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A preliminary zonation of the continental Neogene of Anatolia based on rodents

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The inventory of one hundred and sixty rodent assemblages from Anatolia ranging in age from Late Oligocene to Early Pleistocene has resulted in an informal local zonation for the Neogene. The sixteen zones recognized and the correlations to the MN scale suggested are based on the stage of evolution of the Muroidea. The Neogene succession of the Anatolian rodent faunas is briefly reviewed and compared to that of Europe. This leads to the conclusion that the Miocene faunas of Anatolia show a very pronounced endemism, which comes to an abrupt end during the Mio/Pliocene boundary interval.

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INTRODUCTION

The systematical search for fossil mammals in the Anatolian continental basins started in the 1960's when the need for biostratigraphical control was imminent for lignite exploration. The results of the collaborative programme of the M.T.A. (Geological Survey of Turkey) and the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, clearly showed the potential of a mammal-based biostratigraphy for unravelling the sedimentary and tectonic history of the complex intramontane basins of Anatolia (Sickenberg *et al.* 1975). As a consequence, this line of research became a standard addition to many M.T.A. mapping projects dealing with continental Tertiary sediments. In this way the information on the Neogene mammal fauna now available is overwhelming, but poorly accessible because it is either recorded in internal reports of the M.T.A. or published in specialized papers. Notable exceptions to this rule are Sickenberg *et al.* (1975), who presented a biostratigraphical overview of the Turkish Neogene mammal bearing deposits known at the time and Andrews *et al.* (1990), who elaborated on all aspects of the Middle Miocene hominoid site at Pasalar. More recently, teams working on tectonics and basin analysis feel the need for detailed mammal-based biostratigraphical data. Simultaneously the interest in fossil mammal communities is enhanced, because they serve as a tool for making paleogeographical and paleoclimatological reconstructions. In order to make the exact location,

faunal content and inferred age of all Turkish fossil mammal localities accessible we have started to make a database that more or less follows the Helsinki based NOW system. So far the coordinates of almost all of the ± 260 Anatolian mammal sites have been measured and the data from the literature have been entered. In the next phase we have (re)identified the rodents at the genus level and, when possible without taxonomical revision, at the species level. The first results of this work, essentially concentrating on the Neogene Muroidea because they dominate the rodent assemblages in terms of diversity as well as in number of specimens and show a high rate of evolution, are presented in the Tables 1 and 2. These tables, giving a selected number of taxa from forty-two selected localities that have been grouped into sixteen 'zones', should be seen as our interpretation of the data. The database contains about 160 rodent assemblages of different content and sample size. The 'zones' A to P are basically defined on a combination of species, but since some assemblages have not been studied in detail some of the species characterizing a particular zone are not yet formally named. First and last occurrences of genera in the Anatolian record are considered to have limited biostratigraphical value at this stage, because the record is incomplete. They have, however, been used in order to detect major migration events. Isolated, but interesting, occurrences of genera have, with the exception of *Calomyscus*, been omitted in this first concept. It is clear, however, that a single tooth of a *Melissiodon* in Kargı 2, or of a *Protalactaga* in Sofça will eventually be of primary importance for correlating our local zonation to other zonal systems. Tie points provided by radiometrical ages and by correlation of a locality to the GPTS are given in the column remarks of Table 1.

REMARKS ON THE TABLES 1 AND 2

The selected forty-two localities (Fig. 1) listed in the first column of Table 1 are grouped into sixteen zones A to P on the basis of the stage-of evolution of the Muroidea and Zapodidae. Their sequence within a zone is more or less arbitrary because many of the assemblages have not been studied in sufficient detail to establish their age relationship. The first and last occurrences of genera of other (super) families given in columns 4 and

