middle Pleistocene Emirkaya-2 (Montuire et al, 1994), the Holocene of Zuurland Boreholes (Reumer, 2003) and from the Late Pleistocene of Gondrenas as well as recent species from Kirchdorf and Berlin (Germany; Pasquier, 1974). In overall, *A. atavus* of this study differs from *A. flavicollis* in having a t1 rather rounded and posteriorly situated t3, isolated from the t2 and without a posterior spur, the spur of t3 oriented towards t5 rather than t6, direct connection between t8–t9 without a t12, robust t12 individualized by a transverse valley on the posterolingual corner and three roots rather than four on M1; stronger t7, prominent t9 rather than reduced displaying weak connection with t6 and t12 generally well developed on M2; shorter t1 which is not fused with t5, deeper anterolingual valley, t8-t9 forming a bilophed posterior complex and isolated from t6 and t4 in less worn

specimens of M3. As to lower molars, the m1 of *A. atavus* can be distinguished from the *A. flavicollis* by its more robust tma, much rounded, robust and frequent three accessory buccal cuspids, lack of connection between the anteroconid complex and protoconid-metaconid via the anterocentral crest (except in one worn specimen in Ortalıca), C1 mostly lower and isolated, lack of distinct longitudinal crest on m1; greater and rather rounded anterobuccal cuspid, more developed buccal cuspids, at least one specimen with strong C1, equal volume of lingual and buccal cuspids in protoconid-metaconid and hypoconid-entoconid complexes, and absence of longitudinal crest on m2. The m3s are quite similar in morphology.

The fossil remains of recent species *Apodemus sylvaticus* from Turkey are unknown except the ascribed specimens as "*Apodemus flavicollis* or *sylvaticus*" from the Villanyian-Biharian boundary of Kürttepe (Germencik) and the MN17-MQ1 of Hamamayağı (Ünay and de Bruijn, 1998). The distinction between fossil remains of these extant species based only on measurements and morphology of molars is very difficult as discussed in Erdal et al. (2018). Therefore it is not surprising that Ortalıca wood mouse differs from the figured *A. flavicollis* or *sylvaticus* remains (Ünay and de Bruijn, 1998, pl. 3-7) in having the same features as above mentioned for *A. flavicollis*, as well as from *A. sylvaticus* from the Early Pleistocene Loma Quemada-1 (Granada Basin – Spain, Tarraco et al, 2015) and the Middle Pleistocene Sima de los Huesos localities (lower layer-CH&B, Cuenca-Bescos et al, 1997) which are really close to the mean size of Ortalıca wood mouse M1.

As mentioned previously, the time interval between the first and last occurrences of *Apodemus atavus*/*dominans* are very long (i.e. Late Miocene–Early Pleistocene) and therefore the age constrain of the basin would not be plausible based on this species. However, the Ortalıca wood mouse should be older than *A. atavus* from the latest Villanyian Bıçakçı (Hoek Ostende et al, 2015a) and from the MN16 Yenice-1 localities (Ünay and de Bruijn, 1998) because of bearing three roots on M1 rather than four, and similar in age than *A. atavus* (=*dominans*) from the MN15b Muselievo locality at North Bulgaria (Popov, 2004) in having four roots on M2.

4.1.2 Fossil remains from Sapaca 1 and 2 localities

4.1.2.1 *Mimomys* cf. *polonicus*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Arvicolinae Gray, 1821

Genus: *Mimomys* Forsyth Major, 1902

Mimomys cf. *polonicus* Kowalski, 1960

Figure 4.9

Material: 1 M2d (SPC-1), 1 M3s (SPC-2), 2 m1d (SPC-3–4), 2 m3d (SPC-5–6).

Localities: Sapaca-1 (SPC-1–3, 5–6) and Sapaca-2 (SPC-4).

Measurements in mm: M2: L=2.45, W=1.69, h=3.57, Prs=2.33, As=2.44, Ds=2.86, PA-index=3.37; M3: L=2.29, W=1.32, h=2.23, P=1.38, WP=1.19, Prs=1.66, As=1.17, Ds=1.44; Hys=1.04; PA-index=2.03; (*) m1s: L=3.58, W=1.56, a=1.40–1.43, b=0.7–0.56, c=0.35–0.40, A/L=~40.97, SDQ (on five triangles)=152.14, Asd=>2.57, Hsd=>2.32, Hsld=>1.97, HH-index=>3.04, Hsd/L=>66.4; m3: L=2.09–2.14, W=1.33–1.36, h=0.56–1.71, As=1.62; Hsd=1.42; Hsld=1.12; HH-index= 1.80. (*) Note that *linea sinuosa* measurements for m1 as well as L and A/L ratio must be considered as an estimation due to the wear level and missing PL, and therefore they must be greater than this present values.

Description: Among the arvicoline molars found so far in the Tosya Basin, these are the greatest by means of dimensions. All molars have *Mimomys*-type enamel thickness or negative enamel thickness.

The hypsodont M2 (PA-index=3.37, Figure 4.9.A) with two roots displays low density cementum in re-entrant angles but they do not reach occlusal surface. The AL is followed by 3 closed triangles. The enamel is continuous without interruption. BRA2 is as deep and wide as LRA2, BRA1 is narrower.

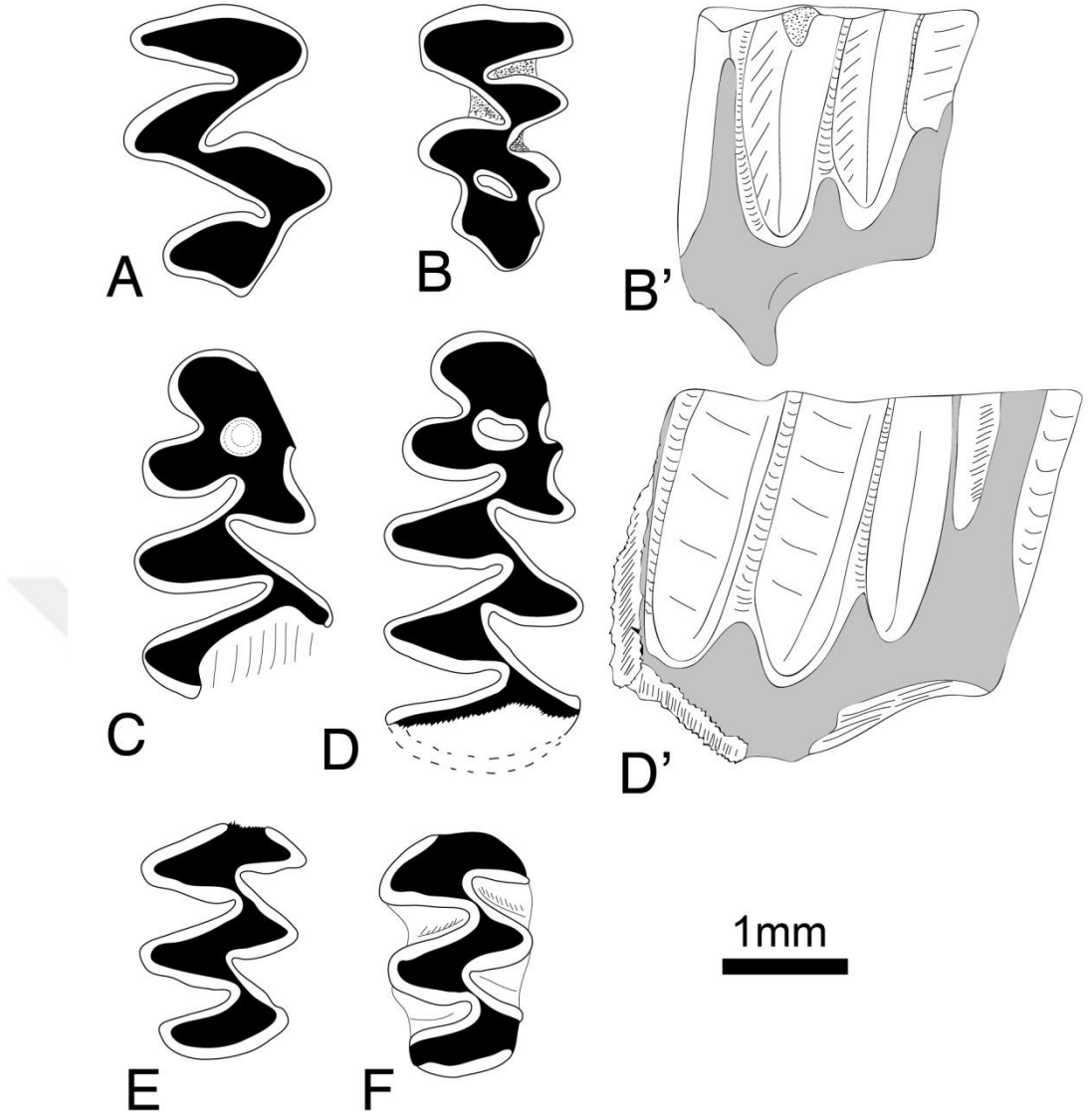


Figure 4.9 : Molars of *Mimomys* cf. *polonicus* from the Sapaca-1 and Sapaca-2 layers. A, M2d, B, M3s with B' for lingual view; CD, m1d and D' for labial view of D; EF, m3d.

The M3 (Figure 4.9.B and Figure 4.9.B') is formed by closed AL and T2 whereas T3 and T4 are widely confluent with the PC. There is an enamel island on PC at the level of BRA3 and LRA3. The PC is wide and not elongate. The enamel is continuous but gets thinner on the posterior side of PC. The cementum on buccal re-entrant angles is relatively abundant to lingual ones, though it is still very weak.

None of m1 in Sapaca material is complete although they provide important information (Figure 4.9.C–D'). Close occlusal morphology and metric values (e.g. a, b and c) on ACC of both specimens as well as their width, allow to consider them

belonging to the same species. The PL is followed by three closed salient angles, and T4, T5 and T7 are confluents within the wide ACC1. On the middle of ACC1, lined between LRA4 and BRA4, there is a faint trace of a rounded enamel islet despite the wear degree of the specimen SPC-3 (h= 1.35 mm; Figure 4.9.C) whereas it has an oval shape and is larger on less worn specimen (SPC-4 h= 2.53 mm; Figure 4.9.D–D'). The *Mimomys*-ridge is prominent in less worn specimen, and on the other it is somewhat disappeared. As other molars, the presence of cementum is weak and not reaching at all the occlusal surface. The *Linea sinuosa* can be observed only on SPC-4 (Figure 4.9.D'); anterosinuid, mimosinuid (sinuid of *Mimomys*-ridge, between BRA3–BRA4 *sensu* Rabeder, 1981, fig. 22) and the hyposinuid reach the occlusal surface contrary to prismosinuid and protosinuid. There are incisions for two roots.

The m3s constitute a PL preceded by 4 salient angles of which T1–T2 and T3–T4 are confluent. The enamel lacks only on the mesial side of less worn m3 (SPC-5; h=0.56, Figure 4.9.E) and enamel free areas increase (i.e. on lateral tips of PL and anterobuccal side of T4) whenever the molar is heavily worn as seen on SPC-6 (h= 1.73, Figure 4.9.F).

Comparison and discussion: The presence of roots and *Mimomys*-ridge (= prism-fold) as well as general morphology (e.g. three closed triangles, negative enamel thickness, enamel islets on ACC of m1 and on PC of M3, enamel free areas relatively low, confluent elements on PC of M3 with isolated T2) point out that the Sapaca arvicoline belongs undoubtedly to the genus *Mimomys*. The large size of these specimens excludes comparison with the moderate-sized *Mimomys* species such as *M. reidi*, *M. hintoni*, *M. gracilis*, *M. pusillus*, *M. tornensis* and *M. tigliensis* (cf. Janossy and Meulen ,1975; Rabeder, 1981; Carls and Rabeder, 1988; Markova, 1990, 2005; Ünay and de Bruijn, 1998; Tesakov, 1998, 2004; Maul et al, 1998; Marchetti et al, 2000; Ghinassi et al, 2005; Mayhew, 2012; Pogodina and Strukova, 2013; Hoek Ostende et al, 2015b).

However, the occlusal and buccal morphology of the m1 of *Mimomys reidi*, which is illustrated by Tesakov (1998) from the late Villanyian Tegelen fauna (Netherlands), is strikingly similar to that of Sapaca but the Tegelen specimens are generally smaller

and much hypsodont, as shown by higher *linea sinuosa* values of M2, M3 and m3 (Tesakov, 1998, fig. 4–4a, tabl. 8–13).

It is worth noting that for *Mimomys* species succession during the Pliocene–Pleistocene), the evolution of the *linea sinuosa* (=enamel free area) is an important feature to distinguish species whenever their morphology and metrics are similar to each other. Unfortunately, both m1 from Sapaca locality are worn enough just to let anterosinuid, hyposinuid and hyposinulid to reach the occlusal surface, hence, that obscures the secure measurements of buccal elements and, eventually, the comparison of hypsodonty level with the m1s of other species. However, it is possible to use M2, M3 and m3 from the Sapaca material for hypsodonty level, whenever it is provided in the literature.

The Sapaca arvicoline molars have somewhat comparable length, width and A/L values in addition to general occlusal morphologies (e.g. wide ACC and T7 on m1, presence of enamel islet despite of increase in wear) with *Mimomys hajnackensis, M. hassiacus* and *M. stehlini* (e.g. Rabeder, 1981; Bachelet et al, 1991; Maul et al, 1998; Tesakov, 2004; Minwer-Barakat et al, 2004, 2008; Ghinassi et al, 2005; Mayhew et al, 2008).

Although *M. hajnackensis* is now considered a synonym of *M. hassiacus* by several authors (e.g. Fejfar et al, 1997; Mörs et al, 1998; Minwer-Barakat et al, 2008), that discussion is beyond the scope of this study. *M. hajnackensis* from the MN16 type locality Hajnácka (Slovakia; Fejfar 1961; 1964) and from the Arcille (Tuscany, central Italy, Masini and Torre, 1987; Maul et al, 1998) differs from *Mimomys* of Sapaca by its elongated ACC, much confluent PL–T3 and ACC elements, not an isolated T4 and T5, LSAs much larger than BSAs and laterally oriented LRAs.

Mimomys remains from Sapaca constitute the upper size limit of *Mimomys hassiacus* from the MN15 type locality Gundersheim (Germany; Heller, 1936; Fejfar and Storch, 1990) and from the Pliocene of Tollo de Chiclana (MN15 for layer TCH-1B, Granada, SE Spain, *sensu M. stehlini* by Minwer-Barakat et al, 2004; *erratum M. hassiacus* by Minwer-Barakat et al, 2008). However, the Spanish specimens differs from the Sapaca *Mimomys* in having a broad confluence between T1–T2, less deep LRA4 on worn specimen, mesially oriented BRA2 on the m1 (contra SPC-3 specimen), also with smaller and not isolated T2 which is slightly confluent with the

PC and AL, less developed BRA3 and LRA3 and T4 on M3. According to the authors (Minwer-Barakat et al, 2004), Spanish M3 has a distosinus higher than others and very low anterosinuid, protosinus and hyposinus, and mimosinuid is never high as anterosinuid (*contra* SPC-4). In that case, *Mimomys* from Sapaca should be considered as more hypsodont, since the protosinus is greater than distosinus and has higher level of mimosinuid.

Despite the slightly smaller size of *Mimomys stehlini* from the early Villanyian of Seynes and Balaruc-2 (France, Bachelet et al, 1991, tabl. 1) and from the Pliocene of Tollo de Chiclana (MN16 for layers TCH-3 and 13, Minwer-Barakat et al, 2008, tabl. 2), it is possible to compare the enamel free areas with that of Sapaca m1 and M3 by indirect observation on the relation of wear sequence measured after the crown height and *linea sinuosa* (e.g. Bachelet et al, 1991, figs. 2 and 6). In *M. stehlini*, at the height around 2.5 mm of m1 (for SPC-4 it is 2.53 mm), the anterosinuid reaches the occlusal surface whereas mimosinuid is not (*contra* Sapaca specimen), and on the M3, the distosinus is lower than the protosinus. These observations demonstrate again a lesser hypsodonty of *M. stehlini*.

As to *M. savini* which is considered as a key species to date Biharian age, it displays close measurements despite many morphological differences. For instance, the m1 of *Mimomys* from Sapaca are within the range of length and SDQ values fit that of *M. savini* from the late Biharian–early Toringian (MNQ21–23, 0.7–0.45 Ma) Voigtstedt and late Early Pleistocene (MNQ20, 1.1–1.05 Ma) Untermassfeld localities from Germany (Maul et al, 1998, tabl. 2). According to these authors, SDQ mean value is higher in Untermassfeld specimens compared to that of Voigtstedt (153.2 over 135.45), and therefore it represents more primitive character of *Mimomys*-type enamel thickness. That character difference is also supported by calibrated ages (Maul et al, 1998, tabl. 3). Note that SDQ values of the Sapaca m1 (152.14) is really close to that Untermassfeld specimen. On the other hand, the same authors suggested that the ratio Hsd/L (ratio of hyposinuid to length; also see Maul, 1996) is useful to detect the hypsodonty degree of arvicolines with rooted molars, rather than HH-index ($\sqrt{Hsd^2 + Hsld^2}$) suggested by Rabeder (1981). Unfortunately, these values for the Sapaca m1 cannot be safely used due to the high degree of wear. However, three figured m1 of *M. savini* from early Biharian German localities (Maul et al, 1998, plate 1) display anterosinuid and hyposinuid already reaching occlusal surface and

therefore, their height are given as >170 and >140 by the same authors (Maul et al, 1998, tabl. 6). By indirect measurements based on the scale provided by these authors, I could estimate the maximum height of these molars. The height of most worn m1 (Maul et al, 1998, plate.1, fig.2b) is 2.58 mm which is closer to the Sapaca *Mimomys* m1 with h=2.53 mm. On the same specimen, there is no *Mimomys*-ridge on occlusal side, nor a mimosinuid on the buccal. Also, none of three figured elements display enamel islet on ACC, which is not the case on the Sapaca arvicoline. Even if it is not secure to compare the Hsd/L ratio, the Sapaca *Mimomys* is well below than of both German *M. savini*, with 66.4 over >170 and >140 for Voigtstedt and Untermassfeld, respectively (Maul et al, 1998, tabl. 6). In sum, these results may indicate that the Sapaca specimens are truly less hypsodont compared to the Biharian *Mimomys* and possibly much older than Biharian (e.g. Figure 1.5). That hypothesis is also supported by the presence of enamel islet on ACC1 of m1 with well-developed *Mimomys*-ridge on the Sapaca arvicoline even after some degree of wear (i.e. even after mimosinuid reaches the occlusal surface; Figure 4.9.D-D').

Similar morphological differences are apparent when the Sapaca specimens are compared to the Spanish *M. savini* from the late Biharian of Trinchera Dolina 6 locality (Atapuerca, Spain; Cuenca-Bescos et al, 1999). Despite the length of the Sapaca arvicoline m1 which is within the range that of the Spanish arvicoline, but with its greater width, none of Spanish m1 specimens display at the same time an enamel islet and *Mimomys*-ridge. In addition, the Sapaca specimens have a wider ACC and more prominent T7 on m1, and lesser confluent triangles on the m3.

Mimomys savini from Anatolia is reported from the Middle Pleistocene (late Biharian–early Toringian) Emirkaya-2 locality (Seydişehir, Konya) with only an M2 and some fragmented other molars (Montuire et al, 1994). The M2 of the Sapaca arvicoline has a greater size and the T2-T3 are not confluent and there is no enamel interruption. The latter may be a consequence of the early stage of wear which avoid the *linea sinuosa* reaching the occlusal surface.

The Sapaca *Mimomys* is also compared to *M. ostramosensis* from the late Villanyian Osztramos-3 (?MNQ18; Janossy and Meulen, 1975) and Schernfeld (Carls and Rabeder, 1988) with addition of further studies provided by Tesakov (1998) and, Kosciow and Nadachowski (2002). In overall of metric comparison, the length, width and SDQ of the Sapaca specimens are within the range of *M. ostramosensis*

but the m1 of *M. ostramosensis* has a T4 much closed and mimosinuid reaching the occlusal surface after a degree of wear somewhat higher than in the Sapaca *Mimomys*.

That great difference of hypsodonty which is an important evolutionary stage let me think that the Sapaca *Mimomys* cannot belong to *M. ostramosensis*. On the other hand, Maul et al. (1998) and Maul and Markova (2007) stress that *M. ostramosensis* is a synonym of *M. pliocaenicus*, *contra* Tesakov (1998) and Kosciow and Nadachowski (2002). Tesakov (1998) states that *M. pliocaenicus* from MN17 Tegelen fauna represents an ancestor of *M. ostramosensis*. Kosciow and Nadachowski (2002) consider *M. ostramosensis* from the type locality Osztramos-3 an intermediate form between *M. pliocaenicus* from Tegelen and more advanced form of *M. ostramosensis* from Schernfeld. These suggestions are mainly based on the increase in hypsodonty level.

In order to distinguish specimens belonging to one of the species of *M. polonicus–M. pliocaenicus* (*–M. ostramosensis*) lineage, characterizing the transition Late Pliocene–Early Pleistocene (MN16b–MN17), it is generally used the difference of hypsodonty by combining many measurements and ratios of *linea sinuosa* provided by some authors (e.g. Chaline, 1974; Rabeder, 1981; Maul, 1996; Maul et al, 2014). Otherwise, it is quite difficult to distinguish these species just based on the m1 and M3 occlusal morphology, their lengths and width, even A/L, presence or absence of cementum in re-entrant folds or the disappearing of enamel islet; they may vary from one geographic population to another and also after individual age of the specimens (e.g. Rabeder, 1981; Carls and Rabeder, 1988; Maul, 1996; Tesakov, 1998, 2004; Maul et al, 1998, 2014; Mayhew et al, 2008; Bona et al, 2015).

Unfortunately, there is not enough data to compare *Mimomys* cf. *pliocaenicus* previously recorded by Ünay and de Bruijn (1998) at Karasapaca Village which is not far from our sampling section (Figure 2.2).

The only material in common of *Mimomys* from the early Biharian Kerimoğlu locality (=*M.* cf. *pliocaenicus*, Suluova Basin, Chapter 4.2; Figure 4.12.HK; Erturaç et al, 2019, fig. 11-I) is the M2. The Kerimoğlu M2 differs from the Sapaca arvicoline in having more rounded triangles, lack of enamel on tips of AL and posterior of T4, heavily filled by cement all of its height (h= 5.03 mm), lower length

and width but much greater PA-index (=7.04) which results in greater hypsodonty level.

The *Mimomys* from Sapaca differs from the *M. pliocaenicus* of latest Villanyian Bıçakçı locality (Çameli Basin, Hoek Ostende et al, 2015b) in having a broader confluence of dentine field between T2 and PC, much protruding T5, relatively lower dentine tracks and PA-index (as Bıçakçı specimen varies of 3.4–4.9 mm) on M3 with slightly greater size. The description of m1 from the Çameli Basin, on the other hand, matches well with the Sapaca specimens.

Compared to *M. pliocaenicus* from the late Villanyian (=MN17–MNQ18) Tegelen fauna (Netherlands; Tesakov, 1998) there are quite a few morphological differences such as wider T5, less protruding T7 and narrower distance between LRA4 and BRA4 on unworn Tegelen m1. Although all length and width measurements are within the range of the Tegelen specimens, *linea sinuosa* heights are lower in M2 and M3 compared to the Sapaca molars, especially less developed hyposinus on M3. Therefore the Sapaca *Mimomys* is less hypsodont than the Tegelen species (e.g. Tesakov, 1998, fig. 6, 11 and tabl. 5–6).

The morphological similarities of the Sapaca arvicoline with that of *Mimomys pliocaenicus* from the late Villanyian (MN17) of Coste San Giacomo (Anagni Basin, central Italy) are significant, including all measurements provided by the authors (Bona et al, 2015, plate.1, tabl. 2), and the position of mimosinuid relative to anterosinuid on m1. However, the Sapaca specimens differ from the Italian *Mimomys* by near absence of cementum in neither older nor younger specimens, and also the presence of enamel islet, even as a trace on ACC on the very worn specimen (h=1.36 mm). The enamel islet on the m1 of Italian *Mimomys*, however, seems to disappear at maximum height of 3.31 mm, given the scale provided by the authors (Bona et al, 2015, fig. 6.4a–b).

The description as well as figured specimen of *Mimomys pliocaenicus* from the late Villanyian (MN17) locality of Saint-Vallier (Drôme, France) matches well with the Sapaca arvicoline (Martin-Suarez and Mein, 2004). However, the French *Mimomys* differs in having lower size of m1 and M3, confluent AL–T2 and T2–PC, narrower PC by restriction between LRA3 and BRA3 on M3.

Finally, the Sapaca arvicoline is compared to *M. polonicus* from the Pliocene type locality Rebielice Krolewskie (Poland, Kowalski, 1960; Ghinassi et al, 2005), from the Late Pliocene (MN16a) Zverinogolovskoye (Southern Trans-Urals region; Pogodina and Strukova, 2013), and from the Late Pliocene–Early Pleistocene (MN16b according to Tesakov et al, 2007) Altenburg (Germany; Rabeder, 1981), Kushkuna (Azerbaijan; Tesakov, 2004) and Rebielice Krolewskie-1 (Poland; figured in Chaline, 1974, measurements in Mayhew et al, 2008). In overall, the length and width of all molars of *M. polonicus* match well with the Sapaca arvicoline but it differs only in having T1–T2 and T2–T3 much confluent on m1 (e.g. Rabeder, 1981, figs 136-1a; Chaline, 1974, fig. 10; Tesakov, 2004, fig. 4.7). The difference concerning hypsodonty degree of the Sapaca *Mimomys* becomes obvious after comparison the *linea sinuosa* of M2 and m3 (e.g. for M2, see Mayhew et al, 2008, tabl. 1–2 for Rebielice Krolewskie-1 specimens), Rabeder (1981, tabl. 36) and Tesakov (2004, tabl. 4.16); for M3, see Tesakov (2004, tabl. 4.13)). However, the M3 of the Sapaca arvicoline appears to be more hypsodont than *M. polonicus* from Zverinogolovskoye (calculated PA-index=1.73 after values of Prs and As provided by Pogodina and Strukova (2013, p. 175) although it matches well with the PA-index of M3 from Kushkuna locality (Tesakov, 2004, tabl. 4.17 and 4.18).

Based on all comparison and measurements, *Mimomys* from Sapaca locality is closer to *M. polonicus* from the Kushkuna locality rather than *M. pliocaenicus*. That would be plausible if we take into consideration *M. praepliocaenicus* from MN17 Stranzendorf (Germany; Rabeder, 1981) and Kryzhanovka-3 (Ukraine; Tesakov, 2004), which is considered an intermediate species between *M. polonicus* and *M. pliocaenicus* because of its intermediate hypsodonty (Tesakov, 1998). For the comparable specimens of the Sapaca arvicoline, the length and width values are within the measurements of the Ukrainian species (except the M2 which is slightly greater) and slightly greater than the German arvicoline, but the M2 and M3 of both *M. praepliocaenicus* have greater PA-index (e.g. Rabeder, 1981, tabl. 37; Tesakov, 2004, tabl.4-19, 22, 25 and 26). Although it is beyond the scope of this thesis if *M. praepliocaenicus* is a valid species or not, the *Mimomys* remains from Sapaca should be considered as *Mimomys* cf. *polonicus*, until new material is collected. Therefore, the possible age of the Sapaca locality would be MN16b (late early Villanyian), as of Kushkuna.

4.1.3 Fossil remains from Kumkapı locality

4.1.3.1 *Microtus* (*Microtus*) cf. *arvalis*

Class: Mammalia Linnaeus, 1758

Order Rodentia Bowditch, 1821

Suborder Myomorpha Brandt, 1855

Family Cricetidae Fischer, 1817

Subfamily Arvicolinae Gray, 1821

Genus *Microtus* Schrank, 1798

Microtus (*Microtus*) cf. *arvalis* Pallas, 1778

Figure 4.10

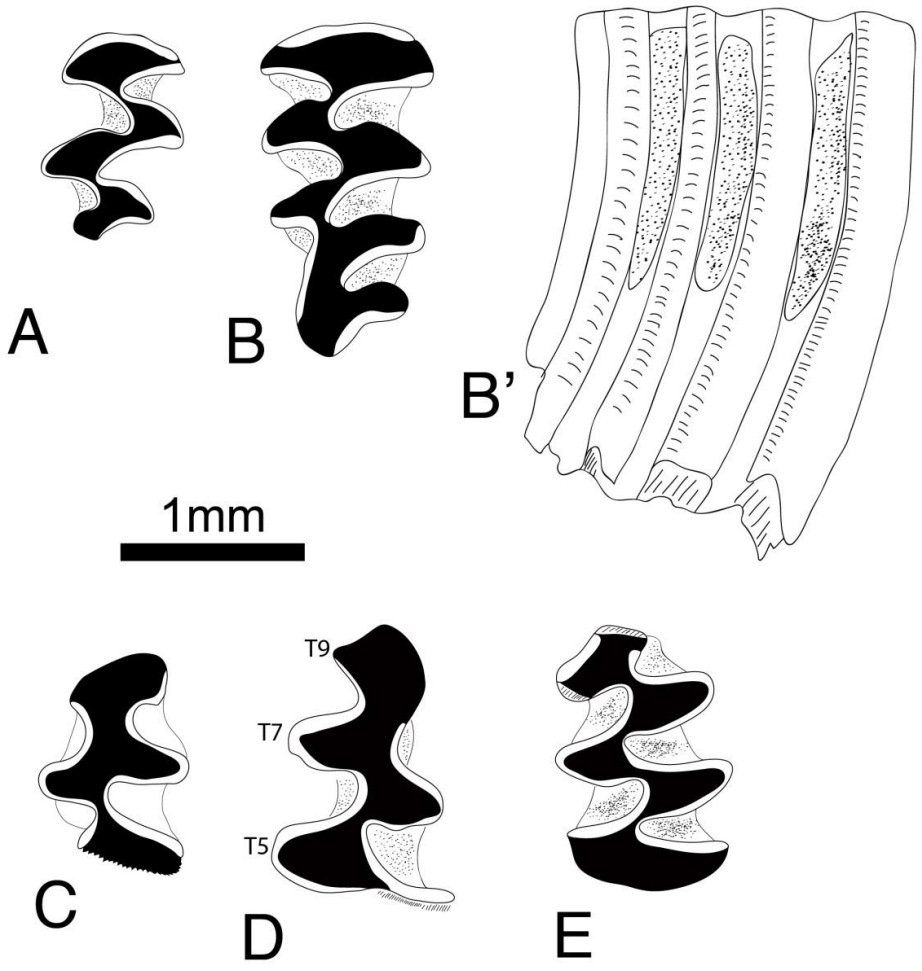


Figure 4.10 : Molars of *Microtus* (*M.*) cf. *arvalis*. A, M2s; B, M3d with B' for lingual view; CD, anterior fragments of m1s and m1d, E, m2s.

