The Evolution of Western Eurasian Neogene Mammal Faunas

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Raymond L. Bernor, Volker Fahlbusch, and Hans-Walter Mittmann

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Circum-Mediterranean Neogene (Miocene and Pliocene) Marine—Continental Chronologic Correlations of European Mammal Units

F. F. STEININGER, W. A. BERGGREN, D. V. KENT,
R. L. BERNOR, S. SEN, AND J. AGUSTI

This paper is an update of Steininger et al. 1989. It is mainly concerned with the chronologic correlation of the Miocene and Pliocene European Mammal Biozonations, the "European Neogene Mammal Faunal Zones" (MN zones, for discussion see Steininger et al. 1989) and the "European Mammal Faunal Units" (Agenic, Orleanic, etc., of Fahlbusch 1975; for discussion see Steininger et al. 1989), with the new Geomagnetic Polarity Time Scale (Cande and Kent 1992; in press) and the revised Geomagnetic Polarity Time Scale, Cenozoic Geochronology, Chronostratigraphy, and Planktonic Foraminifera Zonation (Berggren et al., in press).

Within the last years rapid progress has been made in dating mammal-bearing Miocene and Pliocene sediments, either by radioisotopic dating (see also Swisher et al., this volume) and/or by geomagnetic dating (see also the following articles in this volume: Bernor et al.; Kappelman et al.; Sen; and Woodburne et al.). These recent results have been incorporated into this new data base. For a more recent compilation of the Pleistocene record see Agusti 1991 and Agusti et al. 1987.

This paper could not have been written without the continuous input of comments and new data by the following colleagues, who, in a more correct sense, are coauthors of this paper and are listed (in alphabetical order) gratefully below: Jean-Pierre Aguilar (Montpellier, France); Hans de Bruijn (Utrecht, Netherlands); Gudrun Daxner-Höck (Wien, Austria); Volker Fahlbusch (München, Germany); Leonard Ginsburg (Paris, France); Kurt Heissig (München, Germany); K. Kowalski (Kraków, Poland); G. D. Koufos (Thessaloniki, Greece); Pierre Mein (Lyon, France); Jacques Michaux (Montpellier, France); Michael Rasser (Wien, Austria); Fred Rögl (Wien, Austria); Danilo Torre (Firenze, Italy); Engin Ünay (Ankara, Turkey).

The Neogene (Miocene and Pliocene) Geomagnetic Polarity Time Scale, Geochronology, Chronostratigraphy, and Planktonic Foraminifera Magnetobiochronology

Neogene Chronostratigraphy

A three-fold subdivision of the Miocene is generally accepted by most stratigraphers (Berggren et al. 1985a, b). The relationship between calcareous plankton biostratigraphy and standard chronostratigraphic units was discussed at length in Berggren et al. 1985a and 1985b, and the reader is referred to that source for background information. We review here only several (minor) adjustments and/or studies that have been made since 1985.

The Paleogene/Neogene Working Group of the IUGS Neogene Subcommission (under the leadership of Fritz F. Steininger) has been focusing on the definition of a GSSP (Global Stratigraphic Section and Point) for the Neogene and the Paleogene/Neogene boundary for over a decade. It has recently been decided (Steininger et al. 1994) to recommend that the GSSP be located at the 35-m level of the Rigoroso Formation in the Lemme-Carrosio section of NE Italy corresponding to the base of Chron C6Cn.2n and the FAD of *Globorotalia kugleri* with an age estimate of 23.8 Ma (Cande and Kent, in press; Berggren et al., in press; Hodell and Woodruff 1994). For a somewhat different point of view see Srinivasan and Kennett (1983).

The Aquitanian/Burdigalian Boundary The Aquitanian/Burdigalian boundary in the Contessa section (Gubbio, Italy) has been correlated with the FAD of *Globigerinoides altiapertürus* (Iaccarino 1985), and the Burdigalian/

Langhian boundary with the FAD of *Praeorbulina sicana* (Cita and Blow 1969).

The Burdigalian/Langhian Boundary The base of the Langhian Stage was subsequently said (Cita and Blow 1969) to correspond to the FO of *Praeorbulina bisphericus* (vel *sicana*), which is stratigraphically slightly lower in order than the FO of *Praeorbulina glomerosa* (Blow 1969; Cita and Premoli Silva 1968; Jenkins et al. 1981). We use the FO of *Praeorbulina sicana* (not *bisphericus*) to denote the base of the Langhian Stage.

The Langhian/Serravallian Boundary The Langhian/Serravallian boundary remains somewhat controversial (see discussions in Berggren et al. 1985a, b; Iaccarino 1985). Originally defined so as to coincide with the LAD of *Praeorbulina glomerosa* (Cita and Premoli Silva 1968), which occurs within the interval of Zone N 9 (Blow 1969), it was subsequently defined to coincide with the N 10/11 boundary of Blow (1969) in Cita and Blow 1969. Iaccarino (1985) draws attention to the fact that the upper limit of the type Langhian coincides with the top of the Cessole Formation as originally defined by Cita and Premoli Silva (1960), coincident in turn, with the top of their *Orbulina suturalis* Zone, a level that is within the upper part of Zone N 9 of Blow (1969). Iaccarino (1985) accordingly equated the Langhian/Serravallian boundary with the LAD of *Praeorbulina glomerosa,* which she indicates is approximately correlative with the upper part of the *Orbulina suturalis* Zone, which is correlative, in turn, with the upper part of Zone N 9. Our data indicate that these events occur essentially simultaneously and coincident with the FAD of *Globorotalia peripheroacuta* (= Zone N 9/10 boundary of Blow 1969, 1979 and M 6/7 boundary of Berggren et al., in press), and we have thus drawn the Langhian/Serravallian boundary coincident with the Zone N 9/10 (= M 6/7) boundary. This level would appear to be consistent with, and equivalent to, the base of the Serravallian type section as (re)defined by Vervloet (1966) and correlated with the base of his *Globorotalia menardii* (including *Gt. praemenardii*) Zone. The FAD of *Gt. praemenardii* coincides essentially with the base of Zone N 10 (Bolli and Saunders, 1985).

The Serravallian/Tortonian Boundary The upper limit of the Serravallian Stage, as redefined by Boni (1967) and Mosna and Micheletti (1968) in the Gavi section, is older than the FAD of *Globorotalia lenguaensis,* whereas the Arguello-Lequio parastratotype section of Cita and Promoli Silva (1968) includes a *Globorotalia mayeri–Gt. lenguaensis* Zone in its upper part, indicating that the upper stratigraphic limit of the Serravallian Stage is within Zone N 14 (Blow 1969) = M 11 of Berggren et al. (in press). There is thus a short gap between the top of the Serravallian and the base of the Tortonian that lies within (the lower part of) Zone N 15 (= M 12) and perhaps upper N 14 (= M 11).

The Tortonian/Messinian Boundary The lower boundary of the Messinian Stage has undergone several modifications over the past forty years (compare Gianotti 1953; Selli 1960; d'Onofrio et al. 1975; Colalongo et al. 1979); Colalongo et al. (1979) suggest that the GSSP of the Tortonian/Messinian boundary stratotype be linked with the FAD of *Globorotalia conomiozea* in the Falconara section in Sicily. In this study we follow this convention.

The Miocene/Pliocene Boundary This boundary is equated here with the base of the Zanclean Stage as stratotypified at Capo Rosello in Sicily (Cita 1975; Hilgen 1991; Hilgen and Langereis 1993; Langereis and Hilgen 1991), which appears to be bracketed by the FADs of *Globorotalia tumida* and *Gt. sphericomiozea* (below) and the FADs of *Ceratolithus acutus* and *G. puncticulata* and the LAD of *Discocaser quinqueramus* (above). An alternative point of view suggests that in view of the Perimediterranean lithologic unconformity between the nonmarine Messinian (below) and marine Zanclean (above) sediments and the difficulty of biostratigraphically extending the lithostratigraphic base of the Zanclean Stage away from its stratotype area, a boundary stratotype section should be sought in a continuous marine section outside the Mediterranean (for further discussion see Benson and Hodell 1994; Berggren et al., in press). For the purpose of this paper we follow the commonly accepted usage of base Pliocene = base Zanclean *sensu* Cita 1975 (see also Hilgen and Langereis, 1993).

Paratethys Chronostratigraphy

Correlation of the Paratethys Neogene chronostratigraphic stage system has undergone an extensive revision by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) for upper middle Miocene, upper Miocene, and Pliocene. An extensive compilation including new radioisotopic ages for the Miocene of the Eastern Paratethys was published lately by Chumakov et al. (1984; 1992a, b) and a compilation of the geomagnetic calibration of the Sarmatian s.l. mammal localities has coincidently been published by Pevzner and Vangengeim (1993). Only the most pertinent results will be summarized here.

Central Paratethys The base of the Sarmatian Stage sensu SUESS is recalculated by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 13.6 Ma; the base of the Pannonian Stage by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 11.5 Ma; the base of the Pontian Stage by Rögl et al. (1993) and Rögl and Daxner-

Höck (this volume) at 7.1 Ma; and the base of the Dacian Stage by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 5.6 Ma.

Eastern Paratethys The confusion in correlation of middle to late Miocene between the Central and the Eastern Paratethys arises because of inappropriate use of the Sarmatian Stage in the Eastern Paratethys; its stratotypic characterization is actually in the Central Paratethys. The base of the Eastern Paratethys Sarmatian "Stage" (sensu lato) in the Eastern Paratethys has been calibrated by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) as being 13.6 Ma; however the top of the Sarmatian s.l. is calibrated by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) as being 9.5 Ma. This Sarmatian s.l. of the Eastern Paratethys is subdivided into the following stages: Volhynian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 13.6 Ma; Bessarabian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 12.2 Ma; and Khersonian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 10.2 Ma. Above the Sarmatian s.l. follows the Maeotian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume): 9.8 Ma, followed by the Pontian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 7.1 Ma; and the Kimmerian Stage: base by Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) at 5.4 Ma. With this calibration the duration of the Pontian in the Central Paratethys seems to be somewhat shorter (0.2 m.y.) than the Pontian Stage as used in the Eastern Paratethys. This calibration of Rögl et al. (1993) and Rögl and Daxner-Höck (this volume) is based on biostratigraphic correlations and in accordance with the radioisotopic ages published by Chumakov et al. (1984; 1988; 1992a, b).

Pevzner and Vangengeim (1993) have summarized lately the geomagnetic results of the middle (= Bessarabian) and late (= Khersonian) Sarmatian mammal localities of the Eastern Paratethys. In their figures 5 and 6, the boundary of the early Sarmatian = Volhynian and the middle Sarmatian = Bessarabian falls into the lower part of Chron 11 = Chron C5An.2n. The base of subchron C5An.2n according to Berggren et al. (in press) is at 12.40 Ma, and the top at 12.18 Ma. The top of the Bessarabian, and the boundary between the Bessarabian and the Khersonian (= late Sarmatian), would fall into the upper third of Chron 10 = Chron C5r. In their figures 5 and 6, Chron 10 is shown to be a completely reversed zone. However, the geomagnetic pattern of their Eldari section (= their fig. 3) shows for Chron 10 the following pattern from base to top: longer normal = N-1-short reversal = R-1-normal = N-2-longer reversal = R-2-short normal = N-3-longer reversal = R-3, followed by the long normal of Chron 9 = subchron 5n.2n. According to the GPTS of Berggren et al. (in press) this geomagnetic pattern can be interpreted as follows: N-1 = C5An.1n; R-1 = C5r.3r; N-2 = C5r.2n; R-2 = C5r.2r; N-3 = C5r.1n; and R-3 = C5r.1r. The Bessarabian/Khersonian boundary in this section is drawn for biostratigraphic reasons below normal N-3 = C5r.1n: base at 11.09 Ma and top at 11.05 Ma. These ages are in good accordance with Rögl and Daxner-Höck (this volume), which we follow here. The Khersonian spans the upper part of Chron 10 = approximately Chron C5r.2r, C5r.1n, C5r.1r, Chron 9 = Chron C5n.2n up to the lowermost reversed part of Chron 8 = Chron C5n.1r. The Khersonian/Maeotian boundary would then fall at the Chron C5n.1r/C5n.1n boundary, with an age of 9.88 Ma, according to Berggren et al. (in press).

For the discussion concerning the proposed European Continental Chronostratigraphic Stages see discussion in Steininger et al. 1989 (pp.24 ff).

Chronology of Neogene Chronostratigraphy

The *Paleogene/Neogene*, or the *Oligocene/Miocene*, boundary, as calibrated to Chron C6Cn.2n, has an estimated age of 23.8 Ma and corresponds to the FAD of *Globorotalia kugleri* (Berggren et al. 1985; Cande and Kent 1992, 1994; Berggren et al., in press). The early Miocene is biostratigraphically bracketed by the FAD of *Gt. kugleri* (in Hodell and Woodruff 1994: slightly older: 23.99 Ma) and the FAD of *Praeorbulina sicana* (C5CN.1n: 16.49 Ma), giving the early Miocene a duration of 7.4 Ma.

The Aquitanian/Burdigalian boundary has been correlated with the LAD of *Globorotalia kugleri* (= Zone N 4/5 boundary of Blow 1969, 1979; = M 1/2 boundary of Berggren et al., in press), but it has also been correlated with the FAD of *Globigerinoides altiapertunus* in Mediterranean and Aquitaine Basin stratigraphies (see discussion in Montanari et al. 1991). The LAD of *Gt. kugleri* has been observed in Chron C6Ar (with an estimated age of 21.5 Ma: Cande and Kent, in press; Berggren et al., in press) in Hole 516F, whereas it has been recorded at the base of C6An (with an estimated age of 21.32 Ma; Cande and Kent, in press; Berggren et al., in press) in the Contessa Highway section (Montanari et al. 1990; 1991) and with an estimated age of 21.07 Ma in Hole 289 (Hodell and Woodruff 1994). The FAD of *Globigerinoides altiapertunus* has been recorded at the top of C6An (with an estimated age of 20.52 Ma [Cande and Kent, in press]) in Hole 516F, whereas it has been recorded in the older part of C6r (with an estimated age that is indistinguishable from that of the record at Hole 516F: 20.5 Ma, in view of the fact that the entire C6r is only 0.387 kyrs long) in Cande and Kent's chronology (1993 unpublished); Berggren et al. (in press) on the Contessa Highway section (Montanari et al. 1991).

Accordingly, we would recommend correlation of the Aquitanian/Burdigalian boundary with the top of Chron

C6An (with an estimated age of 20.52 Ma; (Cande and Kent 1992, 1993; Berggren et al. 1995); this procedure would facilitate regional/global correlation and would correspond with generally accepted practice in Mediterranean stratigraphies where Neogene chronostratigraphy is rooted (Van Couvering and Berggren 1977). We note, in passing, the close temporal correspondence between the estimated ages of Chron C6An in the chronologies of Cande and Kent (in press), Berggren et al. (1995), and Montanari et al. (1991). The latter have obtained an isochron age of 21.17 ±0.23 Ma based on $^{40}Ar/^{39}Ar$ dating of plagioclase on an ash termed the Livello Rafaello, about a half meter below the LAD of *Gt. kugleri* and the base of C6An. Chron C6An has an estimated age of 20.518–21.320 Ma in the magnetochronology of Cande and Kent (in press).

The Burdigalian/Langhian boundary (= FAD of *Praeorbulina glomerosa*) is calibrated to the base of C5C.2n: 16.49 Ma (Cande and Kent 1992, 1994; Berggren et al., in press).

The middle Miocene is biostratigraphically bracketed by the FAD of *Praeorbulina sicana* and a level within Zone M 12 (i.e., between the LAD of *Neogloboquadrina mayeri* and the FAD of *N. acostaensis* (cf. Berggren et al. 1985a, b, in which the middle/upper Miocene boundary was pragmatically, but incorrectly, correlated with the FAD of *N. acostasensis*). The restoration of Zone M 12 = N 15 (Berggren 1993) with an estimated duration of about 0.5 m.y. between 11.4 and 10.9 Ma (Berggren et al. 1995) suggests that the middle/late Miocene (Serravallian/Tortonian) boundary is in Chron C5r.2r at 11.2 Ma.

The Langhian/Serravallian boundary is correlated here with the FAD of *Globorotalia peripheroacuta* at the top of C5Bn.1n: 14.8 Ma (Cande and Kent 1992, 1995; Berggren et al., in press). The middle Miocene has a time span of about 5.3 Ma (16.49–11.2 Ma).

The late Miocene (Tortonian and Messinian Stages) is bracketed biostratigraphically by a level within Zone M 12 (= Zone N 15, 7E11.2 Ma) to a level slightly higher/younger than the FAD of *Globorotalia tumida* (M 14/Pl 1 boundary) and/ or *G. sphericomiozea*, which lies within Chron C3r with an estimated age of 5.6 Ma (Berggren et al., in press).

The Tortonian/Messinian boundary is correlated here with the FAD of *Globorotalia conomiozea*, which has been magnetobiostratigraphically correlated in Crete with Chron C3Br.1r and has an estimated (astrochronologic) age of 7.1 Ma (Krijgsman et al. 1994). Calibration to Cande and Kent 1992 yields an age estimate of 6.92 Ma and to the chronology subsequently derived by Cande and Kent (1995) and adopted here a magnetochronologic age estimate of 7.12 Ma, essentially identical to the age estimate of Krijgsman et al. (1994). A slightly younger position for the FAD of *G. conomiozea* in Chron C3Bn has been reported by Benson and Rakic-El Bied (1991) in the Vera Basin of Spain, which would place this event at approximately 7.0 Ma in the chronology adapted here. Thus the astrochronologic and the magnetochronologic scales are seen to be coherent and concordant back to Chron C3Br, at approximately 7.0 Ma. At the same time we note that the late Miocene (Chron 6) carbon shift has been observed to start near the base of Chron 6 in Hole 588 (Hodell and Kennett 1986) = Chron C3Br.2r (7.20 Ma in Cande and Kent 1992; 7.4 Ma in Cande and Kent 1995; 7.34 Ma in Berggren et al., 1995).