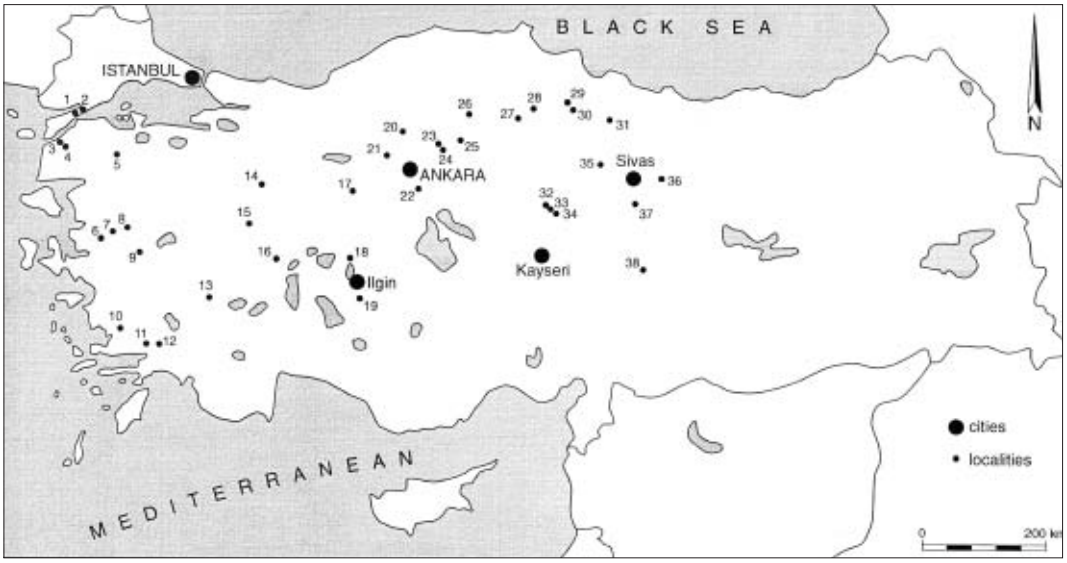

Figure 1 Map of Turkey indicating the approximate position of the localities listed in Table 1. The numbers refer to the Appendix.

5 have been added after the sequence had been established, so these have not influenced the position of the 'boundaries' between the zones. Selection criteria for the assemblages have been sample size, faunistic diversity and availability for study. The geographical position of the localities has not influenced our choice, because we have not been able to establish a correlation between geographical distance and fauna composition. The composition of the assemblages from Pasalar and Çandır, two localities that are similar in age but far apart, shows much more similarity than the ones from, for instance, Kangal 1 and Süleymanlı 2, which are grouped in the same zone and are geographically much closer. It therefore seems that difference in the biotope sampled has a much stronger influence on the composition of an assemblage than geographical distance does. The species that 'define' the zones, listed in the third column, are in some cases not formally named, so it is impossible at this stage to name the assemblage zones after the species that characterize them. The fourth and fifth column give, respectively, the first and last record in Anatolia of a selection of rodent genera. The main criteria for selection have been that they are relatively easy to identify and have biostratigraphical potential. In spite of the incompleteness of the Neogene rodent record of Anatolia the list of first and last occurrences shows conclusively that the Miocene sequence of entrees and exits is very different from that in Europe and central Asia. Although this listing is no doubt biased by differences in documentation between different zones, it strongly suggests that periods of fauna renewal alternated with periods in which endemic evolution prevailed.

In the sixth column 'Remarks' we have indicated when the rodent fauna of a particular zone has not been studied sufficiently, so formal names of the species characterizing the zone are not available. In this column we have also indicated the localities that have been radiometrically dated or have been correlated to the GPTS (data from the literature).

The last column of Table 1 gives our tentative correlation of the local zones A to P with the MP/MN schemes. This correlation is at this stage little more than a sophisticated guess based on the stage-of-evolution of the rodent faunas.

THE ZONES A TO P

The zones A to P are based on the association of the species of muroids and zapodids present in the associations assigned to a particular zone. The species selected to define the zones are usually common and relatively easy to identify in order to promote access to the zonal system by non-specialists.

Zone A is characterized by the dominance of *Meteamys alpani* and/or *Muhsinia steffensi*.

Zone B and C share *Eumyarion microps*, *Spanocricetodon sinuosis*, *Cricetodon versteegi* and *Heterosminthus* cf. *firmus*, but contain different species of *Deperetomys* and *Mirabella*: *D. anatolicus* and *Mirabella* sp. (de Bruijn & Saraç 1992) in zone B and *D. intermedius* and *M. anatolica* in zone C.

Zone D is charactized by *Cricetodon kasapligili*, *Eumyarion intercentralis*, *Mirabella crenulata* and *Democricetodon doukasi*.

Zone E is characterized by *Cricetodon tobieni*, *Anomalomys minor* or *aliveriensis*, *Democricetodon franconicus* or *gracilis* and *Mirabella tuberosa*.