Material: 1 M2s (KK-1), 1 M3d (KK-2), fragments of 1 m1s (KK-3) and 1 m1d (KK-4), 1 m2s (KK-5).

Locality: Kumkapı (Figure 4.1)

Measurements in mm: M2: L=1.59, W=1.12; M3: L=1.89, W=0.94, P=1.31, WP=0.89; m1s: not available; m2: L=1.51, W=0.98.

Description: All molars are rootless and hypsodont. M2 is formed by AL and alternating three triangles (Figure 4.10.A). Tip of buccal side of AL lacks enamel; all re-entrant angles filled of crown cement except buccal re-entrant angle although cement is observed on lateral side. Buccal re-entrant angles have same deepness as lingual ones.

The M3 (Figure 4.10.B-B') is formed by AL, followed by confluent T2–T5 and well developed T7, and displays "*principalis*" morphotype with (*sensu* Rörig and Börner, 1905). The confluence degree is highest between T2 and T3, and T5 is broadly fused with T7 and the posterior cap (PC). PC is short and wide. There is no prominent formation of T6. The enamel is absent on both lateral tips of AL, on the posterior edge of PC and on the anterior parts of salient angles. Therefore it has positive enamel thickness.

m1 (Figure 4.10.C-D) is represented only by the AC and T7-T6 and T5. AC lacks the enamel. A prominent formation of lingual salient angles (T9) is observable on both specimens. The enamel on trailing edges is much thinner than leading ones. The re-entrant angles are filled of cement although on the specimen KK-3, the cement does not reach the crown along the LRA5 in lateral view.

The m2 has a wide posterior loop (PL) which lacks the enamel (Figure 4.10.E). It is followed by four closed triangles. The postero-buccal side of T4 is damaged as the anterior part. However it is seen that there is no evidence of enamel on the anterior tip of that molar. Two buccal and three lingual re-entrant angles are filled with crown cement. Buccal re-entrant angles are wider yet less deep than lingual ones. It displays positive enamel thickness.

Comparison and discussion: The only complete material which would permit to species identification is the M3, since the all of m1 are damaged and lack

measurement. However, ACC of m1 as well as the M2 can provide some information for some species comparison.

The arvicoline specimen belongs to the genus *Microtus* rather than *Arvicola* or *Mimomys*, with the absence of roots, positive enamel thickness and relatively complex M3 occlusal surface. Therefore, the material from Kumkapı is compared to *Microtus* (*Terricola*) *arvalidens* from several localities of Middle Pleistocene of Ukraine (Rekovets and Nadachowski 1995; Rekovets et al, 2014a; Popov, 2017); to *M. gregalis* from early Toringian (Middle Pleistocene) of Ukraine (Lysa Gora 1, Rekovets et al, 2014a; Mezhyrich, Rekovets et al, 2014b) and of France (Baume Moula-Guercy, Defleur et al, 2001); to *M. agrestis* from the Late Pleistocene of Serbia (Bogicevic et al, 2012; 2017); to *M. guentheri* from the Late Pleistocene Karain B and Üçağızlı caves in Turkey (Storch, 1988; Suata-Alpaslan, 2011b, respectively) and from the Middle Pleistocene Qesem Cave (Maul et al, 2011); to *M.* (*T.*) *subterraneus* from the early Toringian Umurlu locality of Niksar Basin (section 4.3; Erdal et al, 2018) and to extant specimen from Anatolia (Krystufek and Vohralik, 2005); finally, to *M.* (*M.*) *arvalis* from the Middle Pleistocene of Emirkaya-2 (Montuire et al, 1994), the early Toringian of Umurlu locality (section 4.3; Erdal et al, 2018), the Late Pleistocene of Karain B Cave near Antalya (Storch, 1988), the early Holocene of Bedburg-Königshoven (Germany; Kolfschoten, 1994) and the Middle Holocene of Tepecik-Çiftlik (Niğde, Erdal et al, 2019).

The *Microtus* M3 specimens from Kumkapı display some resemblance with that of *M.* (*T.*) *arvalidens* from the Lysa Gora 1 locality (Middle Pleistocene of Ukraine; Rekovets et al, 2014a) such as well developed T7, elongated PL, in addition to measurements. However, the M3 remains in that study are attributed to *M.* (*T.*) *arvalidens* in accordance with the abundance of the material of m1 of the same species and therefore, they display many variability on occlusal surface morphology (Rekovets et al, 2014a, fig. 8.8). On the other hand, the ACC of m1 from Kumkapı, the only preserved part, is different in having relatively well developed T9, broader area without enamel and narrower isthmus between BRA4 and LRA5. All *M.* (*T.*) *arvalidens* M3 from many localities of Ukraine in the work of Rekovets and Nadachowski (1995, p. 224) have a T7 not fully independent of PC except the ones from Tikhonovka-1 (Rekovets and Nadachowski, 1995, fig. 69B). However, it is not observed any initiation of T6 on the Kumkapı M3 material contrary to that of the

Ukrainian specimens. The Kumkapı material differs also from the *M.* (*T.*) *arvalidens* from Futjova Cave in having well developed T7 (it is not formed in Futjova specimens) and greater size. The Ukrainian m1 has also symmetrically confluent T6–T7 as well as broader isthmus between BRA4 and LRA5 and more elongate ACC with less prominent T9 (Popov, 2017, fig. 13).

The *Microtus* of Kumkapı differs from *Microtus gregalis* by its remarkable shape of ACC of m1, in other words, the presence of robust T6 and more developed T7 on M3 (Defleur et al, 2001; Rekovets et al, 2014a, b).

As to *Microtus agrestis*, which is an extant species, there are two criteria for its discrimination from *M. arvalis*: the asymmetry of lingual and buccal triangles on m1 (Chaline, 1972), and the development of additional triangle T5 on posterolingual side of M2 (Dienske, 1969; Rekovets and Nadachowski, 1995; Krystufek and Vohralik, 2005; Bogicevic et al, 2012; Stoetzel et al, 2016). In the absence of M2, specimens are generally attributed to *M. arvalis*/*agrestis* group (e.g. Kolfschoten, 1994; Ivanov and Vörös, 2014). It is hard to observe a symmetry on the fragmented m1 of Kumkapı, and there is no presence of additional loop of T5 on the M2 contrary to that of recent studies (Krystufek and Vohralik, 2005; Bogicevic et al, 2012, 2017). Therefore I cautiously eliminate the candidate *M. agrestis* for Kumkapı material.

The m1 ACC of *Microtus* from Kumkapı is similar to *M. guentheri* from Karain B Cave (Storch, 1988) and Qesem Cave (Maul et al, 2011) as well as to that of extant specimen from Turkey (Krystufek and Vohralik, 2005). However, the *M. guentheri* material from Üçağızlı Cave worked by Suata-Alpaslan (2011b) display completely different m1 and M3 occlusal morphology compared to the Kumkapı specimen with slightly larger length and width of M3. However, the M3 of extant animals and fossil specimen from Karain B caves display rather much greater metric values than Kumkapı material (see Storch, 1988, tabl. 2; Krystufek and Vohralik, 2005). Despite the morphological resemblance, the greater size of *M. guentheri* allows me to exclude for the Kumkapı *Microtus*.

All *Microtus* molars from the Kumkapı locality have greater length, width, as well as greater P and WP values compared to *M.* (*T.*) *subterraneus* from the Umurlu locality (Erdal et al, 2018, tabl. 2 and 5) and to that of extant species in Anatolia (Krystufek and Vohralik, 2005). Besides, none of the M3 from Umurlu displays a well-

developed T7 contrary to some extant sample although there is also a T6 on the latter (Krystufek and Vohralik, 2005, fig. 147C).

Finally, *Microtus* of Kumkapı is within the available measurements range with other specimens described as *M. arvalis* mentioned above for any molar remains (see also Storch, 1988, tabl.2; Montuire et al, 1994; Erdal et al, 2018, tabl. 2 and 5; Erdal et al, 2019 tabl. 2; also Chapter 4.3.1.4). However, the Kumkapı specimens are slightly wider than the Middle Holocene Tepecik-Çiftlik remains. The morphology of all molars also is very similar to these of *Microtus arvalis* remains with few exceptions: The ACC of Kumkapı arvicoline m1 has a much prominent T9 compared to Umurlu specimen, the M3 from Karain B Cave lacks the T7 with more simple occlusal morphology (Storch, 1988, fig. 3.19-20), whereas M3 remains of Umurlu *Microtus* display much variable structures with the faint presence of T6 and T7 fused with PC, except one specimen (Erdal et al, 2018, fig. 5.B8).

Based on well-matching measurements and minor morphological differences, which would be considered as intraspecific variations, the Kumkapı arvicoline should be conferred to *M. arvalis,* thus as *Microtus* cf. *arvalis* until new remains are gathered.

4.1.3.2 *Mus* cf. *macedonicus*

Family Muridae Illiger, 1811

Subfamily Murinae Illiger, 1811

Genus *Mus* Linnaeus, 1758

Mus cf. *macedonicus* Petrov and Ruzic, 1983

Figure 4.11

Material: 1 M2s (KK-6) and 1 m1s (KK-7).

Locality: Kumkapı

Measurements in mm: M2: L=1.13, W=1.08; m1: L=1.48*, W=0.89. (*)estimated.

Description: The murine species is represented by a left upper second molar (Figure 4.11.A) and fragmented left lower first molar (Figure 4.11.B). None of molars has accessory cusps or cuspids; roots are not preserved.

The M2 has a weakly developed t3 which is far smaller than t1. Tubercules t4-t5-t6 are interconnected; t4 is situated posterior to the t5 and t6. The t7 is absent. The t9 is fused with t8 and projected anterolaterally.

On the trigonid of m1, the buccal anteroconid is missing. The dentine fields of protoconid-metaconid and hypoconid-entoconid are confluent. The longitudinal crest is absent. The posteroconid is well developed.

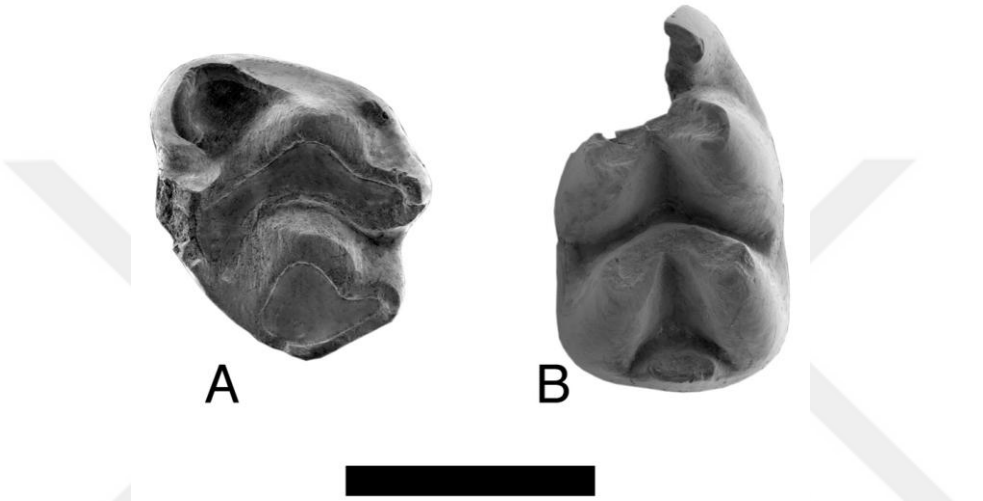


Figure 4.11 : Molars of *Mus* cf. *macedonicus* from Kumkapı. A, M2s and B, m1s.

Comparison and discussion: The murine subfossils identified from Turkey which display such simple occlusal morphology point out rather two extant species of the genus *Mus*, *M. musculus* and *M. macedonicus* (cf. Çolak et al, 2006; Krystufek and Vohralik, 2009; Suata-Alpaslan, 2011a; Erdal et al, 2018; 2019). According to Krystufek and Vohralik (2009; fig. 134A), the extant *M. musculus* from Turkey lacks the t3 on M2, but it is occasionally present in *M. macedonicus*. On the other hand, M2 of *Mus* from Kumkapı is slightly greater in size than *Mus* cf. *musculus* from the Middle Holocene of Tepecik-Çiftlik (Niğde, Erdal et al, 2019) and than *M. macedonicus* from the Late Pleistocene of Üçağızlı Cave (Hatay, Suata-Alpaslan, 2011a), contrary to the m1 which is smaller than the Hatay m1 and is within the range of Tepecik-Çiftlik material. However, m1 and M2 matches well with the measurements of *M.* cf. *macedonicus* from Qesem Cave.

Based on a work on the extant *Mus macedonicus* and *M. musculus* (=*domesticus*; *sensu* Çolak et al, 2006), the occlusal morphologies such as the presence of t3 on M2 and crescent shaped dentine field of protoconid-metaconid and hypoconid-entoconid on m1 of *M. macedonicus* are much suitable with Kumkapı murine (Çolak et al, 2006, figs. 3–4).

As to present geographic distribution of both species, they are found in large scale in Anatolia except East-Southeast for *M. macedonicus* (Krystufek and Vohralik, 2009, figs. 129 and135).

In these circumstances, it would be rather suitable to attribute the Kumkapı specimens cautiously to *M.* cf. *macedonicus*. According to Tchernov (1992), *M. macedonicus* has been present in Israel for the last 160 ka (=latest Middle Pleistocene) while it is introduced in Anatolia, according to fossil record so far, much later (Krystufek and Vohralik, 2009). For instance, it was not present in the rich fossil fauna from the Middle Pleistocene Emirkaya-2 locality (Montuire et al, 1994) but appeared in the Late Pleistocene in Karain Cave (=*M. abbotti sensu* Storch, 1988).

Therefore, the Kumkapı deposit bearing *Microtus* (*Microtus*) cf. *arvalis* and *Mus* cf. *macedonicus* together would limit the lower age of that layer as Late Pleistocene.

4.2 Suluova Basin

Five fossil localities, although poor, delivered different micro- and macrofauna (see section 2.2). Here below, the specimens are indicated under the relevant locality. At sum, there are 27 molars and one mandible of rodents, two molar series of a giraffid, one molar and a fragment of a phalanx of equids. In addition, some damaged molars of arvicolid are not measured nor included in this study. Note that measurements are provided with before the description instead of a table of measurements.

4.2.1 Fossil remains from Kurnaz locality

4.2.1.1 *Kalymnomys* sp.

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Arvicolinae Gray, 1821

Genus: *Kalymnomys* Koenigswald, Fejfar and Tchernov, 1992

***Kalymnomys* sp.**

Figure 4.12.A

Material: 1 M2 (KU-3).

Occurrence: Late Villanyian; ?MN17– ?MNQ18

Measurements in mm: L=2.06, W=1.1.

Description: Medium sized hypsodont and rootless vole molar formed by confluent AL and T2–T4. The cementum is absent. Re-entrant angles are wide and deep except BRA3 and LRA3. Tips of triangles are generally pointed but BSA1, LSA2 and LSA3 are rather blunt. There is no enamel differentiation or discontinuity.

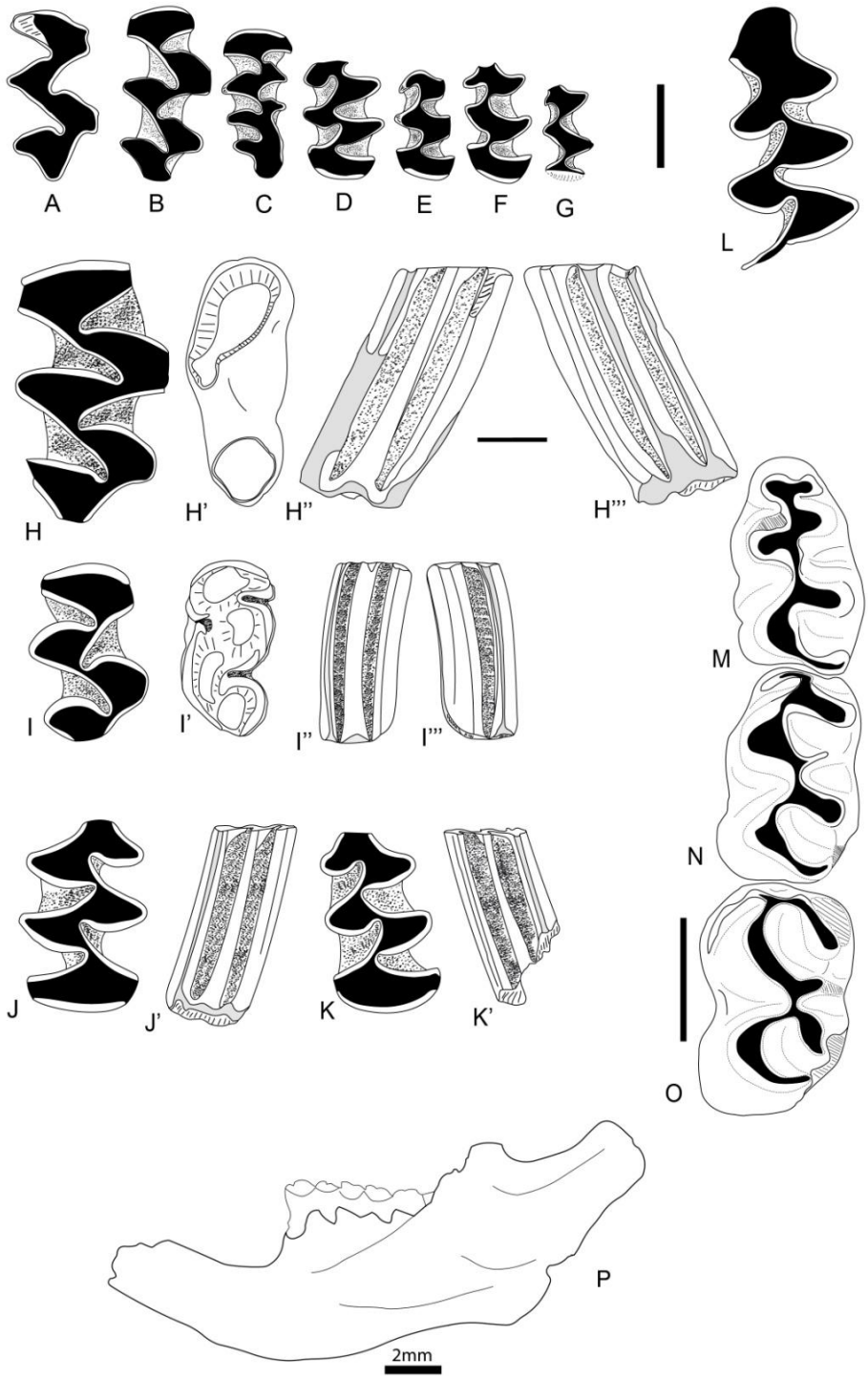


Figure 4.12 : (A–K) Arvicolines and (M–P) a cricetine from the Suluova Basin. (A) M2 of *Kalymnomys* sp. from Kurnaz (KU-3). (B–G) upper and lower molars of *Microtus* (*Allophaiomys*) aff. *nutiensis* from Kerimoğlu; (B) M1 (KO-1); (C) M3 (KO-2); (D) m2 (KO-3); (E–G) m3 (KO-4–6). (H–K) *Mimomys* aff. *pliocaenicus* from Kerimoğlu; (H) M1 occlusal (KO-7), (H') ventral, (H'') buccal and (H''') lingual views; (I) M2 occlusal (KO-8), (I') ventral, (I'') buccal and (I''') lingual views; (J–K) m2 occlusal (KO-9 and KO-10), (J' and K') ventral views. (L) m1 of *Arvicola* cf. *mosbachensis* from Yolpınar locality (YP-1). (M–P) *Mesocricetus* aff. *arameus* from Kızıleğrek locality: (M) m1, (N) m2, (O) m3 and (P) buccal view of mandible bearing molar series. Horizontal scale is 1mm, vertical 2mm, for occlusal and lateral views, respectively, except the mandible.

Comparison and discussion: The absence of any m1 or M3 remains from Kurnaz locality beclouds the identification of the lagurine material. At generic level however, it can be distinguished from *Borsodia* by the absence of roots and enamel differentiation (Jánossy and Meulen 1975); from *Prolagurus* (=*Lagurodon*, *sensu* Mayhew 2012) in having greater size, more confluent dentine field and also in lack of "lagurine-fold" *sensu* Rabeder 1981 (i.e., a slight fold in LRA2 on upper molars, on trailing edge; see Rabeder 1981, p. 81). As to *Kalymnomys major*, Kurnaz M2 is greater in length, has a wider dentine field confluence (Kuss and Storch 1978, figs. 64–65), posteriorly curved tips of LRA2 and BRA2, blunt shape of lingual salient angles. *Kalymnomys* sp. is documented from the latest Villanyian Havutçulu and Bıçakçı localities in Anatolia (Ünay et al, 1995; Hoek Ostende et al, 2015a). The size of *Kalymnomys* from the latter locality is clearly lower than *Kalymnomys major* (e.g., Kuss and Storch 1978, p. 220) and with simple occlusal morphology of M3, Hoek Ostende et al. (2015a) state that their animal of Bıçakçı is probably ancestral to *K. major*. In these circumstances and due to the scarcity of material, the M2 from Kurnaz is considered as *Kalymnomys* sp., having slightly greater size than *Kalymnomys major* and much greater than Bıçakçı specimen, until new remains are obtained. Therefore, the age of Kurnaz locality is most likely similar in age of Bıçakçı locality or slightly younger.

4.2.1.2 *Sivatherium* sp.

Order: Artiodactyla Owen, 1848

Family: Giraffidae Gray, 1821

Subfamily: Sivatheriinae Bonaparte, 1850

Genus: *Sivatherium* Falconer and Cautley, 1836

***Sivatherium* sp.**

Figure 4.13.A-B

Material: 1 m2 (KU-1) and 1 m3 (KU-2).

Occurrence: Late Villanyian; ?MN17– ?MNQ18

Measurements in mm: m2, L=51.4; W1=24.4–27.4 / W2=25.7–28; m3, Length=64.1; W1=23.2–27.4 / W2=25.5–28.

Description: Hypsodont, rectangular and moderately worn molars with four crescent-shaped cuspids in addition to well-developed back fossette on m3. Lingual cuspids are higher than buccal ones in labial view, in the exception of hypoconulid and entoconulid which are lowest. Possibly due to attrition level, median ribs of metaconid and entoconid on m2 have comparable volume to that of protoconid and hypoconid whereas the latter are much voluminous and buccaly projected than lingual ones on m3. Buccal walls of molars have rather smooth surface but lingual ones are undulated with dorso-ventral bulbs of stylids, metaconids, entoconids and entoconulid. The dentine field of metaconid and protoconid is mesially confluent on both molar but it is broader on m2. Fossettes are compressed. The cingulid is weakly developed and absent on the buccal junction of lobes if not post-damaged. The most posterior tip of postentocristid of m2 is perfectly in continuum with the anterior tip of the premetacristid of m3 if junction occurs. Only posterior root of m2 is preserved.

On the m2, postmetacristid appears to be in continuum with preentocristid via metastylid. Hence, the dentine field of metaconid and entoconid is narrowly merged. This connection is much wider between dentine fields of protoconid, hypoconid and entoconid parallel to the form of postprotocristid, prehypocristid and preentocristid which results in postero-lingual enclosure of the anterior fossette.

On m3, a stylid on the anterior edge of the premetacristid is much robust than on m2. Fossettes are not filled with cementum. Postmetacristid, postprotocristid, prehypocristid and preentocristid are separated contrary to these of m2, hence anterior fossette and posterior fossette are open on the posterior and anterior sides, respectively. Similarly, there is an enamel discontinuity between the stylid on the posterior edge of postentocristid and entoconulid. The back fossette is oblique and elongate, pinched at the very end of posthypoconulidcristid and on the posthypocristid-prehypoconulidcristid junction area although permitting to dentine confluence between that of hypoconulid and hypoconid. The hypoconulid and pre-, posthypoconulid cristids are buccaly bulged.

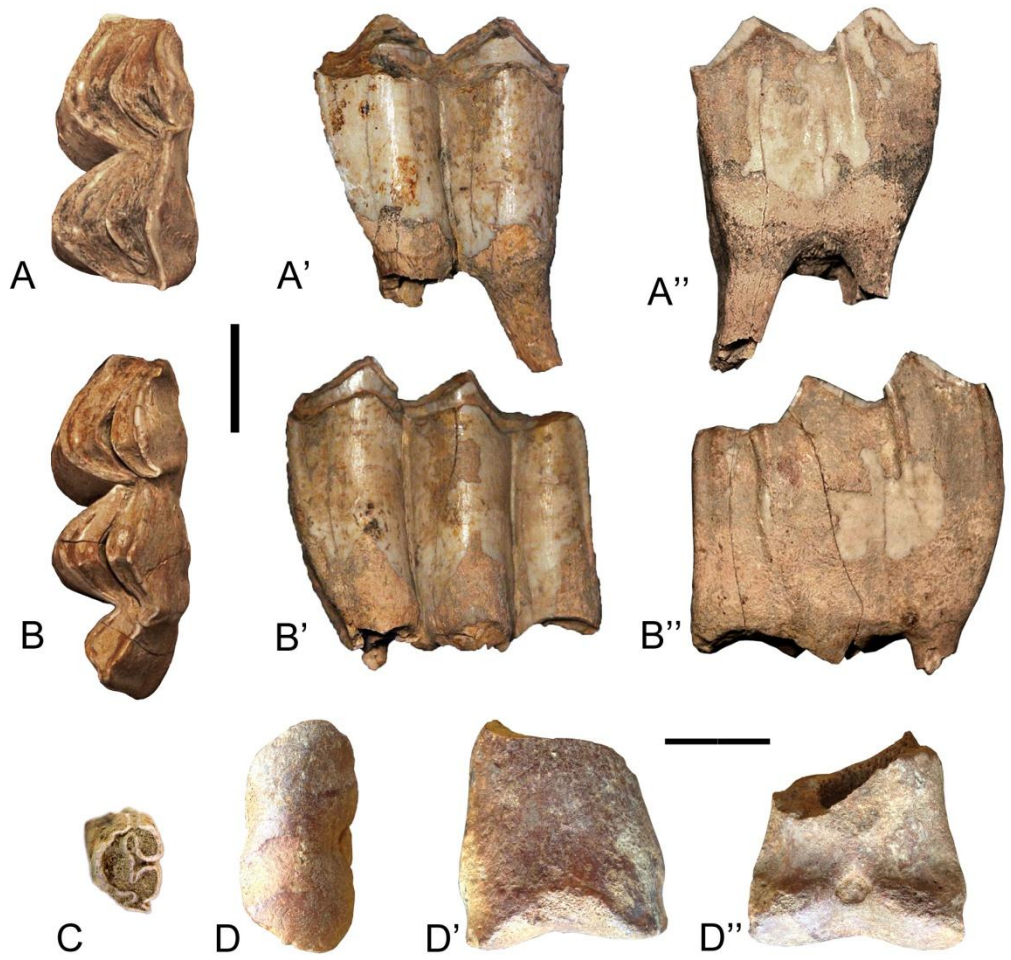


Figure 4.13 : Large mammal remains from Suluova Basin. (A–B) lower molars *Sivatherium* sp. from Kurnaz locality; (A) occlusal, (A') buccal and (A'') lingual view of m2 (KU-1), (B) occlusal, (B') buccal and (B'') lingual views of m3 (KU-2). (C) possibly talonid of p3 of ?*Equus* sp. (KA-1) from Kamışlı locality. (D) dorsal view distal part of first phalanx of *Equus* sp. (YP-4) from Yolpınar locality, (D') anterior and (D'') posterior view. Scale bar is 2 cm for each; vertical for *Sivatherium*, lateral for equids.