An age of 7.26 ±0.1 Ma for the Tortonian/Messinian boundary in the Northern Apennines of Romagna was recently suggested by Vai et al. (1993) based on a K/Ar (biotite) and a $^{40}Ar/^{39}Ar$ (plagioclase) date of 7.33 Ma on volcanogenic horizons a few meters below the FAD of *Globorotalia conomiozea* and *Gt. mediterranea* and a K/Ar (biotites) date of 7.72 ±0.15 Ma on the stratigraphically lower FAD of *Globorotalia suterae* (which agrees closely with the magnetochronologic estimate for this datum event proposed here; cf. the estimate of 5.6 Ma and correlation to Chron C3An for the Tortonian/Messinian boundary by Langereis and Dekkers [1992]). The late Miocene thus has a span of about 6 m.y. (11.2–5.3 Ma). In a recent integrated magnetobiostratigraphic study of the Sorbas (Andalusia, Spain) and Caltanisetta (Sicily, Italy) Basins the evaporitic phase ("salinity crisis" of the Mediterranean) has been shown to be restricted to Chron C3r (Gilbert reversed) and to have a duration of approximately 0.57 m.y.—from 5.89 to about 5.32 Ma in the chronology of this paper (Gaultier et al. 1994). The implication of these results is that the pre-evaporitic Messinian (7.12 to 5.8 Ma: 1.32 m.y.) represents about two-thirds of the duration of the Messinian Age itself (7.12 to 5.32 Ma: or 1.8 m.y.), whereas the "late"/evaporitic Messinian represents but one-third the duration of the Messinian Age (5.89 to 5.32 Ma: 0.57 m.y.).

There is considerable debate regarding the adoption of an astronomically (Hilgen and Langereis 1989) versus a magnetostratigraphically (Cande and Kent 1992; 1994) based Neogene time scale, but this is beyond the scope of this paper. At the present time the two scales have been reconciled and are consistent back to the Gilbert (= C3n + C3r)/C3An boundary at 5.89 Ma. The situation has been discussed at length in Berggren et al. (1995), to which the reader is referred.

Neogene Planktonic Foraminiferal Magnetobiochronology

Miocene About seventy planktonic foraminiferal datum levels have been identified in the Miocene, many of which were already recognized in Berggren et al. 1985a, b. We have (re)calibrated these datum levels following the revised magnetochronology of Cande and Kent (1992; 1995) (see also Berggren et al., 1995) and added several more. In some instances revisions/reinterpretations of magnetostratigraphy have resulted in revised age estimates for several datum levels as well. In general we have found our current analysis and/or evaluation of new (post 1985) date to be quite consistent with earlier interpretations and/or calibrations. The major difference between Berggren et al. 1995 and Berggren et al. 1985a, b is the more secure documentation of the regional correlation of the biogeographically overlapping zonal schemes adopted here within a more precise magnetochronologic framework.

Early Miocene We have recognized some twenty-two datum events spanning the 7.3 Ma interval of the early Miocene (23.8–16.49 Ma), or an average of about 2.7 events/1 m.y. Zones M 1 (2.24 Ma), M 2 (2.75 Ma), and M 3 (1.50 Ma) can be contrasted with the much shorter Zones M 4 and M 5 (and indeed middle Miocene Zones M 6, M 8–10 as well), reflecting the late/early to early/middle Miocene global warming trend and concomitant flurry of speciation events in (sub)tropical environments, which allows fine-scaled biostratigraphic subdivision. Of some consternation is the (continuing) lack of a direct magnetobiostratigraphic correlation of the FAD of *Globigerinatella insueta* (which defines the base of Zone M 3).

Middle Miocene Some twenty-five datum events have been identified in the middle Miocene (16.4–11.2 Ma) interval of 5.2 Ma, or an average of 4.6 events/1 m.y., which provides the highest degree of biostratigraphic resolution for the Cenozoic except for the Pliocene, where nearly forty-five different types of biostratigraphic events spread over the ca. 3 m.y. extent of the Pliocene provides some fifteen datum events/1 m.y. (Berggren et al. 1995). The warming trend responsible for the high degree of middle Miocene biostratigraphic resolution may be contrasted with the accelerated (and punctuated) cooling trends of the Pliocene responsible for the relatively rapid LADs of numerous (predominantly Miocene) taxa, the various biogeographic immigration/disappearance events and FADs of several taxa.

Late Miocene Some twenty-three datum events have been recognized in the 5.9 Ma interval of the late Miocene (11.2–5.3 Ma), or an average of events of about 3.9/1 m.y. Of particular significance is the replacement of the *Globorotalia merotumida-plesiotumida*–group by *Globorotalia lenguaensis* in subdividing the upper Miocene of (sub)tropical and transitional regions, which provides more confident calibration to the GPTS. The joint occurrence of the FAD of *Globorotalia sphericomiozea* and *Globorotalia tumida* in Hole 519 has provided a means for regional correlation between (sub)tropical and transitional regions at the Miocene/Pliocene boundary (5.2 Ma in the chronology of Cande and Kent 1992; 5.3 Ma in Cande and Kent 1995 and Berggren et al. 1995).

Plio/Pleistocene A comprehensive compilation has recently been made of some forty-five Pliocene and eight Pleistocene planktonic foraminiferal datum events in connection with a larger review of the current status of late Neogene (Plio/Pleistocene) astro- and magnetobiochronology (Berggren et al. 1995), and the interested reader is referred to that source for additional information. We adopt the current three-fold scheme for the Pliocene: Zanclean (early), Piacenzian (middle), and Gelasian (late) (Rio et al. 1994).

Correlation and Ages of Continental European Mammalian Biostratigraphic Units: "Neogene Mammal Faunal Zones" (MN Zones) and "Neogene Mammal Faunal Units"

For a general discussion of the philosophy of these mammalian biostratigraphic units, the "Neogene Mammal Faunal Zones" (the MN zones) and the "Neogene Mammal Faunal Units" (as there are: Agenian, Orleanian, etc.), see Steininger et al. 1989:20ff.

Here we discuss only the results of the present correlation to the different chronostratigraphic units, the geomagnetic time scale, and their most probable ages implied by these correlations according to Berggren et al. 1995. The biostratigraphic definition of the Faunal Zones (MN zones) and the Faunal Units is taken in general from Bruijn et al. 1992; Agusti et. al. 1986, 1991; and Berger 1992.

In our data base we have arranged the mammal localities: (1) according to their biochronological position and ages within the specific Mammal Zone, following in general the biochronologic arrangements of mammal localities by de Bruijn et al. (1992; see also their comments on pp. 69–71) and comments of various colleagues; and (2) followed by mammal localities that cannot be specifically arranged within the particular Mammal Zone.

Agenian (MN 1 to MN 2) (fig. 2.1)

The base of the Agenian (= base of MN 1) is best estimated with an age of: 23.8 Ma and correlates with the Oligocene/Miocene = the Paleogene/Neogene boundary as proposed by Steininger et al. (1994). This correlation is based on the geomagnetic calibration of the locality Torrente del Cinca 68 (Ebro Basin, Spain). The top is best geomagnetically calibrated by the upper MN 1 localities Findreuse 3, 4, 22, 27, 31, 33 and Fornant 13 (11) (Haute-Savoie, France) to an age of approximately 22.8 Ma.

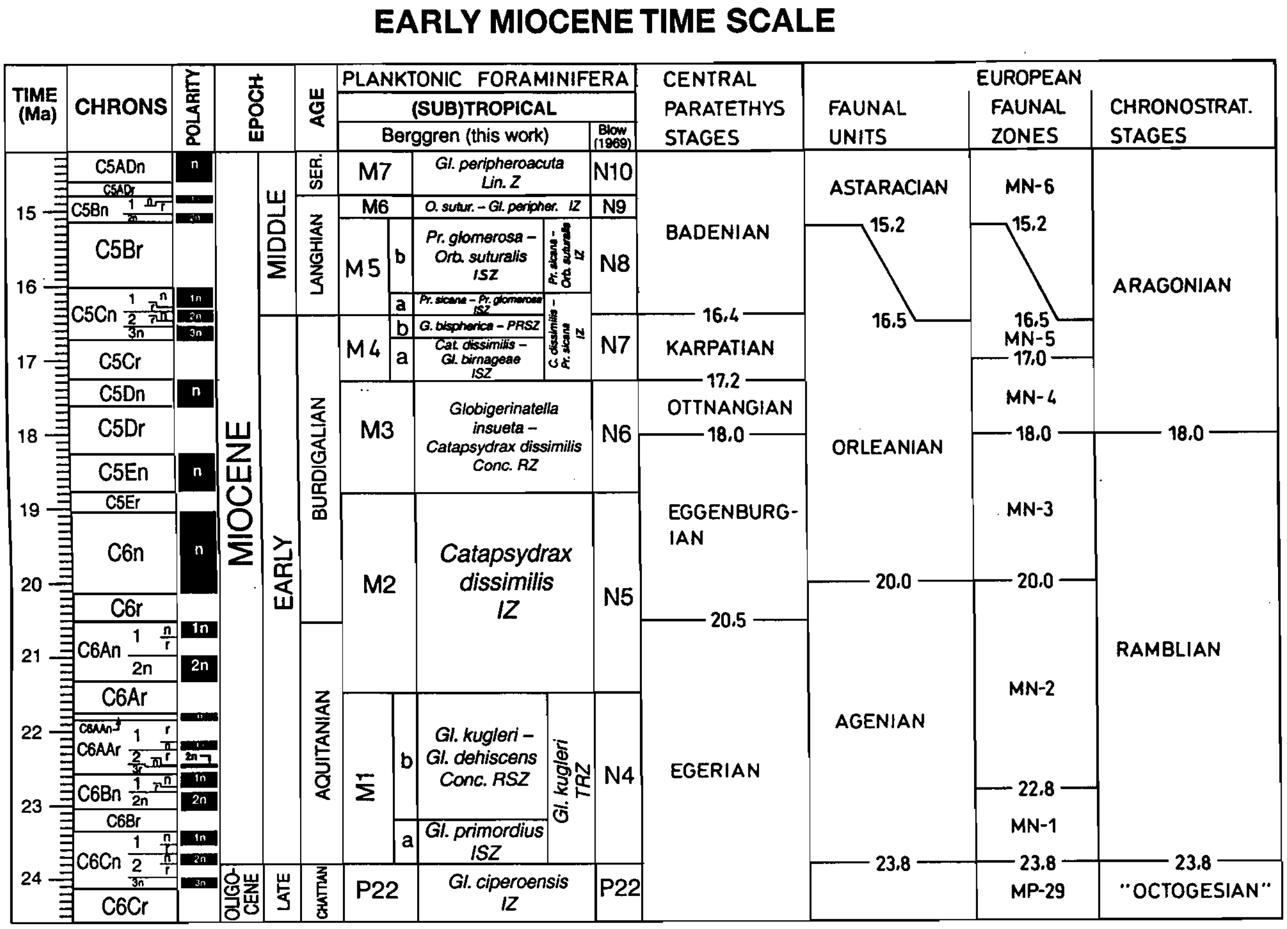

FIGURE 2.1 Early Miocene circum-Mediterranean marine-continental chronologic correlations of the European Mammal Units and Zones.

The base of MN 2 (fig. 1) is best estimated with an age of 22.8 Ma based on biostratigraphic ties and "grade dating" of Gans and Aillas (Bordeaux Basin, France); as is the top by localities Balizac, La Brete, and Laugnac (Bordeaux Basin, France), still intercalated into the type Aquitanian sediments and "grade dated" around 19.8 Ma with an age of 20.0 Ma.

Orleanian (MN 3 to MN 5) (fig. 2.1)

The base of Orleanian (= base of MN 3) is best estimated with an age of 20.0 Ma. This estimate is based mainly on unpublished strontium dates (87Sr/86Sr: 0.708581; Scharbert and Steininger, in prep.) from Maigen (Molasse Zone, Austria) and the litho-biostratigraphic correlations of Lisboa (Portugal), Estrepouy, and Laugnac (Bordeaux Basin, France) with "grade dates" circa 19 Ma. Averages for the top are best estimated at Beaulieu (France) by biostratigraphic ties and radiometric estimates of 18.7 to 17.5 Ma with an age of 18.0 Ma.

The base of MN 4 is best estimated around 18 Ma by the locality Belchatowc (Poland). The top can be estimated by the geomagnetically calibrated localities of Gemerek, Horlak 1a, 1b and 2 (Kayseri-Sivas Basin, Turkey), with an age of 17.0 Ma. However, ages younger than 17 or 16.5 Ma have to be considered in relation to the oldest well-established estimates of MN 5 and MN 6 (see below). The age of 14.1 Ma for the MN 4/5 boundary calculated by Krijgsman et al. (1994) is in contradiction with all estimated ages for this boundary so far.

The base of MN 5 is best estimated as being 17 Ma based on the localities of Gemerek, Eibiswald (Styrian Basin, Austria), Belthalów (Poland), and Teiritzberg (Korneuburg Basin, Austria).

Astaracian (MN 6 to MN 8) (figs. 2.1, 2.2)

The base of the Astaracian (= base of MN 6) depends on where the biostratigraphic position of the Devinska Nova Ves fissure fillings is placed. This locality is correlated with basal MN 6 by de Bruijn et al. (1992) and by Fejfar (pers. comm. 10/9/1994). For tectonic and paleogeographic reasons (Fejfar 1989; Rögl and Steininger 1983) those fissures could have been filled only before the Langhian (= Badenian) transgressive event. By placing the Devinska Nova Ves fissure fillings into basal MN 6, the base of the Astaracian (= base of MN 6) is estimated to be circa 16.5 Ma.

The age of the MN 6 type locality, Sansan (France), has a geomagnetically calculated age of 15.2 Ma (Sen, this volume), which Sen correlates with lowermost MN 6. The localities of Devinska Nova Ves sandhill (Slovakia), Luc sûr Orbieu (France), and Inónü I-loc. 24, 24A (Turkey; Kappelman et al., this volume) indicate ages around 15 Ma and younger for lower MN 6. The localities of Goldberg and Steinberg (Germany) have an age younger than 14.7 Ma. The age of these European lower MN 6 vertebrate localities (ca. ≤15.2 Ma) contradict the age for basal MN 6, based on tectonic and paleogeographic considerations, but are more congruent with one another than Krijgsman et al.'s (1994) 13.8 Ma determination for the MN 5/6 boundary.

As set forth in Steininger et al. (1989), it is Bernor's opinion that the base of MN 6 corresponds with the end Langhian regression ≥14.8 Ma, when an extensive biogeographic interchange occurred between Eurasia and Africa. Bernor and Tobien (1990) further recognized that MN 5 and MN 6 were distinctive by virtue of their first occurrence of immigrant species and correlated MN 5 with the terminal Burdigalian regression (ca. 16.5 Ma here) and MN 6 yet again with the terminal Langhian regression (ca. 15 Ma). Bernor (here) still advocates these correlations and believes that Sen's estimation of Sansan's age at 15.2 Ma represents a sound age determination for the base of MN 6.

The base of MN 7 + 8 (fig. 2.2) is best estimated at 12.5 Ma by the biostratigraphically correlated localities of La Grenatiere, Santarem (Portugal), La Grive (France), St. Stephan (Austria), and Comanesti 1 (Roumania) in Volhynian sediments. The base of MN 8 is estimated by biostratigraphic ties, according to the locality C. Almirall (Spain), to have an age of 11.9 Ma. This estimated age for the MN 6/7 + 8 boundary is in good agreement with the geomagnetically calculated age of 12.5 Ma by Krijgsman et al. (1994).