Zone F is characterized by *Cricetodon pasalarensis* or *candirensis*, *Pliospalax marmarensis* and *Democricetodon gaillardi*.

Zone G is characterized by two not named species of *Cricetodon* that differ strongly in size and *Heterosminthus* cf. *mongoliensis*.

Zone H is characterized by *Byzantinia ozansoyi* and/or *bayraktepensis* and/or *cariensis* and/or *eskihisarensis*, *Anomalomys gaudryi*, *Myocricetodon eskihisarensis*, *Pliospalax canakkalensis* and *Heterosminthus orientalis*.

Zone I is characterized by *Progonomys cathalai* and *Byzantinia nikosi* and/or *dardanellensis*.

Zone J is characterized by *Byzantinia pikermiensis* and/or *uenayae*, *Pseudomeriones latidens* and the associated occurrence of

Table 1 An informal biozonation of the Anatolian continental Neogene based on Muroidea and Dipodidae and its tentative correlation to the European MN scheme. The entries and exits of a number of selected rodent genera that do not define the informal zones are given in the columns three and four.

Local Zones	Selected Localities	Rodent species (primarily Muroidea) that characterise the (sub) zone	First record selected genera in Anatolia	Last record selected genera in Anatolia	Remarks	Preliminary correlation to MN scale
P	Hamamayağı Yağmurlu	*Mimomys pliocaenicus/ostramosensis* *Tibericola sakaryaensis*	*Borsodia* *Clethrionomys* *Tibericola* *Kalymnomys*			17
O	Havza-Yenice Gülyazı	*Mimomys polonicus/septimanus* *Pliomys graecus* *Pliospalax tourkobouniensis*	*Lagurini*	*Pliomys*		16
N	Taşova Çalta Ortalıca	*Mimomys occitanus/gracilis* *Mesocricetus primitivus* *Pliospalax macovei* *Rhagapodemus frequens*	*Pliomys* *Solurus ** *Orientalomys **	*Pseudomeriones* *Occitanomys*		15
M	Kangal 2 Babadat İğdeli	*Mimomys cor/davakosi* *Promimomys insuliferus/cor*	*Mesocricetus ** *Cricetus ** *Mimomys ** *Promimomys ** *Bjornkurtenia **	*Promimomys* *Keramidomys* *Bjornkurtenia*	**Faunas not sufficient studied**	14
L	Süleymanlı 2 Kangal 1	*Hansdebruijnia neutrum* **two *Apodemus* species with fully developed t7** *Calomyscus ** *Micromys*	*Calomyscus ** *Micromys*	*Calomyscus* *Dipoides*	***Calomyscus* from Süleymanlı only. Faunas not sufficient studied**	13
K	Bayırköy Amasya 1 Düzyayla	*Byzantinia hellenicus* **two species of *Parapodemus/Apodemus* with t7 incompletely developed**	*Dipoides ** *Allactaga* *Hystrix **	*Byzantinia*		12
J	Cumalı Hayranlı 1 Karaözü	*Byzantinia pikermiensis/uenayae* *Pseudomeriones latidens* **The associated occurence of *Progonomys*, *Parapodemus*, *Apodemus* and *Occitanomys*** *Byzantinia dardanelensis/nikosi*	*Apodemus* *Parapodemus* **cf. *Blancomys **** *Pseudomeriones* *Occitanomys*	*Protalactaga* *Progonomys*	**Faunas not sufficient studied**	11 10
I	Aşağiçiğil Bayraktepe 2	*Progonomys cathalai*	*Progonomys **	*Cricetulodon*		9
H	Yenieskihisar ** Bayraktepe 1 Bağiçi Sarıçay Sofça	*Byzantinia ozansoyi/bayraktepensis* *Byzantinia cariensis/eskihisarensis* *Anomalomys gaudryi* *Myocricetodon eskihisarensis* *Pliospalax canakkalensis* *Heterosminthus* **cf.** *orientalis*	*Myocricetodon* *Cricetulodon ** *Atlantoxerus ** *Schreuderia* *Byzantinia* *Miopetaurista **	*Heterosminthus* *Atlantoxerus* *Eumyarion* **(medium)** *Megacricetodon* *Democricetodon* *Myocricetodon*	**Yenieskihisar radiometric 13.2. Ma**	7 + 8
G	Zambal	**Two unnamed *Cricetodon* species** *Heterosminthus* **cf.** *mongoliensis*		*Cricetodon*	**Faunas not sufficient studied**	6
F	Çandır 2 Paşalar	*Cricetodon pasaslarensis/ candirensis* *Pliospalax marmarensis* *Democricetodon gaillardi*	*Forsythia* *Albanensia ** *Eomyops ** *Protalactaga ** *Keramidomys **	*Sayimys*		5
E	Belenyenice ** Kaplangı Horlak 1a Dededağ	*Cricetodon tobieni* *Anomalomys minor/aliveriensis* *Democricetodon franconicus/gracilis* *Mirabella tuberosa*	*Pliospalax*	*Aliveria* *Mirabella* *Debruijnia*	**Belenyenice radiometric Ma 17.3 ± 0.4**	4
D	Kınık 1 Harta Keseköy	*Cricetodon kasapligili* *Eumyarion intercentralis* *Democricetodon doukasi* *Mirabella crenulata*	*Aliveria ** *Sayimys ** *Debruijnia ** *Megacricetodon **	**(small)** *Eumyarion* *Spanocricetodon*		3
C	Kınık 2 Harami 3 Harami 1 **	*Eumyarion microps* *Mirabella anatolica* *Spanocricetodon sinuosus* *Deperetomys intermedius*			**Harami 1 corr. to GPTS 22.9 Ma**	2
B	Kargı 2 Kılçak 0-3b	*Deperetomys anatolicus* *Cricetodon versteegi* *Mirabella* **sp.** (De Bruijn & Saraç, 1992) *Heterosminthus* **cf.** *firmus*	*Heterosminthus ** *Eumyarion ** *Mirabella ** *Democricetodon* *Enginia ** *Deperetomys **	*Meteamys* *Muhsinia*		1
A	Kargı 1 İnkonak **	*Meteamys alpani* *Muhsinia steffensi*	*Muhsinia ** *Meteamys ** *Spanocricetodon ** *Cricetodon **		**İnkonak corr. to GPTS 25.3-23.2 Ma**	MP 30