Comparison and discussion: The systematic definitions and positions among the family Giraffidae are mainly established after cranial and post-cranial elements, but also dental characters although the latter is not always sufficient or efficient (Geraads 1996, 2009; Gentry et al, 1999; Geraads and Güleç 1999; Harris et al, 2010; Khan et al, 2011; Rios et al, 2017). Therefore, such identification is difficult with two lower molars as in present study. However, following the molar characteristics used by Bhatti et al. (2012), the Kurnaz material with overall morphology (selenodont molars, hypsodonty level, highly rugose enamel, size) belongs to Giraffidae. Furthermore, the size of these molars are similar to that of *Sivatherium giganteum*

from the Early Pleistocene of Siwalik (e.g., Colbert 1935, p. 345; Khan et al, 2011, tabl. 1) would place the Turkish material within the subfamily of large girrafids Sivatheriinae. This subfamily includes three genera, *Bramatherium*, *Helladotherium* and *Sivatherium* although some synonymy is apparently still subject to debate based on sexual dimorphism between remains of the first two genera, as well as for *Hydaspitherium* (e.g., Colbert 1935, p.342; Geraads and Güleç 1999; Harris et al, 2010; Khan et al, 2014; Mahmood et al, 2015; Rios et al, 2017). The only material of *Helladotherium* which would be suitable for lower molar comparison is the type species from the Turolian of Pikermi (Greece) which is represented only by deciduous molars (Gaudry 1862, p. 257 and pl. XLI, fig.3). Concerning comparable *Bramatherium* spp. material from the middle Siwalik, sivathere from Kurnaz are generally greater in size than *B. megacephalum* and *B. grande* except one specimen of the latter (=*Hydaspitherium magnum sensu* Khan et al, 2011; Khan et al, 2014, tabl. 2). The Kurnaz specimens differ from *Bramatherium* in having much lingually directed metastylid, much rounded buccal conids on m2; comparable size of anterior and posterior lobes, postmetacristid shorter than preentocristid and much elongate back fossette, less buccaly pointed hypoconulid, weakly developed posterior stylids and cingulids on m3 (Khan et al, 2014).

Among *Sivatherium* species, *S. maurusium* (Geraads 1996) from the late Pliocene of Ahl al Oughlam (Casablanca, Morocco) and *S. hendeyi* (Harris 1976) from the early Pliocene of Langebaanweg (Western Cape Province) are not taken into consideration due to geographic distribution and lack of comparable material with that of Kurnaz. This is also valid for European *S. garevskii* (Geraads 2009) from the ?Pliocene of Macedonia. Kurnaz sivathere material matches well with the description of *Sivatherium* sp. reported by Khan et al. (2011) from the Pleistocene of Punjab (Upper Siwaliks) although the present material has greater m2 but smaller m3 than the Punjab sivathere.

In Turkey, sivathere remains are reported as a left posterior horn of *S. giganteum* from the “early Tertiary” of Edirne (=Adrianopel in Abel 1904) and, as a skull of *Bramatherium* sp. from the Late Miocene of Kavakdere (Geraads and Güleç 1999). The latter is considered synonym with *Helladotherium* and *Decennatherium* according to Harris et al. (2010). However, the recent study of Rios et al. (2017) demonstrate that the sivathere clade is well supported except the South African

species *H. hendeyi*, and *Decennatherium* represents rather a sister taxon. In a way or another, the molars in this study are much greater than that of *Bramatherium* in size and rather approach the dimensions of *Sivatherium giganteum* from Upper Siwaliks (Khan et al, 2011). *S. giganteum* record spans from 2.5 Ma to 0.78 Ma (Patnaik and Nanda 2010) but the presence of *Kalymnomys* molar would limit the age of Kurnaz locality to late Villanyian (MN17–MNQ18) in Early Pleistocene. The presence of such giraffid in Anatolia from Pleistocene is important and in order to have solid identification as well as assumptions on the paleobiogeography, the material available must be increased with future excavation. Therefore, that specimen is temporarily attributed to *Sivatherium* sp.

4.2.2 Fossil remains from Kerimoğlu locality

4.2.2.1 *Microtus* (*Allophaiomys*) aff. *nutiensis*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Arvicolinae Gray, 1821

Genus: *Microtus* Schrank, 1798

Microtus* (*Allophaiomys*) aff. *nutiensis Chaline, 1972

Figure 4.12.B–G

Material: 1 M1 (KO-1), 1 M3 (KO-2), 1 m2 (KO-3), 3 m3 (KO-4–6).

Occurence: Late Villanyian–Early Biharian; ?MNQ18–19

Measurements in mm: M1 L=2.11, W=1.06; M3 L=1.74, W=0.82, P=0.94, WP=0.7; m2 L=1.4, W=0.93; m3 L=1.34–1.38, W=0.67–0.79.

Description: All rootless molars have abundant cementum in re-entrant angles. The first upper molar is formed by AL and four alternating closed salient triangles (T1–T4). The enamel lacks on lateral edges of AL, T1 and posterior to T4. The leading edges of triangles are thinner than trailing ones.

The M3 has rather a complex occlusal surface with AL followed by confluent T2–T3 couplets and broadly confluent T4–T5, T7 and posterior cap. The dentine field

between T2–T3 and T4 is separated with restriction of deep BRA2 and LRA3. T7 is well distinct and comparable to T5 in size. BSA4 is not formed. The enamel free areas are at the buccal and lingual sides of AL and at the posterior of PC.

The lower m2 has a posterior lobe and four alternating triangles. T2 and T3 appear to be more or less confluent. T4 is wide, posteriorly blunt and postero-buccally oriented. The buccal re-entrant angles are deep and rather mesially directed while lingual ones are transverses. The negative enamel differentiation is prominent. The enamel lacks broadly on triangles tips of PL and on the mesial edge.

All of three m3 from Kerimoğlu display some variation, dentine confluence of T1–T2 and T3–T4 couplets and absence of enamel on lateral sides of PL. One specimen (KO-4) seems to be somehow digested regarding to dorso-ventral obliquity of buccal salient angles. Also, the LSA2 and LSA3 are not sharply pointed just as observed on LSA1 and the enamel is absent on both triangles.

Comparison and discussion: The only molar which allow to compare with other arvicolines and ensure as much as possible the identification is eventually the M3 (Figure 4.12.C). Regarding the morphological complexity of that molar (i.e., presence of T7) in addition to measurements of length, width, p and WP values, the Kerimoğlu material would have affinity with that of *M.* (*M.*) *arvalis* from the Umurlu locality, early Toringian in the adjacent Niksar Basin (Chapter 4.3; Erdal et al, 2018, fig. 5B.3, tabl. 2 and 5). However, the latter is different in having invariably thicker and positive enamel differentiation and less confluence dentine field between T2–T3. The Kerimoğlu material is compared also to *Microtus* (*Allophaiomys*) *deucalion* (e.g., Meulen 1973, 1974), *M.* (*A.*) *pliocaenicus* (e.g., Meulen and Zagwijn 1974; Hír 1998), *M.* (*A.*) *chalinei* (e.g., García-Alix et al, 2009), *M.* (*A.*) *burgonidiae* (Maul et al, 1998) and *M.* (*A.*) *nutiensis* (e.g., Ünay 1998; Ünay et al, 2001). None of them but the latter, especially *M.* (*A.*) cf. *nutiensis* from Early Biharian Çaybaşı locality at Adapazarı Basin (Ünay et al, 2001; pl. II) would approach morphologically to the present material by its M3 complexity, thinner and less remarkable enamel differentiation as well as overlapping measurements. The specimen in question would have affinity with *Microtus* (*Allophaiomys*) *nutiensis* and therefore is attributed cautiously here as *M.* (*A.*) aff. *nutiensis*.

4.2.2.2 *Mimomys* aff. *pliocaenicus*

Genus: *Mimomys* Forsyth Major, 1902

Mimomys* aff. *pliocaenicus Forsyth Major, 1902

Figure 4.12.H–K

Material: 1 M1 (KO-7), 1 M2 (KO-8), 2 m2 (KO-9–10).

Occurence: Late Villanyian–Early Biharian; ?MNQ18–19

Measurements: M1 L=3.15, W=1.85, PA-index=8.62; M2 L=2.05, W=1.39, PA=7.04; m2 L=2.26–2.3, W=1.33–1.52, HH-index=7.2.

Description: All molars display *Mimomys*-type enamel differentiation; the leading edges are thinner than trailing ones on lower molars and vice-versa on upper molars. The crown cementum is abundant in re-entrant angles but less on lingual side of one specimen (KO-10).

The M1 is hypsodont and formed by wide triangles; anterior lobe followed by alternating T1–T4. The labial triangles chewing surface appears to have larger dentine field. The BSA2 is wider than BSA1 but less deep. The enamel is clearly corrupted on labial and lingual edge of AL and on tips of T2 and T4. Therefore, all salient angles are blunt except for BSA2 and LSA3 which are rounded. The anterosinus and distosinus on buccal view, the protosinus and anterosinulus on lingual view reach the occlusal surface (Figure 4.12.H’’). There are two roots, fused in lingual view but distinguishable in buccal view (Figure 4.12.H’).

The M2 has a wide anterior lobe and alternating T2–T4 more or less of the same volume. The enamel is overall thick. Enamel wall is corrupted on lateral tips of AL and posterior to T4. The anterosinulus (*sensu* Carls and Rabeder, 1988), protosinus and distosinus reach the chewing surface (Figure 4.12.I’’–I’’’). The postero-ventral corner of the molar is curved. Although roots are not preserved, the incision would indicate that there should be at least three or four roots (Figure 4.12.I’).

Both m2s display posterior lobe and four alternating triangles. The dentine field between T1 and T2 is variably confluent (Figure 4.12.J–K) but widely connected on T3–T4. The enamel corruption is observed only on the tips of PL and anterior face of the molars. The hyposinuid is continuous. On ventral view, there are traces for three roots.

Comparison and discussion: In this vole assemblage, neither m1 nor M3 is present and the secure identification of the material at the species level is almost impossible. However, the presence of roots, high degree of hypsodonty, abundant cementum in re-entrant angles, *Mimomys*-type enamel differentiation, relatively thick enamels and great size of these molars would somewhat point out to a *Mimomys* species. Based on descriptions and drawings of *Mimomys pliocaenicus* from Tegelen (Tesakov 1998) and *Mimomys ostramosensis* from Osztramos-3 and Schernfeld localities (Jánossy and Meulen 1975; Carls and Rabeder 1988), the Kerimoğlu specimens morphologically match both species with some minor differences observed on detailed measurements; length of M1 and m2 from Kerimoğlu overlap with ones from Tegelen and Schernfeld material whereas M2 is greater. On the other hand, the calculated PA-index for KO7 and KO8, and HH-index for KO10 (after Carls and Rabeder 1988) result in much greater values than for both localities although closer to the upper limit of Schernfeld for M1 and m2, and overlap with M2. Tesakov (1998) stresses that HH-index higher than 5.5 would signify rather *M. ostramosensis* dating to the latest MN17 (Tesakov 1998, fig. 54), while Maul and Markova (2007) consider *M. ostramosensis* as synonym of *M. pliocaenicus*. Despite the lack of m1 and M3, the available specimens are tentatively attributed to *Mimomys* aff. *pliocaenicus* until new material is gathered.

4.2.2.3 *Apodemus* cf. *dominans*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Muridae Illiger, 1811

Subfamily: Murinae Illiger, 1811

Genus: *Apodemus* Kaup, 1829

Apodemus* cf. *dominans Kretzoi, 1959

Figure 4.14

Material: 1 M1 (KO-11).

Occurence: Late Villanyian–Early Biharian; ?MNQ18–19

Measurements in mm: L=1.95, W=1.23.

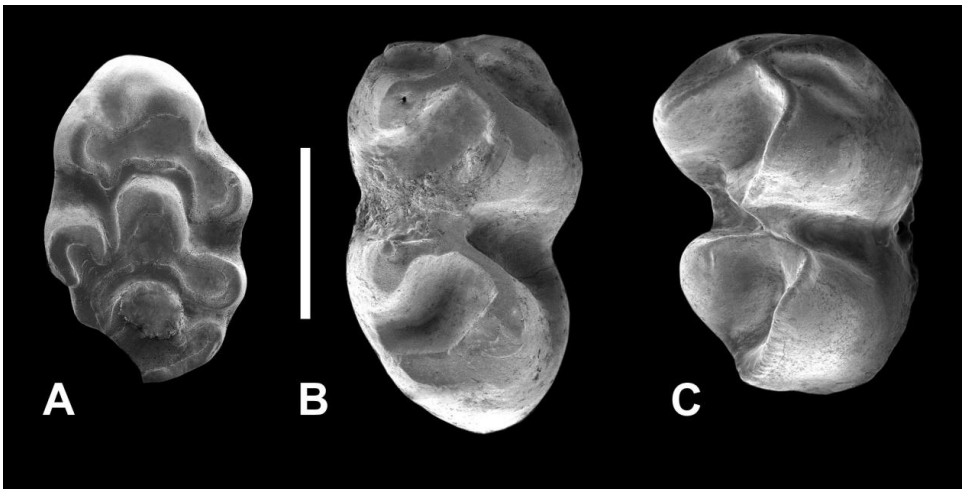


Figure 4.14 : Murine and cricetine specimens from the Suluova Basin. (A) *Apodemus* cf. *dominans* M1 (KO-11) from Kerimoğlu. (B and C) *Mesocricetus* cf. *brandti* m3s from Yolpınar (YP-2 and YP-3). Scale bar is 1 mm.

Description: The medium sized, elongated M1 is moderately worn. Largest cusps t2, t5 and t8 are longitudinally elongate. The t1 fused to t2, is posteriorly situated in regard to t3 and possess a faint spur directed toward t5. t3 is fused to t2, smaller than t1 and displays a salient spur close to the base of t5. t1bis, t2bis and any accessory cusps are absent. t4 is laterally elongate and in backward position compared to t6. The latter is almost totally mesially directed and equal in size to t4. The valley between t3 and t6 is the widest. The postero-labial corner of the molar is damaged; t9 and t12 are not observable. However, the ring-like connection between t4-t5-t6-t9-t8 and t7 appears to be present, taking into consideration of the continuous dentine field and closed valley on labial side of t8. t7 is separate from t4. Only anterior root is preserved and ventro-mesially oblique.

Comparison and discussion: The presence of t7 and overall shape permit to attribute that single specimen to the genus *Apodemus*. Concerning the size, M1 from Kerimoğlu falls well within the range of *Apodemus dominans*, *A. atavus*, *A. flavicollis* and *A. sylvaticus* (Chapter 4.3.1.7, Figure 4.17; Erdal et al, 2018, fig.6A). However, the backward position of t1 and t4 relative to t3 and t6 respectively, connection between t7 and t8 as well as t6-t9-t8 despite the early state of attrition, avoid the identification of Kerimoğlu specimen as *A. flavicollis* or *A. sylvaticus*. Majority of *A. atavus* M1 remains described from Europe and Anatolia spanning from MN13 to Early Biharian in age differs from Kerimoğlu specimens in having a

t7 isolated from t8, t4 posterior or in equivalent position relative to t6 and more mesially oriented t4 (e.g., Fejfar and Storch 1990; Ünay and de Bruijn 1998; Marchetti et al, 2000; Minwer-Barakat et al, 2005, 2011; García-Alix et al, 2008, 2009; Colombero et al, 2014; Hoek Ostende et al, 2015a, b), whereas *A. dominans* in the same age range share similarities such as t7 fused to t8, lingually elongated t4 at backward position compared to t6, which is more or less mesially directed (e.g., Pasquier 1974; de Bruin and Meulen 1975; Sen 1977; Ünay and de Bruijn 1998; Popov 2004; Suata-Alpaslan et al, 2010; Vasileiadou et al, 2012). Strikingly, the M1 material of *A. dominans* from the early Pliocene of Mahmutlar displays the exact morphology and perfect size match (Sen et al, 2018).

Based on insufficient material and despite of unresolved debate on the synonymy (e.g., Fejfar and Storch 1990; Martin-Suárez and Mein 1998) or descendence history of *A. atavus* and *A. dominans* accepted by some authors (Martin-Suárez and Mein 1998; Hoek Ostende et al, 2015a) or refuted (Martin-Suárez and Mein 2004), the Kerimoğlu murine M1 is carefully attributed to *Apodemus* cf. *dominans* due to morphological features mentioned above.

The Kerimoğlu locality delivered a faunal complex including some arvicolines such as *Mimomys* aff. *M. pliocaenicus*, *M.* (*A.*) aff. *nutiensis* and a murine *Apodemus* cf. *dominans*. This assemblage would provide a possible age range between latest Villanyian–Early Biharian, or roughly 1.8–1.4 Ma, where the maximum age is for the latest occurrence of *Mimomys pliocaenicus*/*ostramosensis* (Maul and Markova 2007) and the minimum age is for the first occurrence of the advanced *Allophaiomys nutiensis* (Chaline et al, 1999). Note also that rodent fauna in Anatolian Quaternary is poorly studied (Erdal 2017). In this case, however, the Kerimoğlu locality must be younger than Bıçakçı locality with *M. pliocaenicus* (Hoek Ostende et al, 2015b) but much older than Çaybaşı locality bearing *A. nutiensis* (Ünay et al, 2001).

4.2.3 Fossil remains from Kamışlı locality

4.2.3.1 ?*Equus* sp.

Class: Mammalia Linnaeus, 1758

Order: Perissodactyla Owen, 1848

Family: Equidae Gray, 1821

Genus: *Equus* Linnaeus, 1758

?*Equus* sp.

Figure 4.13.C

Material: a talonid of p3 (KA-1).

Occurence: ?mid-Early Biharian

Comparison and discussion: The only material available from the Kamışlı, a distal half of p3, probably belongs to *Equus* but not characteristic enough for species identification. Therefore, the age of the locality is not certain, although stratigraphically it is older than Kerimoğlu and correlative with Kızıleğrek localities (Erturaç et al, 2019; fig. 10).

4.2.4 Fossil remains from Kızıleğrek locality

4.2.4.1 *Mesocricetus* aff. *arameus*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Cricetinae Fischer, 1817

Genus: *Mesocricetus* Nehring, 1898

Mesocricetus* aff. *arameus Bate, 1943

(Figure 4.12.M–P)

Material: A left mandible with m1–m3 (KE-1).

Occurence: Early Biharian; ?MNQ19–21

Measurements in mm: m1 L=1.94, W=1.18; m2 L=1.92, W=1.23; m3 L=2.03, W=1.38.

Description: The specimen is highly corroded and the mandible lacks any important diagnostic characteristic. As to molars, cuspids and their connections are sufficiently preserved to be described. In overall shape, the m1 is widening posteriorly, m2 is rectangular and m3 is narrowing posteriorly (Figure 4.12.M–O). Lingual cuspids are situated much mesially than labial ones and posteriorly oblique. The m1 (Figure 4.12.M) is the narrowest molar almost with the same length as m2 but smaller than m3. The anterolophid is low, clover shaped and seems to be connected to metaconid and protoconid via attrition. The connection between metaconid and protoconid is damaged but apparent since the valley of protosinusid and mesosinusid are separate. The longitudinal crest provides a connection between protoconid and entoconid-hypoconid couple. The mesolophid is absent. The mesosinusid is equally wide and deep as sinusid. The posterolophid is well developed and curves antero-lingually to reach the base of entoconid.

The m2 (Figure 4.12.N) displays a robust anteroconid and labial anterolophid. The lingual anterolophid is absent. The mesosinusid is clearly interrupted by a mesolophid curved anterolingually. The ectolophid connects to hypolophulid. As on m1, the posterolophid encloses the posterosinusid but less protruded posteriorly. The lingual cingulid is well developed.

The m3 (Figure 4.12.O), least worn tooth, displays a deep protosinusid anteriorly limited by a long labial anterolophid. The anteroconid is damaged therefore anterior connection between metaconid and protoconid is lost. The mesolophid and ectolophid are similar to that of m2. The posterosinusid is deep and narrow, enclosed by the posterolophid. The postero-lingual side of entoconid and lingual cingulid are damaged.

Comparison and discussion: The hamster from Kızıleğrek can be securely referred to *Mesocricetus* based on general occlusal morphology with the clear presence of mesolophid on m2 and m3 as well as smaller size compared to *Cricetus* spp., but greater than *Allocricetus* or *Cricetulus* (e.g., Popov 1994, 2000, 2017; Hoek Ostende et al, 2015a). In addition to features mentioned for *M.* cf. *brandti* collected from Yolpınar (this study),the Kızıleğrek *Mesocricetus* differs from *M. primitivus* in having much robust m3 than m2 and m1, m2 rectangular rather than subrectangular

(e.g., Sen 1977; Ünay and de Bruijn 1998; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015a). The m3 of Kızıleğrek specimen is slightly smaller than the Yolpınar material as it is valid also for m1 of *M. brandti* in general (e.g., Hír 1992; Krystufek and Vohralik 2009). Finally, based on some m1 and m3 features shared between *M. arameus* from Kalymnos and Kızıleğrek material, it differs from *M. brandti* in having broad and low connection between anteroconid and metaconid-protoconid complex, similar volumes and shapes of sinusids and similar volumes of conids on m1, talonid narrower than trigonid, absence of lingual anteroconid and narrower posterosinusid on m3 in addition to absence of lingual anterolophid and more posteriorly shifted lingual cuspids on m2 (cf. Kuss and Storch 1978; Krystufek and Vohralik 2009). The main difference between the Kalymnos and Kızıleğrek specimens is that the m1 is slightly greater and broader than m3 on the Greek species. This feature is considered as a main criterion of distinction between fossil and recent species by Kuss and Storch (1978, p. 214) as initiated by Bate (1943, p. 820), although it might be related to wear degree (Ellerman 1941). Despite the preservation state of Kızıleğrek hamster material, the morphological similarities and slight differences in molar size would allow some affinity with *M. arameus* from the Early Biharian of Kalymnos.

4.2.5 Fossil remains from Yolpınar locality

4.2.5.1 *Mesocricetus* cf. *brandti*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Cricetinae Fischer, 1817

Genus: *Mesocricetus* Nehring, 1898

Mesocricetus* cf. *brandti Nehring, 1898

Figure 4.14.B–C

Material: 2 m3 (YP-2 and YP-3).

Occurence: Early Toringian; ?MNQ22–23

Measurements in mm: L=2.09–2.23, W=1.38–1.42.

Description: Molars have elongated rectangular shape. Slightly narrower but elongate talonid compared to trigonid in addition to wide mesosinusid. Lingual cuspids are higher than labial ones and inclined backwards. In both specimens, protoconid and hypoconid are shifted posteriorly compared to metaconid and entoconid. Labial anterolophid is prominent and reaches the base of protoconid forming a deep and wide protosinusid. Although damaged on specimen YP-2 (Figure 4.14.B) has mesolophid high and directed towards metaconid and on YP-3 (Figure 4.14.C) it reaches the base. Lingual cingulid is much developed than labial one. A low cingulid between posterolophid and entoconid encloses the posterosinusid. The longitudinal crest is rather oblique and lower than mesolophid. The main variations between the two m3 of Yolpınar are that YP-2 has a distinct lingual anterolophid forming a deeper "metasinusid" and a more transverse posterolophid on YP-2. There are two roots preserved on YP-2.

Comparison and discussion: The hamster molars from Yolpınar can be distinguished in having smaller size than *Cricetus*, greater size than *Allocricetus* and *Cricetulus*, beside a well developed mesolophid which is absent in these genera (e.g., Popov 1994, 2000, 2017; Hoek Ostende et al, 2015a; Sen et al, 2018). Based on measurements and overall occlusal morphology the Yolpınar material belongs to the genus *Mesocricetus*. The Yolpınar cricetine differs from the Pliocene–Pleistocene species of *Mesocricetus* from Anatolia, *M. primitivus*, by its greater size and much elongated but less narrower talonid, lingual cuspids oriented backward rather than transverse, strong and anteriorly protruded labial anterolophid, wide protosinusid and posterosinusid, anteriorly oblique mesolophid (e.g., Sen 1977; Ünay and de Bruijn 1998; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015b). Despite some morphological similarities between the Yolpınar material and *M. arameus* from the Early Biharian of Kalymnos Island, the former has much greater molar dimensions (Kuss and Storch 1978). On the other hand, the extant *M. brandti* and *M. auratus* found in fossil forms in Anatolia display many interpecific similarities on occlusal morphology, so that some authors consider *M. brandti* synonym of *M. auratus* (e.g., Hír 1992; Suata-Alpaslan et al, 2011b) whereas some others make the distinction based on phylogeny, biogeography and morphology (e.g., Neumann et al, 2006, 2017; Krystufek and Vohralik 2009; Erdal et al, 2018, 2019). The measurements of

the Yolpınar material fits well to that of *M. auratus* from the Holocene localities of Meydan (Hír 1992) and to *M. brandti* of Tepecik-Çiftlik (Erdal et al, 2019) but much greater than extant populations of *M. auratus* from the Northern Syria (see Shehab et al, 1999; Krystufek and Vohralik 2009). As a result, the Yolpınar hamster should be cautiously identified as *Mesocricetus* cf. *brandti*, which would enhance the idea that this species exists in Amasya region and in adjacent Niksar Basin since Early Toringian at least (Erdal et al, 2018).

4.2.5.2 *Arvicola* cf. *mosbachensis*

Class: Mammalia Linnaeus, 1758

Order: Rodentia Bowditch, 1821

Family: Cricetidae Fischer, 1817

Subfamily: Arvicolinae Gray, 1821

Genus: *Arvicola* Lacépède, 1799

Arvicola* cf. *mosbachensis Schmidtgen, 1911

Figure 4.12.L

Material: 1 m1 (YP-1).

Occurence: Early Toringian; ?MNQ22–23

Measurements in mm: L=3.14 min., W=1.44, a=1.32, b=0.62, c=0.36, A/L~39.4, SDQm1 (5 triangles): 144.78.

Description: Hypsodont, rootless and large vole molar is formed by a broad and simple anteroconid complex with widely confluent AC1 and T4-T5, followed by three alternating triangles. The posterior lobe is missing. Lingual triangles are much voluminous. There is *Mimomys*-type enamel differentiation with high value calculated after five triangles (SDQm1: 144.78%). The enamel is absent on mesial side. The cementum is faintly present, even absent or not reaching the occlusal surface in lingual re-entrant angles.

Comparison and discussion: Simple occlusal morphology, rootless condition and great size of the specimen would allow to compare with *Arvicola* spp. which are still poorly known in the Pleistocene of Anatolia. Up to date, all species described from

Middle Pleistocene localities are *A. amphibius* from Yarımburgaz Cave (Santel and Koenigswald 1998), *A. mosbachensis* from Emirkaya-2 (Sen et al, 1991; Montuire et al, 1994) and Umurlu (Erdal et al, 2018), and *Arvicola* sp. from Gölbaşı (Suata-Alpaslan 2011a).

The Niksar Basin is one of the nearest basins to Suluova, wherein Umurlu locality delivered *Arvicola mosbachensis* m1 very similar in morphology and measurements to the one from Yolpinar (Erturaç et al, 2019). Values such as width, A/L, B/W are greatly overlapping except smaller length, lower C/W in Yolpınar water vole (25) and SDQm1 values being much higher (144%) than Umurlu *Arvicola* m1 (SDQm1 mean: 119%). The same distinction is observed within other materials and species of *Arvicola* as detailed in Erdal et al. (2018). According to Maul et al. (2000, 2014), higher SDQm1 values and smaller length of the Yolpınar water vole is within the range of Mosbach-2 material, and would point out to a somewhat older age than the Umurlu locality, for instance latest Biharian–Early Toringian.

4.2.5.3 *Equus* sp.

Class: Mammalia Linnaeus, 1758

Order: Perissodactyla Owen, 1848

Family: Equidae Gray, 1821

Genus: *Equus* Linnaeus, 1758

***Equus* sp**.

Figure 4.12.D

Material: distal part of first phalanx (YP-4).

Measurements in mm: Transverse diameter= 97; articular DT= 75; DAP maximum= 90; articular DAP= 80.

Comparison and discussion: The material belongs possibly to *Equus* sp. due its dimensions and age of the locality inferred after *Arvicola* cf. *mosbachensis*.

4.3 Niksar Basin

During the field campaigns in 2013 and 2016, 240 kg of sediments have been collected and screen-washed from the layer A, 140 kg from B, 100 kg from C and 20 kg from B' (see Figure 2.13). Screen-washed samples provided 281 complete or fragmented rodent molars of which arvicolines constitute the majority with 123 of 183 identified specimens in total (cf. Table 4.10). In addition, there are 44 soricid teeth, over 100 rodent incisors and some lacertilian as well as gastropod remains which are not included in this thesis, but will be published later.

4.3.1 Fossil remains from Umurlu locality

In this section, a new rodent fauna of early Toringian (Middle Pleistocene) age is presented from the locality Umurlu in the Niksar pull-apart Basin (Tokat, Turkey) (Figure 2.12). This fauna contributes to the paleontological data of Quaternary micromammals in Turkey and enhances the age constrain for the initiation and long-term geological slip rate of the Ezinepazar Fault as well as the minimum age of the Niksar Basin. It provides paleoenvironmental insights, and makes a part of studies on small mammals from the adjacent NAFZ basins such as the Suluova (Amasya; Chapter 2.2) and Tosya (Kastamonu; Chapter 2.1) basins within this thesis.

Musser and Carleton (2005) is followed in the section of muroid systematics, otherwise mentioned in the relevant section. Therefore, representation of the faunal elements follows that systematic order.