Vallesian (MN 9 to MN 10) (fig. 2.2)

Based on the evolutionary history of "Hipparion" (= *Hippotherium* of Bernor et al., this volume a) in the Pannonian and Central Paratethys (= Vienna Basin; see Bernor et al. 1988, 1993a, b; Swisher, this volume; Woodburne et al., this volume) and on the correlation of the Pannonian zonation (see Rögl and Daxner-Höck, this volume), the Gaiselberg (Pannonian C, Vienna Basin, Austria) hipparion is considered to best represent the actual

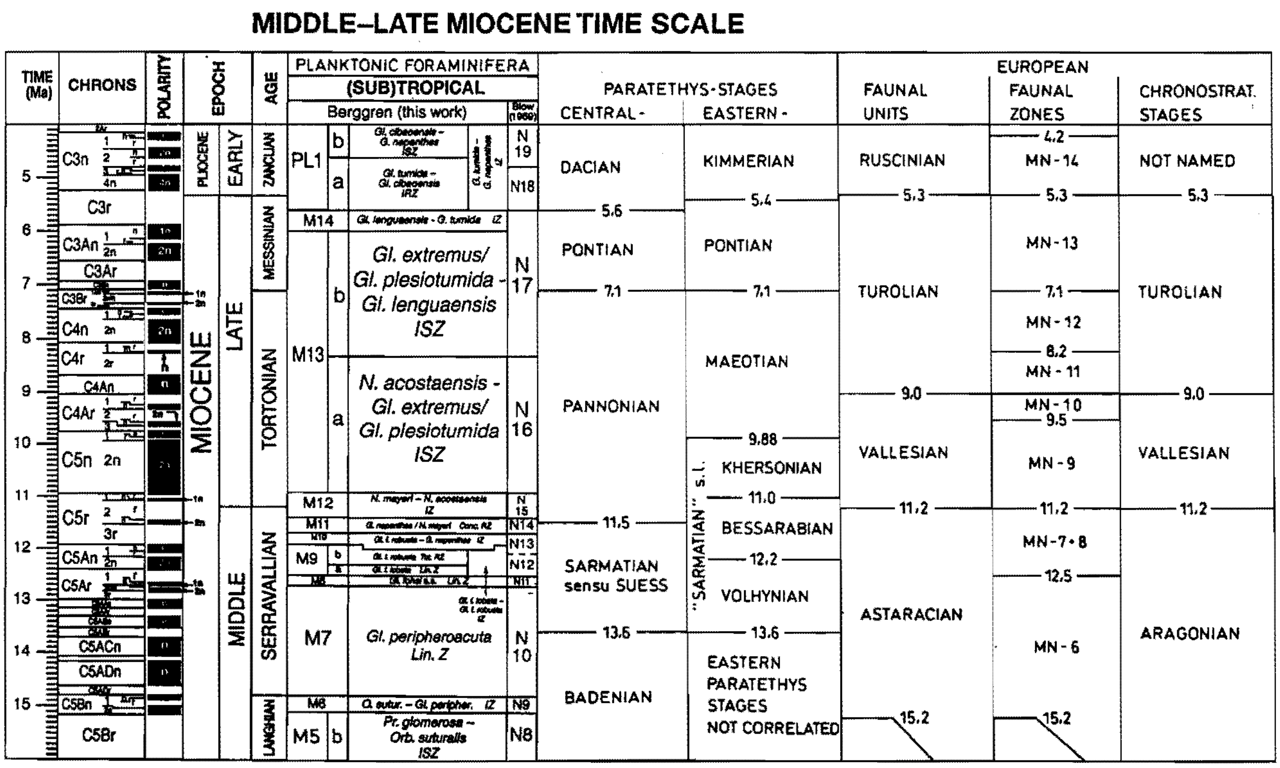

FIGURE 2.2 Middle and late Miocene circum-Mediterranean marine-continental chronologic correlations of the European Mammal Units and Zones.

Old World "Hipparion Datum" on combined morphologic and stratigraphic grounds. Rögl and Daxner-Höck (this volume) estimate the age of Pannonian C deposits, and the Gaiselberg hipparion, to be 11.2 Ma based on Central–Eastern Paratethys correlations, but not direct dating of Vienna Basin Pannonian C hipparions themselves. Within the Eastern Paratethys realm, the first MN 9 faunas are known from the upper Bessarabian Stage (base at 12.2, top at 11.0, for arguments see Rögl and Daxner-Höck, this volume), providing further support of this age estimation of 11.2 Ma for the base of the Vallesian.

The most precise chronologic estimates for the Old World "Hipparion" Datum are derived from the Siwaliks (ca. 10.5 Ma, Swisher, this volume; 10.45 Ma, Kappelman et al., this volume; but note Pilbeam et al. [this volume] estimate this to be 10.7 Ma) and the Sinap sequence (ca. 10.44 Ma, estimating the occurrence between Sinap localities 64 [without hipparion] and 94 [with hipparion and dated 10.38 Ma], Kappelman et al., this volume), where relatively continuous rock sequences make possible magnetostratigraphic correlations of first occurring hipparions that are directly pertinent to an Old World "Hipparion Datum" (Bernor et al., this volume; Swisher, this volume; Woodburne et al., this volume). The Höwenegg hipparions are slightly more evolutionarily derived than Pannonian C hipparions (Bernor et al., this volume; Woodburne et al., this volume) and are directly dated by $^{40}Ar/^{39}Ar$ at $\leq$10.3 Ma (= the maximum age of the Höwenegg fossil localities; Swisher, this volume). Bernor's position here is that until evidence is documented that a primitive hipparion is found in a magnetostratigraphically robust (long "continuous" sequence with good magnetic control) older than the lower middle portion of Chron 5's long normal interval (the interval is calibrated here as being 10.949–9.740, giving a 10.5 Ma age estimate for the lower middle portion and the "Hipparion Datum"), or in association with a precise $^{40}Ar/^{39}Ar$ date, it would be imprudent to accept a date older than at least the base of Chron 5n (= 10.95 Ma) and most probably lower middle portion (= 10.5 Ma). for the Old World "Hipparion Datum." Swisher (pers. comm.) and Kappelman (pers. comm.) concur with this point of view. The base of MN 10 (fig. 2.2) is best estimated to have an age of 9.3 Ma, following the geomagnetic interpretation of the locality Bou Hanifia BH 5 (Algeria) with a calibration of either 9.75 to 9.55 or 9.55 to 9.25 Ma. There are no possibilities to establish an estimate on the top of MN 10.

Turolian (MN 11 to MN 13) (fig. 2.2)

The base of the Turolian (= base of MN 11) is best estimated to have an age of 9.0 Ma by Bernor et al. (this volume). This estimate is based on the following localities: base of Maragheh (Kopran locality, Iran) fossiliferous section estimated by Bernor et al. (this volume b) as being 9.0 Ma; Kayadibi (Turkey) with radiometric dates below mammal horizon of 9.4 Ma; Prochroma 1 (Macedonia, Greece) with geomagnetic calibrations around 9.6 to 9.3 Ma.

The base of MN 12 is best estimated to have an age of 8.24 Ma for the base of the *Hipparion prostylum* zone at Maragheh (Iran). The top of MN 12 is estimated by the localities Samos Main Bone Bed levels (MBB; Greece) radioisotopically between 7.3 and 7.1 Ma.

The base of MN 13 is best estimated with an age of 7.1 Ma. It contains localities like Samos L (Greece), with a radiometric age of 6.2 Ma, and Venta del Moro, geomagnetically calibrated at 6.55 to 5.9 Ma. The top can be estimated with an age of 5.3 Ma by the localities La Alberca (Spain)—still within marine sediments of uppermost Messinian and the Brisighella (Faenza, Italy) mammal fauna overlain by lowermost marine Zanclean sediments.

Ruscinian (MN 14 to MN 15) (figs. 2.2, 2.3)

The base of the Ruscinian (= base of MN 14) is best estimated to have an age of 5.3 Ma (figs. 2.2, 2.3). An older age could be derived from the locality Celleneuve (France), geomagnetically calibrated to 5.9 to 4.2 Ma. The top is best estimated to have an age of 4.2 Ma at the locality of Villalba Alto Rio 1 (Spain). Younger ages of approximately 3.5 Ma for this boundary are indicated by the localities Mesas de Asta (Spain) and Elbistan (Turkey). However, these ages are contradicted by the ages of numerous MN 15 localities (see below).

The base of MN 15 (fig. 2.3) is best estimated to have an age of 4.2 Ma. This age is derived from the geomagnetically dated section of Villalba Alta Rio 2 (Teruel Graben, Spain), with a calibrated age of 4.2 to 2.6 Ma and an inferred age of 3.85 to 3.4 Ma. The top can be estimated to have an age of 3.4 Ma by the localities Villalba Alta Rio 5 (Teruel Graben, Spain), geomagnetically calibrated with an age of 3.8 to 3.6 Ma and an inferred age of 3.4 Ma, and Escorihuela B (Teruel Graben, Spain), geomagnetically calibrated to an age of 4.2 to 3.6 Ma and an inferred age of 3.4 Ma.

Villanyian (= "Villafranchian"; MN 16 to MN 17) (fig. 2.3)

The base of the Villanyian is best estimated with an age of 3.4 Ma by the localities Escorihuela (Teruel Graben, Spain), with an inferred age of 3.4 Ma; Triversa (Asti, Italy), geomagnetically and biostratigraphically calibrated to an age of 4.18 to 3.2 Ma; Arcille (Grosseto, Italy), biostratigraphically younger than 3.6 Ma; Vialette (France) fauna on top of a basalt flow radioisotopically dated at 3.33 Ma. The top can be best estimated to have an age of 2.6 Ma at the localities Valdeganga 14, 15 (Júcar Basin,

PLIOCENE TIME SCALE

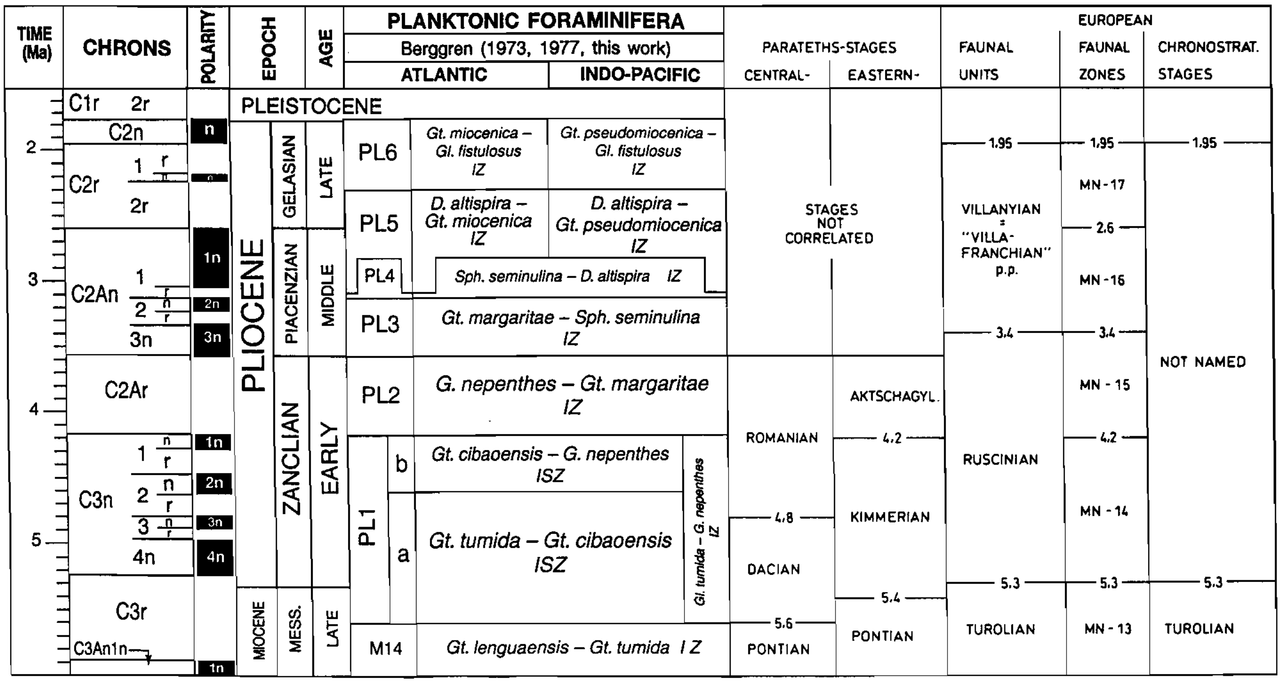

FIGURE 2.3 Pliocene circum-Mediterranean marine-continental chronologic correlations of the European Mammal Units and Zones.

Spain), geomagnetically calibrated to an age of 3.0 to 2.6 Ma, and Stranzendorf C (Molasse Zone, Austria), geomagnetically calibrated, horizon C with an inferred age of 3.04 to 2.58 Ma.

The base of MN 17 is best estimated to have an age of 2.6 Ma at the localities of Valdeganga 7, 10 and 2, 3 and 6 (Júcar Basin, Spain), geomagnetically calibrated with an age of 2.6 to 2.25; Rocca Neyra (Italy), with radioisotopic dates of 2.5 to 2.4 Ma; and Stranzendorf D (Molasse Zone, Austria), geomagnetically calibrated to 2.58 Ma. The top can be best estimated by the locality of Stranzendorf L (Molasse Zone, Austria), geomagnetically calibrated and with an inferred age of 1.95 Ma. Therefore, the top of MN 17 is inferred to correlate with the Plio/Pleistocene boundary.

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Appendix 2.1

NEOGENE FAUNA CORRELATION DATA BASE

This data base contains only those mammal localities which: (1) are biostratigraphically well correlated to the Neogene Mammal Faunal Zones (MN zones), and (2) provide correlation tie points to marine biostratigraphies, the geomagnetic polarity time scale, or chronostratigraphic stages, or have isotopic ages. The data base is arranged from the oldest to the youngest Neogene (Miocene and Pliocene) Mammal Faunal Zones (the *MN zones*) followed by the general *Geochronologic Age* of this zone.

Locality: the locality name is given here, as far as possible, arranged after locality, province, and country.

Lithostratigraphic Position: this paragraph provides a general lithologic description of the sequence from which the mammal remains are recovered and cites where the correlation tie points lie in relationship to the faunal horizons. Unfortunately, it is often impossible to extract these data from the literature.

Mammal Correlation: gives the present state of the art of the biostratigraphic unit/zone (MN zone) to which the fauna is correlated.

Correlation Tie Points: lists the different biostratigraphic possibilities for the correlation of the particular mammal fauna.

Paleomagnetic Calibration and *Isotopic Ages:* are given in millions of years (Ma).

Inferred Age: (follows Berggren et al. 1995) for inferring the ages of these Neogene Mammal Faunal Zones, or alternatively Units, with a certain constancy, we use here the most recent compilation of Berggren et al. 1995, since it includes the most recent revision of the geomagnetic time scale by Kent, the most recent radioisotopic determinations by Swisher (this volume) and the most recent correlation of planktonic foraminifera biozonation and magnetobiochronology by Berggren and Aubry.

References: only those references are listed that provide the most recent results.

Remarks: since many of our colleagues have contributed original data on these correlations, these are individually acknowledged within the data base.

The mammal localities within the data base itself are arranged according to their biochronologic position and ages within the specific Mammal Zone, following in part the biochronologic arrangements of mammal localities by de Bruijn et al. (1992: see their comments on pp. 69–71) except in those circumstance where authors to this volume have refined their correlation estimates.

European Mammal Faunal Unit: Agenian

European Mammal Faunal Zone: MN 1

MN 1

Age: early Miocene

Locality: Torrente del Cinca 68, SE Ebro Basin, Spain

Lithostratigraphic Position: an alluvial and lacustrine succession at the base of a fluviatile sequence with channel fill sandstones and flood plain deposits overlain by the carbonate dominated "Mequinenza Unit" (about 500 m) followed by alluvial sequence "Cuesta de Fraga Mudstones" (approximately 35 m) with red and variegated mudstones. This sequence is overlain by the upper lacustrine carbonate unit the "Torrente de Cinca Unit" (approximately 70 m). The locality Torrente de Cinca 68 is situated in a limestone body 45 m below the top of the section (Agusti et al. 1988: fig. 4).

Mammal Correlation: lowermost MN 1 in the *Rhodanomys transiens* Biozone (Agusti et al. 1985, 1987, and 1994; previously in the *Rhodanomys schlosseri* Biozone, Agusti et al. 1988: fig. 5)

Paleomagnetic Calibration: Agusti et al. (1994) report that the geomagnetic reversal pattern recovered from this section can be interpreted in two ways: Option I and Option II. Since Option I is considered the most consistent solution in comparison with the GPTS it is followed here and would place the Torrente del Cinca 68 faunal level within Chron C6Cn.2n.

Inferred Age: (Berggren et al. 1995) Chron C6Cn.2n: base at 23.8 Ma top at 23.67 Ma

References: Agusti et al. 1985, 1987, 1988, 1994, in press

MN 1

Age: early Miocene

Locality: Paulhiac, Bordeaux Basin, Agenais, France

Lithostratigraphic Position: brown marls intercalated in the "Calcaire blanc de l'Agenais" (Hugueney and Ringeade 1989).

Mammal Correlation: MN 1, lower part, according to de Bruijn et al. (1992)

Correlation Tie Points: "Oligocene" by cross correlation, below the "Marnes à Ostrea aginensis" correlated to the Aquitanian transgression into the Bordeaux Basin.

Inferred Age: (Berggren et al. 1995) base of the Aquitanian Stage, 23.8 Ma

References: de Bonis 1973; de Bruijn et al. 1992; Huegeney and Ringeade 1989; Ringeade 1978

MN 1

Age: early Miocene

Locality: La Paillade, France

Mammal Correlation: Mammal Zone A 2 (Aguilar and Michaux, pers. comm., 1990), MN 1; lower MN 1, slightly younger than Paulhiac (de Bruijn et al. 1992)

Correlation Tie Points: foraminifera correlate the section with the Aquitanian Age (Aguilar and Michaux, pers. comm., 1990).

Inferred Age: (Berggren et al. 1995) Aquitanian Stage: 23.8 to 20.5 Ma

References: Aguilar 1974, 1981, 1982a; de Bruijn et al. 1992

Remarks: Aguilar and Michaux (pers. comm., 1990) correlate this locality with Paulhiac.

MN 1

Age: early Miocene

Locality: Les Cevennes, France

Lithostratigraphic Position: the micromammal fauna "Les Cevennes" was discovered in black freshwater marls succeeding the marine blue marls with oysters and bivalves. This freshwater marl is itself succeeded by lignites, which are overlain by a transgressive marine sequence with a basal mollusc lumachelle followed by blue marine marls with foraminifera and selachien teeth.

Mammal Correlation: Mammal Zone A 2 (Aguilar); MN 1 (Aguilar and Michaux, pers. comm., 1990); MN 1 (de Bruijn et al. 1992)

Correlation Tie Points: early Miocene, Blow Zone N 4 and Nannoplankton Zone NN 1, according to Aguilar and Michaux (pers. comm., 1990)

Inferred Age: (Berggren et al. 1995) N 4 (Blow) = M 1 (Berggren et al. 1995), 23.8 Ma to 21.5 Ma

References: Aguilar 1974, 1981, 1982a; de Bruijn et al. 1992

Remarks: according to Aguilar and Michaux (pers. comm., 1990) Les Cévennes correlates with Paulhiac. De Bruijn et al. (1992) position Les Cévennes slightly older than Paulhiac.