*** No potential ancestor known from older levels in study area**
**** Localities that are radiometrically or magnetostratigraphically dated**

Progonomys, *Parapodemus*, *Apodemus* and *Occitanomys*.
Zone K is characterized by *Byzantinia hellenicus* and two species of murids with dental patterns that are intermediate between *Parapodemus* and *Apodemus*.
Zone L is characterized by *Occitanomys* (*Hansdebruijnia*) *neutrum* and two species of *Apodemus* with a fully developed t7.
Zone M is characterized by *Promimomys insuliferus* and/or *cor* and *Mimomys davakosi*.
Zone N is characterized by *Mimomys occitanus* and/or *gracilis*, *Mesocricetus primitivus*, *Pliospalax macovei* and *Rhagapodemus frequens*.
Zone O is characterized by *Mimomys polonicus* and/or *septimanus*, *Pliomys graecus* and *Pliospalax tourkobouniensis*.
Zone P is characterized by *Mimomys pliocaenicus* and/or *ostramosensis* and *Tibericola sakaryaensis*.

CONCLUSIONS

The succession of Neogene rodent faunas of Anatolia presented schematically in the Tables 1 to 3 is very different from the European record in its composition as well as in the position of fauna turnovers. The change in composition of the rodent assemblages in Europe during the Oligocene/Miocene boundary interval is gradual (Alvarez Sierra *et al.* 1987), but in Anatolia there seem to be two sharp breaks: one within the Late Oligocene that is marked by the local extinction of the Ctenodactylidae while all the Muroidea are replaced, and the other (situated between zone A and B and provisionally correlated with the Oligocene/Miocene boundary) is marked by the appearance of the *Eumyarion microps* group, *Deperetomys*, *Democricetodon*, *Enginia* and *Heterosminthus*. The Early Miocene rodent record of Anatolia shows a surprisingly large number of genera that are neither known from Europe, nor from central Asia, while some others arrive much earlier in Anatolia than elsewhere. This suggests an east to west migration route. This assumption is in line with the paleogeographical map for the Early Miocene of the Peritethys recently published (Meulenkamp *et al.* 2000a,b), that shows the area that is now Anatolia bounded by the Tethys to the south and by the Alpine, Black sea, Caucasian and Caspian basins to the west and the north.