For material and methods (e.g., measurement methods, nomenclature etc.) see Chapter 3. As shown in Chapter 2.3 (Figure 2.13), the four layers which delivered the studied fossils (Table 4.10), although sheared, tilted and offset, were possibly deposited approximately at the same time period and there is no major difference between the common faunal elements.

Table 4.10 : Rodents from the Umurlu locality with total number of specimen by species, molar type of remains, and number of identified specimen by layers (NISP), and relative abundance per layers. Asterisks indicate the most abundant taxon for each layer.

Taxon		Total	Layer	Remain	NISP	% per layer
Cricetinae						
	Mesocricetus cf. *brandti*	1	B	1 M2	1	3.1
	Cricetulus migratorius	1	A	1 m2	1	0.8
Arvicolinae						
	Arvicola cf. *mosbachensis*	36	A	1 M1, 5 M2, 2 M3; 3 m1, 2 m2, 3 m3	16	12.8
			B	1 M1, 2 M2; 1 m1, 1 m2, 2 m3	7	21.9
			B'	1 m1, 1 m3	2	50*
			C	3 M1, 3 M2, 2 M3; 2 m1, 1 m2	11	50*
	Microtus arvalis	51	A	9 M1, 7 M2, 3 M3; 6 m1, 7 m2, 5 m3	37	29.6
			B	3 M3; 3 m1, 4 m2, 1 m3	11	34.4*
			B'	1 M1	1	25
			C	2 M1	2	9.1
	Microtus arvalidens	34	A	3 M1, 4 M2, 4 M3; 6 m1, 3 m2, 3 m3	23	18.4
			B	3 M1; 1 m2	4	12.5
			B'	1 m2	1	25
			C	2 M1, 1 M3; 1 m2, 2 m3	6	27.3
	Clethrionomys cf. *glareolus*	2	A	2 m1	2	1.6
Murinae						
	Apodemus flavicollis	57	A	9 M1, 7 M2, 2 M3; 16 m1, 9 m2, 3 m3	46	36.8*
			B	2 M1, 2 M2; 2 m1, 2 m3	8	25
			C	1 M1; 2 m1	3	13.6
Spalacinae						
	Nannospalax cf. *xanthodon*	1	B	1 m3	1	3.1

4.3.1.1 *Mesocricetus* cf. *brandti*

Order Rodentia Bowditch, 1821

Suborder Myomorpha Brandt, 1855

Family Cricetidae Fischer, 1817

Subfamily Cricetinae Fischer, 1817

Genus *Mesocricetus* Nehring, 1898

Mesocricetus cf. *brandti* (Nehring, 1898)

Figure 4.15.1

Material: 1 M2 sin. (Table 4.10)

Measurements (in mm): L= 2.26, W= 1.6

Description: This medium sized rectangular molar has a posterior part slightly narrower than anterior. The four main cusps are interconnected via anterior and posterior lophules as well as a longitudinal crest. Buccal cusps are higher and situated backwards than lingual ones. The buccal anteroloph is transverse and curves towards the base of the paracone forming the anterobuccal wall and encircles the deep and wide anterosinus. The lingual anteroloph is lost. The mesosinus is narrower than lingual sinus and both are bordered by a low cingulum. The posteroloph is strong, more or less transverse and in continuum with the posterior lophule of hypocone. The posterosinus is reminiscent due to the short posterior metalophule directed backward. There are four roots.

Comparison and discussion: It seems to be impossible to refer this M2 by morphological characters to one of the potential genera *Cricetus* (Leske, 1779), *Cricetulus* (Milne-Edwards, 1867), *Allocricetus* (Schaub, 1930) and *Mesocricetus* due to the high morphologic uniformity of this group.

The size of specimen in question differs from that of other fossil finds of *Cricetus cricetus* (Linnaeus, 1758). The molar from Umurlu is smaller than the M2 from the Late Pleistocene of Temnata and Gradašnica caves in Bulgaria (Popov 1994, 2000; Markovic 2008), similar in length but much narrower compared to that of late Early Pleistocene Futjovka Cave (North Bulgaria, Popov 2017) and larger than that of the Middle Pleistocene Emirkaya-2 locality (Turkey, Montuire et al, 1994).

Popov (2017) stresses that the material from Futjovka Cave that he referred to *Cricetus cricetus* is at the lower limit or even below the dimensions of known recent specimens. He also noted that *Mesocricetus* molars are narrower than in *Cricetus*. *Cricetus* is absent in the extant Anatolian fauna (Krystufek and Vohralik 2009), but Pleistocene fossils of this genus have been reported from Emirkaya-2 (Montuire et al, 1994) and Bıçakçı (Hoek Ostende et al, 2015a).

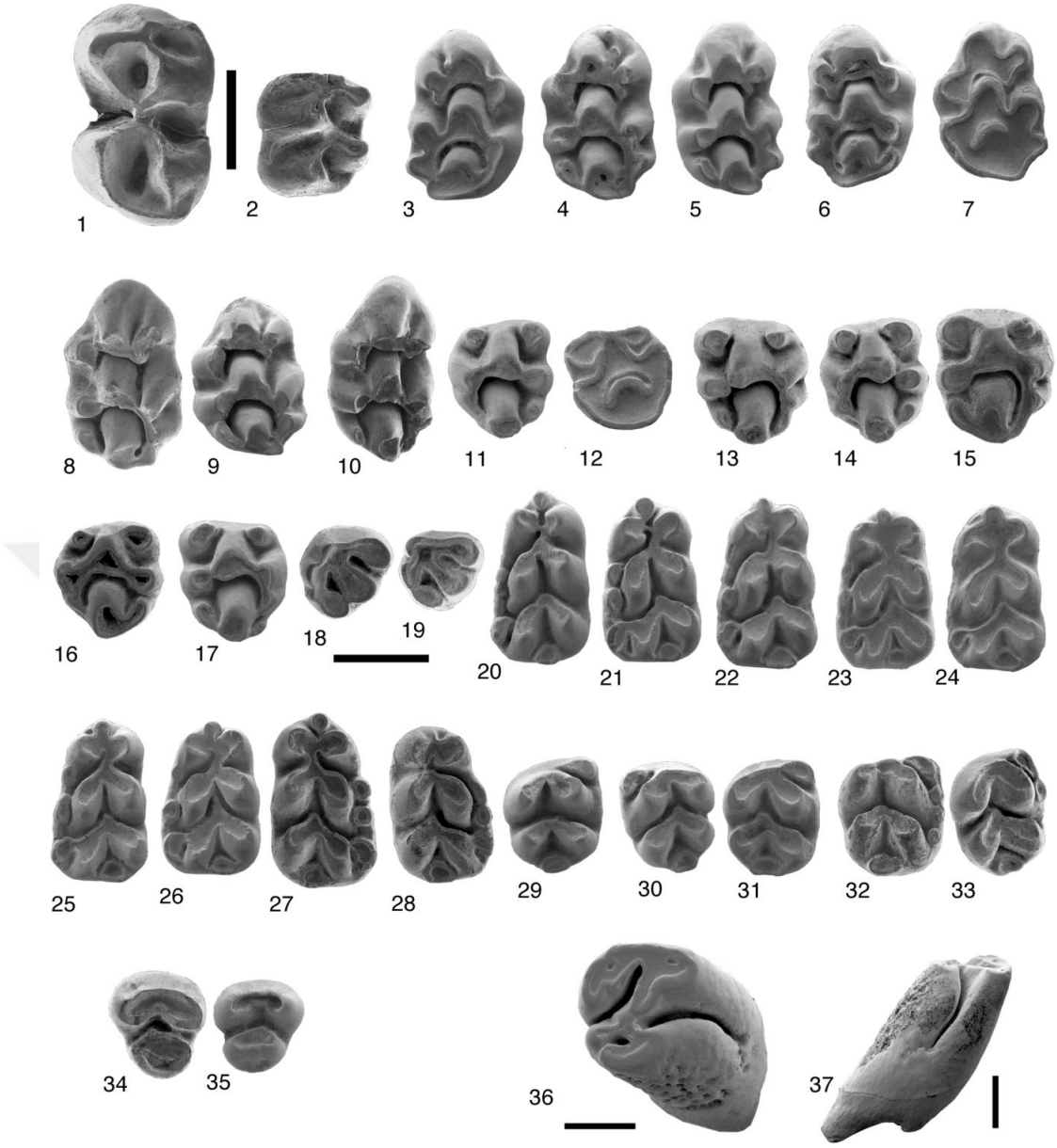


Figure 4.15 : Cricetinae, Murinae, and Spalacinae from Umurlu. 1, M2 of *Mesocricetus* cf. *brandti* (UM-B35); 2, m2 of *Cricetulus migratorius* (UM-A128); 3–35, *Apodemus flavicollis* M1: 3–10; UM-A82–86, 88, UM-B27, UM-C22; M2: 11–17; UM-A91–96, UM-B29; M3: 18–19; UM-A98–99; m1: 20–28; UM-A101–107, 110, 112; m2: 29–33; UM-A116–118, UM-A122–123; m3: 34–35; UM-A126, UM-B33; m3 of *Nannospalax* cf. *xanthodon* (36, occlusal; 37, buccal; UM-B36). Scales are 1 mm.

Metrically, the M2 of the Umurlu hamster belongs more likely to *Mesocricetus* rather than to the larger *Cricetus* and the smaller *Cricetulus*. This genus is known in Anatolia with four species from the Pliocene–Holocene: *M.* (cf. / aff.) *primitivus* (De Bruijn et al, 1970) (e.g., Sen 1977; Ünay and de Bruijn 1998; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015b), *M. brandti* (e.g., Storch 1988; Suata-Alpaslan

2011b; Erdal et al, 2019), *M. auratus* (Waterhouse, 1839) (Hír 1992), and *M. newtoni* (Nehring, 1898) (Santel and Koenigswald 1998).

The Umurlu hamster differs from the Pliocene *M. primitivus* by its larger size, absence of a lingual anteroloph, well-developed anterior metalophule reaching the metacone on M2. The strong lingual anteroloph is present on the type material of *M. primitivus* from Maritsa (de Bruijn et al, 1970) as well as from İğdeli (Suata-Alpaslan et al, 2010) and Silata (Vasileiadou et al, 2003). However, in other specimens referred to *M. primitivus*, that loph is rather faint or absent (i.e., Sen 1977; Ünay and de Bruijn 1998; Hoek Ostende et al, 2015b).

Some authors suggest that fossil remains identified as *Mesocricetus brandti* from Anatolia should be referred to *M. auratus* because of great similarities on molar morphology (i.e., Hír 1992; Suata-Alpaslan et al, 2010 *contra* Suata-Alpaslan 2011b). However, a recent genetic study on four *Mesocricetus* species resulted in two main lineages, *M. brandti*/*newtoni* and *M. auratus*/*raddei*, which are separated 2.5–2.7 Ma ago (see Neumann et al, 2006, 2017). *M. newtoni* branched around 1.7–1.8 Ma from the common ancestor with *M. brandti* (Neumann et al, 2006). This species is currently restricted to southern Romania and northern Bulgaria but it was widespread during the Pleistocene in the western Balkans (Kowalski 2001; Bogicevic et al, 2017) and is also reported tentatively from Turkish Thrace (Santel and Koenigswald 1998). Therefore, *M. brandti* and *M. auratus* are considered distinct species based on karyological and phylogenetic analyses on captive specimens, and currently isolated reproductively (e.g., no offspring) and geographically (Yiğit et al, 2000; Krystufek and Vohralik 2001; Musser and Carleton 2005; Neumann et al, 2006; Krystufek and Vohralik 2009; Neumann et al, 2017). According to these authors, *M. brandti*/*newtoni* would rather be descended from the western population of *M. primitivus*, whereas the lineage of *M. auratus*/*raddei* appeared after the eastern stock and, the differentiation of Central and Eastern Anatolian population of *M. brandti*, based on haplotypes, happened ca. 0.3–0.5 Ma (Neumann et al, 2017). The latter argument coincides with the age of Umurlu locality and would permit again the attribution of fossil material to *M. brandti*.

Nevertheless, the lack of sufficient fossil material of that time interval from the region does not allow reliable distinction between *M. auratus* and *M. brandti*. The fossil records of *M. auratus* date back to the Late Pleistocene (Tchernov 1992; Ross

1992) whereas the oldest known *M. brandti* is reported from the Middle Pleistocene of Chios Island, Greece (Storch 1975; Sen 1998).

As a conclusion, the distinction of *Mesocricetus* spp. seems to be difficult on fossil material, especially when it is scarce. For instance, the size of the M2 from Umurlu is within the range of *Mesocricetus auratus* according to data by Hír (1992) from the Holocene of Meydan locality (Bolkar Mt, Mersin) and both are greater than the recent *M. auratus* from Northern Syria (Shehab et al, 1999). *M. brandti* from the Holocene (ca. 7 ka) of Tepecik-Çiftlik has upper and lower molars (Erdal et al, 2019) surprisingly identical in size to that of mean values from Meydan (Hír 1992). On the other hand, the distinction of *M. brandti* and *M. newtoni* is also based on morphometric differences (Popov 1994, 2000; Bogicevic et al, 2017), the latter species being larger.

The fossil records, results of molecular phylogenies as well as fossil and current geographic range of *Mesocricetus* species permit to assign the thesis material tentatively to *Mesocricetus* cf. *brandti* which would be also supported by its (paleo-) geographical distance to any southern *M. auratus* localities.

4.3.1.2 *Cricetulus migratorius*

Genus *Cricetulus* Milne-Edwards, 1867

Cricetulus migratorius (Pallas, 1773)

Figure 4.2

Material: 1 m2 sin. (Table 4.10)

Measurements (in mm): L= 1.255, W= 1.097

Description: The small squarish m2 displays four alternating cuspids which are connected via relevant lophids. The posterior part is slightly narrower than anterior part. The strong buccal anterolophid extends rather transversally and encloses the protosinusid at the base of protoconid. The lingual anterolophid is faint, and leaves a high and shallow depression for anterosinusid. The metalophulid is curved anteriorly rather than transversal, and connects the metaconid to the protoconid. The mesolophid is absent. The mesosinusid and posterosinusid are comma shaped and

lingually bordered by lingual and posterior cingulids, respectively. The sinusid is oblique and enclosed by a buccal cingulid. The posterolophid issued from the hypoconid descends gradually low towards the posterolingual corner of the crown and curves anteriorly reaching the base of entoconid. Roots are not preserved but according to the trace they left, there might be two roots.

Comparison and discussion: By its small size and the absence of a mesolophid, the Niksar cricetine differs from *Cricetus* and *Mesocricetus*. It is also smaller than *Allocricetus bursae* and *A. ehiki* (Schaub, 1930) (e.g., Hír 1993b; Popov 2017).

Cricetulus is currently widespread in Turkey by one species out of six in Eurasia, namely *C. migratorius* (Krystufek and Vohralik 2009). It is well known in the fossil record of Turkey since the Early Pliocene (Suata-Alpaslan et al, 2010), and more frequently in Pleistocene and Holocene localities (e.g., Storch 1988; Sen et al, 1991; Hír 1993a; Montuire et al, 1994; Santel and Koenigswald 1998; Hoek Ostende et al, 2015a). In addition, this species is also well known from the Pleistocene of Balkans (e.g., Terzea 1971; Popov 2000) and Israel (e.g., Maul et al, 2011). There is no morphologic difference between the m2 from Umurlu and C. *migratorius* remains described in previous studies except some variation in size. For instance, the Umurlu m2 is smaller compared to the specimens from the Early Pliocene of İğdeli (Suata-Alpaslan et al, 2010) and Early Pleistocene of Bıçakçı (Hoek Ostende et al, 2015a) as well as from the Middle Pleistocene of Emirkaya-2 (Montuire et al, 1994) but comparable with younger specimens from Turkey and the Balkans (e.g., Terzea 1971; Hír 1993a; Popov 2000; Nedyalkov 2016).

The m2 of *C. migratorius* from Bıçakçı and İğdeli are more elongate in relation to its width (mean L/W ratio) whereas the m2 of Umurlu as well as some other younger and recent specimens are more squarish. For instance, the L/W ratio after mean values of m2 is 1.28 for Bıçakçı (Early Pleistocene, Hoek Ostende et al, 2015a), 1.30 for İğdeli (Early Pliocene, Suata-Alpaslan et al, 2010), 1.14 for Umurlu (Middle Pleistocene; this study), 1.17 for Emirkaya-2 (Middle Pleistocene, Montuire et al, 1994), 1.18 for Cave 16 (Late Pleistocene; Popov 2000), 1.18 for Moldova (recent, data from Popov 2000) and 1.2 for the remains from Bulgaria (recent, Nedyalkov 2016). In other words, the older species have m2 longer, but shortened in time in

younger representatives of *C. migratorius*. As a conclusion, the m2 from Umurlu can be securely referred to *C. migratorius*.

4.3.1.3 *Arvicola* cf. *mosbachensis*

Subfamily Arvicolinae Gray, 1821

Genus *Arvicola* Lacepede, 1799

Arvicola cf. *mosbachensis* Schmidtgen, 1911

Figure 4.16.A

Material: 5 M1, 10 M2, 4 M3, 7 m1, 4 m2 and 6 m3 (Table 4.10).

Measurements: Tables 4.11 and 4.12.

Description: Hypsodont rootless arvicoline molars with alternating prismatic triangles. This is the largest arvicoline found in the Niksar Basin. The re-entrant angles are filled with abundant cement. All molars display negative enamel thickness (*Mimomys*-type; primitive *sensu* Martin 1987), i.e. the enamel in the trailing edges is thicker than in leading ones.

The M1 has an anterior lobe (AL) and four closed, alternating triangles (T1–T4). The enamel free areas are situated at the buccal and lingual tips of AL, T1 and posterior edge of T4 (Figure 4.16.A.1).

The occlusal surface of M2 is similar to M1 but has fewer triangles. One M2 specimen displays thicker enamel on all edges with much rounded AL and T3–T4, compared to other nine specimens (Figure 4.16.A.2).

The M3 has a simple occlusal pattern with an anterior lobe followed by two totally formed triangles (T2–T3) and by T4 which is broadly confluent with posterior lobe. T3 is also broadly confluent with the posterior part of M3. The size of T3 is a little larger than other triangles on two specimens (Figure 4.16.A.3–4) and more or less comparable on two others (Figure 4.16.A.5–6). The LRA2, LRA3 and BRA1, BRA2 are well developed but BRA3 is weak and does not display a distinct T4. The absence of LRA4 prevents the formation of T5. As in other upper molars, the enamel lacks on tips of AL and distal edge of PL. Lower first molars have a rather simple anteroconid complex (ACC) with a rounded, widely enamel-free mesial side and

anterior cap broadly confluent with T4–T5. There is no indication of a *Mimomys*-kante. The rest of the molar is formed by three alternating triangles and PL. The latter triangle lacks enamel on buccal and lingual tips. The cementum is usually absent on LRA4 and BRA3, except in one specimen (Figure 4.16.A.9) where LRA4 is filled by cement. Another m1 displays the lowest amount of cement in re-entrant angles (Figure 4.16.A.11). That specimen shows also incipient formation of LSA5 which is less accentuated on two other specimens (i.e., Figure 4.16.A.10). Lingual salient angles are relatively longer than buccal ones. All BRAs are wide and more or less mesially oriented while LRAs are rather narrower but deeper and more transverse. In buccal view, the enamel free area of the AL and PL is in continuum anteroposteriorly with the gingival mark, if preserved (Figure 4.16.A.7a, 9a).

The m2s display three BSA and three LSA. The enamel is absent on both lateral side of PL and anterior edge of the molar. The dentine field of triangles T3 and T4 is broadly confluent whereas T1–T2 and PL are not (Figure 4.16.A.12).

Finally, the m3 has a widely confluent dentine field between each couple of BSA and LSA (e.g., BSA1 and LSA1, BSA2 and LSA2, etc.). The LRAs are deeper than BRA (Figure 4.16.A.13).

Comparison and discussion: Based on the lack of roots and the occlusal morphology of the lower first and upper third molars, the largest Umurlu arvicoline is compared with *Allophaiomys* and *Arvicola* species from Early to Late Pleistocene (late Villanyian–Toringian) of Turkey (Sen et al, 1991; Montuire et al, 1994; Ünay et al, 1995, 2001; Ünay 1998; Ünay and de Bruijn 1998; Santel and Koenigswald 1998; Suata-Alpaslan 2011a; Vasilyan et al, 2014), and of Europe (Alcade et al, 1981; Agusti 1991; Rekovets and Nadachowski 1995; Tesakov 1998; Abbassi et al, 1998; Hír 1998; Markova and Kozharinov 1998; Cuenca-Bescos et al, 1999, 2010, 2016; Maul et al, 2000; Defleur et al, 2001; Markova 2005; Kalthoff et al, 2007; Rekovets et al, 2007, 2014; Minwer-Barakat et al, 2011; Ruddy 2011; Bogicevic et al, 2012, 2017; Mayhew 2012; Lozano- Fernandez et al, 2013; Maul et al, 2014; Lopez-Garcia et al, 2015; Stoetzel et al, 2016; Shchelinsky et al, 2016; Gabarda et al, 2016).

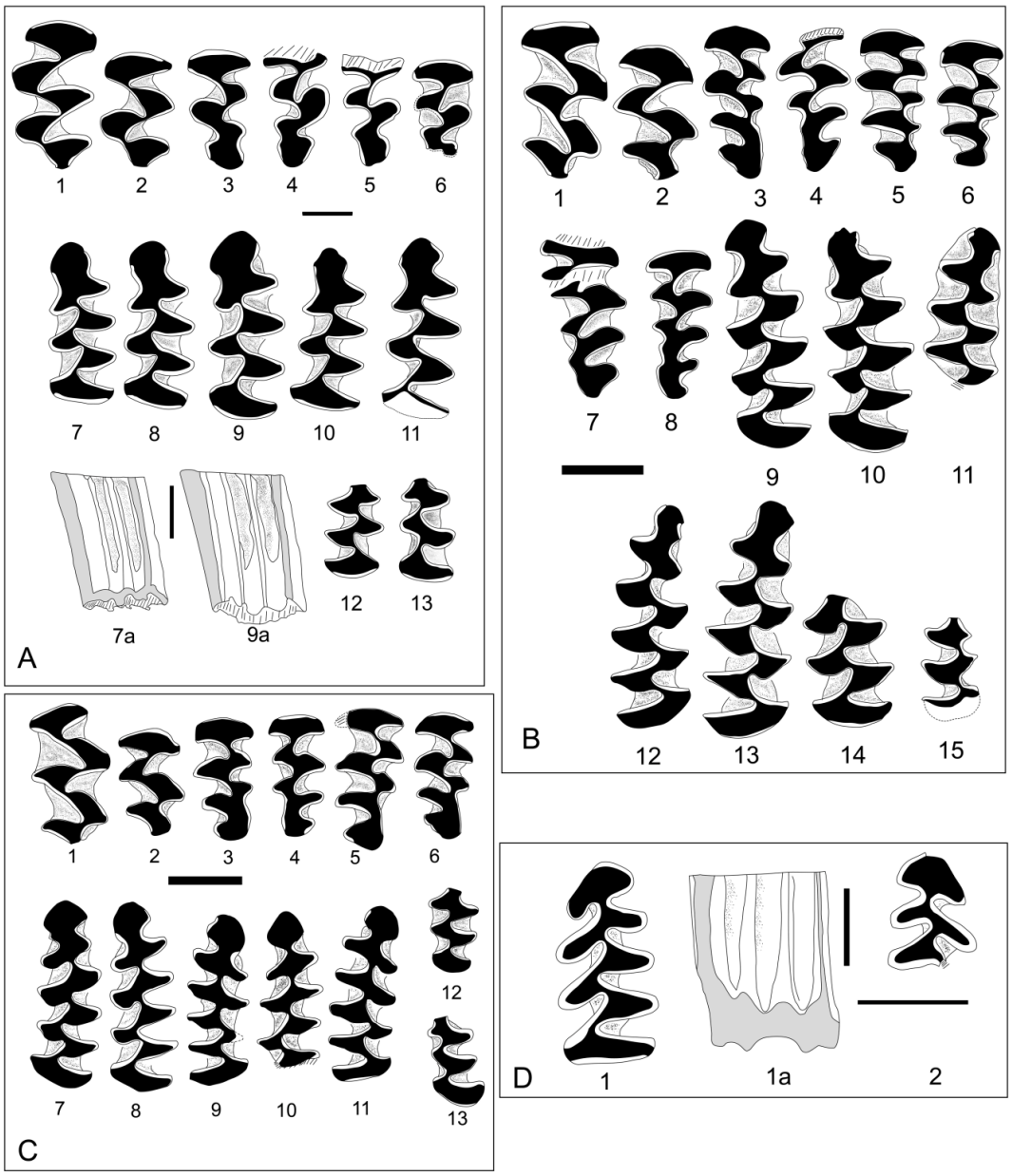


Figure 4.16 : Four arvicolines species from Umurlu: A– *Arvicola* cf. *mosbachensis* M1 (1; UM-B3), M2 (2; UM-B8), M3 (3–6; UM-C12, UM-C14, UM-A36, UM- A39), m1 (7–11; UM-A42, UM-B'4, UM-A57, UM-C17, UM-B16), m2 (12; UM-C18) and m3 (13; UM-A78); B– *Microtus* (*Microtus*) *arvalis* by M1 (1; UM-A8), M2 (2; UM-A18), M3 (3–8; UM-A32, UM-A40, UM-B11, UM-B12, UM-B10, UM-A38), m1 (9–13; UM-A52, UM-A43, UM-B17, UM-A50, UM-B13), m2 (14; UM-A69) and m3 (15; UM-A75); C– *Microtus* (*Terricola*) *subterraneus* by M1 (1; UM-B6), M2 (2; UM-A20), M3 (3–6; UM-A33, UM-A37, UM-C13, UM-A34), m1 (7–11; UM-A56, UM-A49, UM-A51, UM-A54, UM-A45), m2 (12; UM-A61) and m3 (13; UM-A79); D– *Clethrionomys* cf. *glareolus* by two m1 (1–2; UM-A46, UM-A55). Buccal views of some m1s are indicated by an 'a'; scales are horizontal for occlusal and vertical for lateral views; all scales represent 1 mm, except the vertical one in (A) 2 mm.

Table 4.11 : Measurements of length and width (in mm) of various rodent species with complete upper and lower tooth rows from Umurlu.

			Length			Width	
Species	Tooth	N	range	Mean	N	range	Mean
Arvicola cf. *mosbachensis*	M1	4/5	2.88–3.19	3.04	5	1.67–1.77	1.71
	M2	7/10	2.08–2.45	2.32	10	1.19–1.56	1.41
	M3	1/4	–	2.31	4	1.19–1.28	1.22
	m1	4/7	3.36–4.17	3.58	7	1.3–1.59	1.38
	m2	1/4	–	2.156	3/4	1.18–1.39	1.28
	m3	4/6	1.67–2.24	1.94	6	0.94–1.21	1.07
Microtus arvalis	M1	10/12	1.66–2.14	1.89	12	0.99–1.27	1.01
	M2	7	1.47–1.66	1.58	7	0.93–1.06	0.98
	M3	4/6	1.62–1.86	1.77	5/6	0.75–1.01	0.88
	m1	8/9	2.41–2.96	2.68	9	0.88–1.19	1
	m2	10/11	1.33–1.89	1.49	10/11	0.84–1.2	0.97
	m3	4/6	1.27–1.62	1.44	6	0.6–1.01	0.79
Microtus (*T.*) *subterraneus*	M1	8	1.73–2.02	1.92	8	0.98–1.14	1.06
	M2	4	1.36–1.5	1.42	4	0.8–0.93	0.86
	M3	5	1.52–1.87	1.62	5	0.75–0.84	0.79
	m1	5/6	2.3–2.59	2.44	6	0.85–0.97	0.90
	m2	6	1.15–1.43	1.26	6	0.73–0.97	0.93
	m3	5	1.15–1.37	1.29	5	0.59–0.75	0.67
Apodemus flavicollis	M1	12	1.69–2.02	1.85	12	1.12–1.28	1.18
	M2	9	1.19–1.40	1.3	9	1.09–1.25	1.14
	M3	2	0.88–0.98	0.93	2	0.83–0.84	0.83
	m1	15/20	1.63–1.93	1.78	16/20	0.97–1.09	1.03
	m2	8/9	1.19–1.36	1.27	9	1.01–1.12	1.05
	m3	5	0.96–1.09	1	5	0.874–1.0	0.92

Table 4.12 : Ratios of *Arvicola* cf. *mosbachensis* m1 from Umurlu.

		A/L			B/W			C/W			SDQm1 (%)	
Species	N	range	Mean	N	range	Mean	N	range	Mean	N	range	Mean
A. cf. *mosbachensis*	4/7	37.98–41.12	39.72	7	42.2–53.8	48.38	6/7	28.13–40.7	35.04	5/7*	112.6–126.5	119.53

*The range is usually based on mean values of each seven triangles of six m1 out of seven; two specimens have PL missing and thus, mean values are calculated on five instead of seven.