MN 1

Age: early Miocene (lowermost)

Locality: Findreuse 3, 4 and 22, 27, 31, 33, Haute-Savoie, France

Lithostratigraphic Position: almost continuous 270 m thick section of sandstones, siltstones, marls, carbonates, and gypsum divided into six lithologic/depositional units of the "Lower Freshwater Molasse" Formation, following unconformably on the lower Cretaceous and transgressively overlain by the "Upper Marine Molasse" Formation. Unit 1 (lacustrine carbonates) yielded from sample numbers 15, 16, 17, 18, 24, and 25 micromammal faunas of Mammal Zone MP-29 (reference locality: Rickenbach); top of unit 2 (braided streams) unit 3 (lacustrine-palustrine carbonates and clastics) and base of unit 4 (playa) yielded from sample numbers 13, 14 (unit 2); 8, 11 (unit 3) and 5, 6, 7 (unit 4) micromammal faunas of the Mammal Zone MP-30 (reference locality: Brochene Fluh 33). Within unit 5 (lacustrine-palustrine carbonates) sample numbers 3, 4 and 22, 27, 31, 33 yielded micromammal faunas of the Mammal Zone MN 1 (reference locality: Fornant 11). The entire section was calibrated paleomagnetically.

Mammal Correlation: faunas from localities Findreuse 3, 4 and 22, 27, 31, 33 according to Burbank and al. (1992) are correlated to Mammal Zone MN 1 (upper part, see Burbank and al. 1992, p. 425, fig. 9, and p. 426, tab. 1).

Correlation Tie Points: the unit 5 belongs to the Charophyte "nitida" and "berdotensis" Zone (Berger 1983, 1986; and Riveline 1984).

Paleomagnetic Calibration: unit 5 (the uppermost lacustrine-palustrine carbonates) containing the micromammal localities belonging without any doubt to the upper part of Mammal Zone MN 1 contains the magnetic polarity Zones N 4–R 5 and N 5. According to the correlation of Burbank and al. (1992, p. 422, fig. 7) with the geomagnetic time scale the magnetic Zone N4 is correlated to Chron C6Cn.1n; R5 to Chron C6Bn.2r; and N5 to Chron C6Bn.2n.

Inferred Age: (Berggren et al. 1995) Chron C6Cn.1n, 23.53 Ma, to the top of Chron C6Bn.2n, 22.80 Ma

References: Berger 1983, 1986; Burbank and al. 1992; Cande and Kent 1994; Riveline 1984

MN 1

Age: early Miocene

Locality: Fornant 13 (11), near the village of Frangy, Haute-Savoie, France

Lithostratigraphic Position: a 370 m-thick section of sandstones, siltstones, marls, carbonates, and gypsum divided into six lithologic/depositional units belonging to the "Lower Freshwater Molasse" Formation, following unconformably on a Lower Cretaceous unit and transgressively overlain by the "Upper Marine Molasse" Formation. Between the 187 m and 265 m levels there is a gap of 80 m. Unit 1 (lacustrine sediments) sample number 7, micromammals indicative of Mammal Zone MP-28; unit 2 (meandering stream sediments) sample number 6 with micromammals indicative of Mammal Zone MP-28; unit 4 (playa sediments) sample number 13 with micromammals indicative of Mammal Zone MN 1 (reference locality: Fornant 11) and above the gap: unit 5 (lacustrine-palustrine sediments) sample number 11 with micromammals indicative of Mammal Zone MN 1 (this is the reference locality: Fornant 11).

Mammal Correlation: the micromammal faunas of Fornant samples 11 and 13 are correlated by Burbank and al. (1992) to the Mammal Zone MN 1 (upper part, see Burbank and al. 1992, p. 425, fig. 9, and p. 426, tab. 1).

Correlation Tie Points: unit 4 belongs to the "notata" Charophyte Zone and unit 5 (above the gap) into the "?nitida" Charophyte Zone (Berger 1983, 1986; and Riveline, 1984).

Paleomagnetic Calibration: the section is paleomagnetically dated from the base to the gap and unit 4 and correlated at the top of a longer reversed part (= R2) of the top of the measured section (from meter 100 until meter 187). The reversed part at the top of the section containing Fornat sample number 13 (= MN 1, upper part) is interpreted either as Chron C6Cn.1r or C6Cn.2r.

Inferred Age: (Berggren et al. 1995) Chron C6Cn.1r, 23.68 to 23.53; Chron C6Cn.2r, 23.99 to 23.80 Ma

References: Berger 1983, 1986; Burbank and al. 1992; Riveline 1984.

Remarks: The paleomagnetic assignment of the upper part of the section is uncertain.

MN 1

Age: early Miocene

Locality: Weisenau 34b Strasseneinschnitt, near Mainz, Germany

Lithostratigraphic Position: from brackish, calcareous marls, "Obere Cerithien Schichten"

Mammal Correlation: MN 1 upper part according to Engesser et al. (1993).

Correlation Tie Points: Nannoplankton Zone NP-25 in samples 38/39 below the mammal bearing sample 34b.

Inferred Age: (Berggren et al. 1995) younger than 23.8 Ma

References: Engesser et al. 1993

European Mammal Faunal Zone: MN 2

MN 2

Age: early Miocene

Locality: Gans, Bordeaux Basin, France

Lithostratigraphic Position: from the "Marnes à Unios du Bazadais."

Mammal Correlation: MN 2a, according to Hugueney and Ringeade (1989); lowermost MN 2 faunal level (de Bruijn et al., 1992).

Correlation Tie Points: the "Marnes à Unios de Bazadais" are correlated with the marine transgression of the Aquitanian (Hugueney and Ringeade 1989).

Inferred Age: (Berggren et al. 1995) marine transgression of Aquitanian, and therefore above the base of the Aquitanian Stage and younger than 23.8 Ma (Gourinard et al. 1987; Magné et al. 1987) using a "grade-dating" methodology: between 22.7 and 21.2 Ma

References: de Bruijn et al. 1992; Gourinard et al. 1987; Hugueney and Ringeade 1989; Magné et al. 1987; Ringeade 1978

MN 2

Age: early Miocene

Locality: Aillas, Bordeaux Basin, France

Lithostratigraphic Position: from the "Marnes à Unios du Bazadais"

Mammal Correlation: MN 2a (Hugueney and Ringeade 1989); lowermost faunal level of MN 2 (de Bruijn et al. 1992).

Correlation Tie Points: the "Marnes à Unios de Bazadais" are correlated with the marine transgression of the Aquitanian (Hugueney and Ringeade 1989).

Inferred Age: (Berggren et al. 1995) marine transgression of Aquitanian and therefore above the base of the Aquitanian Stage and younger than 23.8 Ma. Inferred age between 22.7 and 21.2 Ma (Gourinard et al. 1987; Magné et al. 1987) using a "grade-dating" methodology.

References: de Bruijn et al. 1992; Gourinard et al. 1987; Hugueney and Ringeade 1988, 1990; Magné et al. 1987; Ringeade 1978

MN 2

Age: early Miocene

Locality: Quarry Rüssingen, north of Rüssingen, TK 25 Sheet 6314 Kirchheimbolanden R:3434340 H:5498880, south of Mainz, Germany

Lithostratigraphic Position: section within "Obere Cerithienschichten" and "Corbicula Schichten." Mammals from sample Rü 005,15 cm of darkgreen to greyish marls with lithoclasts, including "Aufarbeitungshorizont" from "Obere Cerithienschichten," RÜ 013: 14 to 18 cm of marls with calcareous congretions, "Kalkknollenhorizont" from "Untere Corbicula Schichten"

Mammal Correlation: Lower portion of MN 2a (Engesser et al. 1993).

Correlation Tie Points: Upper part of "Obere Cerithienschichten" and lower part of "Corbicula Schichten" within the Charophyte Zones: *Rantzieniella nitida* (MN 1 in lowermost part to MN 2a) to *Stephanochora berdotensis* Zone (MN 2a, lower part).

Inferred Age: (Berggren et al. 1995) the Charophyte Zones: *Rantzieniella nitida* to *Stephanochora berdotensis* Zone correlate to the Aquitanian stratotype, base of the Aquitanian is estimated to be 23.8 Ma.

Reference: Engesser et al. 1993

MN 2

Age: early Miocene

Locality: Caunelles, France

Lithostratigraphic Position: rodent fauna out of marine sediments

Mammal Correlation: Mammal Zone A 3 (Aguilar, pers. comm.); upper part of MN 2a (Steininger et al. 1989); alternatively middle part of MN 2 (de Bruijn et al. 1992)

Correlation Tie Points: foraminifera probably Aquitanian age (Aguilar and Michaux, pers. comm., 1990); Nannoplankton Zone NN 1 (Steininger et al. 1989)
Inferred Age: (Berggren et al. 1995) Aquitanian Stage (lower portion), 23.8 to 20.5 Ma
References: Aguilar 1974, 1981, 1982; de Bruijn et al. 1992; Hugueney and Ringeade 1989; Steininger et al. 1989

MN 2

Age: early Miocene
Locality: Balizac, Bordeaux Basin, Gironde, France
Lithostratigraphic Position: clay level on top of alternating lacustrine and brackish water sediments with a gray limestone on top; overlain by the marine "Gres de Bazas."
Mammal Correlation: MN 2b (Hugueney and Ringeade 1989); medial MN 2 (de Bruijn et al. 1992)
Correlation Tie Points: according to sedimentological interpretations, directly comparable to the Aquitanian stratotypic section.
Inferred Age: (Berggren et al. 1995) A marine transgression of the Aquitanian Stage within the Aquitanian stratotype and therefore younger than 23.8 Ma (lower boundary of the Aquitanian Stage). Inferred age according to Gourinard et al.'s (1987) and Magné et al.'s (1987) "grade-dating" is 19.8 Ma.
References: Alvinerie and Gayet 1971; de Bruijn et al. 1992; Gourinade et al. 1987; Hugueney and Ringeade 1989; Magné et al. 1987; Ringeade 1978.
Remarks: according to Hugueney and Ringeade (1989) Balizac represents a direct correlation point to the marine Aquitanian.

MN 2

Age: early Miocene
Locality: Lespignan, France
Lithostratigraphic Position: rodent fauna from marine deposits.
Mammal Correlation: Mammal Zone A 4 (Aguilar); MN 2b (Steininger et al. 1989); medial MN 2 (de Bruijn et al. 1992)
Correlation Tie Points: Nannoplankton Zone NN 1 (Steininger et al. 1989)
Inferred Age: (Berggren et al. 1995) Aquitanian Stage: 23.8 to 20.5 Ma (lower part of the Aquitanian)
References: Aguilar 1974, 1981, 1982a; de Bruijn et al. 1992; Steininger et al. 1989

MN 2

Age: early Miocene
Locality: La Brete, Bordeaux Basin, Gers, France
Lithostratigraphic Position: in an alternating succession of lacustrine marls and limestones overlying brackish sediments
Mammal Correlation: middle part of MN 2b (Hugueney and Ringeade 1989); middle part of MN 2 (de Bruijn et al. 1992)
Correlation Tie Points: correlated by geological and sedimentological reasons to upper part of the type Aquitanian.
Inferred Age: (Berggren et al. 1995) upper part of the type Aquitanian and therefore well above the base of the Aquitanian Stage and younger than 23.8 Ma. Gourinard et al. (1987) and Magné et al. (1987) give a "grade-dating" estimate of 19.8 Ma.
References: de Bruijn et al. 1992; Gourinade et al. 1987; Hugueney and Ringeade 1988, 1989; Magné et al. 1987; Ringeade 1978

MN 2

Age: early Miocene
Locality: Laugnac, Bordeaux Basin, Lot-et-Garonnes, France
Lithostratigraphic Position: marls intercalated in the "Calcaires gris de l'Agenais."
Mammal Correlation: upper portion of MN 2b (Hugueney and Ringeade 1989); upper portion of MN 2 (de Bruijn et al. 1992).
Correlation Tie Points: correlated by geological and sedimentological criteria to upper part of type Aquitanian.
Inferred Age: (Berggren et al. 1995) upper part of the type Aquitanian and therefore above the base of the Aquitanian Stage and younger than 23.8 Ma. Gourinard et al. (1987) and Magné et al. (1987) estimate an age of 19.8 Ma, using their "grade-dating" methodology.
References: de Bonis 1973; de Bruijn et al. 1992; Ginsburg and Morales 1989; Gourinade et al. 1987; Hugueney and Ringeade 1989; Magné et al. 1987; Ringeade 1978

European Mammal Faunal Unit: Orleanian

European Mammal Faunal Zone: MN 3

MN 3

Age: early Miocene
Locality: Lisboa, Universitá Catolica and Avenue do Uruguay, Portugal
Lithostratigraphic Position: "terrigenous sediments" corresponding to R 1 regressive event (Antunes 1989)
Mammal Correlation: MN 3a (Antunes 1989); lowermost MN 3 (Steininger et al. 1989); lower part MN 3 (de Bruijn et al. 1992); Zone A 5 of Aguilar
Correlation Tie Points: regressive sediments (= R 1) on top of Aquitanian transgression (= C 1) and below the Burdigalian transgression (= C 2). Overlying marine deposits Blow Zone N 5; R 1 (containing local stratigraphic horizons I and II) inferred biostratigraphic correlation: N 4–N 5 Blow Zone.
Inferred Age: (Berggren et al. 1995) younger than the regional Aquitanian transgression but older than the regional Burdigalian transgression. The base of Aquitanian Stage is equal to 23.8 Ma, the base of the Burdigalian Stage is equal to 20.5 Ma; the base of Blow Zone N 5 = M 2 (Berggren et al. 1995) is equal to 21.5 Ma.
References: Antunes 1988, 1989; Antunes and Mein 1986; Ginsburg 1984; Steininger et al. 1989

MN 3

Age: early Miocene
Locality: Estrepouy, Bordeaux Basin, Gers, France
Lithostratigraphic Position: from the "Continental Molasse de l'Armagnac," which overlies the "Calcaires gris de l'Agenais" and the "Marnes à Ostrea aginensis."

Mammal Correlation: MN 3 (Hugueney and Ringeade 1989); lower part of MN 3 (de Bruijn et al. 1992)
Correlation Tie Points: the "Marnes à Ostrea aginensis" belong to sedimentary trangressive cycle of the type Burdigalian of the Bordeaux Basin; i.e., the Agenais. Correlative to the Burdigalian of La Peloua: Nannoplankton Zone NN 2.
Inferred Age: (Berggren et al. 1995) Burdigalian Stage, 20.5 to 16.4 Ma; the Burdigalian transgression in the Bordeaux Basin and Agenais is post 20.5 Ma; Nannoplankton Zone NN 2; if correlative with the base of *Discoaster druggi*, then the age is ca. 23.2 Ma. The top of NN 2 is 18.7 Ma. Inferred "grade dating" age from the "Marne à Ostrea agenensis" yields an age of 19 Ma (re: Gourinard et al. 1987; Magné et al. 1987).
References: de Bruijn et al. 1992; Ginsburg 1974; Gourinade et al. 1987; Hugueney and Ringeade 1988, 1989; Magné et al. 1987; Ringeade 1978

MN 3

Age: early Miocene
Locality: Maigen near Eggenburg, Molasse-Zone, Lower Austria
Lithostratigraphic Position: marine shallow water sands with molluscs, Burgschleinitz Formation (Steininger et al. 1989)
Mammal Correlation: lowermost MN 3 (de Bruijn et al. 1992)
Correlation Tie Points: Nannoplankton Zone NN 2; Blow Zone N 5; Central Paratethys pollen zone NGZ II.
Inferred Age: (Berggren et al. 1995) Blow Zone N 5 = Berggren et al. 1994 Planktonic Foraminifera Zone: M 2: 21.5 to 18.8 Ma; Nannoplankton Zone NN 2. If the base is defined by *Discoaster druggi*, then the age is ca. 23.2 Ma; top of NN 2 is equal to 18.7 Ma.
References: de Bruijn et al. 1992; Mein 1989; Steininger et al. 1989

MN 3

Age: early Miocene
Locality: Eggenburg, Brunnstube-Schindergraben, Molasse-Zone, Lower Austria
Lithostratigraphic Position: coarse marine sands on top of crystalline granitic rocks; Burgschleinitz Formation (Steininger et al. 1989)
Mammal Correlation: MN 3 lower part (de Bruijn et al. 1992)
Correlation Tie Points: Blow Zone N 5; Central Paratethys pollen zone NGZ II
Inferred Age: (Berggren et al. 1995) Blow Zone N 5; Planktonic Foraminifera Zone M 2: 21.5 to 18.8 Ma
References: de Bruijn et al. 1992; Daxner-Höck 1971; Hochuli 1978; Steininger et al. 1989, 1989, 1991