Table 2 shows a number of minor faunal turnovers during the Early and Middle Miocene that seem to coincide with the boundaries between our zones that are based on the stage-of-evolution of the Muroidea. This coincidence may, however, be due to lack of information from intermediate levels. The endemism of the Anatolian rodent fauna discussed above comes to an abrupt end at the boundary between zones L and M, a level that is provisionally correlated to the Miocene/Pliocene boundary. This level that is marked by the entry of *Promimomys*, *Microtodon*, *Mimomys*, *Cricetus* and *Mesocricetus* seems to mark an immigration event coming from the north that brings the Anatolian and European records in tune.

The Eomyidae, a family that is presumably of North American origin, reached central Asia and Europe at the 'Grande Coupure', but appears in the Anatolian record as late as the Middle Miocene. This immigration of the genera *Keramidomys* and *Eomyops* occurring in zone F may well correlate with the entry of these genera in MN5 in Europe.The Ctenodactylidae, a family that is presumably of central Asiatic origin is represented in the Oligocene record of Anatolia by two genera per assemblage, but is absent from zones A to C, the ctenodactylid vacuum. The entrance of the genus *Sayimys* in zone D seems to mark a second westwards migration of to the ctenodacylids that has reached the Arabian plate (Sen & Thomas 1979) and Africa where it formed the ancestral stock of the Miocene to Recent representatives of the family.

The Miocene history of the Murinae, a subfamily that seems to be of southeast Asiatic origin, is quite different in Anatolia and Europe. Although the genus *Progonomys* is