This large vole from Umurlu would match the late Villanyian *Allophaiomys deucalion* of Villany-5 (Meulen 1974) in having similar occlusal morphology (i.e., number of triangles, simple shape of ACC, enamel-free wall positions on m1 and M1, broad AC2 and T4–T5 connection and confluence, cementum presence and simple M3 without significant development of T5 as a part of PL, etc.) and negative enamel differentiation. However, a greater length and slightly larger C/W values of Umurlu molars prevent a referral to that species. It differs also from *Allophaiomys* spp. from Anatolia by much greater length in all available molars, higher B/W and C/W but lower A/L values and generally larger SDQ values (near to 120), while *A. deucalion* and *A. pliocaenicus* (Kormos, 1932) have rather undifferentiated enamel

thickness (i.e., SDQ ~100) (i.e., Ünay et al, 1995; Ünay and de Bruijn 1998; Vasilyan et al, 2014). The Umurlu specimens differ also from *A. pliocaenicus* from Europe by its shorter, wider and less complicated AC2 (i.e., formation of LSA5 or development of BSA4), broader confluence between T4–T5 on m1, shallower LRA3 and near absence of LSA4 on M3 (see e.g., data in Terzea 1971; Esteban and Lopez-Martinez 1990; Repenning 1992; Hír 1998; Rekovets 1998; Markova 2005; García-Alix et al, 2008).

Other species of *Allophaiomys* (e.g., *A. chalinei*, *A. ruffoi*, *A. vandermeuleni*, etc.) are not taken into consideration for comparison since their occlusal features and size differ from the Umurlu specimens even more than *A. deucalion* or *A. pliocaenicus* (e.g., Alcade et al, 1981; Agusti 1991; Cuenca-Bescos et al, 1999; Lopez-Garcia et al, 2015).

The overall size and morphology (i.e., number of triangles and simple ACC) distinguish the Umurlu material from any *Microtus* species and its relatives, and support its affinity with the genus *Arvicola*.

The dimensions observed on the Umurlu specimens led to compare with *Arvicola amphibius* (Linnaeus, 1758), *A. mosbachensis* and *A. jacobaeus* (Cuenca-Bescos et al, 2010). Escudé et al. (2008) proposed to synonymise all *Arvicola* species described from the earlier part of the Middle Pleistocene with *A. cantianus* (Hinton, 1910) after their morphometric analyses. However, Maul et al. (2000) had restricted *A. cantianus* exclusively to the type specimen of Hinton's (1910) species because of its fragmentary preservation, and they proposed to use the name *A. mosbachensis* for this evolutionary level of *Arvicola*. This opinion is also followed by Minwer-Barakat et al. (2011), and it is also adopted in the present study.

In Anatolia, the Pleistocene remains of *Arvicola* spp. are scarce. Fossil remains of *Arvicola amphibius* are reported thus far only from the Middle Pleistocene localities of Yarımburgaz Cave (Turkish Thrace; Santel and Koenigswald 1998), of *A. mosbachensis* from the Middle Pleistocene of Emirkaya-2 (Sen et al, 1991; Montuire et al, 1994) and of *Arvicola* sp. from Gölbaşı (Suata-Alpaslan 2011a).

Besides this scarcity, the SDQ values of recent water voles from Anatolia do not follow the evolutionary trend observed in European populations. For instance, the study of Röttger (1987) shows that the extant populations of *A. amphibius persicus*

from eastern Anatolia and adjacent Iran retain the primitive feature of enamel differentiation (i.e. SDQ values much higher) contrary to the *A. amphibius* from Central and Eastern Europe (Röttger 1987; Kolfschoten 1990). That feature usually follows an evolutionary trend in the lineage *Mimomys–Arvicola* of Europe in addition to other features (e.g., increasing size, loss of roots etc., cf. Lozano-Fernandez et al, 2013; Maul et al, 2014), and therefore it is considered as an important biostratigraphic tool. As to *A. sapidus* from Spain, similar to water vole from Anatolia, is easily distinguished from the European *A. amphibius* with its greater SDQ values. The higher SDQ values observed in the European *A. sapidus* and Anatolian *A. amphibius persicus* would be rather a result of convergence based on their great geographic distance, or an evolutionary stasis which preserved the ancestral state observed in *A. mosbachensis* and *Mimomys* (see also Taberlet et al, 1998; Krystufek and Vohralik 2005; Musser and Carleton 2005; Cuenca-Bescos et al, 2010; Ruddy 2011; Lozano-Fernandez et al, 2013). Although the study of Röttger (1987) is important for revealing such feature, she sampled only five specimens of one subspecies from one locality at the very East of Anatolia, and therefore the generalisation of that trait for entire Anatolian population before any further research would be hazardous. This discussion is beyond the scope of the present study and that plesiomorphic condition of *persicus* water voles requires a special attention on many populations of modern *Arvicola* spp. in Anatolia, as well as on fossil material.

Arvicola from Umurlu can be distinguished from European *A. amphibius* by its generally smaller molar size and negative enamel differentiation on m1 (Tables 4.11 and 4.12 and data in Kolfschoten 1994; Rekovets and Nadachowski 1995; Maul et al, 2000; Krystufek and Vohralik 2005; Kalthoff et al, 2007; Cuenca-Bescos et al, 2010; Bogicevic et al, 2012; Lozano-Fernandez et al, 2013; Stoetzel et al, 2016). Although the range of measurements overlap with the extant *A. amphibius* from some localities (i.e., Central Germany in Maul and Parfitt 2010), the SDQ values are smaller than in the Umurlu arvicoline.

The remains of *A. mosbachensis* described by lower molar series from Emirkaya-2 (Montuire et al, 1994) are within the range of the Umurlu sample for the measurements of m1 but slightly larger for m2 and m3. Their description fits well the Umurlu material although the isthmus “c” looks narrower (cf. Figure 3.2.C), in other words, LRA3 seems to be deeper and more mesially situated than the tip of BRA2.

A. mosbachensis from several localities of early Middle Pleistocene of Ukraine displays a higher morphological variation of the anteroconid complex, a *Mimomys*-kante in up to 20% of m1s, and higher morphometric ranges (e.g., Length, A/L, B/W, SDQ), in which specimens from Bolshevik 2- 1, Medzhybozh and Lysa Gora localities are the closest to Umurlu *Arvicola*, especially the specimens with simpler structures (Rekovets and Nadachowski 1995; Rekovets et al, 2007, 2014).

Arvicola mosbachensis from the EVT-3 layer of the Middle Pleistocene of Torrent de Vallparadis (Spain) clearly involves many similarities with the Umurlu material except the shallow BRA4 and more acute LRA4 on m1 (Minwer-Barakat et al, 2011), the m1 length of Vallparadis is generally greater than Umurlu m1 (except one specimen) as it is for the mean values. The A/L proportions greatly overlap and SDQ values (SDQ7 in Minwer-Barakat et al, 2011) are slightly higher than in the Anatolian arvicoline.

A. mosbachensis from the early Middle Pleistocene (late Biharian–early Toringian) of its type locality Mosbach-2 (Schmidtgen 1911) is clearly similar to the Umurlu arvicoline with its general occlusal morphology of m1 and M1, and it shares some primitive features such as shallow LRA4 and BRA3 on m1 as well as broad confluence between T3 and T4 on M3 (Maul et al, 2000). On the other hand, two other primitive features of *A. mosbachensis*, i.e., incipient root formation on m1 and M3 as well as the presence of *Mimomys*-kante on one fourth of all specimens, might distinguish it from the Umurlu sample at population level.

SDQ index range of Umurlu m1 overlaps with the lower limit of *A. mosbachensis* from Petersbuch-1 and the mean values are situated at the lower limit of that geologically younger locality (Maul et al, 2000, text-fig.3). However, the length range of m1 of Turkish arvicoline encloses the ranges of Petersbuch-1, Bilzingsleben-2, Miesenheim-1 and upper limits of Mosbach-2 whereas the mean value is slightly lower than Bilzingsleben-2 (Kolfschoten 1990; Maul et al, 2000, text-fig.4). As to upper M3, the maximum length of Mosbach-2 arvicoline is equal to the only measurable M3 from Umurlu (2.31 mm).

The *Arvicola* remains from Niksar share some features with *Arvicola jacobaeus* from the Early Pleistocene of Sima del Elefante (Cuenca-Bescos et al, 2010) such as highly overlapping size ranges, similar A/L values of m1 and comparable SDQ

values. Nevertheless, the confluence of AL and T1 on M1 of *A. jacobaeus* as well as basal thickening on M3 and equally thick enamel on occlusal surface of molars serve to distinguish the Turkish material at the species level.

In conclusion, the *Arvicola* fossils from the Umurlu locality display many affinities with *Arvicola mosbachensis* rather than with other *Arvicola* species or *Allophaiomys*, in having moderate molar dimensions (i.e., *Allophaiomys* < Umurlu < *A. amphibius*) and, SDQ values close to *A. mosbachensis*. In addition, the Umurlu sample with an A/L index of 39.72 is situated at the lower limit of *Arvicola* assemblages from the Toringian–Holocene time interval, especially closer to *A. mosbachensis* (Table 4.12 Maul et al, 2014). Considering the scarcity of fossil material and the potential regionality of SDQ values among modern *Arvicola* spp. from Anatolia, it is cautiously ascribed the larger arvicoline from Umurlu to *Arvicola* cf. *mosbachensis* because of its many morphological affinities with the type material. Thus, in fossil faunas *Arvicola* finds with similar SDQ values might be much younger in SW Europe and Anatolia than in Central Europe.

4.3.1.4 *Microtus* (*Microtus*) *arvalis*

Genus *Microtus* Schrank, 1798

Microtus (*Microtus*) *arvalis* Pallas, 1778

Figure 4.16.B

Material: 12 M1, 7 M2, 6 M3, 9 m1, 11 m2 and 6 m3 (Table 4.10)

Measurements: Tables 4.11, 4.13 and 4.14.

Description: Upper first molars are formed by AL and four alternating triangles (Figure 4.16.B.1). Both sides of the AL, the tip of the LSA2 (T1) and the posterior margin of M1 lack enamel. Buccal re-entrant angles are deeper and wider than lingual ones and oriented backward while lingual re-entrant angles are rather transverse.

Table 4.13 : Ratios of *Microtus arvalis* m1 from Umurlu.

		A/L			B/W			C/W	
Species	N	range	Mean	N	range	Mean	N	range	Mean
Microtus arvalis	8/9	52.12–56.8	53.94	9	7.78–15.3	10.41	9	9.05–14.71	11.69

		D/W		L/W		
	N	range	Mean	N	range	Mean
Microtus arvalis	9	0.22–0.41	0.29	8/9	2.42 – 2.9	2.66

Table 4.14 : Ratios of *Microtus arvalis* and *M.* (*T.*) *subterraneus* M3 from Umurlu.

		P			WP	
Species	N	range	Mean	N	range	Mean
Microtus arvalis	6	0.77–1.07	1		0.64–0.82	0.75
M. arvalidens	5	0.751–1.01	0.86		0.7–0.79	0.72

M2 has a similar pattern to M1, might lack enamel on the tip of T2 at least on two out of seven specimens (Figure 4.16.B.2). Also, the LRA2 is as deep as BRA2 on M2.

The upper third molars have morphotypes *principalis* (e.g., Figure 4.16.B.3–4) with well- developed T7, *duplicata* (e.g., Figure 4.16.B.5–7) or *variabilis* (e.g., Figure 4.16.B.8) but not complex (*sensu* Rörig and Börner 1905). The latter has a LRA5 quite prominent and T7 fully formed. AL is followed by four confluent triangles (T2–T5). The relatively short posterior cap is formed by an incipient T6 and well-developed T7. One specimen out of seven, the *variabilis* morphotype, has broadly confluent T4–T5 with the rest of the PC. The enamel lacks on lateral tips of AL and posterior margin of PL. All lingual re-entrant angles are broader and deeper than buccal ones.

Lower first molars (Figure 4.16.B.9–13) are formed by ACC3 and broadly confluent secondary wings *sensu* Repenning 1992 (T6–T7), followed by five alternating sharply prismatic triangles and a posterior lobe with four buccal and five lingual re-entrant angles. The enamel lacks on the mesial edge of ACC3 as well as on the buccal and lingual tips of posterior lobe. In addition, the enamel on trailing edges of triangles is extremely thin. The lingual re-entrant angles are deeper than the buccal ones and thus, the lingual salient angles seem to be much voluminous though

symmetrical. In general, the re-entrant angles are oriented slightly mesially. The anteroconid complex is rather simple with relatively narrow isthmus “d”. However, on some specimens, BSA5 (Figure 4.16.B.12) and LSA6 are faintly formed (Figure 4.16.B.10–11). BRA3 and LRA4 are never antagonist, the latter being more mesially situated. All lower first molars have the arvaloid morphotype (*sensu* Rekovets and Nadachowski 1995).

The m2 has all triangles alternating and consequently, LRA and BRA are more or less equally deep. However, the buccal triangles are smaller than the lingual ones. In some specimens, BRA2 tends to curve mesially and T4 elongates distally (e.g., Figure 4.16.B.14). Enamel lacks on mesial and lateral sides. In several specimens, the trailing edges are very faint.

Each salient angle pair (i.e., LSA and BSA) on the m3 is confluent but separated from the other pairs. Triangles can be oblique or rather transverse (Figure 4.16.B.15).

Comparison and discussion: The *Microtus* molars from Umurlu have some affinities with *M. guentheri* (Danford and Alston, 1880) from the Middle Pleistocene Qesem Cave (Maul et al, 2011) and from middle–upper Paleolithic (Late Pleistocene) sites of Karain B and Üçağızlı caves in Southern Anatolia (Storch 1988; Suata-Alpaslan 2011b) in having similar m1 and M3 occlusal morphologies. However, *Microtus* m1 from Umurlu has much greater A/L index, is rather smaller in the size of molars than *M. guentheri*.

One of the main distinction criteria of *M. agrestis* (Linnaeus, 1761) from *M. arvalis* is the asymmetry of lingual and buccal triangles (Chaline 1972). The m1 specimens from Umurlu display rather symmetrical appearance, similar in that to *M. arvalis*. The other criterion is the development of additional triangle T5 on posterolingual side of M2 (see Dienske 1969; Rekovets and Nadachowski 1995; Krystufek and Vohralik 2005; Bogicevic et al, 2012; Stoetzel et al, 2016) which is not observed on any of 12 M2 of thesis faunal assemblage. The m1 or M3 which are thought to belong to *M. arvalis* or to *M. agrestis*, are often referred to as *M. arvalis*/*agrestis* group in studies where M2 remains are absent (e.g., Kolfschoten 1994; Ivanov and Vörös 2014). Hence, the *Microtus* material from Umurlu differs from *M. agrestis* in the M2 morphology as well as in its smaller size. *M. gregalis* (Schrank, 1798) differs

from the Umurlu Microtus by its typical anteroconid complex with “gregaloid” morphotype, and slightly higher A/L values (e.g., Defleur et al, 2001; Rekovets et al, 2014a).

The material from the early Middle Pleistocene of Mosbach-2 and Voigtstedt described by Maul et al. (1998) as *Microtus arvalinus* (synonym of *M. nivaloides sensu* Rekovets and Nadachowski 1995) and considered as the “ancestor” of *M. arvalis*, differs from the Umurlu specimens by its smaller A/L index values (50.34 and 51.3) and slightly greater m1 length as well as much broader confluence between T6–T7 and AC3, and shorter ACC (Maul et al, 1998, plate 3.21–22). The Umurlu specimens have A/L index within the range of the extant *M. arvalis* (Table 4.13).

On the other hand, *Microtus arvalis* remains from Turkey, described from the Middle Pleistocene of Emirkaya-2 (Montuire et al, 1994) as well as from Karain B cave near Antalya (Storch 1988), match extremely well with the m1 morphology and measurements of *Microtus* from Umurlu. The Turkish material displays very close metric and morphological similarities with *M. arvalis* from the early Holocene of Bedburg-Königshoven (Germany; Kolfschoten 1994), early Middle Pleistocene of Ukraine (Rekovets and Nadachowski 1995), Late Pleistocene of North-Eastern Iberia (Luzi et al, 2016), as well as with specimens from early Toringian of Isernia and Visogliano (Italy; Maul et al, 1998). As a consequence, the *Microtus* molars from Umurlu can be securely referred to *Microtus arvalis*.

4.3.1.5 *Microtus* (*Terricola*) *subterraneus*

Microtus (*Terricola*) *subterraneus* de Sélys Longchamps, 1836

Figure 4.16.C

Material: 8 M1, 4 M2, 5 M3, 6 m1, m2 and 5 m3 (Table 4.10)

Measurements: Tables 4.11, 4.14 and 4.15.

Description: Compared to *M. arvalis*, the molars referred to *M.* (*T.*) *subterraneus* are smaller and have symmetrical anteroconid complex on m1. The upper M1 has AL followed by four triangles, and in overall view it is slightly elongate and transversally stretched; LRA and BRA are almost equally wide and deep, which

results in less compact BSA-BRA and LSA-LRA as seen in *Microtus arvalis* (Figure 4.16.C.1).

Table 4.15 : Ratios of *Microtus* (*T.*) *subterraneus* m1 from Umurlu.

	A/L			B/W			C/W			D/W			L/W	
Species	N	range	Mean	N	range	Mean	N	range	Mean	N	range	Mean	N	range	Mean
M. arvalidens	5/6	51.88–53.75	52.9	6	8.57–10.27	9.44	6	7.3–25.76	22.2	6	0.11–0.36	0.26	5/6	2.59–2.92	2.76

The M2 has AL and three triangles of which T2 and T3 display slight dentine field confluence. There are two buccal and three lingual re-entrant angles of which BRA2 and LRA2 are similarly deep and wide. The connection between AL and T2 is rather situated medial to the AL whereas on *M. arvalis* it is shifted lingually. None of M2 displays an additional triangle (e.g., T5) on the posterolingual side (Figure 4.16.C.2).

The M3 has a simplex morphotype in having three buccal and three lingual re-entrant angles, AL followed by four well-developed triangles (T2–T5) and shorter and narrower posterior cap (see Table 4.14). LRAs are deep and wide, and both re-entrant angles are filled with cement. The dentine field of T2–T3 can be broadly confluent (e.g., Figure 4.16.C.3–4) or separated (e.g., Figure 4.16.C.5–6). The molars displaying T2–T3 confluence involve also wide confluence between T4 and posterior cap. T5 and T7 are broadly confluent in all specimens.

The lower first molars bear the main characters which serve to differentiate that *Microtus* species, in particular the prominent presence of *Pitymys*-rhombus shape (*sensu* Hinton 1923) that is the high confluence of the primary wing (T4-T5) on lower first molars (Figure 4.16.C.7–11). In addition, the mesial edge of the AC3 is rounded and the tips of T4–T5 as well as T6–T7 are slightly sharp or mostly rounded. The isthmus “d” separating AC3 from the secondary wing varies from narrow to wide. There are five well-developed LRA and four BRA. In general, LRA4- BRA3 and LRA5-BRA4 couples display mirror image (opposed) and are as deep as its opposite on four out of six specimens. The connection between T4–T5 and T6–T7 is rather elongate. There might be slight confluence between T1 and T2 in half of specimens. One specimen display a very incipient BRA5 formation (Figure 4.16.C.7) while other two have poorly-developed LSA6 (Figure 4.16.C.8–9). In one

specimen, cement fill in lingual side does not reach the occlusal surface, therefore not seen directly on occlusal view (Figure 4.16.C.8).

The triangles of m2 have equal volume on both lingual and buccal sides. T1–T2 is somewhat widely confluent (Figure 4.16.C.12). Also, the confluence between T3–T4 is obvious and present on all specimens.

The m3 has PL and two couples of triangles which are all broadly confluent. The enamel lacks on the mesial and lateral edges of PL, while it is thicker and much clearly observable on the posterior edge of PL (Figure 4.16.C.13).

Comparison and discussion: The (sub)genus name *Pitymys* is used for the Nearctic species and *Terricola* for the palearctic species with confluent T4-T5 (e.g., Brunet-Lecomte and Chaline 1990; Repenning 1992; Laplana et al, 2000; Rekovets et al, 2014a) or both considered synonym (e.g., Cuenca-Bescos et al, 1999). For further discussion see Martin (1987). Rekovets et al. (2014) is followed in the generic (subgeneric) name definition for *Microtus* (*Terricola*).

Among the *Microtus* species with "*Pitymys*-rhombus" morphology on m1, the Umurlu material can be compared to the fossil species *M. arvalidens* (Kretzoi, 1958) or extant species such as *M.* (*T.*) *subterraneus*, *M.* (*T.*) *majori* (Thomas, 1906), *M.* (*T.*) *daghestanicus* (Shidlovsky, 1919), *M.* (*Stenocranius*) *gregaloides*, *M.* (*T.*) *savii* (de Selys-Longchamps, 1838) and *M.* (*T.*) *multiplex* (Fatio, 1905). *Microtus* (*T.*) *savii* from the Italian Peninsula differs from the Umurlu specimen by its wider anterior cap (cf. isthmus "d" in Figure 3.2) and asymmetrical triangles on m1, also in having more confluent triangles and weakly developed T7 on M3. Molar size of *M.* (*T.*) *savii* is greater in overall than of Umurlu species (cf. Rörig and Börner 1905; Bonfiglio et al, 1997; Petruso et al, 2011).

Another extant species *Microtus (T.) multiplex* is known from the southern part of Central Europe (Shenbrot and Krasnov 2005; Tougard 2017) and fossil forms are rather regrouped in *Microtus* (*T.*) as *multiplex-subterraneus* by some authors because of the morphological resemblance to *M.* (*T.*) *subterraneus* (e.g., Masini and Sala 2007; Petruso et al, 2011; Berto et al, 2016; Lopez-Garcia et al, 2017). However, the greater size of *M.* (*T.*) *multiplex* than of Umurlu specimen (cf. data compilation in

Kalthoff et al, 2007), its absence in Anatolia, and phylogenetic distance to Anatolian and Caucasian species (cf. Tougard 2017) prevent the attribution to *M*. (*T*.) *multiplex*.

M. (*Stenocranius*) *gregaloides* differs from this Umurlu arvicoline in having well-reduced T6 and consequently nearly absent BRA4, also less-developed ACC, in other words, lower A/L index values (see Maul and Parfitt 2010).

In Anatolia, the modern species *Microtus* (*T*.) *subterraneus* is reported mostly from the North and North-West Anatolia including Turkish Thrace, *M*. (*T*.) *majori* from the northeastern Anatolia, and *M*. (*T*.) *daghestanicus* from a narrower area at the north-easternmost part of Turkey. *M*. (*T*.) *daghestanicus* is not sympatric with *M*. (*T*.) *subterraneus* whereas *M*. (*T*.) *majori* may be found together with two others (Krystufek and Vohralik 2005, figs.150, 159 and 166). *M*. (*T*.) *daghestanicus* can be distinguished from the Umurlu specimen in having narrower restriction between T6–T7 and AC3 on m1, asymmetrical triangles on m1 and m2 and more complex morphology of M2 with the formation of T5. The m1 of *M*. (*T*.) *majori* frequently tends to have mushroom-shaped AC3 and incipient formation of T5 on M2 contrarily to the Umurlu specimens. Also, the studied specimens are smaller in length than the Late Pleistocene and extant *M*. (*T*.) *majori* and *M*. (*T*.) *daghestanicus* from Caucasus (Baryshnikov and Baranova 1983, table 7) as well as the extant species from Anatolia (i.e., *M*. (*T*.) *subterraneus, M*. (*T*.) *daghestanicus* and *M*. (*T*.) *majori*) provided by Krystufek and Vohralik (2005, table 37) except the *subterraneus* and *daghestanicus* material collected from Eastern Anatolia in their work. Among these extant species mentioned above, the Umurlu specimens are display greater morphological affinity to *M*. (*T*.) *subterraneus* rather than to the others.

On the other hand, the occurrence of the fossil forms of *M*. *arvalidens* and *M*. (*T*.) *subterraneus* are not known in Anatolia, except *Microtus* (*T*.) sp. from the Middle Pleistocene of Yarımburgaz (Santel and Koenigswald 1998) and Emirkaya-2 (Montuire et al, 1994). Krystufek and Vohralik (2005) suggested that remains from the two latter localities would be *Microtus* (*T*.) *majori* based on the m1 length but since the fossil and recent species measurements largely overlap, it remained unresolved.

The m1 of the Umurlu *Microtus* (*T*.) is clearly smaller in length than in the specimens of Yarımburgaz and Emirkaya-2. *Microtus* (*Terricola*) sp. from

Emirkaya-2 has somewhat shorter AC3, less confluent dentine field between T4–T5 and much broader confluence between T6-T7 and AC3 compared to Umurlu specimens. Also, the shape of salient angles is pointed in Emirkaya-2 whereas it is clearly much rounded in the m1 from Umurlu. According to Kolfschoten (1990, p.57) that shape difference is used to distinguish *M*. (*T*.) *arvalidens* with pointed angles from *M*. (*T*.) *subterraneus* with rounded ones. Based on that feature and also on the older age of the fauna from Emirkaya-2 involving also *Mimomys savini*, the attribution of *Terricola* sp. from this locality to *M*. (*T*.) *arvalidens* would be plausible. The upper second molar of the extant Turkish *M*. (*T*.) *subterraneus* displays an additional triangle (T5), which is not observed in the Umurlu specimens. Some variations on the M3, such as the confluence between T2-T3 and isolation of T4 dentine field from T5 or posterior cap can be present or not in extant species *M*. (*T*.) *subterraneus* as observed also on the Umurlu material (see Krystufek and Vohralik 2005, p. 155; Barkaszi 2017).

M. (*T*.) *arvalidens* from the Early Pleistocene Futjova Cave (Northern Bulgaria; Popov 2017) and Middle Pleistocene Lysa Gora 1 locality (Southern Ukraine; Rekovets et al, 2014a) differ from the Umurlu vole in having molars greater in length, pointed salient angles, broader isthmus "d" (cf. Figure 3.2.D), and asymmetrical triangles on the anteroconid complex on m1. In addition to variations on M3 morphology indicated by Krystufek and Vohralik (2005) and Barkaszi (2017), which can be observed on both species, the Bulgarian *M*. (*T*.) *arvalidens* appears to be closer to Umurlu specimen by its simpler posterior cap whereas in the Ukrainian *arvalidens* the posterior cap is narrower and elongated. However, the development of T7 is more prominent on these two *M*. (*T*.) *arvalidens* and it is absent on the Umurlu material.

Microtus (*T*.) remains from Umurlu are similar to *M*. (*T*.) *subterraneus* from the Late Pleistocene of Baranica and Hadži Prodanova caves in Serbia by occlusal morphology of m1 and largely overlapping length and A/L values (Bogicevic et al, 2012; 2017, pers. comm. for measurements).

On the other hand, the material from Umurlu displays some morphometric resemblances with *M. arvalidens* from the early Middle Pleistocene of West Runton (Maul and Parfitt 2010) especially with very close A/L values which are slightly lower than in the extant *M*. (*T*.) *subterraneus* (see data compilation in Maul and

Parfitt 2010). The idea that smaller A/L indexes or weakly developed ACC, as seen generally in *M. arvalidens*, would indicate a primitive feature compared to extant species (Maul and Markova 2007) is also supported by Brunet-Lecomte (2016). In that latter study, some morphometric comparisons for recent *M.* (*T.*) *subterraneus* and *M. arvalidens* are provided and the range of total length values points out that the Umurlu specimens are whether within the range of the *M. arvalidens* or situated at the lower limit of *M. subterraneus*.

Another *Microtus* (*T.*) *arvalidens* assemblage, which displays many common features of m1 and M3 with the Umurlu specimens, is from the latest Biharian of San Lorenzo locality (Masini et al, 2005): confluences and shape of the secondary wings, the AC3 and T1-T2, development of T6 and BRA3-LRA4 on m1 as well as simple morphotype of M3 with some specimens bearing T2-T3 confluence. The length of the Italian m1 specimens is somewhat similar to the Umurlu material and is very close in width; the length of ACC (cf. "a" in Figure 3.2.D) largely overlap with almost the same mean value (1.31 mm in the Umurlu sample) in addition to comparable A/L, B/W and C/W indexes, although their mean values are slightly lower than on the Umurlu m1. The only difference on m1 would be rather broader confluence of T4-T5 in the Umurlu sample, according to C/W values and width.

The identification of the Umurlu material appears to be complicated probably because of poor data on *Microtus* (*Terricola*) fossil remains in Anatolia in addition to the overlapping morphometric features between *arvalidens* and *subterraneus*. However, the strong morphological distinction between two Middle Pleistocene Anatolian *Terricola* samples, one from older Emirkaya-2 fauna and the other from Umurlu, would allow ascribing the Umurlu vole as *Microtus* (*Terricola*) *subterraneus*.

4.3.1.6 *Clethrionomys* cf. *glareolus*

Genus *Clethrionomys* Tilesius, 1850

Clethrionomys cf. *glareolus* Kretzoi, 1958

Figure 4.16.D

Material: One complete and one fragmentary m1 (Table 4.10)

Measurements (in mm): L = 1.96, W = 0.958–0.968, a = 0.77–0.80, b = 0.12–0.13, c = 0.172–0.182, A/L = 39.08, the height of anterosinuid = 1.72, hyposinuid = 1.97, HH-index = 2.91, Hsd/L = 100.51. The measurements and indices of *linea sinuosa* are minimal estimates since the dentine tracks are interrupted by wear.