MN 3

Age: early Miocene
Locality: Beaulieu, France
Lithostratigraphic Position: in a volcanic sequence interfingering with sedimentary sequences
Mammal Correlation: Mammal Zone B (Aguilar); MN 3 (Steininger et al. 1989); alternatively upper MN 3 (de Bruijn et al. 1992)
Correlation Tie Points: a contemporaneous sequence of marine sediments containing a foraminifera and ostracod fauna assigned by a few planktonic elements to Blow Zones N6 + N7
Isotopic Age (Ma): Emplacement of the volcanic sequence is 18.3–17.5 Ma (re: Baubron and al. 1975); alternatively, 18.0 Ma (Aguilar and Michaux, pers. comm., 1990); or 17.5, 18.7 (Steininger et al. 1989).
Inferred Age: (Berggren et al. 1995) Blow Zone N 6 + N 7 (= Berggren et al. 1995); Planktonic Foraminifera Zone M 3 + M 4a and b: 18.8 to 16.0 Ma.
References: Aguilar 1981, 1982a; Aguilar in Steininger et al. 1987; 1989; Aguilar et al. 1986; Baubron et al. 1975; de Bruijn et al. 1992; Clauzon 1982; Clauzon and Aguilar 1982; Steininger et al. 1989

European Mammal Faunal Zone: MN 4

MN 4

Age: early/middle Miocene
Locality: El Casots, Valles Penedes, Spain
Mammal Correlation: *Megacricetodon primitivus* Zone (= MN 4a) of Agusti and Moyá-Solá (1991).
Correlation Tie Points: intercalations of marine horizons with *Globigerinoides bisphaericus* followed by horizons containing *Praeorbulina*.
Inferred Age: (Berggren et al. 1995) approximately 16.0 Ma
References: Agusti and Moyá-Solá 1991

MN 4

Age: early Miocene
Locality: Belchatów coalmine; Belchatow C (Bel-C); Central Poland
Lithostratigraphic Position: According to Stworzewicz and Szynkiewicz (1989), a brown coal environment correlative to the base ?Oligocene/early Miocene. Includes quartz sands (20 to 120 m thickness) with minor coal seams, containing molluscs, covered by a 3 to 5 cm thick volcanic tephra layer (TS-5), succeeded by brown coal layers with TS-4; on top, 40–60 m clays, clays with pebbles, coaliferous sands, and the main coal seam with the faunal horizon of Belchatów C with TS-3 at the very top. The uppermost portion of the section between TS-3 and TS-2 has three coal seams with sand, clay, and lacustrine limestones and the faunal horizon of Belchatów B (freshwater mollusc fauna and mammals) (= Bel-B, Stworzewicz and Szynkiewicz 1989). Fossil pollen has been located from the main seam below TS-3 and the three seams above, between TS-3 and TS-2 (Stuchlik et al. 1990).
Mammal Correlation: Rzebik-Kowalska (1994) report that from the base to the top of the sequence, there are three successive mammal horizons: (1) The lowermost mammal horizon is Belchatow C, and is correlated by the rodents and insectivore assemblage to MN 4. This horizon is found below a "tuffite horizon" = TS-3 dated 18.1 ± 1.7 Ma (Burchart et al. 1988). Also found here is the proboscidean *Gomphotherium angustidens* and a chalicothere (Kowalski 1993a; Kowalski and Kubiak 1993). (2) A middle mammal horizon referred here to Belcha-

tow B (= Bel-B) and correlative with MN 5 (Kowasliski 1993a), or MN 5/6 (Rzebik-Kowalska 1994; see below). (3) An upper mammal horizon referred here to Belchatow A, which is tentatively correlated to MN 9 (Kowalski 1993b).

Isotopic Age: Stworzewicz and Szynkiewicz (1989) have reported fission track zircon dates from TS-2 (4 samples) with an average age of 17.05 ±0.69 Ma; TS-3 (3 samples) has an average age of 17.25 ±0.4 Ma. Statistically, the difference between TS-2 and TS-3 is meaningless, with all age values clustering around 17.0 Ma. Rzebik-Kowalska (1994), Kowalski (1993a), and Kowalski and Kubiak (1993) have reported the "lower tuffite" 's (= TS-3) age as being 18.1 ±1.7 Ma.

References: Burchart et al. 1988; Kowalski 1993a, b; Kowalski and Kubiak 1993; Rzebik-Kowalska 1994; Stuchlik et al. 1990; Stworzewicz and Szynkiewicz 1989

MN 4

Age: early Miocene

Locality: Horlak 1a, 1b, Gemerek area, Kayseri-Sivas Basin, Turkey

Lithostratigraphic Position: mammal localities near base of Yenicubuk Formation with sandstone, siltstone, marl, limestone, and lignite. The Horlak 1a, 1b localities are above a prominent gypsum bed of the Burtepe Formation and approximately 120 m below Horlak 2 and Gemerek locality (Sümengen et al. 1989: fig. 2).

Mammal Correlation: local Mammal Zone C 1 correlative to MN 4 according to Sümengen et al. (1989); middle portion of MN 4 according to de Bruijn et al. (1992)

Correlation Tie Points: localities Horlak 1a and 1b are approximately 120 m below Horlak 2 and Gemerek (see below).

Inferred Age: (Berggren et al. 1995) According to the interpretation of geomagnetic results, Langereis et al. (1989) place Horlak 1a and 1b below Chron C5Cn and therefore with an age older than 16.7 Ma.

References: de Bruijn et al. 1988, 1992; Langereis et al. 1989; Sümengen et al. 1989

MN 4

Age: early Miocene

Locality: Gemerek, Horlak 2, Gemerek area, Kayseri-Sivas Basin, Turkey

Lithostratigraphic Position: lower Yenicubuk Formation, sandstone, siltstone, marl, limestone, and lignite. Gemerek and Horak 2 localities approximately 120 m above Horlak 1a, 1b locality (Sümengen et al. 1989: fig. 2).

Mammal Correlation: local Mammal Zone C 2, clearly younger than Horak 1a, 1b (see above), probably MN 4 according to Sümengen et al. (1989).

Paleomagnetic Calibration: paleomagnetic investigations in the Gemerek section demonstrate a small reversed zone (of ca. 20 m), followed by a normal zone (of ca. 70 m), and to the top a reversed zone (of ca. 75 m). After a gap (ca. 80 m) a basalt flow dated at 14.9 ±0.7 Ma. This pattern is considered to represent parts of the upper normal part of Anomaly 5C (Chron 16) (Langereis et al. 1989); = Chron C5C.

Inferred Age: (Berggren et al. 1995) Horlak 2 and Gemerek are 120 m above the Horlak 1a and 1b localities (Langereis et al. 1989) in a normal geomagnetic interval followed by a short reversed portion of Chron C5C here interpreted to be C5Cn.3n and lower part of Chron C5C, interpreted here as being C5Cn.3n, and the lower part of Chron C5Cn.2r: 16.7 to 16.5 Ma.

References: de Bruijn et al. 1988, 1992; Langereis et al. 1989; Sen, this volume); Sümengen et al. 1989

Remarks: de Bruijn (pers. comm., 1992) reports that there is a hiatus above the Yenicubuk Formation, therefore there is no upper age limit other than MN 7+8. However, on the basis of its composition, this fauna is closely correlative with Horlak 1a and 1b (see above).

MN 4

Age: early Miocene

Locality; Orechov, Moravia, Czechoslovakia

Lithostratigraphic Position: in littoral marine facies

Mammal Correlation: middle to upper MN 4 (Steininger et al. 1989; de Bruijn et al. 1992)

Correlation Tie Points: below the so-called Oncophora-facies of Central Paratethys; late Ottnangian

Inferred Age: (Berggren et al. 1995) older than 16.5 Ma

References: Cicha et al. 1977; de Bruijn et al. 1992; Fejfar 1988, 1989; Steininger et al. 1989

MN 4

Age: early Miocene

Locality: Aliveri-Kymi, Euboa, Greece

Lithostratigraphic Position: below main coal, underlain with tree roots

Mammal Correlation: lower to middle MN 4 (Steininger et al. 1989); upper MN 4 (de Bruijn et al. 1992)

Correlation Tie Points: Kale-Eskihisar E-Mediterranean pollen zone

References: Benda and de Bruijn 1982; Benda and Meulenkamp 1989; de Bruijn and Van der Meulen 1979; de Bruijn et al. 1992; Klein Hofmijer and de Bruijn 1988

European Mammal Faunal Zone: MN 5

MN 5

Age: early Miocene

Locality: Teiritzberg near Korneuburg, Lower Austria

Lithostratigraphic Position: marine, nearshore environment with clays and silts to sands

Mammal Correlation: middle to upper MN 5, according to Steininger et al. (1989) and de Bruijn et al. (1992).

Correlation Tie Points: upper part of Karpatian Stage based on molluscan fauna.

Paleomagnetic Calibration: Mauritsch and Scholger (1994) lately finished a report on the magnetostratigraphy on this locality and could demonstrate that the entire section including the mammal-bearing part is within a normal magnetozone.

Inferred Age: (Berggren et al. 1995) Central Paratethys Karpatian

Stage with its base approximately at 17.2 Ma and its top at 16.4 Ma. Upper part of the Karpatian Stage within the normal polarity intervals of Chron C5Cn. Because of biostratigraphic reasons (base of Badenian Stage near base of Chron C5n.1n) the measured normal polarity interval can be correlated either to Chron C5Cn.3n, 16.72–16.55 Ma or to Chron C5cn.2n, 16.48 to 16.32 Ma.

References: Daxner-Höck et al. 1989; de Bruijn et al. 1992; Grill 1962; Mauritsch and Scholger 1994; Sovis 1987; Steininger et al. 1989

MN 5

Age: early Miocene
Locality: Eibiswald, Styria, Austria
Mammal Correlation: basal MN 5 (Steininger et al. 1989; de Bruijn et al. 1992)
Correlation Tie Points: Karpatian age
Inferred Age: (Berggren et al. 1995) the Central Paratethys Stage Karpatian; the base is approximately 17.2 Ma, the top is ca. 16.4 Ma.
References: de Bruijn et al. 1992; Kollmann 1965; Mottl 1970; Rabeder and Steininger 1975; Steininger et al. 1989

MN 5

Age: middle Miocene
Locality: Thenay, Loire et Cher, France
Lithostratigraphic Position: Falune de Touraine
Mammal Correlation: MN 5 (de Bruijn et al. 1992)
Correlation Tie Points: Langhian Stage (Ginsburg, pers. comm., 1990)
Inferred Age: (Berggren et al. 1995) base of Langhian Stage: 16.4 and top: 14.8 Ma
References: de Bruijn et al. 1992; Ginsburg and Sen 1977; Sen and Makinsky 1983
Remarks: During the time of the 1992 Reisenburg meeting this locality was retained together with Pontlevoy-Thenay as a reference locality for Mammal Zone MN 5 (de Bruijn et al. 1992).

MN 5

Age: middle Miocene
Locality: Chios, Greece
Lithostratigraphic Position: in sandy clays of the Keremaria Formation, flood plain deposits
Mammal Correlation: upper MN 5 (Steininger et al. 1989; de Bruijn et al. 1992)
Correlation Tie Points: lower Yeni-Eskihisar E-Mediterranean pollen zone
Paleomagnetic Calibration: currently under investigation by Sen.
References: Benda and Meulenkamp 1989; de Bruijn et al. 1992; Steininger et al. 1989; Tobien 1968

MN 5

Age: middle Miocene
Locality: Rimbez, Landes, France
Mammal Correlation: MN 5 (Ginsburg, pers. comm., 1990)
Correlation Tie Points: "Helvetien" with ***Pecten subarcuatus***

MN 5

Age: middle Miocene
Locality: Sos, Garonne, France
Lithostratigraphic Position: mammal remains recovered from marine sands
Mammal Correlation: MN 5 (Ginsburg, pers. comm., 1990)
Correlation Tie Points: "Helvetien" with ***Pecten subarcuatus***

MN 5

Age: early/middle Miocene
Locality: Pontlevoy-Thenay; France
Lithostratigraphic Position: "Falunes": marine, unsorted near shore deposits with sands to very coarse sands
Mammal Correlation: upper MN 5 (de Bruijn et al. 1992)
Correlation Tie Points: mammal remains intercalated with marine sediments
References: de Bruijn et al. 1992; Ginsburg 1989; Sen and Makinsky 1983
Remarks: During the Reisensburg meeting (1992), this locality, together with the locality of Thenay, was retained as the reference locality for MN 5 (de Bruijn et al. 1992).

MN 5

Age: middle Miocene
Locality: Dumlupinar, Turkey
Mammal Correlation: MN 5 (Benda and Meulenkamp 1989)
Correlation Tie Points: upper Eskihisar E-Mediterranaen pollen zone
Isotopic Age: radiometric date above mammal locality is 14.75 ±0.3 Ma
References: Becker-Platen et al. 1975; Benda and Meulenkamp 1989; Sickenberg et al. 1975; Steininger et al. 1989

MN 5/6

Age: early Miocene
Locality: Belchatów-coalmine; Belchatów B (= Bel-B); Central Poland
Lithostratigraphic Position: Rzebik-Kowalska (1994) reports that from the base to top of the coal mine there are three mammal horizons currently known. The lowermost mammal horizon is referred in this paper to Belchatów C = MN 4 (see above) and is found below a tuffite horizon (TS-3) dated at 18.1 ±1.7 Ma. A middle mammal horizon called Belchatów B correlates with MN 5 based on its rodent assemblage (Kowalski 1993a); however, the insectivore assemblage has led Rzebik-Kowalska (1994) to infer an MN 5/6 age. It is found between the "lower tuffite horizon" (= TS-3) and below a "higher tuffite horizon" (= TS-2) dated at 16.5 ±1.3 Ma. An upper mammal horizon, Belchatow A, is tentatively correlated to MN 9 (Kowalski 1993b) (see Stworzewicz and Szynkiewicz 1989 for the position of tuffite horizons TS-3 and TS-2 see MN 4: Belchatów C).
Mammal Correlation: Kowalski (1993a) correlates the middle

mammal horizon (Belchatów B) with MN 5; Rzebik-Kowalska (1994) correlates the same horizon with MN 5/6, using the insectivore assemblage. These assemblages are found between/ above the "lower tuffite horizon" (= TS-3) and below a "higher tuffite horizon" (= TS-2, dated at 16.5 ±1.3 Ma).
Isotopic Age: Rzebik-Kowalska (1994) reports that the "lower tuffite" (= TS-3) is dated 18.1 ±1.7 Ma and the "upper tuffite" (= TS-2) is dated 16.5 ±1.3 Ma (see also Storzewicz and Szynkiewicz 1989).
References: Burchart et al. 1988; Kowalski 1993a, b; Rzebik-Kowalska 1994; Stworzewicz and Szynkiewicz 1989

European Mammal Faunal Unit: Astaracian

European Mammal Faunal Zone: MN 6

MN 6

Age: middle Miocene
Locality: Devinska Nova Ves: fissures 1–3 (Neudorf Spalten 1–3 of Zapfe 1948 1949; Fejfar 1988, 1989); Slovakia
Lithostratigraphic Position: continental fissure fillings in Jurassic limestone surrounded by marine early Badenian deeper water clays with microfauna and partly overlain by marine late Badenian silts with microfauna (see Fejfar 1989:217, fig. 4)
Mammal Correlation: Lowermost MN 6 (Steininger et al. 1989 and de Bruijn et al. 1992; Fejfar, pers. comm., 1994). Bernor believes that since this locality "must predate the Langhian (re: Rögl and Steininger 1983), it must predate MN 6 and is correlative therefore with MN 5."
Correlation Tie Points: The microfauna of the clays surrounding the karstic fissures indicates the base of the Central Paratethys Badenian Stage (Lower Lagenid (Bio-) Zone = M5a of Berggren et al. 1995. The microfauna within the silts directly overlying the fissure filling indicates late Badenian (Bulimina-Bolivina Zone). Since the entire Jurassic limestone hill within which the fissures occur is surrounded by early Badenian sediments, the continental filling must predate the M 5a Zone of Berggren et al. (1994) and predate the Langhian (Rögl and Steininger 1983).
Inferred Age: (Berggren et al. 1995) base of the Central Paratethys Badenian Stage, ca. 16.0 Ma
References: Cicha et al. 1972; de Bruijn et al. 1992; Fejfar 1988, 1989; Rabeder and Steininger 1975; Rögl and Steininger 1983; Steininger et al. 1989; Zapfe 1948, 1949

MN 6

Age: middle Miocene
Locality: Sansan, France
Lithostratigraphic Position: The partly outcropping 40 m of section are composed of sandy marls, silts, sands and sandstones, and calcareous intercalations. The mammal fauna from the upper part of the section is found in facies ranging from sandy marls to silts. This part of the section belongs to the uppermost part of the lower normal and the short reversed part of the magnetostratigraphic sequence (see below).
Mammal Correlation: MN 6 reference locality, medial MN 6 according to de Bruijn et al. (1992). Lower MN 6, according to Bernor and Tobien (1990), Bernor et al. (this volume a, b) and Sen (this volume).
Geomagnetic Calibration: the lower part of the section contains a long reversed interval, which ends about 32 m above the first reversed magnetic sample. Above this level a shorter normal sequence (about 3 m, containing mammal remains) is followed by a short reversed part (about 1 m, containing mammal remains), followed by a longer normal part (about 5 m); the uppermost 2 to 2.5 m of the section are within a reversed sequence.
Inferred Age: (Berggren et al. 1995) this geomagnetic polarity sequence is correlated pro parte to Chron C5Br to Chron C5ADn.1r; the mammal faunas are correlative with Chron C5Bn.2n and C5Bn.1r: 15.15 to 14.88 Ma.
References: Bernor and Tobien 1990; de Bruijn et al. 1992; Sen, this volume; Sen and Ginsburg (in prep.)