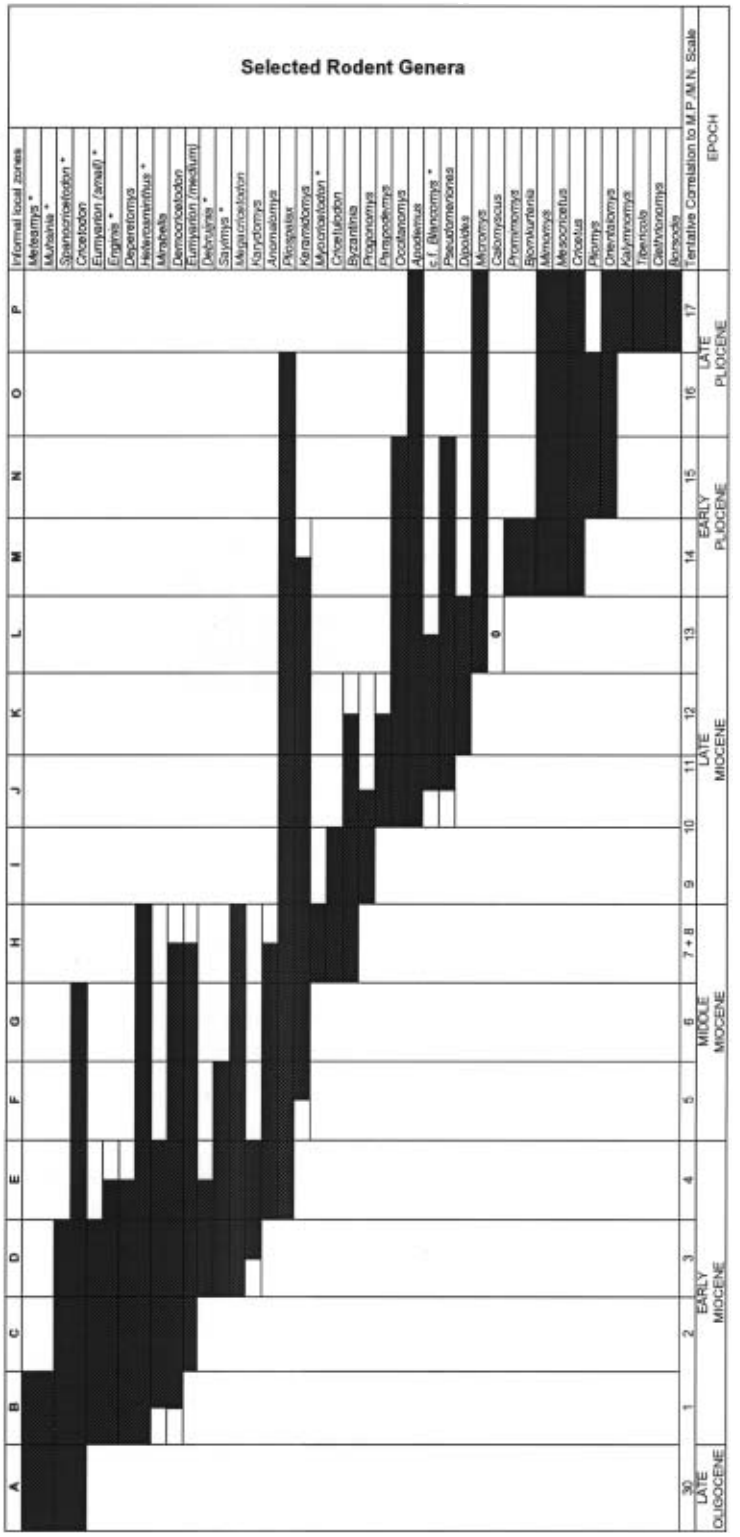

Table 2 The stratigraphical ranges of a number of selected rodent genera found in Anatolia relative to the informal zones defined above.

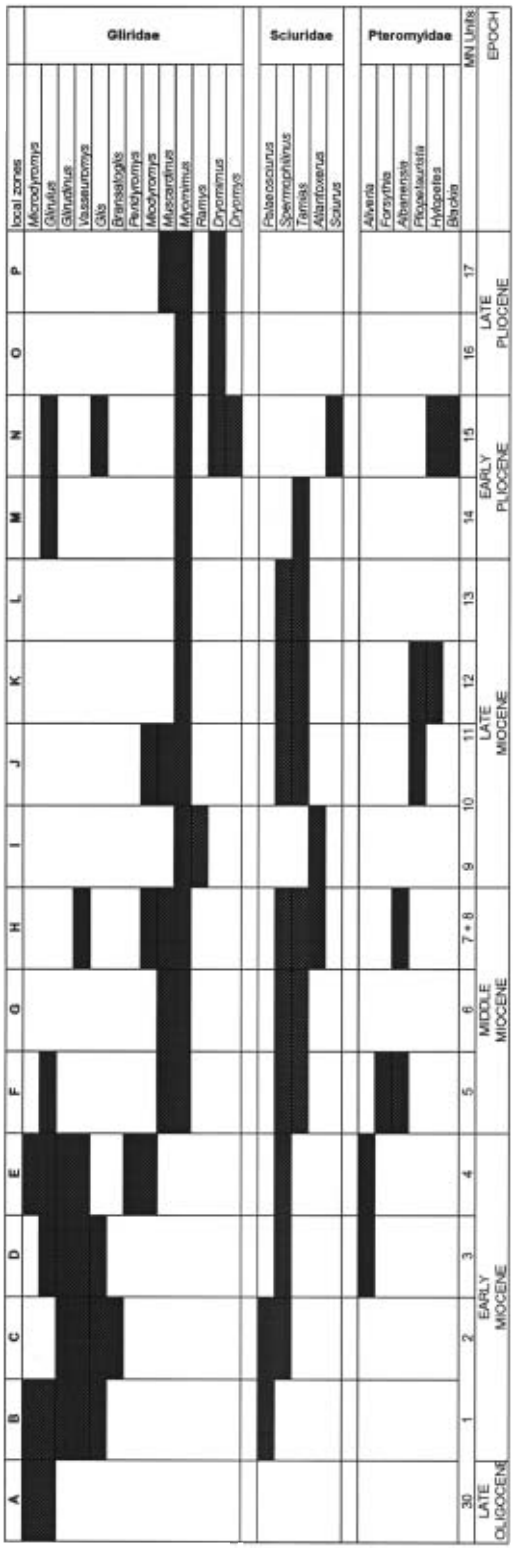

Table 3 The stratigraphical ranges of the genera of the rodents families Gliridae, Sciuridae an Pteromyidae found in Anatolia relative to the informal zones defined above.

the first to arrive in both areas, the next younger level in Anatolia contains *Progonomys* associated with *Parapodemus*, *Apodemus* and *Occitanomys* (zone J) an association that is not known from Europe.

The Gliridae, a family that is considered to have its origin in Europe, appears in Anatolia during the Late Oligocene. Although the family plays a modest role in the Neogene rodent record of Anatolia, it is quite diverse (six genera) in zones B to E, which are correlated with the Early Miocene (Ünay 1994). Their Middle Miocene record is erratic, with the exception of the ever-present genus *Myomimus* that does not seem to show much evolutionary change (Table 3). The entry of the genera *Dryomimus* and *Dryomys* is in zone N.