Description: The m1 of this small sized arvicoline has two roots and four buccal and five lingual salient angles sparsely filled with cementum (Figure 4.16.D.1). On the anteroconid complex, AC2 is fused with prominently well-developed T6–T7, separate from T4–T5. The latter is confluent whereas PL, T1, T2 and T3 are separated and alternating. AC2 is short and has a "mushroom" shape (symmetrical AC2) but anterobuccal side is flattened without any trace of BRA4 initiation. Apical edges of salient and re-entrant angles are rounded. Buccal re-entrant angles are deeper and more oblique than lingual re-entrant angles. Enamel differentiation is absent or slightly positive. Enamel lacks on the anterobuccal side of AC2 as well as on the lateral edges of the posterior lobe. In the fragmented specimen (Figure 4.16.D.2), the enamel free area on the mesial edge is broader than in the complete molar. In buccal view, linea sinuosa reaches occlusal surface on T6 and PL (anterosinuid and hyposinuid) and the former is well broader than the posterior one (Figure 4.16.D.1a). The parasinuid is situated higher than protosinuid but both are well below compared to the anterosinuid and hyposinuid.

Following the typical feature such as the small size, absence of enamel differentiation, slanting edge of mesiobuccal side of AC2, enamel thickness and confluence between T4–T5, that Umurlu m1 belongs to the bank vole genus, *Clethrionomys*.

Comparison and discussion: The evolutionary history of *Clethrionomys* from the Pliocene- Pleistocene up to Recent follows the succession *C. kretzoii* (Kowalski, 1958) – *C. hintonianus* (Kretzoi, 1958) –*C. acrorhiza* (Kormos, 1933) – *C. glareolus*, and the major distinction is based on the degree of hypsodonty, linea sinuosa height, confluence of triangles and development of re-entrant angles (Rabeder 1981; Carls and Rabeder 1988).

Nevertheless, the discrimination between *C. hintonianus*, *C. acrorhiza* and *C. glareolus* is difficult and rather based on the morphotype abundance in the fossil

material (e.g., Carls and Rabeder 1988). That is why fossil specimens, in most cases, are described as *C. glareolus* (Maul and Markova 2007). *C. sokolovi* from the late Biharian of Eastern Europe, which has mostly the mushroom-shaped anterior cap (symmetrical AC2), is considered conspecific with *C. hintonianus* and/or *C. kretzoii* (Rekovets and Nadachowski 1995) or synonym of *C. hintonianus* (Tesakov 1996). In addition, the debate on the generic name of *Clethrionomys* over *Myodes* is beyond the scope of this study and Tesakov et al. (2010) is followed for binomial nomenclature (see Musser and Carleton 2005; Tesakov et al, 2010; Carleton et al, 2014).

The remains of *C. glareolus* from the Middle Pleistocene of Emirkaya-2 (Montuire et al, 1994), which is slightly larger than the specimens from Umurlu, have a T5 included somewhat in the AC2 and it may be due to a less deep LRA4 compared to the Umurlu specimens. A similar morphology is also observable on *Clethrionomys* sp. from the Early Pleistocene (MN17) of Pekecik (Ünay and de Bruijn 1998, fig. 9.3) and on *C. kretzoii* from the latest Villanyian of Bıçakçı (Hoek Ostende et al, 2015a). However, the deeper LRA4 (opposite to the BRA3) which separate the AC2 from the rest of triangles observed on the m1 of the Umurlu bank vole is not seen in the other *Clethrionomys* from other Anatolian localities. In addition, the anterior cap of m1 in the Pekecik and Bıçakçı specimens is rather elongate, the length and width are greater in than in the Umurlu material. Finally, confluence between T1–T2 in *C. kretzoii* from Bıçakçı is greater than in the Umurlu material, and the HH-index higher. Consequently, *Clethrionomys* from Umurlu locality is somewhat different from other Anatolian species. Nevertheless, the m1 of the extant species from North Anatolia displays all variations involving occlusal features mentioned above (Krystufek and Vohralik 2005, fig. 123).

The *C. glareolus* remains from diverse European localities differ from the Umurlu material in having broader T1–T2 confluence, as well as weak/rare development of T7 and LRA4 on the lingual side of AC2 (asymmetrical AC2) (see Rekovets and Nadachowski 1995; Parfitt 1999; Bogicevic et al, 2012; Ivanov and Vörös 2014, Lenardic 2014). Those characters are frequently observable in *C. kretzoii* as well (Tesakov 1996, 1998; Maul et al, 1998; Hoek Ostende et al, 2015a). The same differences are also observed in other Anatolian material. The findings of *C. acrorhiza* are scarce and therefore the comparison is not efficient.

The m1 of *C. kretzoii* has the lowest linea sinuosa height (cf. Hsd/L) and also its molars are less hypsodont. It has been pointed out that those features display increasing trend from the (Early) Pleistocene species *Clethrionomys hintonianus* towards the extant *C. glareolus* (Rekovets and Nadachowski 1995; Tesakov 1996; Maul and Parfitt 2010). In addition, earlier Pleistocene species (i.e., *C. kretzoii, C. hintonianus*) display broad confluence between T4–T5 and anteroconid, contrary to that of *C. glareolus* which has these folds rather separate (see Carls and Rabeder 1988, fig.16). That statement seems to be correct according to the comparison cited above, and therefore, those features are used to distinguish *C. glareolus* from earlier *Clethrionomys* species (Maul and Parfitt 2010; Ivanov and Vörös 2014; Lenardic 2014). Following these criteria, *Clethrionomys* from Umurlu differs from C. glareolus in having broader confluence of T4–T5 as well as lower linea sinuosa height, and it differs from *C. kretzoii* by its slightly higher linea sinuosa and crown height.

The m1 of *Clethrionomys* from Umurlu is generally smaller than the extant or fossil *C. glareolus* (Terzea 1971; Nadachowski 1984; Rekovets and Nadachowski 1995; Bogicevic et al, 2012; Lenardic 2014; Ivanov and Vörös 2014), except a few specimens from the late Middle Pleistocene of Petersbuch (Maul et al, 1998) and early Middle Pleistocene of Boxgrove (Parfitt 1999). Its length is also within the range of *C. hintonianus* from the late Early Pleistocene of Neuleiningen 5 (Maul et al, 1998) and early Middle Pleistocene of West Runton (Maul and Parfitt 2010). Based on the linea sinuosa height, the Umurlu material is rather close to *C. hintonianus* than to *C. glareolus*.

The comparisons of measurements, occlusal morphology and linea sinuosa height, as discussed above, evidence the affinity of the Umurlu material with *C. hintonianus* rather than with other *Clethrionomys* species. On the other hand, the high variability of the occlusal surface morphology on m1 in extant species of Anatolia as well as its current geographic distribution restricted in the northern part of Turkey, including the Niksar Basin, and the previous occurrence *C. glareolus* in Emirkaya-2 locality would favour the identification of the Umurlu material as *Clethrionomys* cf. *glareolus*. This would also avoid the problematic extension of the last occurrence of *C. hintonianus* from the Central and Eastern Europe up to Anatolia.

4.3.1.7 *Apodemus flavicollis*

Family Muridae Illiger, 1811

Subfamily Murinae Illiger, 1811

Genus *Apodemus* Kaup, 1829

Apodemus flavicollis Melchior, 1834

Figure 4.15.3–35

Material: 12 M1, 9 M2, 2 M3, 20 m1, 9 m2 and 5 m3 (Table 4.10)

Measurements: Table 4.11, Figure 4.17.

Description: Medium sized murine molars with t7 on M1 and M2, prominent buccal cingulids on m1 and m2. All these features point out the genus *Apodemus*.

The largest tubercles on M1 are t2, t5 and t8, similar in size. The t1 is situated more posteriorly than t2 and t3 and is isolated on 2 out of 12 specimens. In general, the posterior spur on t1 is less remarkable than on t3, and if present, it is very low and connects barely to the base of t5 on 5 out of 12 specimens. The tubercle t3 appears to be smaller than t2 and t1. The posterior spur of t3 is well developed and oriented toward t6 rather than t5 in all specimens. Three specimens out of 12 display a t2bis (Figure 4.15.4, Figure 4.15.10). The former bears also one accessory cusplet on the mesial edge, named here “apical style” (see also Figure 3.6.A). Depending on the degree of wear, a continuous connection (a ring) is established throughout t4-t5-t6-t9-t8 and t7. The tubercle t7 is generally well developed, elongated (ridge-like) or subrounded and separated from t4 by a valley. In most cases, t7 is fused with t8 except in some younger specimens (i.e., Figure 4.15.4–5, 8, 10) or rarely reduced and fused with t4 (Figure 4.15.3). The tubercle t9 is as large as t6 but oriented buccally rather than anterobuccally. The tubercle t12 is apparent but reduced and not individualized; apart from worn teeth (Figure 4.15.7), the t12 forms a kind of enamel island in 8 out of 11 specimens and contributes to the strengthening of the connection between t8 and t9; in two cases the t9 is connected to t8 primarily via t12. Lingual or buccal accessory styles are not observed (i.e., Neoantero-, Neoentero-, Para-, Meta-styles *sensu* Lazzari et al, 2010). There are four roots.

The second upper molars display well-developed t1 and t3, and isolated from t5. The t1 is greater than t3, almost double in size. The t1 bears a remarkable posterior spur in 4 out of 9 molars (i.e., Figure 4.15.11, 13, 15) or this spur is very faint. The t3

lacks any posterior spur. The t4 is either totally isolated from t5 (i.e., Figure 4.15.14) or in contact (i.e., Figure 4.15.13, 17) or fused with t5 (i.e., Figure 4.15.11). The t5 and t6 are always connected and t9 joins them. The size of t9 is quite variable in thesis samples; it might be reduced, represented as a wide crest-like structure (i.e., Figure 4.15.16) or well developed and comparable in size to t6 (i.e., Figure 4.15.13–15). The t7 is always strong, generally oval-shaped, separated from t4 by a wide valley on less worn specimens. The tubercle t12 is individualized only in one out of nine specimens (Figure 4.15.17). The rest of M2 molars clearly display some variability of t12: absent on 2 specimens (i.e., Figure 4.15.14, 16), reduced or well developed on some others (i.e., Figure 4.15.13). There are four roots except in one specimen which has lingual roots fused.

M3 is transversely wide. Lingual tubercles, t1, t4 and t6, are connected to buccally situated t5. The t3 is absent. Buccal tubercles are smaller than lingual ones, and the occlusal shape reminds the letter "E" (*sensu* Montuire et al, 1994). The t1 and t4 are separated by a deep valley. The valley between t4 and t8 is enclosed on lingual part. A significant, narrower depression is located on buccal side, between t5 and t6. The tubercle t9 is clearly present on one specimen (Figure 4.15.18) where it forms a node of t8 and already fused with t6. As a consequence, a third depression appears on the posterobuccal wall of the molar where t9 joins the t6 (Figure 4.15.18). There are three roots.

Lower first molars are generally elongate with buccal cuspids slightly shifted posteriorly. The tma (anterocentral cuspid) is rather prominent. One specimen displays a crest-like tma, rather than a cuspid (Figure 4.15.28). The tma is generally smaller than anteroconids. The anteroconid complex is symmetrical. The medial spur of protoconid-metaconid complex has tendency to connect first to the lingual anteroconid on young specimens. Only one m1 (Figure 4.15.28) has a reduced medial spur, thus failing the connection between those two complexes. The medial spur of entoconid-hypoconid complex (longitudinal ridge *sensu* de Bruijn and Meulen 1975) is either absent or short except in two specimens out of 18 (e.g., Figure 4.15.26) where it reaches the mesiolingual base of the protoconid. The accessory cuspid C0 is absent. The C1 is always present, large, low and isolated or fused to the hypoconid depending on wear degree. The other accessory cuspids are up to three and variables in dimensions and position. The posteroconid (posterior

heel) is low, oval- or subtriangular-shaped and well developed but shifted slightly toward lingual side of the molar. There are two roots.

The anterobuccal cuspid on m2 is large, elongate, comma shaped and situated at lower position relative to the protoconid. That cuspid is isolated in almost all unworn molars but it is connected to the mesial base of the protoconid-metaconid complex by a thin enamel ridge. The hypoconid-entoconid complex displays a mesial extension.

The posteroconid is as large as anterobuccal cuspid or slightly smaller, and situated lower than other cuspids. The C1 is present in one specimen (Figure 4.15.32) out of eight. The other accessory cuspids are either absent (Figure 4.15.29–31), otherwise one (i.e., Figure 4.15.33) or two (i.e., Figure 4.15.32) if present. There are two roots.

The subtriangular m3 has paired-cuspids fused but not interconnected by any medial spur. The posterior complex is oval shaped and becomes rounded in advanced age. The protoconid appears to be situated slightly posterior to metaconid. The anterobuccal cuspid is lost, but represented in some specimens by a feint enamel swelling (Figure 4.15.34). There are two roots, the anterior one being transversally elongate.

Comparison and discussion: The *Apodemus* molars from Umurlu are compared to several *Apodemus* species from different ages and localities (see Table A.1). Molars of small to medium sized *Apodemus* spp. overlap metrically and often they cannot be distinguished by size (e.g., *A. dominans* (Kretzoi, 1959), *A. atavus* (Heller, 1936), *A. flavicollis*, *A. witherbyi* (Thomas, 1902), *A. sylvaticus* (Linnaeus, 1758) and the Umurlu *Apodemus*; Figure 4.17)). The three large species *A. mystacinus* (Danford and Alston, 1877), *A. gorafensis* (Ruiz-Bustos et al, 1984) and *A. jeanteti* (Michaux, 1969), however, can be separated by the mean values of M1/m1 length and width (Figure 4.17.A–B). *A. gudrunae* Weerd, 1976 is a little smaller than these three species.

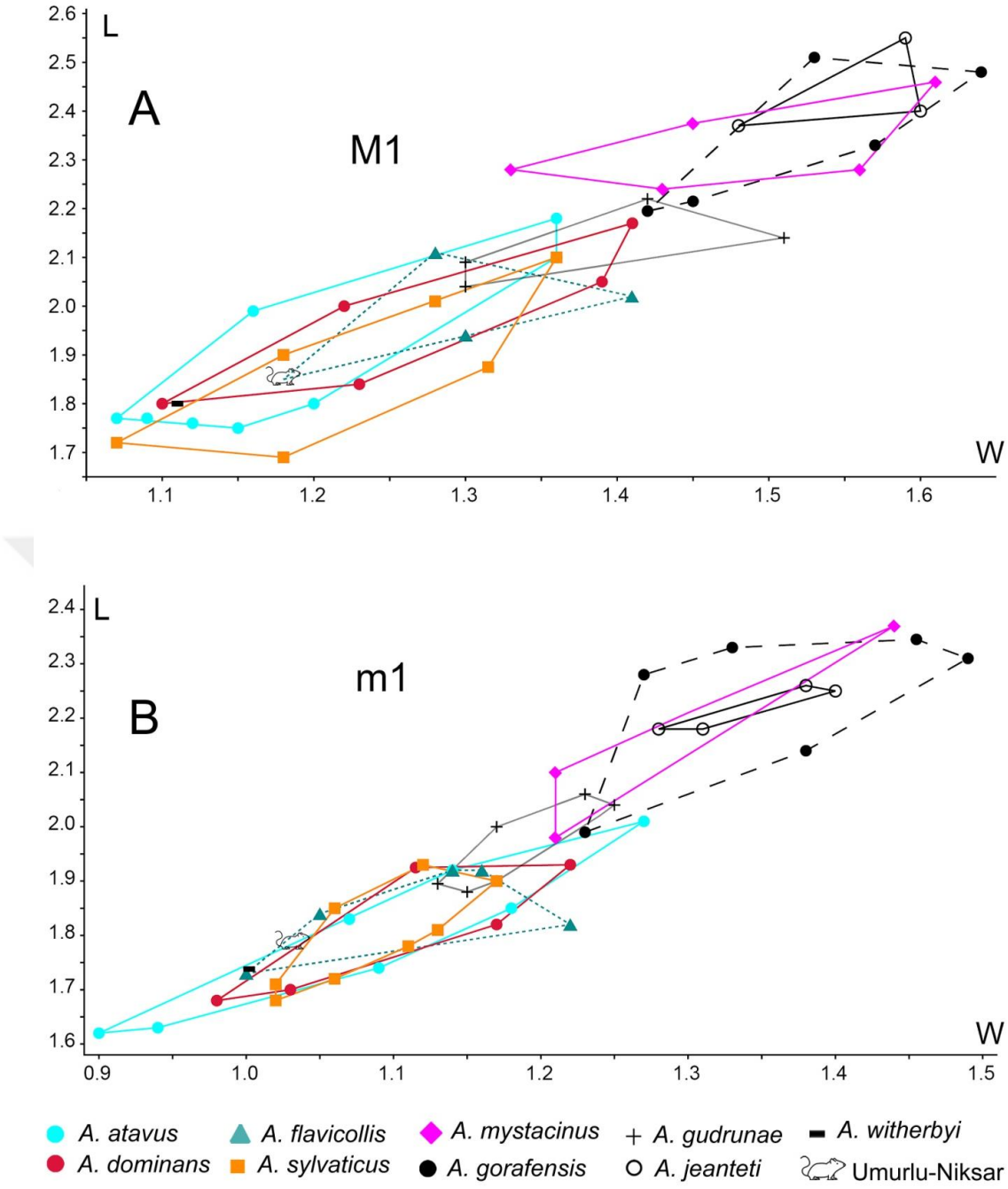


Figure 4.17 : Scatter diagrams displaying mean values of length and width in mm of *Apodemus* spp. from different localities and different ages (See Table A.1 for details): A– M1s; B– m1s. The taxa situated within the size range of the relevant group are not shown to enhance the readability, and symbols delimiting the maximum and minimum range on the figure are marked in Supplementary Table 1. Abbreviations: L– length, W– width.

The Umurlu wood mouse differs from *Apodemus atavus* in having on M1 more mesiodorsally elongate cusps, t1 always connected to t2 but isolated from t5 and more anteriorly situated relative to t3 (except some specimens from Monte la Mesa, early Biharian; Marchetti et al, 2000), the spur of t3 oriented toward t6 rather than t5, well-developed t2bis, although rarely present on the Umurlu sample a cingular cone (*sensu* Tchernov 1979), connection between t8 and t9 generally via t12 rather than a direct connection, t12 relatively reduced, not individualized and generally connected to t9, and finally in having four well-developed roots rather than three. The main differences between the M2 of Umurlu and *A. atavus* are that the former has a larger t3 relative to t1, t7 which might be totally fused to t8 at least in half of the specimens, t9 is much reduced, connection between t6 and t9 is always stronger, t12 is reduced or absent (except two specimens in Figure 4.15.13, 17) and four roots. The M3 of Umurlu murine can be differentiated from *A. atavus* by its t1 fused to t5, t4 straight and posterolingually oriented rather than transverse, t8 always connected or fused to t6 via t9 (case of bilophed posterior complex) or without, and the valley between t4 and t8 rather enclosed lingually, i.e., t8 not totally isolated from the t4.

The main differences of lower molars are the tma smaller than the posterior heel (=posteroconid) on the m1, although that character is variable in *A. atavus*, and the reduced accessory buccal cuspids on the m2 of Umurlu. On the other hand, the anterobuccal cuspid of m2 is always elongate and comma shaped, and the lophs are slightly less symmetrical (protoconid and hypoconid are more voluminous compared to their lingual antagonist).

The other features on lower molars such as the length of medial spur, the size and shape of C1, the position of posteroconid or even the number of roots (i.e., three roots, see Hoek Ostende et al, 2015a) on m1; reduction of absence of medial spur on hypoconid- entoconid complex, size and shape of the posteroconid on m2 are variable features of *A. atavus*, and thus they are not helpful to distinguish species. Thus, one can state that the major discriminant characters are more obvious on upper molars.

The *Apodemus* molars from the Umurlu locality differs from *Apodemus dominans* in the lack of connection of the posterior spur of t3 to the base of t5 on M1. In addition, the tubercle t4 is situated more posteriorly than t6, and the weakly developed t12 is never delimited on the M1 of Umurlu. As to M2, t12, when present, never reaches

the size of t7 as in *A. dominans*. The lower molars display more or less the same differences as in *A. atavus.*

Since the distinction between *A. dominans* and *A. atavus* is not an easy task, some authors consider *A. dominans* a distinct species (e.g., Storch and Dahlmann 1995; Popov 2004; Hordijk and de Bruijn 2009; Suata-Alpaslan 2010; Vasileiadou et al, 2012) based mainly on slight morphometric differences, while for some other authors (e.g., Fejfar and Storch 1990 ; Martín-Suárez and Mein 2004; Minwer-Barakat et al, 2005; García-Alix et al, 2008; Colombero et al, 2014; Siori et al, 2014) *A. dominans* is a junior synonym of *A. atavus* stating that the morphological and size differences are actually intraspecific variations. Some authors ascribed the *Apodemus* specimens found in the same locality in Turkey to both *A. dominans* and *A. atavus*, without giving any persuasive morphological features but measurements (e.g., Ünay and de Bruijn 1998; Suata-Alpaslan 2010; Hoek Ostende et al, 2015a). For Vasileiadou et al, (2012) identification of small to medium sized *Apodemus* species is difficult when the samples size is small or when large samples are not homogenous.

The same difficulty is also pertinent for the distinction of fossil specimens of *A. sylvaticus* or *A. flavicollis*, as pointed out by many previous authors (Filippucci et al, 2002; Popov 2004; Masini et al, 2005; Hordijk and de Bruijn 2009; Minwer-Barakat et al, 2011; Vasileiadou et al, 2012; Siori et al, 2014; Colombero et al, 2014). For instance, Siori et al. (2014) and Minwer-Barakat et al. (2011) distinguish *A. sylvaticus* from *A. flavicollis* collected from the Early Pleistocene of Monte Argentario (Italy) and Biharian–Toringian of Torrent de Vallparadis (Spain), respectively, based on one character of M2, which was proposed first by Pasquier (1974): the t9 is more developed on *A. sylvaticus* and reduced on *A. flavicollis*. As a consequence, while some authors attribute their material to *A. sylvaticus* based on that character (i.e., Cuenca-Bescos et al, 1997), some authors prefer to group under the *A.* gr. *sylvaticus-flavicollis* due to variations among the rest of molar sample (i.e., Ünay and De Bruijn 1998; Masini et al, 2005; Siori et al, 2014).

Recent *Apodemus* samples from Turkey and surrounding regions were intensely worked by Krystufek and Vohralik (2009) wherein *A. sylvaticus* is mainly recorded in Turkish Thrace whereas *A. flavicollis* seems to be spread in Anatolia, except the central and south-eastern regions. One of the most striking features underlined by these authors is the variability of t9, relative to t6 on M2 as well as the connection

types of t12 with t8 and/or t9 on M1 of *A. flavicollis* (Krystufek and Vohralik 2009, fig. 62–63). Those variations match well with sample from the Umurlu locality rather than the variation observed on the M1 of *A. sylvaticus* (Krystufek and Vohralik 2009. fig. 53).

A. sylvaticus differs from the Umurlu wood mouse and *A. flavicollis* in having less broad and elongate "central" cusps (t2, t5 and t8), weaker t7 on M1, a t1 much greater in size than t3, the connection between t1 and t5, when present, situated mesially and low on M2, t1 and/or t8 isolated from the rest of cusps on M3. As to lower molars, m1 of *A. sylvaticus* might possess a clearly isolated buccal anteroconid while the tma is connected to the lingual anteroconid (e.g., recent specimens from northern France in Pasquier (1974), Early Pleistocene of Loma Quemada-1 in Tarraco et al. (2015), an isolated anterobuccal cuspid in any wear stage and a rounded posteroconid rather than oval on m2.

A. witherbyi differs from the wood mouse of Umurlu in having smaller molars (Figure 4.17.A), t1 situated much posterior to t2 and t3, weaker t7 compared to t4 on M1, broader lingual folds on M3, absence of C1 on m1 and much smaller posteroconid on m2 (Krystufek and Vohralik 2009; Suata-Alpaslan 2011b).

Beside its greater size, *A. gudrunae* differs from the Umurlu *Apodemus* in having weak connection between the t1 and t2 as well as t6 and t9, absence of posterior spur on t3 and well developed t12 on M1, absence of connection between t6 and t9 and well developed and frequent t12 on M2, an isolated t1 with deep lingual valleys on M3, well-developed buccal cingulids and accessory cuspids on m1 and m2, generally rounded buccal anteroconid rather than "comma shaped" on m2 and, finally, more developed anterobuccal cuspid (present faintly on one third of Umurlu m3) as well as presence of a cuspid buccal to the entoconid-hypoconid complex on m3 (see Colombero et al, 2014).

In conclusion, despite the general difficulty concerning the distinction of *A. sylvaticus* from *A. flavicollis*, the sample from Umurlu locality should certainly be identified as *A. flavicollis* based on characters mentioned above. In addition, high morphologic similarities of the Umurlu wood mouse to the recent specimens described from Turkey by Krystufek and Vohralik (2009) as well as to upper first molars of *A. flavicollis* from Emirkaya-2 (Middle Pleistocene; Montuire et al, 1994) and Üçağızlı

Cave (Toringian; Suata-Alpaslan 2011b), to *Apodemus* cf. *flavicollis* from the Bıçakçı locality (latest Villanyian; Hoek Ostende et al, 2015a) and to *Apodemus* "*sylvaticus* or *flavicollis*" from latest Villanyian–early Biharian of Hamamayağı (only one M1; Ünay and de Bruijn 1998) are remarkable.

4.3.1.8 *Nannospalax* cf. *xanthodon*

Family Spalacidae Gray, 1821

Subfamily Spalacinae Gray, 1821

Genus *Nannospalax* Palmer, 1903

Nannospalax cf. *xanthodon* Nordmann, 1840

Figure 4.15.36–37

Material: 1 m3 dex. (Table 4.10)

Measurements (in mm): L= 2.45, W= 2.21

Description: The m3 relatively large and highly hypsodont, slightly longer than it is wide and has a subtriangular occlusal surface with reduced hypoconid, thus, posteriorly narrower. It bears two lingual and one buccal re-entrant folds. That molar probably belongs to a young individual due to early stage of wear; enamel islands are not formed since the main re-entrant folds are still open. On the other hand, two small enamel islands are prominent on the anterior loph; the lingual one is a relict of an antesinusid of which a faint mesial protrusion is left, and the buccal one is possibly a relict of protosinusid. The lingual arm of metaconid, pinched mesially, is oriented posteriorly. The mesosinusid is deep, oblique, directed mesially and reaches almost the half of the crown height in lingual view. The mesolophid is absent. The hypolophulid is transverse and connected to the entoconid lingually and to ectolophid buccaly. The posterolophid, curved towards entoconid, encloses the shallow posterosinusid.

The hypoconid is reduced. The posterior arm of protoconid is in contact with ectolophid mesiobuccaly but not fused. The sinusid is deep, transverse. In buccal view, the sinusid is as deep as two third of the crown height. Also the reduction of hypoconid results in widening of the sinusid toward the occlusal surface. Two

transversally elongate but short roots are present. The posterior side of the tooth has a somewhat porous wall, probably related to taphonomy, if not a pathologic effect.

Comparison and discussion: The subfamily Spalacinae is well known in the fossil record of Turkey since the Early Miocene (see Krystufek and Vohralik 2009; Sen and Sarica 2011). On the other hand, systematics of the extant genera and species are still debated (cf. Sarica and Sen 2003; Musser and Carleton 2005; Krystufek and Vohralik 2009; Sen and Sarica 2011; Krystufek et al, 2012; de Bruijn et al, 2015). The arguments of priority for the recent Anatolian mole rats concerning the genus name (i.e. *Nannospalax* over *Spalax*) is followed after Musser and Carleton (2005) and Krystufek et al. (2012), and for the species name (i.e. *xanthodon* over *nehringi* Satunin, 1898) after Krystufek and Vohralik (2009).

One of the major difficulties of spalacid systematics is due to individual variation and different wear stage of molars (de Bruijn and Meulen 1975; Popov 2017). For instance, from the early stages of wear, lophs and lophids become connected or fused, re- entrant folds become transformed into enamel islands or totally disappear (Sen 1998, 2016). In this process, the occlusal surface attains "S-shape" in even young individuals of the recent *Nannospalax* and extinct *Pliospalax* species (Sarica and Sen 2003; Sen 2016) and similarly, it remains one buccal and one lingual re-entrant folds especially on the molars of *Nannospalax* (Topachevski 1969; Kuss and Storch 1978; Krystufek and Vohralik 2009).

The distinction of the genus *Pliospalax* from *Nannospalax*, was first suggested by Kormos (1932) based on the presence of two re-entrant folds on both buccal and lingual sides of the lower first molar and is followed by subsequent authors (i.e., de Bruijn and Meulen 1975; Ünay 1996). However, this character cannot be checked in thesis material which is represented only by m3. Sarica and Sen (2003) observed in *Nannospalax* molars rather wider lophids and narrower re-entrant angles. In addition, Ünay (1990) mentioned that the anterobuccal sinusid on m3 of *Pliospalax* is present as a lake (enamel island), and de Bruijn and Meulen (1975) underlined that m1 and m3 of *Nannospalax* are relatively short and the posterolophid is not isolate.

Although the characters of *Nannospalax* mentioned above are in common with the present material, some similarities with *Pliospalax* are also observed: complicated

occlusal pattern rather than S-shaped, narrower lophids, wider re-entrant folds, isolated posterolophid as well as the presence of an enamel island, relict of a protosinusid, and more than one lingual re-entrant folds. It is noteworthy that, however, those features are subjected to perish somewhat with attrition.