MN 6

Age: middle Miocene
Locality: Devinska Nova Ves, sandhill (Neudorf Sandberg), Slovakia
Lithostratigraphic Position: the mammal remains have been recovered from the transgressive marine nearshore sands.
Mammal Correlation: MN 6 (Steininger et al. 1989 and de Bruijn et al. 1992)
Correlation Tie Points: by micro and macro fauna, middle to upper Badenian
Inferred Age: (Berggren et al. 1995) middle Badenian Stage of Central Paratethys, and therefore younger than 15.2 Ma; (Badenian/Sarmatian boundary is at approximately 13.6 Ma).
References: Cicha et al. 1972; de Bruijn et al. 1992; Fejfar 1988, 1989; Rabeder and Steininger 1975; Steininger et al. 1992

MN 6

Age: middle Miocene
Locality: Luc-sur-Orbieu, France
Lithostratigraphic Position: rodent fauna from marine deposits
Mammal Correlation: Mammal Zone C 3 (Aguilar); MN 6 lower part (de Bruijn et al. 1992)
Correlation Tie Points: benthic and planktonic foraminifera Blow Zone N 9/10
Inferred Age: (Berggren et al. 1995) Blow Zone N 9/10 Planktonic Foraminifera Zone M 6/7: 15.1 to 12.7 Ma
References: Aguilar 1981, 1982; de Bruijn et al. 1992
Remarks: This mammal fauna is correlative with Sansan.

MN 6

Age: middle Miocene
Locality: Veyran, France
Mammal Correlation: Mammal Zone C 3 or C 4 (Aguilar), upper part of MN 6 (re: remarks below)
Correlation Tie Points: Nannoplankton Zone NN 6, according to Aguilar and Michaux (pers. comm., 1990). Nannoplankton Zone NN 5 (Steininger et al. 1989).
Inferred Age: (Rio and Fornacian 1994) base of Nannoplankton

Zone NN 5 (16.0 Ma, top at 13.7 Ma) and top of Nannoplankton Zone NN 6 (11.8 Ma)

References: Aguilar 1981, 1982; Aguilar and Michaux 1984; Rio and Fornacian 1994; Steininger et al. 1989

Remarks: according to Aguilar and Michaux (pers. comm., 1990), the mammal age determination has been revised, and this fauna is younger than Sansan and Luc-sur-Orbieux. On the basis of the *Megacricetodon* its age is correlative to St. Catherine 1 (Aguilar and Michaux 1984).

MN 6

Age: middle Miocene

Locality: Inönü I, localities 24, 24A; Sinap Tepe area south of Sarilar, Central Anatolia, Turkey

Lithostratigraphic Position: localities in upper part of Pazar Formation with a volcanic unit on top

Mammal Correlation: MN 6 by Gürbüz (1981); basal MN 6 here

Inferred Age: (Kappelman et al., this volume) ca. 15.2 ±0.3 Ma

References: Gürbüz 1981; Kappelman et al., this volume

MN 6

Age: middle Miocene

Locality: Paşalar, Turkey

Mammal Correlation: basal MN 6 (Steininger et al. 1989; Bernor and Tobien 1990; de Bruijn et al. 1992)

Correlation Tie Points: Lowermost Eskihisar E-Mediterranean pollen zone

References: Andrews 1989; Benda and Meulenkamp 1989; Benda et al. 1975; Bernor and Tobien 1990; de Bruijn et al. 1992; Engesser 1980; Sickenberg et al. 1975; Steininger et al. 1989

MN 6

Age: middle Miocene

Locality: Steinberg and Goldberg, Franken, Germany

Lithostratigraphic Position: post Ries-event impact lake sediments (travertine)

Mammal Correlation: MN 6 (Steininger et al. 1989 and de Bruijn et al. 1992)

Isotopic Age: younger than Ries Impact Event (dated 14.7 Ma)

References: de Bruijn et al. 1992; Heissig 1988; Heizmann and Fahlbusch 1983; Steininger et al. 1989; Rachl 1983; Ziegler 1983

MN 6

Age: middle Miocene

Locality: Pontigné, Maine et Loire, France

Lithostratigraphic Position: Falun de l'Anjou

Mammal Correlation: MN 6 (Ginsburg, pers. comm., 1990)

Correlation Tie Points: Langhian Stage (Ginsburg, pers. comm., 1990)

Inferred Age: (Berggren et al. 1995) base of the Langhian Stage (16.0)

References: Ginsburg 1989

MN 6

Age: middle Miocene

Locality: Çandir, Turkey

Mammal Correlation: MN 6 upper part, according to Steininger et al. (1989) and de Bruijn et al. (1992)

Correlation Tie Points: Eskihisar E-Mediteranean pollen zone

References: Benda and Meulenkamp 1989; Benda et al. 1975; de Bruijn et al. 1992; Engesser 1980; Sickenberg et al. 1975; Steininger et al. 1989

Remarks: This locality is presently under study by a team directed by E. Gülec (Ankara).

European Mammal Faunal Zone: MN 7 + 8

MN 7

Age: middle Miocene

Locality: Plakia, Greece

Mammal Correlation: lower to middle MN 7 (Steininger et al. 1989)

Correlation Tie Points: base of Yeni-Eskihisar E-Mediterranean pollen zone

References: Benda and Meulenkamp 1990; Steininger et al. 1989

MN 7 + 8

Age: middle Miocene

Locality: La Grenatiere, France

Lithostratigraphic Position: rodent fauna from marine and lacustrine levels

Mammal Correlation: Mammal Zone C 5 (Aguilar); MN 7 lower to middle part (Steininger et al. 1989); lowermost MN 7 + 8 (de Bruijn et al. 1992)

Correlation Tie Points: Nannoplankton Zone NN 6; Blow Zone N 12 (Steininger et al. 1989)

Inferred Age: (Berggren et al. 1995; and Rio and Fornaciari 1994) Blow Zone N 12; Planktonic Foraminiferal Zone M 9, 12.5 to 12.0 Ma; Nannoplankton Zone NN 6, 13.6 to 11.9 Ma.

References: Aguilar 1981, 1982; de Bruijn et al. 1992; Steininger et al. 1989

Remarks: Aguilar and Michaux (pers. comm., 1990) state that based on the stage-of-evolution of the *Megacricetodon*, this fauna is younger than La Grive M (in contrast to de Bruijn et al. 1992: pg. 74, tab. 3).

MN 7 + 8

Age: middle Miocene

Locality: Yeni-Eskihisar 1 (locality No. 2), Turkey

Mammal Correlation: uppermost MN 8 (Steininger et al. 1989); alternatively middle portion of MN 7 + 8 (de Bruijn et al. 1992)

Correlation Tie Points: Yeni-Eskihisar E-Mediterranean pollen zone

Isotopic Age (Ma): Yeni-Eskihisar 1 (locality 1), 13.2 Ma; Yeni-Eskihisar 1 (locality 2), 11.1 Ma. Andrews et al. (1980) have reported that the stratigraphic relationships between the dated tuffs and fossiliferous horizons are unclear. The two tuffaceous levels are separated by only 90 cm of sediments, which cannot justify the age difference claimed by Becker-Platen et al. (1977). For details of this discussion see Andrews et al. 1980.

References: Andrews et al. 1980; Becker-Platen et al. 1975; Benda and Meulenkamp 1990; Benda et al. 1975; de Bruijn et al. 1992; Engesser 1980; Sickenberg et al. 1975; Steininger et al. 1989

MN 7+8

Age: middle Miocene
Locality: Santarem, Portugal
Mammal Correlation: MN 7 (Aguilar Zone C 4) (Steininger et al. 1989); MN 7+8 (de Bruijn et al. 1992)
Correlation Tie Points: Blow Zone N 12; Nannoplankton Zone NN 6
Inferred Age: (Berggren et al. 1995; and Rio and Fornaciari 1994) Blow Zone N 12 (= Berggren et al. 1995, Planktonic Foraminiferal Zone M 9 12.5 to 12.0 Ma); Nannoplankton Zone NN 6: 13.6 to 11.9 Ma
References: Aguilar 1982a; de Bruijn et al. 1992; Steininger et al. 1989

MN 7+8

Age: middle Miocene
Locality: La Grive M, France
Mammal Correlation: middle to upper MN 7 (Aguilar Zone C 4; Steininger et al. 1989); MN 7+8 (de Bruijn et al. 1992)
Correlation Tie Points: Blow Zone N 12; Nannoplankton Zone NN 6
Inferred Age: (Berggren et al. 1995; and Rio and Fornaciari 1994) Blow Zone N 12 (= Berggren and al. 1994, Planktonic Foraminiferal Zone M 9, 12.5 to 12.1/12.0 Ma); Nannoplankton Zone NN 6: 13.6 to 11.9 Ma
References: Aguilar 1982; de Bruijn et al. 1992; Freudenthal and Mein 1989; Mein 1984; Steininger et al. 1989

MN 7+8

Age: middle Miocene
Locality: Sankt Stefan i.L., Styria, Austria
Mammal Correlation: lower part of MN 8 (Steininger et al. 1989); alternatively, MN 7+8 (de Bruijn et al. 1992)
Correlation Tie Points: mammals from lignites intercalated in sediments with lower Sarmatian (= Volhynian) mollusc fauna
Inferred Age: (Berggren et al. 1995) Central Paratethys lower Sarmatian Stage = Eastern Paratethys Volhynian Stage, 13.6 - 12.2 Ma (Rögl and Daxner-Höck, this volume)
References: de Bruijn et al. 1992; Mottl 1964, 1957, 1980; Rabeder and Steininger 1975; Steininger et al. 1989

MN 7+8

Age: middle Miocene
Locality: Sofça, Turkey
Mammal Correlation: lower MN 8 (Steininger et al. 1989); upper MN 7+8 (de Bruijn et al. 1992)
Correlation Tie Points: Yeni-Eskihisar E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989; Benda et al. 1975; de Bruijn et al. 1992; Engesser 1980; Sickenberg et al. 1975; Steininger et al. 1989

MN 8

Age: middle Miocene
Locality: C. Almirall, Spain
Mammal Correlation: MN 8 (Aguilar Zone C 5), Steininger et al. (1989)
Correlation Tie Points: planktonic foraminifera, Blow Zone N 13/14 boundary; Nannoplankton Zone NN 7
Inferred Age: (Berggren et al. 1995; Rio and Fornaciari 1994) boundary of Blow Zone N 13/14 (= Berggren et al. 1995, Planktonic Foraminiferal Zone boundary M 10/11, 11.7 Ma); Nannoplankton Zone NN 7: 11.9 to 10.8 Ma
References: Aguilar 1982a; Steininger et al. 1989

MN 8

Age: middle Miocene
Locality: Comanesti 1, Romania
Mammal Correlation: MN 8 (Feru et al. 1980)
Correlation Tie Points: in sediments with a lower Sarmatian (= Volhynian) molluscan fauna
Inferred Age: (Berggren et al. 1995) Central Paratethys lower Sarmatian Stage = Eastern Paratethys Volhynian Stage: 13.6 to 12.2 Ma (Rögl and Daxner-Höck, this volume). The Volhynian/Bessarabian boundary has been paleomagnetically recalibrated by Pevzner and Vangengeim (1993) as being 12.4 or 12.18 Ma.
References: Bernor et al. 1988; Feru et al. 1980; Pevzner and Vangengeim 1993; Steininger et al. 1989

MN 8

Age: middle/late Miocene
Locality: Yassören localities 64, 65, Sinape Tepe, Central Anatolia, Turkey
Lithostratigraphic Position: from the fluviatile Sinap Formation, with a total thickness of more than 100 m.
Mammal Correlation: MN 8 (Kappelman et al., this volume)
Inferred Age: (Kappelman et al., this volume): 10.38 Ma for Loc. 64 and a little older for Loc. 65
References: Kappelman et al., this volume; Sen 1989, this volume

European Mammal Faunal Unit: Vallesian

European Mammal Faunal Zone: MN 9

MN 9

Age: late Miocene
Locality: Gaiselberg, Vienna Basin, Lower Austria
Lithostratigraphic Position: fluviatile deposits
Mammal Correlation: basal MN 9 (Bernor et al. 1988; Steininger et al. 1989 1992; de Bruijn et al. 1992)

Correlation Tie Points: Lower Pannonian: local Zone C
Inferred Age: Central Paratethys Stage Pannonian: approximately from 11.5 to 7.1 Ma (Rögl et al. 1993); basal MN 9, 11.2 (Rögl and Daxner-Höck, this volume)
References: Bernor et al. 1988a; 1993a, b; de Bruijn et al. 1992; Rögl et al., 1993; Rögl and Daxner-Höck, this volume; Steininger et al. 1989; Zapfe 1948

MN 9

Age: late Miocene
Locality: Hovorany, Moravia, Czechoslovakia
Mammal Correlation: basal MN 9 (Bernor et al. 1988a); medial MN 9 (de Bruijn et al. 1992)
Correlation Tie Points: Lower Pannonian: local Zone B/C
Inferred Age: Central Paratethys Stage Pannonian: approximately from 11.5 to 7.1 Ma (Rögl et al. 1993); basal MN 9, 11.2 Ma
References: Bernor et al. 1988a, 1993a, b; de Bruijn et al. 1992; Ctyrocky in Steininger et al. 1987; Rögl et al. 1993; Rögl and Daxner-Höck, this volume; Woodburne et al., this volume

MN 9

Age: late Miocene
Locality: Eşme Akçaköy, Turkey
Mammal Correlation: basal MN 9 (de Bruijn et al. 1992).
Isotopic Age: radiometric date, 11.6 ±0.5 Ma
References: de Bruijn et al. 1992; Sen 1989; Sickenberg et al. 1975

MN 9

Age: late Miocene
Locality: Comanesti 2, Romania
Mammal Correlation: Medial MN 9 (Bernor et al. 1988a); alternatively basal MN (Steininger et al. 1989; de Bruijn et al. 1992)
Correlation Tie Points: Lower Pannonian, local Zone C/D
Inferred Age: Central Paratethys Stage Pannonian: from approximately 11.5 to 7.1 Ma (Rögl et al. 1993).
References: Bernor et al. 1988; de Bruijn et al. 1992; Feru et al. 1980; Rögl et al. 1993; Steininger et al. 1989

MN 9

Age: late Miocene
Locality: Vösendorf and Inzersdorf, Vienna, Vienna Basin, Austria
Lithostratigraphic Position: greyish silty clays to sands in nearshore environment of "Pannonian" lake system
Mammal Correlation: basal MN 10 (Steininger et al. 1989; 1992); alternatively medial MN 9 (de Bruijn et al. 1992); medial MN 9, slightly older than Höwenegg (Bernor et al. 1988, 1993a, b; Woodburne et al., this volume)
Correlation Tie Points: middle Pannonian: local Zone E
Paleomagnetic Calibration: the existing outcrop of the Inzersdorf section exhibits a normal polarity, which is correlated to Chron C5n.2n (Lantos and Hodi-Korpas, pers. comm., 1993).
Inferred Age: (Berggren et al. 1995) Chron 5n.2n: 10.95 to 9.92 Ma; Bernor et al.'s correlation with Höwenegg would make this locality slightly older than 10.3 Ma.
References: Bachmayer and Wilson 1984; Bernor et al. 1988, 1993a, b; de Bruijn et al. 1992; Rabeder 1985; Rabeder and Steininger 1975; Rögl et al. 1993; Rögl and Daxner-Höck, this volume; Steininger et al. 1989; Woodburne et al., this volume

MN 9

Age: late Miocene
Locality: Höwenegg, Germany
Lithostratigraphic Position: "Höwenegg-Schichten": whitish, lacustrine marls with tuff-horizons, belonging to the "Obere Süßwasser Molass" Formation
Mammal Correlation: medial MN 9 (Bernor et al. 1993a, b; Woodburne et al., this volume); lower MN 9 (Steininger et al. 1989; de Bruijn et al. 1992)
Paleomagnetic Calibration: entire section within a normal polarity zone correlated to Chron C5n.2n (Woodburne et al., this volume)
Isotopic Age: several radiometric dates published ranging between 12.4 and 9.4 Ma for basalts, tuffs and hornblends. Presently most reliable date: 10.3 Ma (Swisher et al., this volume)
Inferred Age: (Berggren et al. 1995) The most recent age coupled with the section's normal polarity provides a correlation within Chron C5n.2n: 10.95 to 9.92 Ma; the slightly advanced stage-of-evolution of the hipparionine horses from the Höwenegg quarry indicate a medial MN 9 age to Bernor et al. (1993a, b).
References: Bernor et al. 1988, 1993a, b, this volume a; de Bruijn et al. 1992; Hünermann 1989; Swisher, this volume; Woodburne et al., this volume; Zöbelein 1988

MN 9

Age: late Miocene
Locality: Gritsev, Chmielnicki Region, Ukraina
Lithostratigraphic Position: clays with shells and bones filling karstic fissures in limestones of middle Sarmatian (Bessarabian) age (Korotkevich 1988)
Mammal Correlation: medial MN 9 (Kowalski 1993b, Pevzner and Vangengeim 1993, and Krakhmalnaya 1994)
Correlation Tie Points: a Bessarabian mollusc fauna was recovered from the bone bearing clays.
Isotopic Age: Radioisotopically dated 12.4 Ma, correlative with the base of the Bessarabian (Chumakov et al. 1988, 1992 a, b); top of the Bessarabian is calibrated as being 10.2 Ma.
Paleomagnetic Calibration: clays with reversed magnetization (Pevzner and Vangengeim 1993)
Inferred Age: Bessarabian, ca. 12.2–11 Ma (Rögl and Daxner-Höck, this volume). The reversed magnetization is correlated by Pevzner and Vangengeim (1993: fig. 6) to Chron 10, which is equal to Chron C5r.3r, 11.93 to 11.53 Ma or Chron C5r.2r, 11.47 to 11.09 Ma.
References: Chumakov et al. 1988, 1992a, b; Korotkevich 1988; Kowalski 1993b; Krakhmalnaya 1994; Pevzner and Vangengeim 1993; Rögl et al. 1993; Rögl and Daxner-Höck, this volume

MN 9

Age: middle Miocene
Locality: Yassören, locality 94, Sinap Tepe, Central Anatolia, Turkey
Lithostratigraphic Position: from the fluviatile Sinap Formation with a total thickness of more than 100 m
Mammal Correlation: early MN 9, according to Kappelman et al. (this volume) and Sen (this volume)
Inferred Age: (Kappelman et al., this volume) 10.24 Ma
References: Kappelman et al., this volume; Sen 1989, this volume
Remarks: Kappelman et al. (this volume) calculate the MN 8/9 boundary half-way inbetween localities 64 and 94 and estimate an age for this boundary of 10.31 Ma.