The Sciuridae and Pteromyidae, two families of unknown origin, are not known from the Anatolian Oligocene and remained rare throughout the Neogene. The first record of the Sciuridae is *Palaeosciurus* in zone B, and the first Pteromyidae is *Aliveria* in zone D (Table 3). These late entries of the families (in comparison to Europe), contrast with the earlier records of many genera of Muroidea in Anatolia. Moreover, all the genera of squirrels and flying squirrels are known from Europe also. This suggests that the squirrels were not part of the same immigration events that brought the Muroidea. In this context it is peculiar that the Xerini (a tribe that is very well represented in the Miocene assemblages of southwestern Europe) is known by a few isolated teeth of *Atlantoxerus* in the zones H and I only.

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APPENDIX List of localities given in column 1 of Figure 1 with coordinates , local zone and epoch assignment.

Number	Locality Name	Coordinates						Local Zone	Epoch
1	Bayırköy	40	22	4,0	26	34	0,4	K	Late Miocene
2	Cumalı	40	19	11,1	26	34	16,1	J	Late Miocene
3	Bayraktepe 1	40	6	14,8	26	25	1,3	H	Middle Miocene
4	Bayraktepe 2	40	6	10,4	26	25	26,2	I	Late Miocene
5	Paşalar	39	58	4,0	26	17	50,5	F	Middle Miocene
6	Belenyenice	38	47	57,2	27	26	43,4	E	Early Miocene
7	Harta	39	2	15,3	27	44	19,9	D	Early Miocene
8	Kınık 1	39	5	36,5	28	11	0,5	D	Early Miocene
9	Yagmurlu	38	25	2,1	28	16	2,4	D	Late Pliocene
10	Dededağ	37	39	5,5	27	23	59,6	E	Early Miocene
11	Sarıçay	37	19	52,4	27	47	39,7	H	Middle Miocene
12	Yenieskihisar	37	18	40,4	28	2	44,7	H	Middle Miocene
13	Amasya 1 *	37	37	0,7	20	27	37,2	K	Late Miocene
14	Sofça	39	38	46,3	30	10	43,4	H	Middle Miocene
15	Kaplangı	38	48	18,1	29	50	11,3	E	Early Miocene
16	Gülyazı	38	16	12,3	30	10	58,1	O	Late Pliocene
17	Babadat	39	31	51,1	31	38	52,5	M	Early Pliocene
18	Harami 1/3	38	27	27,2	31	49	30,8	C	Early Miocene
19	Asağıçiğil 1	37	2	50,1	31	50	1,3	I	Late Miocene
20	Keseköy	40	39	51,6	32	40	51,5	D	Early Miocene
21	Çalta	40	14	21,8	32	32	39,0	N	Early Pliocene
22	Bağiçi	39	31	56,8	32	54	42,0	H	Middle Miocene
23	Kılçak 0-3b	40	12	52,4	33	24	20,5	B	Early Miocene
24	Çandır 2	40	17	41,6	33	29	12,0	F	Middle Miocene
25	Süleymanlı 2	40	30	54,4	33	37	27,6	L	Late Miocene
26	Ortalıca	41	3	2,1	34	14	56,0	N	Early Pliocene
27	Kargı 1/2 *	40	52	41,1	34	52	56,4	A/B	Early Pliocene
28	Zambal	41	2	59,8	34	59	3,0	G	Orta Miocene
29	Hamamayağı	40	58	25,3	35	47	9,3	P	Plio/Pleistocene
30	Yenice *	40	59	20,0	35	48	15,7	O	Late Pliocene
31	Taşova *	40	30	18,5	36	15	22,0	N	Early Pliocene
32	İğdeli	39	11	25,4	35	52	38,4	M	Early Pliocene
33	Karaözü	39	10	28,9	35	55	59,7	J	Late Miocene
34	Horlak 1	39	9	53,2	36	0	11,0	R	Early Miocene
35	Hayranlı 1	39	44	52,9	36	48	51,7	J	Late Miocene
36	Düzyayla	39	55	33,4	37	18	56,5	K	Late Miocene
37	İnkonak *	39	30	0	37	55	50,2	A	Late Oligocene
38	Kangal 1/2	39	21	1,7	37	1	48,7	L	Late Miocene

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