The great similarity between the Umurlu specimen and *Pliospalax macoveii* (Simionescu, 1930) from Çalta (MN15, Turkey) is striking (Sen 1977); two unworn small enamel islands on the anterior lobe, shape and orientation of two lingual and one buccal re-entrant folds as well as transverse hypolophulid, anteriorly curved posterolophid, small hypoconid and absence of mesolophid remind that the Umurlu specimen is kind a "transition form by means of attrition stage" between two specimens illustrated in Sen (1977, pl.14.9–10). However, *P. macoveii* from Çalta constitutes the lower limit of medium sized spalacines (cf. Sarica and Sen 2003, fig.6.7) whereas the Umurlu specimen is within the range of larger mole rats remains.

Based on the same length/width scatter diagram of various spalacine m3s provided by Sarica and Sen (2003), the Umurlu mole rat is close to but smaller than *Nannospalax odessanus* (Topachevski, 1969) from the late Early Pliocene of Odessa Catacombes and Karaburun (MN15, Topachevski 1969; de Bruijn 1984). In addition, *Nannospalax* cf. *odessanus* specimens are described recently from the Early Pleistocene of Futjovka Cave (Northern Bulgaria, Popov 2017), and the largest m3 among the whole sample is still far smaller than the Umurlu m3.

Morphologically, *Nannospalax odessanus* differs from the Umurlu mole rat in having greatly developed hypoconid, anterior lobe oriented lingually and not curved backward, a more transverse mesosinusid, oblique entoconid-posterolophid lophid. On the other hand, the m3 of *Nannospalax* cf. *odessanus* from Bulgaria represents almost identical features with the Umurlu specimen such as one buccal and two lingual re-entrant folds, posteriorly curved lingual arm of metaconid, posterior arm of protoconid and hypolophulid separate. However, Bulgarian species can be distinguished from our Turkish one by its less individualized protoconid and hypoconid as well as much smaller size.

The m3 from Niksar, which displays a weak hypoconid, two lingual (mesosinusid, posterosinusid) and one buccal (sinusid) re-entrant folds, separate posterolophid and entoconid, in addition to high crown and short roots, matches very well with one

recent specimen of *Nannospalax xanthodon* which has a large present day range in Turkey. Besides, "*Spalax*" cf. *nehringi* from the early Biharian of Kalymnos (Greece) reminds the further level of attrition of the Umurlu spalacine where minor enamel islands as well as the posterosinusid are totally disappeared (Kuss and Storch 1978).

As a conclusion, despite some resemblance of the Umurlu specimen to *Pliospalax*, the scarcity of the material and morphological differences noted above prevent its attribution to *Pliospalax*. Moreover, the Umurlu fauna is of younger geological age. Therefore it is preferred to assign the Umurlu m3 to *Nannospalax* cf. *xanthodon*.

5. CONCLUSION AND PERSPECTIVES

The interest in Quaternary Sciences in Turkey, contrary to Europe, is yet growing very recently and has been lagging in decades. Knowing that the Quaternary is not only a geological period but also is an interdisciplinary studies area, of which small mammal paleontology is one of them and indeed, it is unquestionable how Anatolia played an important role in the evolution and adaptative radiation between continents. On the other hand, paleontological studies in our country are mostly focused on the Paleogene and Miocene, while the Pliocene and Quaternary studies are limited (Sen, 1977; Sen et al, 1991, 2017; Hoek Ostende et al, 2015a, b; Saraç, 2003, 2012; Erdal, 2017).

More than fifty percent of Turkey's surface area is covered with Neogene and Quaternary sediments (Sen, 2003). The scarcity of research in such a rich geography in terms of potential fossil findings can be explained by lack of interest and inadequate number of researchers (Saraç, 2012).

This study attempted to draw attention to the afore-mentioned shortcomings and compiles studies on small mammal paleontology of the Quaternary Period to this date, in addition to provide detailed systematic paleontology of small mammals on Pliocene–Quaternary from three basins developed on North Anatolian Fault Zones, a biostratigraphic assumption on adjacent basins and on their formation history, revision of the already known species, unidentified or unpublished specimens as well as the new ones, inferences on paleoclimate on paleoenvironment.

5.1 Tosya

As mentioned in Chapters 2.1 and 4.1 localities in the Tosya Basin involves the ones already visited by Ünay and de Bruijn (1998) whereof some quick descriptions of some small mammals and relatives ages were provided. A new locality Kumkapı, in addition to already known localities (Figure 2.2) after Ünay and de Bruijn (1998) are

revisited and sampled. The small mammal fossil remains are described and identified under the Chapters 4.1, with a provided MSS of the Ortalıca 2 locality (Figure 2.6).

Among the rodent fossil fauna, there are *Mesocricetus primitivus* (Figure 4.2), *Pliomys destinatus* (Figure 4.5) and *Apodemus atavus* (Figure 4.7) besides some unidentified arvicoline remains, from the Ortalıca 1 and 2 localities; *Mimomys* cf. *polonicus* from Sapaca 1 and 2 localities and finally, *Microtus* (*Microtus*) cf. *arvalis* and *Mus* cf. *macedonicus* from the newly discovered Kumkapı locality.

The significance of *Mesocricetus primitivus* in this thesis is that I suggest that all *M. primitivus* fossil species described from the Pliocene *Mesocricetus* species as whether "cf." *primitivus* from Anatolian localities (e.g. Sen, 1977; only M2, Ünay and de Bruijn, 1998; Suata-Alpaslan et al, 2010) and from Greece (e.g. Vasileiadou et al, 2003), or as "aff." *primitivus* (e.g. Ünay and de Bruijn, 1998), and from the latest Villanyian Bıçakçı (e.g. Hoek Ostende et al, 2015a) should be considered as *M. primitivus*, as a result of some possible variation within the species *M. primitivus* from the Pliocene–early Pleistocene.

The main reason is due to differential characters provided by de Bruijn et al. (1970) for the scarce type material of *M. primitivus* from Maritsa which lack naturally such dental features displaying many variations as found in subsequent fossil faunas, including Ortalıca material. Many intraspecific variations are underlined first by Sen (1977, p. 111) and also by the above mentioned authors and also their size and dental morphology are reasonably close.

In this regard, the hamster from Ortalıca is defined as *Mesocricetus primitivus* which represents the smallest specimen found so far, at least, until new fossil are gathered. According previous studies, *Mesocricetus primitivus* is one of the oldest *Mesocricetus* species ranging from the earliest Pliocene (MN14) to latest Villanyian (MN17) (Figure 5.1; e.g. de Bruijn et al, 1970; Sen, 1977; Ünay and de Bruijn, 1998; Vasileiadou et al, 2003; Suata-Alpaslan et al, 2010; Hoek Ostende et al, 2015a). As it is and despite its relatively wide range, it enforces the idea that Ortalıca locality at the NE is older than Sapaca and Kumkapı, toward SW as it was already suggested by Ünay and de Bruijn (1998), based on the specimen of *Mimomys gracilis* found at the same locality which points out MN15 (late Ruscinian). Note that *M. gracilis* is not found in the present study.

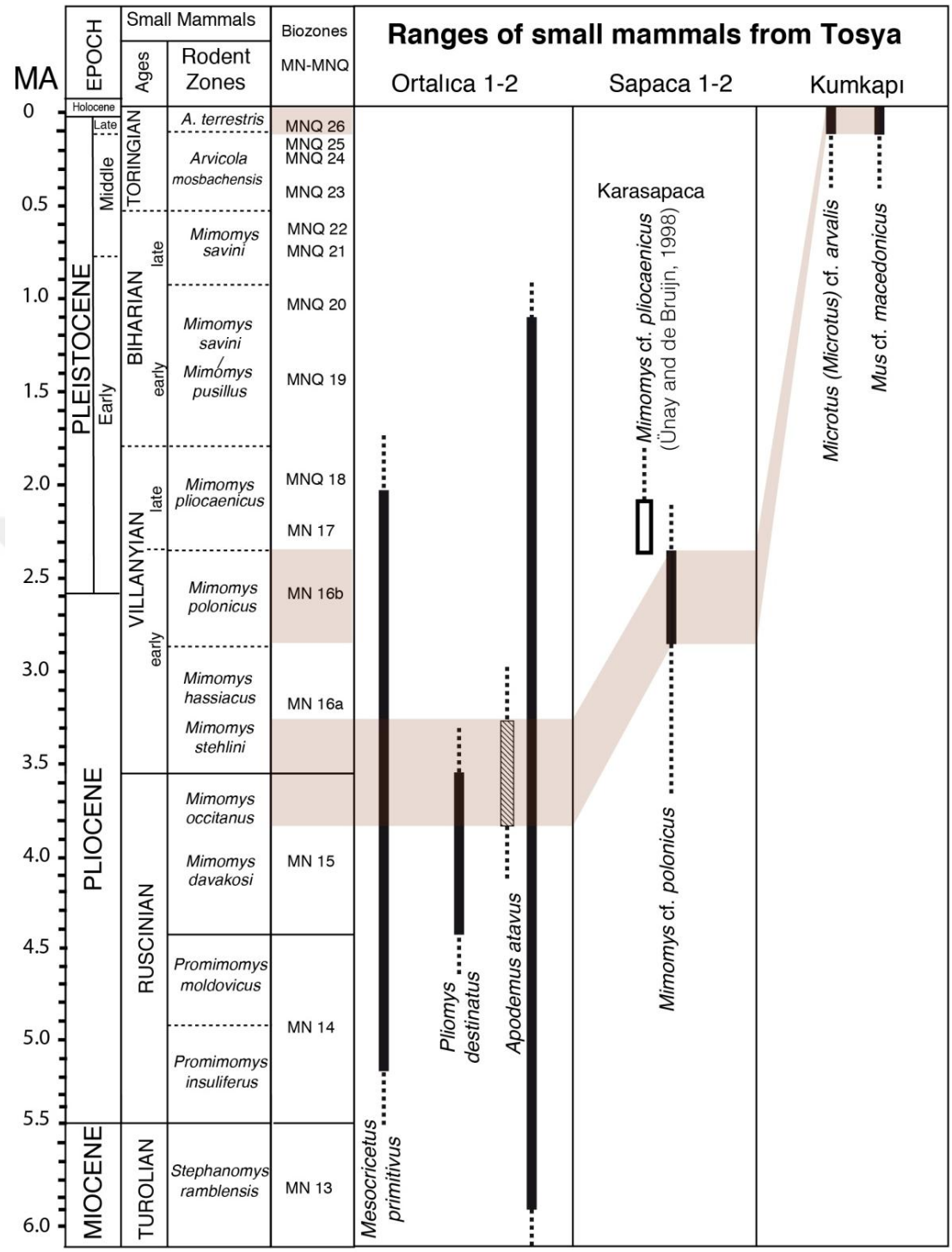


Figure 5.1 : A combined chart between the late Miocene–Holocene which involves small mammal ages, rodent zones, land mammalian biozones (adapted from Masini and Sala, 2007; Popov, 2017; Pazonyi et al, 2018) and age ranges of small mammals from localities of Tosya Basin. The hatched box for *Apodemus atavus* from Ortalıca 1-2 localities indicates the specific age range for that locality according to root developments.

That MN15 age for Ortalıca locality is also supported by the presence of *Pliomys destinatus* as discussed in Chapter 4.1.1.2 of this present study, following the work of Tesakov (2005) conducted in Ukraine. However, it seems that the Turkish *P. destinatus* must be slightly younger than the Ukrainian vole if the minor differences of *linea sinuosa* (<0.1–0.15 mm) are taken into account (i.e. increasing hypsodonty in time, see Neraudeau et al, 1995; Chaline et al, 1999). The age range of Ortalıca locality is also constrained based on the root condition of wood mouse from Ortalıca, *Apodemus atavus*. As discussed in the Chapter 4.1.1.4, the Ortalıca wood mouse should be older than *A. atavus* from the latest Villanyian Bıçakçı (Hoek Ostende et al, 2015a) and from that of the MN16 Yenice-1 localities (Ünay and de Bruijn, 1998) because of bearing three roots on M1 rather than four. On the other hand, Ortalıca *A. atavus* should be similar or slightly younger in age than *A. atavus* (=*dominans*) from the MN15b Muselievo locality at North Bulgaria (Popov, 2004) in having four roots on M2. In sum, the age range of Ortalıca must be considered as MN15b-16a, or around 3.5 Ma, between the latest Ruscinian and the earliest Villanyian (Figure 5.1), therefore slightly younger than previously suggested (Ünay and de Bruijn, 1998, p. 439).

As to adjacent locality Sapaca, the only describable specimen belongs to *Mimomys* cf. *polonicus* (for detailed description and comparison, see Chapter 4.1.2.1) and provides rather the age of late Pliocene (MN16b; Figure 5.1) according to high morphological similarities between the *M. polonicus* from the Kushkuna locality (Azerbaijan; Tesakov, 2004). Note that Ünay and de Bruijn (1998) mention a locality near the Karasapaca village which is close to Sapaca (Figure 2.2; Figure 4.1). During the field campaign for the present thesis, the re-visited Karasapaca village did not yield any identifiable fossil remain and therefore it is subject of further studies. However, the Karasapaca locality appears to be much younger with MN17 based on *Mimomys* cf. *pliocaenicus* suggested by Ünay and de Bruijn (1998, p.439; Figure 5.1) than Sapaca which is rather second half of early Villanyian (MN16b).

As extant species of field mouse like *Microtus arvalis* (*s.l.*), the murine *Mus macedonicus* which are present at Kumkapı locality of Tosya Basin, have a wide geographical distributions and their first occurence dates to Middle–Late Pleistocene (see Chapter 4.1.3; Tchernov, 1992; Krystufek and Vohralik, 2005, 2009). According to Tchernov (1992), *M. macedonicus* has been present in Israel for the last 160 ka

(=latest Middle Pleistocene) while it is introduced in Anatolia, according to fossil record so far, much later (Krystufek and Vohralik, 2009). For instance, it was not present in the rich fossil fauna from the Middle Pleistocene Emirkaya-2 locality (Montuire et al, 1994) but appeared in the Late Pleistocene in Karain Cave (=*M. abbotti sensu* Storch, 1988). In these available material, the Kumkapı deposit bearing *Microtus* (*Microtus*) cf. *arvalis* and *Mus* cf. *macedonicus* together would limit the lower age of that layer as Late Pleistocene (Figure 5.1).

Based on small mammal record of the present study as well as on ongoing studies of ostracods and palynology, there can be stated three distinct opening phase of the Tosya Basin, following alluvial fan development, initiated at MN15 (late Pliocene). The opening of the basin is controlled by a fault located to the north of the basin by the formation and slip resolved on the Oğuz Fault. The thickness of the basin sediments decreases to the west indicating that the fault/basin evolved from the east to the west but increases significantly at the centre of the basin (Sapaca-Karasapaca) indicating limited lacustrine deposition within a closed tectonic basin. The visible thickness of the first stage alluvial fan deposits are over 300 meters.

The second stage of alluvial fan development started at Early Toringian / Middle Pleistocene when intense erosion took place at the basin where all rivers feeding the alluvial fans deeply entrenched the sediments of the first stage deposition. The Kumkapı alluvial fan developed after this period still preserving its original form. Kumkapı locality constrains the age of alluvial fan, Middle-Late Toringian (pre-late Pleistocene).

The recent sedimentation within the basin is represented by young (third phase) alluvial fans to the north and south of the Devrez River and the terraces of the Devrez River (Huber-Ferrari et al, 2021).

5.1.1 Palaeoclimatic and paleoenvironmental assumptions

The Ortalıca 1 and 2 localities situated at the north-eastern part of the studied basin are rather rich in *Pliomys* and *Apodemus* species, which are already found together in all layers sampled, including on the measured stratigraphic section of Ortalıca-2 (Figure 2.6), except the layers A, E, G and H; where the layer A did not yielded any identifiable remain, the layer E yielded a premolar of *Ochotona* sp. (Sen, *in verbis*),

the layer G provided only an incisor of a lagomorphs indet and finally, the layer H, just some molars of *Apodemus* (see section 4.1.1).

The abundance of *Pliomys* and *Apodemus* species in Ortalıca, in overall, points out rather forested, wooded and humid environment rather than grassland (Sen, 1977; Suata-Alpaslan, 2010; Hoek Ostende et al. 2015b; Popov, 2018).

However, the presence of *Mesocricetus* remains on the layer D of Ortalıca-2 locality together with *Pliomys* and *Apodemus*, as in Ortalıca-1, would indicate that for a while between MN15b–MN16a (Pliocene), there have been cooler climatic conditions occurred, which resulted in steppe environment (Sen, 1977; Hoek Ostende et al. 2015a; Popov, 2018) may be with sparse forested area for the food sources.

Sapaca 1 and 2 localities which are younger than Ortalıca but much older Kumkapı localities yielded only *Mimomys* species, which are generally reported from relatively warm and arid, open steppe environment (e.g. Rabeder, 1981; Montuire et al, 1994; Popov, 2017).

Finally, Kumkapı locality with the presence of recent species of *Microtus* and *Mus*, is not much different from the actual climate and environmental condition of the studied area such as mixture of open environment with meadows and grasslands with warm climate, as pointed out in previous studies (e.g. Montuire et al, 1994; Çolak et al, 2016; Erdal et al, 2018, 2019).

5.2 Suluova

Stratigraphy of Suluova Basin indicates a complex basin formation under control of internal and external processes of the Earth and provides a new insight on regional paleogeography. Evolution of the faults within the Amasya Shear Zone caused formation and further extension of the basin, where climate changes and river capture process led to the deposition of different sedimentary units. Suluova Basin hosts a continuous sedimentary record of the Quaternary and stands as a key locality to investigate the faunal and climate changes for north central Anatolia such as the onset of the Quaternary, middle Pleistocene transition (MPT) and onset glacial periods with ~100 ka duration.

As hypothesized previously, relative ages of localities within continuous sedimentary deposits from the older to younger, namely Kurnaz-Kerimoğlu in Yolpınar Fm, Kamışlı-Kızıleğrek in Eraslan Fm. and Yolpınar in Harmanağılı Fm do not differ in large scale. Although fossil fauna is relatively poor, it could provide relatively good precision for relative age.

The stratigraphic positions of Suluova Group are outlined in stratigraphic columnar section (Figure 2.8; Erturaç et al, 2019, figure 10) representing the facies changes and relevant depositional environment. Identification of the mammal fossils gathered from various positions of the basin fill enabled to correlate these formations in geological time scale by means of MN-MNQ Zones and mammal ages. The first age constraints are from Kurnaz Locality (KU) at the NW of the basin (Figure 2.7 and Figure 2.8) revealing Late Villanyian age (MN17–MNQ18; ~2 Ma) with micro- and macrofauna remains (*Klymnomys* sp. and *Sivatherium* sp.) dating the upward fining floodplain litofacies of the Yolpınar Formation. The introduction of Suluova Lake, proven with the presence of fossil fish teeth gathered from Kerimoğlu locality (not pictured in this thesis) and related deposits are dated with Kerimoğlu (KO) fauna (*Microtus* (*Allophaiomys*) aff. *nutiensis*, *Mimomys* aff. *pliocaenicus*, *Apodemus* cf. *dominans*) as late Villanyian–early Biharian (MNQ18–19; ~1.7 Ma). The fossil fauna from Kızıleğrek (KE; *Mesocricetus* aff. *arameus*) and Kamışlı (KA; a talonid of p3 of an *Equus*) fauna reveal MNQ19–21 (~1.3-0.8 Ma) ages for the uppermost part of the Suluova Lake. The Yolpınar fauna indicate an early Toringian (MNQ22–23, ~0.5 Ma) age with the occurrence of extant species *Mesocricetus* cf. *brandti*, and fossil *Arvicola* cf. *mosbachensis*. Within this time constraints one can assume that the Suluova Lake existed in between 1.7 to 0.8 Ma and fluvial deposition reigns afterwards until recent.

5.2.1 Paleoclimatic and paleoenvironmental assumptions

The reconstruction of Quaternary climate is based upon the sedimentary architecture and the fossil record (mammal and preliminarily mollusc fossils). During the initiation of the basin, the climate was rather dry and rainfalls were seasonal. The rivers feeding the alluvial fans of Değirmendere and Yolpınar formations were subjected to stage fluctuations and alternating periods of erosion and deposition

which are reflected in channel-fill sequences. The well-developed paleosol sequences formed in between the very coarse grained channel fill are observed along the Gerger, Kutlu and Sivri sections both indicate the migration of active channel and possibly a pause in sedimentation.

The faunal association from five localities would allow to make some assumptions concerning the past environment. For instance, the paleoenvironment of *Sivatherium* is reported as grasslands and well-watered landscape with much warmer temperature for the early part of Early Pleistocene (MN17–MNQ18) which results in local extinction of the large browsers afterwards with colder climate in Siwaliks (Patnaik and Nanda 2010, p.134). The environmental preference of *Kalymnomys* on the other hand, is not well known but based on actual relatives (e.g., *Lagurus lagurus*) it is thought that should be rather dry steppe environments (Alçiçek et al, 2017, p.242). The floodplain deposits at Kurnaz locality would support the former hypothesis in addition to environmental changes with the presence of paleolake at younger Kerimoğlu locality which would point out rather warmer climate.

Kerimoğlu locality, as it is important for the formation of a paleolake which is also supported by the remains of unidentified fossil fish teeth, represents an environment surrounded with deciduous woodland and bushy vegetation covers with streams and marsh-like areas by the presence of large vole *Mimomys* aff. *pliocaenicus*, *Apodemus* cf. *dominans* and possibly *Microtus* (*A.*) cf. *nutiensis* although the latter is related with open environments (Siori and Sala 2007; Hoek Ostende et al, 2015a; Erdal et al, 2018; Sen et al, 2018).

The macromammal remains at Kamışlı has been previously reported by Sickenberg and Tobien (1971, p.60–61) where faunal elements including *Equus* sp. point out steppe environment crossed by forest along the water courses and lakes.

A complete right M3 of *Mammuthus trogontherii* from Armutlu locality at NE part of the basin (Figure 2.7 and Erturaç et al, 2019, fig. 4) is reported by Albayrak and Lister (2012). Suluova is on the route of the Pleistocene dispersion of steppe Mammoth which originates from central Asia (Kahlke, 2013) and this finding can be correlated by the earliest occurrence of eastern European relatives (~0.8 Ma, Muttoni et al, 2015) thus supports the age of the upper levels of Eraslan Formation. The rich fauna listed by Sickenberg and Tobien (1971), Albayrak and Lister (2012) and in this

study indicate that shores of Suluova Lake acted as refugia (cf. Stewart et al, 2010) supplying favourable conditions for temperate species of large mammals during the increased aridity of MPT prior to MIS 22.

Shifts in regional precipitation and water income into the basin caused variations in lake level. It can be observed the magnitude of changes along the measured sections where slight changes modified the depositional units. When there is an apparent drop in lake level, riverine channels intrude to lake depositing coarse grain sediments exhibiting fluvial architecture. Sharp boundaries between the facies suggest that response to climate change was rapid. Organic-rich silty/clayey sediments correspond to a "drowning" period when the lake expanded and deepened before carbonate precipitation could catch up. The carbonated sandy layers indicate that humid climate reigns during overall lake formation (Hostetler, 1995; Boggs, 2001). *Unio* sp., *Pisidium* sp. and *Valvata* sp. remains from Kamışlı and Kızıleğrek localities indicate fresh water with rich vegetation environment for Suluova Lake. The other species are terrestrial and hydrophilic molluscs (Pupilloidea) such as, *Vallonia* sp?, *Daudebardia* sp. and *Carpathica* sp. indicates humid environment (B.A. Gümüş, pers. Comm. 2019). Following the MPT, the basin and the Suluova Lake was captured from SE part by the Yeşilırmak River. The timing is compatible with the MIS 22 (0.87 Ma), the first significant glacio-eustatic sea level low stand and the onset of first Pleistocene glaciations in the Alps (Muttoni et al, 2003). The sea level drop should have forced the river system to erode backwards leading way to the capture of Suluova Lake at today's Boğazköy Gorge. (Erturaç et al, 2019, fig. 17E–F). After this significant step in basin evolution, the lake should have drained almost instantly and the unconsolidated sediments of the basin started to erode with advancing river valleys (Erturaç et al, 2019, fig. 2). This event also initiated the deep erosion within its gorges such as Havza and Boğazköy. When the base level was stabilized, fluvial clastics of Harmanağılı Formation started deposition.

The presence of *Mesocricetus* spp. at Kızıleğrek and Yolpınar localities would indicate somewhat dry, semi-arid steppes covered by sparse vegetation (Krystufek and Vohralik 2009). Note that Anatolia is playing an important role for the evolution of *Mesocricetus* during Middle Pleistocene, which is favoured by alternating dry periods and spreading lakes causing steppe-corridors for hamsters' dispersals and adaptations (Neumann et al, 2017). On the other hand, *Arvicola* findings together

with *Mesocricetus* as at Niksar Basin (Erdal et al, 2018), demonstrate rather a mixture of steppe-like environments with water streams for that youngest locality to the east of Suluova Basin (Figure 2.7).

5.3 Niksar

The Umurlu locality in the southern part of the Niksar Basin yielded remains of *Mesocricetus* cf. *brandti, Cricetulus migratorius, Arvicola* cf. *mosbachensis, Microtus arvalis, M.* (*T.*) *subterraneus, Clethrionomys* cf. *glareolus, Apodemus flavicollis* and *Nannospalax* cf. *xanthodon*.

In the Umurlu fauna, *Arvicola* cf. *mosbachensis* is the only extinct species, whereas all other recorded species are still living in diverse habitats of Turkey including the Niksar Basin. *Arvicola* plays a key role to re-evaluate the age of the locality, which has been estimated previously to maximum ca. 0.6–0.7 Ma (early Toringian, Erturaç and Tüysüz 2012). Here, the continental small mammal biochronology based on Arvicolinae and developed by Fejfar and Heinrich is used (1980; Fejfar et al, 1998) (Figure 5.2), where the co-occurrence of *Microtus* and *Mimomys* defines the Biharian (*Microtus*/*Mimomys* superzone) and the co-occurrence of *Arvicola* and *Microtus* the Toringian (*Arvicola*/*Microtus* superzone). The Biharian is subdivided in an older zone with *Mimomys pusillus* and a younger zone without this species. The early part of the Toringian is characterized by the presences of *Arvicola mosbachensis* and the later part by *A. amphibius*. The replacement of *Mimomys savini* with roots by the rootless *A. mosbachensis* determines the transition between late Biharian and early Toringian (Rekovets 1990; Fejfar and Heinrich 1990; Kolfschoten 1992; Maul 1996; Fejfar et al, 1997; Chaline et al, 1999). Within the *Arvicola* lineage the evolutionary level can be traced by an increase in size, in A/L and change of enamel thickness differentiation from “negative to positive”, i.e., a successively decreasing SDQ value. (e.g., Koenigswald and Kolfschoten 1996; Maul et al, 2000, 2014; Kalthoff et al, 2007; Maul and Markova 2007; Bogicevic et al, 2012, 2017; Lozano-Fernandez et al, 2013; Rekovets et al, 2014a).

The maximum age of the Umurlu fauna has to be dated to the early Toringian because *A. mosbachensis* appears there for the first time. As discussed in the taxonomic part, it is not finally decided, whether it deals in Umurlu with a "classical" *A. mosbachensis* or with a regional variant of *A. amphibius* with high SDQs, as observed in five extant specimens at Tatvan village (West of Lake Van, Eastern Anatolia; Röttger 1987).

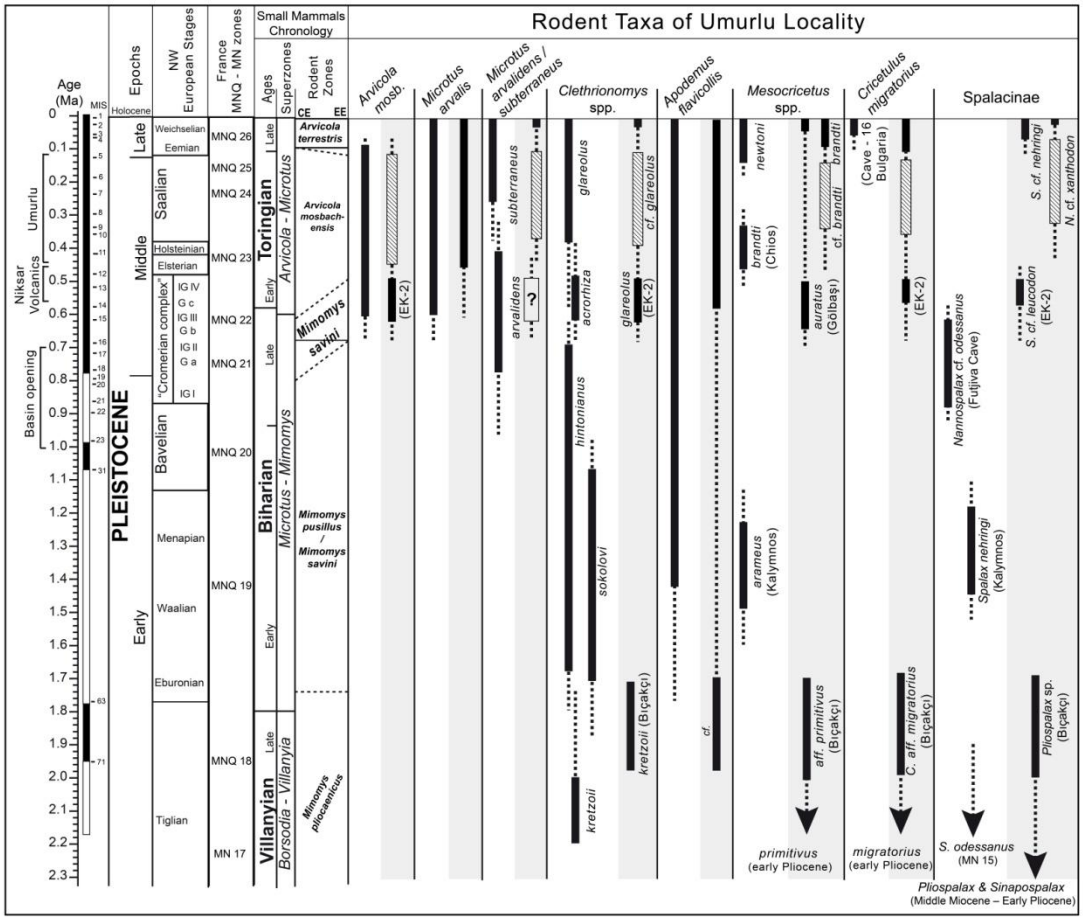


Figure 5.2 : Stratigraphic ranges of taxa mentioned in the text. The ranges of Umurlu species are displayed in light shaded bars. The chronostratigraphy and North-Western European stages are adapted after Global chronostratigraphical correlation table for the last 2.3 million years (GTS 2016); Mammalian Neogene and Quaternary zones after Popov (2017); small mammal ages and superzones after Masini and Sala (2007); MIS series, rodent biozones and non-Anatolian taxon ranges are modified after Maul and Markova (2007); Basin opening age range is after Barka et al. (2000); radiometric date ranges of Niksar Volcanics after Tatar et al. (2007). White columns for European, grey columns for Anatolian species. Abbreviations: CE– Central Europe, EE– Eastern Europe, EK-2– Emirkaya-2 locality, G– glacial, IG– interglacial, mosb.–mosbachensis.