MN 9

Age: late Miocene
Locality: Yassören, locality 8a (= Loc. I of Ozansoy 1957; 1965), 87 Sinap Tepe, Central Anatolia, Turkey
Lithostratigraphic Position: from the fluviatile Sinap Formation with a total thickness of more than 100 m. Mammal localities from base to top in stratigraphic order: locality 87 (with one "Hipparion" molar) and locality 8A (with a rich fauna of large and small mammals).
Mammal Correlation: MN 9 (Kappelman et al., this volume; Sen, this volume)
Inferred Age: (Kappelman et al., this volume; Sen, here) 10.31 Ma for locality 87 and 9.77 Ma for locality 8A
References: Kappelman et al., this volume; Ozansoy 1957, 1965; Sen 1989, this volume

MN 9/10

Age: late Miocene
Locality: Bou Hanifia, Horizon BH 1, Algeria
Mammal Correlation: medial to upper MN 9 (Steininger et al. 1989); alternatively, near to the MN 9/10 boundary (Woodburne et al., this volume; Swisher, this volume); BH 5 MN 10 or younger
Correlation Tie Points: beds with planktonic fauna of Blow Zone N 15 about 100 m below mammal horizon BH 1 with "Hipparion." These marine beds intertongue with dated ash beds (see below).
Paleomagnetic Calibration: Horizon BH 1 is situated within a long reversed polarity zone, which is followed by a short normal and again a reversed zone. On top is BH 5 again, in a normal polarity zone (see MN 10 horizon BH 5).
Isotopic Age: radiometric date 12.03 ±0.25 Ma from ash beds at least 100 m below mammal horizon BH 1 with "Hipparion." These ash beds intertongue with marine beds with a planktonic fauna assigned to Blow Zone N 15 (Berggren, pers. comm.).
Inferred Age: (Berggren et al. 1995) Blow Zone N 15 (= Berggren et al. 1995, Planktonic Foraminiferal Zone M 12 and lowermost part of M 13, 11.35 to 10.7 Ma). The reversed part of the section with mammal horizon BH 1 followed by a short normal can either be correlated to Chron C5n.1r and Chron C5n.1n: 9.92 to 9.74 Ma or to Chron C4Ar.2n and Chron C4Ar.2r: 9.64 to 9.31 Ma.
References: Bernor et al. 1988; Sen 1989; Woodburne et al., this volume

European Mammal Faunal Zone: MN 10

MN 10

Age: late Miocene
Locality: Yassören, locality 84 (Ozansoy 1957; 1965), Sinap Tepe, Central Anatolia, Turkey
Lithostratigraphic Position: from the fluviatile Sinap Formation with a total thickness of more than 100 m.
Mammal Correlation: early MN 10 (Kappelman et al., this volume; Sen, this volume).
Inferred Age: (Kappelman et al., this volume; Sen, this volume) 9.77 Ma
References: Kappelman et al., this volume; Ozansoy 1957, 1965; Sen 1989, this volume

MN 10

Age: late Miocene
Locality: Bou Hanifia, Horizon BH 5, Algeria
Mammal Correlation: BH 5 is MN 10 (or younger, Swisher et al., this volume).
Correlation Tie Points: see explanation for Bou Hanifia I, above.
Paleomagnetic Calibration: see explanation for Bou Hanifia I, above.
Isotopic Age: radiometric date 12.03 ±0.25 Ma from ash beds more than 100 m below mammal horizon BH 1 with "Hipparion." These ash beds intertongue with marine beds with planktonic fauna assigned to Blow Zone N 15 (Berggren, pers. comm.).
Inferred Age: (Berggren et al. 1995) Blow Zone N 15 (= Berggren et al. 1995, Planktonic Foraminiferal Zone M 12 and lowermost part of M 13, 11.35 to 10.7 Ma). The reversed part of the section with mammal horizon BH 1 is succeeded by a short normal interval that can either be correlated with Chron C5n.1r to Chron C5n.1n: 9.88 to 9.74 Ma or with Chron C5n.1r to Chron C4Ar.2r, 9.92 to 9.58 Ma. The beds with BH 5 faunas are in a succeeding normal polarity portion of the sequence. This leads to two possible correlations for the Bou Hanifia faunas: BH 1 is in the reversed part Chron C4Ar.2r and normal part with BH 5 fauna Chron C4Ar.2n: 9.64 to 9.58, or reversed part Chron C4Ar.1r and normal part with BH 5 faunal horizon in Chron C4Ar.1n: 9.30 to 9.23 Ma.
References: Bernor et al. 1988, 1993a, b; Sen 1986, Woodburne et al., this volume

MN 10

Age: late Miocene
Locality: Oued Zra, Morocco
Mammal Correlation: middle to upper part of MN 10 (Steininger et al. 1989); uppermost MN 10 (Sen, pers. comm., 1994)
Isotopic Age: mammal locality younger than: 9.7 ±0.5 Ma
References: Jaeger et al. 1973; Steininger et al. 1989

MN 10

Age: late Miocene
Locality: Kastellios 1, 2, 3, Greece
Mammal Correlation: near the MN 9/10 boundary (Steininger et al. 1989); alternatively MN 10 (Benda and Meulenkamp 1990); alternatively medial MN 10 (de Bruijn et al. 1992); alternatively uppermost MN 10 (KA 1; Mein et al. 1993); see Sen (this volume) for further discussion.
Correlation Tie Points: planktonic foraminifera Blow Zone: N 16; base of Kizilhisar E-Mediterranean pollen zone
Paleomagnetic Calibration: within Chron C4Ar with K 1 in reversed part followed by a normal part, K 2 at the base of the following reversed part followed by a normal part and K 5 in the following reversed part (Opdyke, written comm., 1990).
Inferred Age: Blow Zone N16 = Berggren et al. 1995, Planktonic foraminifera Zone M13a to M13b pro parte: 10.8 to 5.9 Ma. The magnetic pattern is correlated from the base to the top of the section with Chron C4Ar.2r: 9.58 to 9.30 Ma (Kastellios 1) to Chron C4Ar.1r base: 9.23 Ma (Kastellios 2) to Chron C4An: 9.02 Ma (Kastellios 5).
References: Benda and Meulenkamp 1990; de Bruijn and Zachariasse 1979; de Bruijn et al. 1992; Sen et al. 1986; Sen, this volume; Steininger et al. 1989; Woodburne et al., this volume

MN 10

Age: late Miocene
Locality: Ravin de Pluie, Macedonia, Greece
Mammal Correlation: MN 10 (Bonis et al. 1988); alternatively medial MN 10 (de Bruijn et al. 1992); alternatively lower MN 10 (Mein et al. 1993)
Correlation Tie Points: Blow Zone N 16 (Koufos, pers. comm., 1990)
Inferred Age: (Berggren et al. 1995) Blow Zone N 16 (= Berggren et. al. 1994, Planktonic Foraminifera Zone M13a to M13b pro parte): 10.8 to 5.9 Ma
References: Bonis and Koufos 1981; Bonis et al. 1974, 1986, 1988; Bouvrain 1975, 1982; de Bruijn et al. 1992; Koufos 1986, 1989

MN 10

Age: late Miocene
Locality: Lefkon 1, Greece
Mammal Correlation: MN 10 uppermost part, according to Steininger et al. (1989) and de Bruijn et al. (1992)
Correlation Tie Points: lower Kizilhisar E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989, 1990; de Bruijn 1989; de Bruijn et al. 1992; Steininger et al. 1989

MN 10

Age: late Miocene
Locality: Xirochori 1, Macedonia, Greece
Mammal Correlation: MN 10 (Koufos, pers. comm., 1990)
Correlation Tie Points: Blow Zone N 16 (Koufos, pers. comm., 1990)
Inferred Age: (Berggren et al. 1995) Blow Zone N 16 (= Berggren et. al. 1994, Planktonic Foraminifera Zone M13a to M13b pro parte): 10.8 to 5.9 Ma
References: Bonis et al. 1989, 1990

European Mammal Faunal Unit: Turolian

European Mammal Faunal Zone: MN 11

MN 11

Age: late Miocene
Locality: Prochoma 1, Macedonia, Greece
Lithostratigraphic Position: fluviatile deposits
Mammal Correlation: MN 11 (Koufos, pers. comm., 1990); MN 11 (Sen, this volume; Kondopoulou et al. 1992)
Paleomagnetic Calibration: Chron 10 = Chron C4Ar lower part (Sen, pers. comm., 1990). Kondopoulou et al. (1992) report magnetic reinvestigations of 25 m of section that yield the following observations: the basal 5 m have a normal polarity and the remainder of the section has a reversed polarity.
Inferred Age: The current geomagnetic results are correlated tentatively to Chron C4Ar.2n and C4Ar.1r: 9.64 to 9.02 Ma.
References: Bonis et al. 1986, 1988; Geraads 1978, 1979; Kondopoulou et al. 1992; Koufos 1987b, 1989; Sen, this volume

MN 11

Age: late Miocene
Locality: Kayadibi, Turkey
Mammal Correlation: lowermost part of MN 11 (Steininger et al. 1989; de Bruijn et al. 1992)
Correlation Tie Points: lower Kizilhisar E-Mediterranean pollen zone
Isotopic Age: the Bulumya ignimbrite situated below the mammal faunal horizon is dated 9.4 ±0.2 Ma while the Detse ignimbrite above mammal faunal horizon is dated 7.95 ±0.25 Ma.
References: Becker-Platen et al. 1975; Benda and Meulenkamp 1989, 1990; de Bruijn et al. 1992; Sickenberg et al. 1975; Steininger et al. 1989

MN 11

Age: late Miocene
Locality: Kopran, Lower Maragheh, Iran
Lithostratigraphic Position: The Maragheh Formation rests unconformably on top of the "Basal Tuff" dated 10.391 to 10.432 Ma. The Maragheh Formation consists approximately of 300 m of coarsley stratified deposits of brown to tan andesitic volcanic sands and silts. Succeeding an erosional surface follows the "Village Pumice," constituting the top of the Maragheh Formation.
Mammal Correlation: basal MN 11 (Steininger et al. 1989; Bernor et al., this volume b); defines the base of the *Hipparion gettyi* Zone (Bernor et al., this volume b)
Isotopic Age: The lower Maragheh fauna (= faunas in the Kopran and Mirduq sections) have an interpolated age of approxi-

mately 8.64 to 8.24 Ma (Swisher, this volume) interpreted by Bernor et al. (this volume b) to be 9 to 8.24 Ma, based on an interpolated date from the Mirduq Tuff to the stratigraphically lower Kopran horizons.

References: Campbell et al. 1980; Bernor 1985, 1986; Bernor et al., this volume b; Steininger et al. 1989; Swisher et al., this volume

MN 11

Age: late Miocene
Locality: Ravin des Zouaves 5, Macedonia, Greece
Mammal Correlation: MN 10/11 (Bonis et al. 1988); MN 11 (de Bruijn et al. 1992)
Correlation Tie Points: Blow Zone N 16/17 (Koufos, pers. comm., 1990)
Inferred Age: Blow Zone N 16/17 (= Berggren et. al., 1995, Planktonic Foraminifera Zone M13a to M13b pro parte and M 14): 10.8 to 5.6 Ma
References: Arambourg and Piveteau 1929; Bonis et al. 1988; Bouvrain 1982; de Bruijn et al. 1992; Geraads 1978, 1979; Koufos 1987, 1989

MN 11

Age: late Miocene
Locality: La Celia (Los Gargantones), Spain
Mammal Correlation: lower MN 11 (de Bruijn et al. 1992)
Isotopic Age: lava beds immediately above the mammal faunal horizon dated 7.2 to 7.6 Ma
References: Agusti 1990, Agusti in Steininger et al. 1987, 1989, de Bruijn et al. 1992
Remarks J. Agusti (writ. comm., 1994) states that a lava bed in the La Celia section is placed immediately above the layer with the typical MN 11 mammal fauna and believes that the base of MN 11 must not be much older than these age determinations. This interpretation is in conflict with the E-Mediterranean calibration of basal MN 11 (ca. 9 Ma; see above).

MN 11

Age: late Miocene
Locality: Crevillente 1 to 3, Spain
Mammal Correlation: Crevillente 2 correlative with basal MN 11, Aguilar Zone D 3 (Steininger et al. 1989); middle part of MN 11 (de Bruijn et al. 1992); lower MN 11 (Mein et al. 1993)
Correlation Tie Points: planktonic foraminifera assigned to Blow Zone N 16
Inferred Age: Blow Zone N 16 (= Berggren et. al., 1995, Planktonic Foraminifera Zone M13a to M13b pro parte): 10.8 to 5.9 Ma
References: Aguilar 1982a; Alcala and Montoya 1991, 1994; de Bruijn et al. 1992; Steininger et al. 1989

MN 11

Age: late Miocene
Locality: Samos: Old Mill Beds, Quarries X, G and 6, Greece
Lithostratigraphic Position: lithological sequence from base to top: Basal Conglomerate unconformably on Mesozoic basement; Pythagorion Formation: thick-bedded freshwater limestone and paleosoils, lignitic marls, basalts dated 11.2 Ma; Hora Formation: thinly bedded freshwater limestones, with volcanic unit at top dated 9 Ma; Mytilini Formation: floodplain deposits with volcanogenic marls, gravels, soil horizons and rhyolite pumice tuffs and with four members: lowest–Old Mill Beds Member, well-bedded marls and tuffs with paleosoils including Quarries Q X, G and Q 6, best estimated age is 8.33 ±0.05 Ma (Swisher, this volume); Gravel Bed member: channel fills truncating Old Mill Beds; White Beds member: indurated marls and limestones, perhaps quarry Q 4 (7.66 Ma); Main Bone Beds member: volcanoclastic sandy silts, marls, tuffs, local paleosoils, and gravel lenses overlain by a thick limestone conglomerate: quarries: Q 1, Q 2, Q 3, Q 5, S 3, S 4 all late MN 12, approximately 7.3–7.1 Ma. On top of the Mytilini Formation follow with a disconformity, the Marker Tuffs: well-bedded indurated water lain tuffs and marls; quarry L, MN 13 with best estimated age of 6.17 ±0.05 Ma (Swisher, this volume). On top the *Kokkarion Formation:* thick-bedded freshwater algal limestones.
Mammal Correlation: Quarries X, G and 6 from Old Mill Beds: MN 11 (Steininger et al. 1989; Bernor et al., this volume b). Main Bone Beds uppermost MN 12 (Bernor et al., this volume b)
Paleomagnetic Calibration: Old Mill Beds should be in reversed polarity zone.
Isotopic Age: Old Mill Beds 8.33 ±0.05 Ma
Inferred Age: by cross-correlation including radiometric ages and geomagnetic calibration: Old Mill Beds in reversed polarity zone correlated to Chron C4r.1r: 8.22 to 8.07 Ma.
References: Bernor et al., this volume b; de Bruijn et al. 1992; Sen 1986, this volume; Solounias 1981; Steininger at al. 1989; Swisher, this volume; Weidmann et al. 1984

MN 11

Age: late Miocene
Locality: Garkin, Turkey
Mammal Correlation: upper MN 11 (Steininger et al. 1989); alternatively, medial MN 11 (de Bruijn et al. 1992)
Correlation Tie Points: lower Kizilhisar E-Mediterranean pollen zone
Isotopic Age: Radiometric date of 8.6 Ma below faunal horizon
References: Becker-Platen et al. 1975; Benda and Meulenkamp 1989, 1990; de Bruijn et al. 1992; Sickenberg et al. 1975; Steininger et al. 1989

MN 11

Age: late Miocene
Locality: Pertuis, France
Mammal Correlation: Mammal Zone D 3 (Aguilar); medial MN 11 (de Bruijn et al. 1992)
Correlation Tie Points: the rodent-bearing horizon is stratigraphically above marine sediments containing planktonic foraminifera correlative with Blow Zone N 15 or N 16.
Inferred Age: (Berggren et al. 1995) Blow Zone N 15 (= Berggren et al. 1995, Planktonic Foraminifera Zone M 12 and lower-

most part of M 13a): 11.35 to 10.5; Blow Zone N 16 (= Berggren et. al. 1994 Planktonic Foraminifera Zone M13a to M13b pro parte): 10.8 to 5.9 Ma

References: Aguilar 1981, 1982a, b; de Bruijn et al. 1992; Clauzon et al. 1987, 1989

Remarks: There are no marine deposits known in southern France younger than N 15 to N 16.

MN 11

Age: late Miocene

Localities: Andance; Le Combier; St. Bauzile; Valréas -CD 56; Lobrieu and Mollon; Ardèche; France

Lithostratigraphic Position: approximately 170 m of section; in the upper part there are approximately 40–45 m of "diatomites principales" separated by lignites from about 10 m of "conglomerats fluviatiles rouges" overlain by "diatomites supérieures" and "argiles rouges." On top the "coulée basaltique du plateau des Coirons" is dated 6.4 Ma.