However, the Umurlu sample is younger in any case than the early Toringian remains of *A. mosbachensis* from Mosbach-2 in Germany (Maul et al, 2000) and Isernia La Pineta in Italy (Masini and Sala 2007), where some specimens display

primitive characters such as a higher SDQ, incipient root formation and presence of the *Mimomys*-kante. In the Middle Pleistocene site of Emirkaya-2 in Anatolia, *A. mosbachensis* does not display such primitive characters but is associated with a *Mimomys* species (Figure 5.2; Montuire et al, 1994). Because of the high faunal resemblance with Horvölgy Cave in Hungary (Jánossy 1986) Emirkaya-2 is dated to the Holsteinian (ca. 0.4 Ma; Montuire et al, 1994, p. 136). However, Maul and Markova (2007) states that the latest occurrence of *Mimomys savini* population from Eastern Europe is dated somewhat to MIS 12 (~Elsterian). Therefore the age of the Emirkaya-2 fauna would be older than previously suggested, at least older than Elsterian (EK-2 in Figure 5.2) and may well correlate to the transition of *Mimomys*-*Arvicola*.

Since *Mimomys* is absent at Umurlu, this locality must be younger than Emirkaya-2 and much younger than the two Central European localities bearing *A. mosbachensis* with primitive features (e.g. higher SDQ, incipient roots, *Mimomys*-kante). Hence, Umurlu is younger than the early Middle Pleistocene, to maximum Elsterian. Considering that the rest of the Umurlu fauna constitutes extant species, only *A.* cf. *mosbachensis* would provide the minimum age, somewhat Eemian, or the transition between Middle and Late Pleistocene.

Microtus (*Terricola*) *subterraneus* is therefore, the first fossil record of this species from Anatolia. It has similarities but also differences with the *Microtus arvalidens* of which the fossil record is unknown from Anatolia (Krystufek and Vohralik 2005), if the material of *Microtus* (*Terricola*) sp. from Emirkaya-2 is not *M.* (*T.*) *arvalidens* (cf. question mark in Figure 5.2). The earliest occurrence of *M.* (*T.*) *arvalidens* in Central Europe is between Jaramillo Subchron and Cromerian Interglacial II (ca. 0.99–0.7 Ma), and in Eastern Europe after MIS18 (ca. <0.72) (see Maul and Markova 2007). The earliest remains of *M.* (*T.*) *subterraneus* date back to the early Saalian age (ca. 0.38 Ma; cf. Kolfschoten 1990) in Central Europe but, this range reaches to the Eemian (MIS5e; 0.12 Ma) in Eastern Europe (cf. Maul and Markova 2007).

Moreover, some faunas including both *A. mosbachensis* and *Microtus* (*T.*) *arvalidens* are reported from the Middle Pleistocene of Eastern Europe (i.e., Maul and Markova 2007; Rekovets et al, 2007, 2014), and Turkish Thrace (Santel and Koenigswald 1998) whereas *M. subterraneus* is reported together with *Arvicola amphibius* in the

Late Pleistocene Baranica and Hadzi Prodanova caves in Serbia (Bogicevic et al, 2012, 2017). Nevertheless, *M.* (*T.*) *subterraneus* from the early Saalian assemblage of Central Europe involves also specimens to be referred to *A. amphibius* with lower SDQs (i.e., <100), which are thought to be immigrant from Eastern Europe (Kolfschoten 1990), although Eastern European faunas had also *Arvicola* species with higher SDQ values in that period (Maul and Markova 2007).

Regarding the complexity of faunal exchanges as mentioned above, the co-occurrence of a younger *A.* cf. *mosbachensis* associated to the first fossil form of *Microtus* (*T.*) *subterraneus* in Anatolia near the Middle/Late Pleistocene transition appears to be plausible (cf. Figure 5.2).

The fossil fauna from Umurlu provides a biochronological dating for the depositional age of the fluvial unit between ca. 480 ka (i.e., ~Elsterian) and 130 ka (or Eemian, latest occurrence of *A. mosbachensis*). This is also congruent with the previous estimations on the geological age of the initiation of the Niksar Basin opening, which extends from 1–0.7 Ma (Figure 5.2; Barka et al, 2000) based on the radiometric dates of volcanics (0.56–0.46 Ma) which erupted using the NAF as a conduit (Tatar et al, 2007).

The age of the Umurlu site also provides insights on the activity of the North Anatolian Fault. As discussed previously, this unit should have been deposited by Kelkit River possibly within the proto?-Niksar Basin. After deposition, the unit was dissected and offset by the Ezinepazar Fault in dextral manner and uplifted where now it stands (relatively 130 meters higher than to the recent flood plain of the Kelkit River, 305 m amsl). Fault parallel measurements indicate that this offset is 6.5±1 km, which concurs with the maximum morphological offset along the fault (Figure 2.12B; Erturaç and Tüysüz 2012). The age proposed in this study (480–130 ka) does not allow to constrain the rate of horizontal slip for the easternmost portion of the Ezinepazar segment of North Anatolian Fault (~20 mm/year; e.g. Zabcı et al, 2015) or the overall uplift rate resolved on the southern block (up to 0.94±0.26 mm/year; Erturaç and Kıyak 2017). The Umurlu site stands as an excellent candidate to apply numerical dating methods (e.g. luminescence, see Rixhon et al, 2017) which would enable to (1) quantify the long-term horizontal and vertical geological slip rate of the fault and (2) determine the maximum occurrence age of *Microtus* (*Terricola*) *subterraneus* as well as other extant rodent species from Umurlu.

5.3.1 Paleoenvironmental assumption

The fossil faunal assemblage of Umurlu includes six extant species which can provides indications on the paleoenvironmental conditions, given that the ecological requirements of these species did not change in time. One of the most abundant species of arvicolines, *Microtus arvalis* was present in all layers (A–C) together with the wood mouse, *Apodemus flavicollis*, which points out a mixture of open environments with meadows, grasslands (*M. arvalis*) on the one hand, and forested and bushy vegetation covers (*A. flavicollis*) on the other (Krystufek and Vohralik 2005, 2009; Markov et al, 2012; Kolfschoten 2014; Berto et al, 2016). The forested and temperate environment is also supported by the presence of the bank vole, *Clethrionomys glareolus* in layer A. In present day of North Anatolia, *A. flavicollis* is less abundant compared to *A. witherbyi* and it becomes rarer from west to east. In addition, the wood mouse is a competitor of *A. sylvaticus*, especially in the absence of vegetation "shelter/cover" such as bushes or trees (Krystufek and Vohralik 2009).

The extinct *Arvicola mosbachensis* had possibly similar habitat preferences as the extant *Arvicola amphibius* which is mostly associated with streams, marsh-like vegetation cover with possible river banks (Krystufek and Vohralik 2005). *Microtus* (*Terricola*) *subterraneus* lives in moist meadows and temperate conditions in present time (cf. Krystufek and Vohralik 2005; Bogicevic et al, 2017). The Anatolian mammal fauna investigated by Krystufek and Vohralik (2005, 2009) points out rather confluent habitat ranges for all species. That statement is also true for the following members of the fauna which are represented only by one molar: the gray dwarf hamster *Cricetulus migratorius*, Anatolian hamster, *Mesocricetus* cf. *brandti* and the Anatolian mole rat *Nannospalax* cf. *xanthodon*. Nevertheless they are inhabitants of dry, semi-arid steppe-like environments with sparse vegetation cover, and display also tendency to avoid forested regions (Krystufek and Vohralik 2009; Neumann et al, 2017).

In overall, the occurrence of arvicoline species indicates a "mesophile" environment, while the abundance of *Apodemus*, although opportunistic (*sensu* Masini et al, 2005), the presence of *M.* (*T.*) *subterraneus* and the absence of some other rodents (i.e., *Spermophilus, Chionomys*) would indicate rather an interglacial period, according to the age estimation probably within the interval of MIS 12 and 5.

5.4 Perspective

This study attempted to draw attention to the shortcomings and compiles studies on small mammal paleontology of the Quaternary Period to this date, in addition to provide detailed systematic palaeontology of small mammals on Pliocene–Quaternary from three basins developed on North Anatolian Fault Zones, a biostratigraphic assumption on adjacent basins and on their formation history, revision of the already known species, unidentified or unpublished specimens as well as the new ones, inferences on paleoclimate on paleoenvironment.

One of the main motivation of this study is that the Anatolia bears many palaeontological data awaiting to be discovered in order to make a great contribution to the litterature. As to study area, three adjacent basins all along the North Anatolian Fault (NAF), have been studied already in geological manner but very lesser in paleontological aspect. Therefore, it would be a great opportunity to kickstart by these basins, Tosya, Suluova and Niksar, and to jump to other basins repeating the main paleontological and geological basic work to collect data and expand the the projet among the other NAF zones spanning from the Miocene to Holocene.

The Tosya Basin which was studied by many geologist (see Chapter 2.1) but only by two palaeontologists (Ünay and de Bruijn, 1998) are revisited, the number of specimen with detailed description is increased beside the number of new localities, and the age of deposits as well as formation of the basin is reworked. In this thesis, only the rodents are included although there have been collected but not defined many lagomorphs and soricids. These are subjected to future studies. On the other hand, Kumkapı locality is extremely much younger than we hypothetized (late Toringian instead of early Villanyian) which disprove the continual deposition of sediment of Kumkapı locality. That new problematic is subject to another study (Erdal et al., in prep; Erturaç et al, in prep).

The Suluova Basin, well studied by Eruraç (2010) is revisited to collect more sample potentially bearing rich fossil remains. Not surprisingly, the localities were not as rich as Tosya or Umurlu locality at the Niksar Basin, although some identifiable fossil remains are evaluated in a published work (Erturaç et al, 2019).

The Niksar Basin contributed to the Quaternary small mammal paleontology indeed just with one locality named Umurlu. Following detailed identification and

description of fossil material, the age of the deposit is clearly younger than previously thought. In future, some new prospections for potential fossil bearing layers should be organized in order to enhance and correlate the deposit.

According the biochronological ages of localities within three adjacent basins (Figure 5.3), the faunal succession is in accordance so it displays relatively well continuous record but it must be enhanced still by unidentified fossil remains of Tosya Basin.

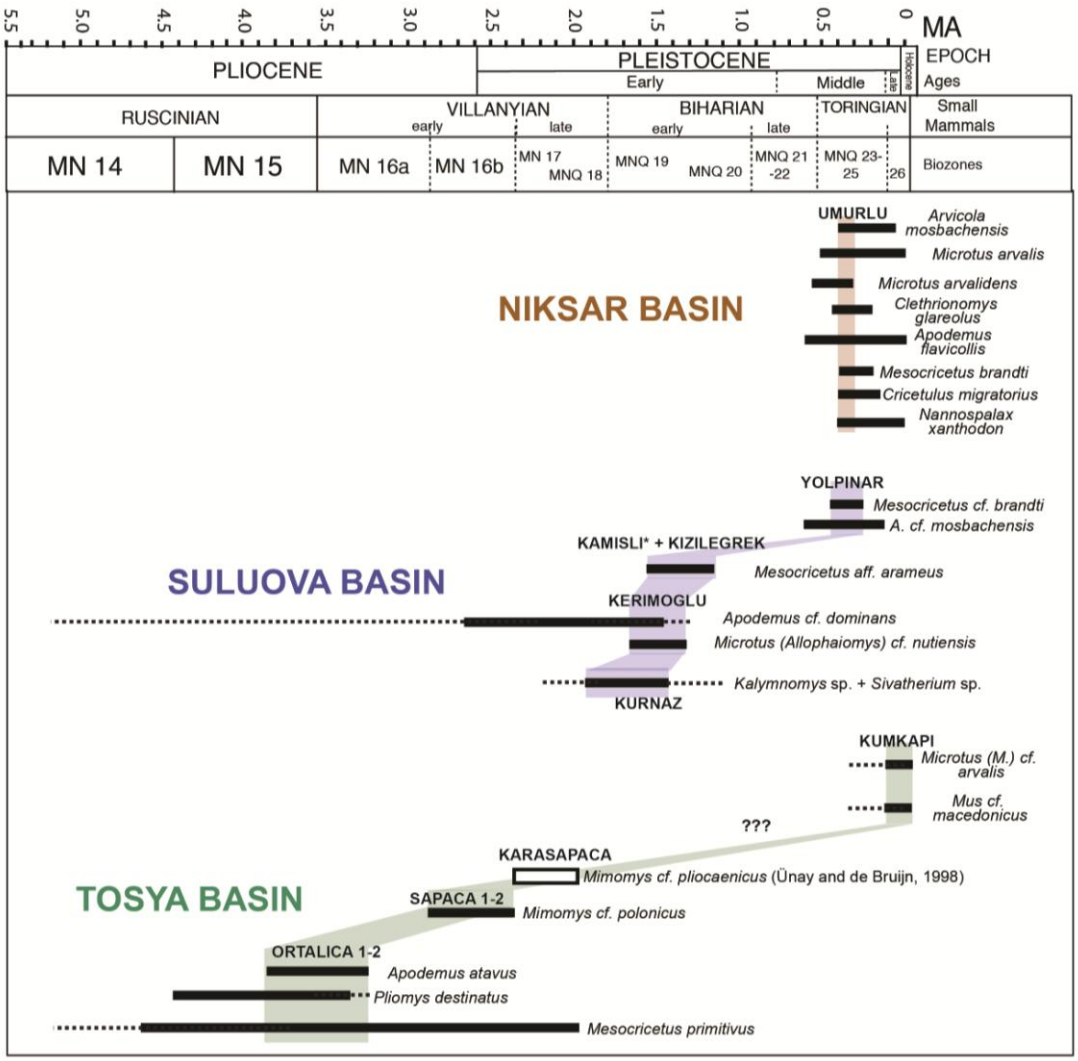


Figure 5.3 : A chronology showing the continuity of the three adjacent basins, based on fossil remains per locality.

It represents also the combination of the sedimentary record and mammal ages from three basins formed on the North Anatolian Fault. There is a distinct hiatus of ~1.2-0.7 Ma corresponding to Middle-Late Pleistocene, which points out a period of

which the climate speculative in origin or cause but evident in paleoclimate record, namely Middle-Late Pleistocene Transition This period is commonly correlated with the transition of dominant orbital parameters of the Earth, controlling and causing glacial-interglacial periods from 40 ka cycles to 100 ka cycles (i.e. Milankovitch Cycles).

One may speculates that this hiatus resulted by three different changes on the paleoenvironment of the study region.

1. Major changes in the watershed of the basins: Opening of Central Anatolian watershed to the Black Sea (Yeşilırmak/Kızılırmak) and capturing closed basins (Suluova and Tosya),

2. Major reconfiguration of the North Anatolian Fault forming new fault segments and rejuvenation of the basins,

3. Interactions between the climate and geodynamics of the region.

I may speculate that the deformation resolved on the NAFZ is not younger than 4.5 Ma in central part (Tosya Basin). The first major synthetic splay fault formation of the NAFZ started at Early Quaternary ~2.5 Ma and final stages of the shear zone development (Şengör et al, 2005, Şengör and Yazıcı, 2020) occurred since ~0.7 ma at the central part of the fault zone.

Note that there are potentially and concretely many Quaternary records of mammal remains in these basins in the exception of these hiatus, which would permit us to understand better the evolution of species as well as of the basins, and much more solid paleoenvironmental and paleoclimatical predictions and assumptions concerning the study area. That latter must be subjected also to span another adjascent basin in order to contribute to important data on the important fault, the North Anatolian Fault.

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APPENDICES

APPENDIX A: Table.A.1

APPENDIX A

Table.A.1. Selected *Apodemus* spp. from different localities for M1/m1 size comparisons (cf. Figure 4.8)

Taxon	Locality	Age	Study
A. atavus	(MCC5) Moncucco Torinese Piedmont NW Italy	Late Miocene	Colombero et al, 2014
	(TCH-1B) Tollo de Chiclana (Granada Basin)	early MN15	Minwer-Barakat et al, 2005
	AGU-1C	late Miocene or Pliocene	Garcia-Alix et al, 2008
	Bıçakçı	latest Villanyian	Ostende et al, 2015a
	CLC-3	late Miocene or Pliocene	Garcia-Alix et al, 2008
	CLC-3B	late Miocene or Pliocene	Garcia-Alix et al, 2008
	DSH-1	late Miocene or Pliocene	Garcia-Alix et al, 2008
	Gundersheim-Findling	MN15b	Fejfar and Storch 1990
	Komanos 1 high	Pliocene	Hordijk and de Bruijn 2009
	Komanos 1 low	Pliocene	Hordijk and de Bruijn 2009
	Moncucco 4	MN13	Colombero et al, 2014
	Moncucco3	MN13	Colombero et al, 2014
	Moncucco7	MN13	Colombero et al, 2014
	Notio 1	Pliocene	Hordijk and de Bruijn 2009
	PUR-13	late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-7	late Miocene or Pliocene	Garcia-Alix et al, 2008
	Saint-Vallier, Drome France	MN17 / early Pleistocene	Martin-Suarez and Mein 2004
	TOJ1 - Granada Basin (Spain)	early Pleistocene	Garcia-Alix et al, 2009
	Tomea Eksi 3	Pliocene	Hordijk and de Bruijn 2009
	Vorio 3a	Pliocene	Hordijk and de Bruijn 2009
	Willershausen	late Pliocene	Rietschel and Storch 1974 (in Maul and Parfitt 2010)
	Ortalıca	**MN15b**	**Erdal et al, in prep. (this study)**
A. aff. *atavus*	PUR-4	late Miocene or Pliocene	Garcia-Alix et al, 2008
A. cf. *atavus*	Elbistan	early Pliocene	Suata-Alpaslan 2009
	Taşova	MN15	Unay and de Bruijn 1998
	Tozaklar	MN15	Unay and de Bruijn 1998
A. dominans	Csarnota	MN15	Weerd 1976
	Çalta	Pliocene	Sen 1977
	Elbistan	early Pliocene	Suata-Alpaslan 2009
	Igdeli	MN14	Suata-Alpaslanet al, 2010
	Mas Rambault 2	MN17	Aguilar et al, 2002
	Muselievo (N Bulgaria)	Late Ruscinian (MN15b)	Popov, 2004
	Notio 1	Pliocene	Hordijk and de Bruijn 2009
	Ortalıca	MN15	Unay and de Bruijn 1998
	Rebielice	early Pleistocene	Pasquier, 1974
	Schernfeld	early Pleistocene	Pasquier, 1974
	Taşova	MN15	Unay and de Bruijn 1998
	Tourkobounia-1 (Greece)	early Pleistocene	Bruijn and Meulen 1975
	Wèze	early Pleistocene	Pasquier, 1974
A. cf. *dominans*	Hamamayağı	MN17-MQ1	Unay and de Bruijn 1998
	Kessani - Greece	MN13-14	Vasileiadou et al, 2012
	La Tour	late Miocene (Messinian)	Aguilar et al, 1982
	Monte Peglia	late early Pleistocene	Meulen 1973 (in Maul and Parfitt 2010)
	Yenice-1	MN16	Unay and de Bruijn 1998
A. flavicollis	Berlin	Recent	Pasquier 1974
	Central Germany	recent	Maul 2001 (in Maul and Parfitt 2010)
	Combe-Grenal	Late Pleistocene	Pasquier, 1974
	Emirkaya-2	Middle Pleistocene	Montuire et al, 1994
	France	Recent	Pasquier 1974
	Gondrenas	Late Pleistocene	Pasquier, 1974
	Kirchdorf	Recent	Pasquier 1974
	Pirro Nord 1	early Pleistocene	de Guili and Torre 1984 (in Maul and Parfitt 2010)
	Rincon de la Victoria (Malaga)	Late Pleistocene	Pasquier, 1974
	Santenay	Late Pleistocene	Pasquier, 1974
	Umurlu-Niksar	**Toringian**	**Erdal et al, 2018; this study**
	Üçağızlı Cave (Hatay)	Toringian	Suata-Alpaslan 2011
	Voigtstedt	early Middle Pleistocene	Maul 2001 (in Maul and Parfitt 2010)
	Zuurland Boreholes	Holocene	Reumer, 2003

Table.A.1 (*continued*.): Selected *Apodemus* spp. from different localities for M1/m1 size comparisons (cf. Figure 4.8)

A. cf. *flavicollis*	Bıçakçı	latest Villanyian	Ostende et al, 2015a
A. gorafensis	CAC-11	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	CAC-5	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	CAC-9	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	CLR-1	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	Dehesa-16	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	DSH-14	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	DSH-15B	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	Kessani - Greece	MN13-14	Vasileiadou et al, 2012
	Mina-4	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	MNA-2	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-23	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-24A	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-25	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-25A	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	PUR-4	Late Miocene or Pliocene	Garcia-Alix et al, 2008
	Tomea Eksi 1	latest Miocene / earlist Pliocene	Hordijk and de Bruijn 2009
	Tomea Eksi 2	latest Miocene / earlist Pliocene	Hordijk and de Bruijn 2009
A. gudrunae	Moncucco5 Italy	Late Miocene	Colombero et al, 2014
	La Fontana	MN13	Weerd 1976
	La Tour	Late Miocene (Messinian)	Aguilar et al, 1982
	Masada del Valle-7	Late Miocene or Pliocene	Weerd 1976 (in Minwer-Barakat et al, 2009)
	Moncucco3	MN13	Colombero et al, 2014
	Moncucco4	MN13	Colombero et al, 2014
	Moncucco7	MN13	Colombero et al, 2014
	Negratin-1	late Turolian - MN13	Minwer-Barakat et al, 2009
	Valdecebro-3	Late Miocene or Pliocene	Weerd 1976 (in Minwer-Barakat et al, 2009)
A. jeanteti	Nimes	MN15	Pasquier 1974
	Sète	MN15	Pasquier 1974
A. aff. *jeanteti*	Maritsa I	MN14	Bruijn et al, 1970
	Mas Rambault 2	MN17	Aguilar et al, 2002
A. mystacinus	Betfia-VII/3a	middle-late Biharian	Terzea, 1992 (in Siori and Sala 2007)
	Castagnone	early Biharian	Siori and Sala 2007
	Cueva Victoria (Murcia, Spain)	Biharian	Agusti 1982
	Emirkaya-2	Middle Pleistocene	Montuire et al, 1994
	Le Vallonet	Early Pleistocene	Lopez et al, 1976 (in Siori and Sala 2007)
	Mycènes	Recent	Pasquier, 1974
	Sivas Univ	Middle Pleistocene	Suata-Alpaslan 2009
	Üçağızlı Cave (Hatay)	Toringian	Suata-Alpaslan 2011
	Varkiza 1	Middle Pleistocene	Weerd 1972
	Varkiza 2	Middle Pleistocene	Weerd 1972
A. sylvaticus	Boxgrove	early Middle Pleistocene	Parfitt 1999 (in Maul and Parfitt 2010)
	Central Germany	recent	Maul 2001 (in Maul and Parfitt 2010)
	Grotte du Prince at Grimaldi	Late Pleistocene	Pasquier, 1974
	Hohensülzen	late Early Pleistocene	Storch et al, 1973 (in Maul and Parfitt 2010)
	Le Lazaret	Late Pleistocene	Pasquier, 1974
	Loma Quemada-1 (Granada Basin - Spain)	Early Pleistocene	Tarraco et al, 2015
	Orgnac	Middle Pleistocene	Pasquier, 1974
	Rhenen (Netherland)	Holocene	Kolfschoten, 1981 (in Reumer, 2003)
	Sima de los Huesos (lower layer-CHandB)	Middle Pleistocene	Cuenca-Bescos et al, 1997
	Sima de los Huesos (upper layer-DCBG)	Middle Pleistocene	Cuenca-Bescos et al, 1997
	Zuurland Boreholes	Holocene	Reumer, 2003
A. cf. *sylvaticus*	Podumci	late early Pleistocene	Malez and Rabeder 1984 (in Maul and Parfitt 2010)
	Torrent de Vallparadis (EVT7)	pre-post Jaramillo Event (Biharian-Toringian)	Minwer-Barakat et al, 2011
	West Runton (UK)	early Middle Pleistocene	Maul and Parfitt 2010
A. gr. *sylvaticus/ flavicollis*	Monte Argentario	Early Pleistocene	Siori et al, 2014

Table.A.1 (*continued*.): Selected *Apodemus* spp. from different localities for M1/m1 size comparisons (cf. Figure 4.8)

A. sylvaticus/ flavicollis	Hamamayağı	MN17-MQ1	Unay and de Bruijn 1998
	Kürttepe (Germencik)	Villanyian-Biharian boundary	Unay and de Bruijn 1998
A. witherbyi	Üçağızlı Cave (Hatay)	Toringian	Suata-Alpaslan 2011

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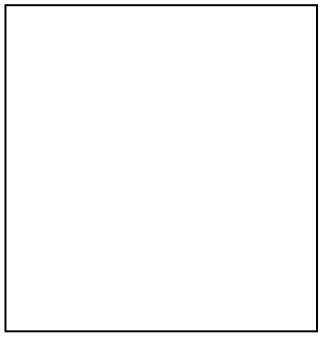

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- **B.Sc. Biology** **:** 2008, Uludağ University, Faculty of Sciences, Biology Department (Bursa, Turkey)
- **M.Sc. Paleontology** **:** 2012, Montpellier 2 University (France), Geosciences Faculty, Ecology and Biodiversity Department

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PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Erdal, O.,** Sevket, S & Erturaç, M.K. (*in prep*). Tosya revisited: Micromammals from the Pliocene-Pleistocene deposits with enhanced biostratigraphy dealing with climatic and environmental consequences.
- Erturaç, M.K., **Erdal, O.,** Sunal, G., Tüysüz, O. & Sen, Sevket (2019). Quaternary Evolution of the Suluova Basin: Implications on Tectonics and Palaeonvironment of the Central North Anatolian Shear Zone. Canadian Journal of Earth Sciences, 56(11):1239-1261. doi: 10.1139/cjes-2018-0306
- **Erdal, O.,** Erturaç, M.K., Dalfes, H.N. & Sen, S. (2018). Rodents from the Middle Pleistocene of Niksar Basin (Tokat-Turkey): implications on palaeoenvironment and the North Anatolian Fault. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, doi: 10.1127/njgpa/2018/0751
- **Erdal, O. (**2017). Küçük Memeli Paleontolojisinin Türkiye'deki Kuvaterner Çalışmalarına Katkısı: Tanımlar ve Uygulamalar / Contribution of micromammal palaeontology to Quaternary studies in Turkey: definitions and applications. Türkiye Jeoloji Bülteni / Geological Bulletin of Turkey 60, 637–664.
- **July 2019 Poster presentation**: "Paleoenvironment of the central north Anatolia during the MPT: A possible refuge for large & small mammals?" / INQUA 2019, Dublin, IRELAND.– **Erdal, O.**, Gumus, B.A., Erturac, M.K. & Okur, H.
- **July 2018 Oral presentation:** "Micromammals from the Pliocene and Quaternary deposits of North Anatolian Fault Zone: implications on age, paleoenvironment and dispersal in Anatolia" / 5th International Palaeontological Congress - The Fossil Week, Paris, FRANCE.– **Erdal, O.**, Erturaç, M.K., Dalfes, H.N. & Sen, S.
- **September 2017 Oral presentation**: "Tosya Havzası Pliyosen-Pleyistosen Depolanma Alanları: Mikromemeli buluntuları ve havza biyostratigrafisi" / Sedimantoloji Çalışma Grubu 2017 Çalıştayı (14-17 Eylül, RTE Üniversitesi, Rize).– **Erdal, O.**, Erturaç, M.K. & Sen, S.
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