Mammal Correlation: MN 11 (Demarcq et al. 1989); upper part of MN 11 (de Bruijn et al. (1992); medial MN 11 (Mein et al. 1993)

Correlation Tie Points: diatomites in connection with the marine gulf of the Montelimar Basin in lower Tortonian: Blow Zone N 16.

Inferred Age: (Berggren et al. 1995) Blow Zone N 16 (= Berggren et. al., 1995, Planktonic Foraminifera Zone M13a to M13b pro parte): 10.8 to 5.9 Ma

References: de Bruijn et al. 1992; Demarcq et al. 1989; Michaux 1971

Remarks: Mammal fauna from "diatomite principalé' and "conglomerat supérieur."

MN 11/12

Age: late Miocene

Locality: Pikermi, Greece

Lithostratigraphic Position: Pikermi Formation, pale to dark red clayey silts with limestone conglomerate lenses and layers of hard limey marls

Mammal Correlation: MN 12/13 boundary (Steininger et al. 1989); alternatively MN 13 (Benda and Meulenkamp, 1989); alternatively uppermost MN 12 (de Bruijn et al. 1992); alternatively near the MN 11/12 boundary because of co-occurrence of *Hipparion gettyi* and *Hipparion prostylum* (Bernor et al., this volume b)

Correlation Tie Points: uppermost Kizilhisar E-Mediterranean pollen zone

Inferred Age: 8.3 to 8.2 Ma (Bernor et al., this volume b)

References: de Bruijn 1979; Benda and Meulenkamp 1989, 1990; Steininger et al. 1989; de Bruijn et al. 1992; Bernor et al., this volume b

European Mammal Faunal Zone: MN 12

MN 12

Age: late Miocene

Locality: Middle Maragheh, Iran

Lithostratigraphic Position: on top of a basal tuff (80 m) dated 10.391 to 10.432 Ma follows the Lower Maragheh *Hipparion gettyi* Zone within approximately 300 m, a coarsley stratified unit of brown to tan andesitic volcanic sands and silts. On top of an erosional surface follows the "Village Pumice," which forms the top of the Maragheh Formation.

Mammal Correlation: middle to upper faunas MN 11 (Steininger et al. 1989); the base of the *Hipparion prostylum* Zone is correlative with basal MN 12 for reasons given by Bernor et al. (this volume).

Isotopic Age: Kerjabad mammal fauna with an interpolated age of approximately 8.1 to 7.9 Ma (Swisher, this volume); base of *Hipparion prostylum* Zone in Maragheh section interpolated to be 8.24 Ma (Bernor et al., this volume b).

References: Campbell et al. 1980; Bernor 1985, 1986; Steininger et al. 1989; Bernor et al., this volume b; Swisher, this volume

MN 12

Age: late Miocene

Locality: Samos: Main Bone Beds Member (Quarries: Q 1, Q 2, Q 3, Q 5, S 3 and S 4) (= also Lower and Upper fossiliferous level; Samos 5 [de Bruijn et al. 1992]; Upper fossiliferous level with localities Q 5, Q 1, and A of Sen and Valet 1986), Greece

Lithostratigraphic Position (lithological sequence from base to top): (1) Basal Conglomerate unconformably resting on Mesozoic basement. (2) Pythagorion Formation: thick bedded freshwater limestone and paleosoils, lignitic marls, basalts dated 11.2 Ma. Hora Formation: thin-bedded freshwater limestones, at top volcanic unit dated 9 Ma. (3) The Mytilini Formation consists of floodplain deposits with volcanogenic marls and gravels, soil horizons, and rhyolite pumice tuffs. (4) The Mytilini Formation includes four members. (5) The lowest is the Old Mill Beds member with well-bedded marls and tuffs with paleosoils and including Quarries X, G and 6; best estimated age is 8.33 ±0.05 Ma (Swisher, this volume). (6) The succeeding Gravel Bed member consists of channel fills truncating the Old Mill beds. (7) The succeeding White Beds member consists of indurated marls and limestones and perhaps includes Quarry 4 (date 7.66 Ma; Swisher, this volume). (8) Next is the Main Bone Bed member, which has yielded the majority of the Samos fossil material. It consists of volcanoclastic sandy silts, marls, tuffs, local paleosoils, and gravel lenses overlain by a thick limestone conglomerate; fossil quarries include Q 1, Q 2, Q 3, Q 5, S 3 and S 4, all correlative with late MN 12, between 7.3 and 7.1 Ma. (9) Succeeding the Mytilini Formation is a disconformity and the "Marker Tuffs," with well-bedded indurated water lain tuffs and marls. Solounias (in Bernor et al., this volume b) has identified quarry L from this unit, which has a best estimated age of 6.17 ±0.05 Ma (Swisher, this volume; Bernor et al., this volume b), and is the only portion of the Samos fauna that is MN 13. The top of the sequence includes the Kokkarion Formation, containing thick-bedded freshwater algal limestones.

Mammal Correlation: (from the Mytilini Formation): Bernor et al. (1980) have argued, based on the Samos hipparion lineages, that the bulk of the Samos fauna is ca. 7 Ma; Weidmann et al. (1984) have argued that there is a Lower and Upper fossiliferous level correlative with MN 12; alternatively Steininger et al. (1989) have correlated the bulk of the Samos fossils with basal

MN 13; de Bruijn et al. (1992) correlate the Samos Main Bone Beds member (Quarries: Q 1, Q 2, Q 3, Q 5, S 3 and S 4) with the lower part of MN 13; Bernor et al. (this volume b) correlate the Samos Main Bone Beds with upper MN 12 (ca. 7.66–7.1 Ma).

Paleomagnetic Calibration: The Mytillini Formation, including the Main Bone Bed member, Lower and Upper fossiliferous levels, respectively in a mixed polarity sequence. Samos 5 is in the "Upper level" within a reversed polarity zone.

Isotopic Age: Mytilini Formation, main quarries of the Main Bone Beds bracketed by radioisotopic determinations of 7.276 ±0.006 Ma and 7.092 ±0.008 Ma.

Inferred Age: (Berggren et al. 1995) by cross-correlation including radiometric ages and geomagnetic calibration, a lower fauna ca. 8.33 Ma and MN 11 equivalent, and an upper fauna ca. 7.66–7.1Ma and MN 12 equivalent.

References: Bernor et al., this volume b; Sen 1986, this volume; de Bruijn et al. 1992; Sen and Valet 1986; Solounias 1981; Steininger at al. 1989; Swisher et al., this volume; Weidmann et al. 1984

MN 12

Age: late Miocene

Locality: Casa del Acero, Spain

Mammal Correlation: basal MN 12 (Steininger et al. 1989; de Bruijn et al. 1992); medial MN 12 (Mein et al. 1993)

Correlation Tie Points: is included within the third Messinian evaporitic (first evaporite overlies *Globorotalia conomiozea* Zone).

Inferred Age: (according to Gaultier and al. 1994) Messinian evaporitic cycles dated 5.8 to 5.32 Ma

References: Agusti in Steininger 1987; Alcala and Montoya 1991, 1994; in press; de Bruijn et al. 1992; Gaultier et al. 1994; Steininger et al. 1989

Remarks: J. Agusti (May 1994) indicates that the typical MN 12 mammal fauna of Casa del Acero is included within the third evaporitic cycle of the Messinian succession in this basin. Therefore the MN 11/12 boundary must be younger than 7.2 Ma (= base of the Messinian).

MN 12

Age: late Miocene

Locality: Kinik, Turkey

Mammal Correlation: medial MN 12 (Steininger et al. 1989); basal MN 12 (de Bruijn et al. 1992)

Correlation Tie Points: upper Kizilhisar E-Mediterranean pollen zone

References: Benda and Meulenkamp 1989; de Bruijn et al. 1992; Sickenberg et al. 1975

MN 12

Age: late Miocene

Locality: Sholàvand, Upper Maragheh, Iran

Lithostratigraphic Position: see description above for the Lower and Middle Maragheh faunas.

Mammal Correlation: early MN 12 (Steininger et al. 1989 and Swisher et al., this volume); Bernor et al. (this volume b) correlate *Hipparion campelli* Zone with medial MN 12.

Isotopic Age: Sholàvand mammal faunal with an interpolated age of approximately 7.9 to 7.64 Ma (Swisher, this volume), or 8.0 to 7.6 Ma (Bernor et al., this volume b).

References: Bernor 1985, 1986; Bernor et al., this volume b; Campbell et al. 1980; Steininger et al. 1989; Swisher et al., this volume

MN 12

Age: late Miocene

Locality: Fuente Podrida, Cabriel Basin south of Venta del Moro, Spain

Lithostratigraphic Position: locality in Fuente Podrida limestones

Mammal Correlation: MN 12 (Opdyke et al. 1988)

Paleomagnetic Calibration: the Fuente Porida fauna occurs in the first normal magnetozone (N 1) at the base of the section, this magnetozone N 1 is correlated with the lowermost normal of Chron 7 by Opdyke et al. (1989) = Chron C4n.

Inferred Age: 7.2 Ma by Opdyke et al. 1988 = Chron C4n.2n: 8.07 to 7.65 Ma

References: Mein et al. 1978; Opdyke et al. 1988; Sen, this volume

Remarks: Opdyke et al. (1989) argue that the boundary between MN 11 and MN 12 should be only slightly older, ca. 7.3 Ma.

MN 12

Age: late Miocene

Locality: Novaya Emetovka 1, NW Odessa, Ukrania

Lithostratigraphic Position: 5 m of cyclic sedimentation of sandstones, sands, silts, and clays with thin intercalations of tuffaceous limestone together with endemic mollusks. Bone horizon in the lowermost cycle. The sequence follows unconformably on top of upper Sarmatian (ca. 13 m).

Mammal Correlation: Lower portion of MN (Krakhmalnaya et al. 1993)

Correlation Tie Points: early Maeotian by endemic mollusk fauna

Paleomagnetic Calibration: mammal fauna in a reversed polarity zone. See also Novaya Emetovka 2. This geomagnetic pattern is correlated near to base of Chron 6 = obviously thought to correlate within Chron C3Br to C3Bn.

Inferred Age: (Berggren et al., 1995) if we follow this interpretation of the geomagnetic polarity, the reversed zone can be correlated to Chron C3Br: 7.43 to 7.09 Ma; the inferred age of the Maeotian ranges from 9.8 to 7.1 Ma.

References: Krakhmalnaya et al. 1993

MN 12

Age: late Miocene

Locality: Novaya Emetovka 2, NW Odessa, Ukrania

Lithostratigraphic Position: 40 m of cyclic sedimentation of sandstones, sands, silts, and clays with thin intercalations of tuffeceous limestone together with endemic mollusks. The bone horizon is about 10 m above the erosional base. Lowermost cycle of Emetovka missing. The sequence follows unconformably on top of late Sarmatian (ca. 10 m).

Mammal Correlation: lower MN 12 (Krakhmalnaya et al. 1993)

Correlation Tie Points: early Maeotian by endemic molluscan fauna

Paleomagnetic Calibration: the basal part of this Maeotian section is above the erosional surface up to 12 m in a reversed zone (the bone bed is between meters 10 and 11 and equal to R-1, up to meter 26, a normal zone equal to N-2, followed by a short reversed part up to meter 27, 5 equals to R-3 and up to meter 40 at the top of the section, a normal zone equals to N-3). The geomagnetic pattern is correlated to Chron 6 and lower Chron 5. According to the GPTS of Berggren et al. (1995), this geomagnetic pattern can be interpreted as follows: the R-1 is equal to Chron C3Br; N-1 equals to Chron C3Bn; R-2 is equal to Chron C3Ar; N-2, R-3 and N-3 equal to Chron C3An.

Inferred Age: (Berggren et al. 1995) if we follow this interpretation, the bone-bearing horizon would correlate to the reversed base of Chron C3Br: 7.43 to 7.09 Ma.

References: Krakhmalnaya et al. 1993

European Mammal Faunal Zone: MN 13

MN 13

Age: late Miocene

Locality: Molina de Segura, horizon D and 1, Spain

Mammal Correlation: lowermost faunal level of MN 13 (Steininger et al. 1989 and de Bruijn et al. 1992); alternatively, MN 12/13 boundary (Agusti et al. 1987a, b)

Correlation Tie Points: overlies third Messinian evaporitic series

Inferred Age: (to Gaultier et al. 1994) Messinian evaporitic cycles and younger than 5.8 (i.e., 5.8 to 5.32 Ma)

References: Agusti in Steininger et al. 1989; de Bruijn et al. 1992

MN 13

Age: late Miocene

Locality: Samos, Marker Tuffs, Quarry L, Greece

Lithostratigraphic Position: lithological sequence from base to top as described above for Samos

Mammal Correlation: MN 13 correlative (Bernor et al., this volume b)

Isotopic Age: Marker Tuffs dated at 6.2 Ma (6.17 ±0.05 Ma) (Swisher, this volume).

References: Bernor et al. 1980, this volume b; de Bruijn et al. 1992; Solounias 1981; Sen 1986, this volume; Sen and Valet 1986; Steininger et al. 1989; Swisher et al., this volume; Weidmann et al. 1984

MN 13

Age: late Miocene

Locality: Venta del Moro, Spain

Mammal Correlation: lower to medial MN 13 (Steininger et al. 1989); medial MN 13 (de Bruijn et al. 1992)

Paleomagnetic Calibration: within a normal polarity zone correlated with Anomaly 3A = Chron C3An

Inferred Age: (Berggren et al. 1995) Chron C3An: 6.56 to 5.89 Ma. Age inferred by Opdyke et al. (1988) is 5.7 Ma.

References: Azanza et al. 1989; de Bruijn et al. 1992; Cerdeno 1989; Morales 1984; Opdyke et al. 1988; Sen, this volume; Steininger et al. 1989

MN 13

Age: late Miocene

Locality: Crevillente 6, Spain

Mammal Correlation: medial MN 13 (Steininger et al. 1989 and de Bruijn et al. 1992); Aguilar Zone E 2

Correlation Tie Points: *Globorotalia conomiozea* Zone = lower Messinian

Inferred Age: (Gaultier and al. 1994) in Messinian pre-evaporitic series, 7.2 to 5.8 Ma

References: de Bruijn et al. 1975, 1992; Aguilar 1982a; Opdyke et al. 1989; Steininger et al. 1989

MN 13

Age: late Miocene

Locality: Librilla, Spain

Mammal Correlation: medial to upper MN 13 (Aguilar Zone E 2; Steininger et al. 1989); upper MN 13 (de Bruijn et al. 1992)

Isotopic Age: mammal faunal horizon underlain by volcanic unit dated at 7.00, 6.5 and 6.2 Ma

References: Aguilar 1982a; Alberdi et al. 1981; de Bruijn et al. 1975, 1992; Montenat et al. 1975; Steininger et al. 1989

MN 13

Age: late Miocene

Locality: Dytiko 1, 2, 3, Macedonia, Greece

Mammal Correlation: MN 13 (Koufos, pers. comm., 1990); alternatively medial MN 13 (de Bruijn et al. 1992)

Correlation Tie Points: Blow Zone N 17 (Koufos, pers. comm., 1990)

Inferred Age: (Berggren et al. 1995) Blow Zone N 17 (= Berggren et al. 1995, upper Planktonic Foraminifera Zones M 13b and M 14): 7.2 to 5.6 Ma.

References: Arambourg and Piveteaux 1929; Bouvrain 1978; Bonis et al. 1988; Koufos 1987c, 1988b, 1989; de Bruijn et al. 1992

MN 13

Age: late Miocene

Locality: La Alberca, Spain

Mammal Correlation: uppermost faunal horizon of MN 13 (= Aguilar Zone E 3; Steininger et al. 1989 and de Bruijn et al. 1992)

Correlation Tie Points: between marine sediments of Messinian age containing planktonic foraminifera of Zone M 12 (Berggren 1977) and the last occurrence of *Discoaster quinqueramus* indicating a late Messinian age

Inferred Age: (Berggren et al. 1995) slightly older than 5.3 Ma (last occurrence of *Discoaster quinqueramus* is at 5.3 Ma).

References: Aguilar 1982a; de Bruijn et al. 1975, 1992; Mein et al. 1973; Morales 1984; Steininger et al. 1989

MN 13

Age: late Miocene
Locality: Brisighella, Monticino quarry, Faenza, Italy
Lithostratigraphic Position: mammal horizon overlain by marine sediments of lowermost Zanclean age; i.e., deposited after the intra-Messinian tectonic phase (Marabini and Vai 1988)
Mammal Correlation: MN 13 (Guilio et al. 1988; Torre, pers. comm., 1990); alternatively uppermost MN 13 (de Bruijn et al. 1992)
Correlation Tie Points: the overlying marine sediments with Planktonic Foraminifera Zone MPL 1 and Nanno Zone NN 12 (lowermost Zanclean)
Paleomagnetic Calibration: the overlying Zanclean marine beds are in a normal magnetozone and correlated to the Thvera subchron = Chron C3n.4n.
Inferred Age: (Berggren et al. 1995; Rio and Sprovieri 1994) older than base of overlying Planktonic Foraminifera Zone MPL 1 (= Berggren et al. 1995 Planktonic Foraminifera Zone PL 1, 5.6 Ma and older than base of overlying Nannoplankton Zone NN 12, 5.3 Ma). The normal polarity of the marine beds is referred to Chron C3n.4n, mammal-bearing beds older than base of C3n.4n, 5.23 Ma.
References: de Bruijn et al. 1992; de Giulio and Vai 1988
Remarks: Torre (pers. comm., 1990) states that the fossiliferous sediments containing the mammal fauna unconformably overlie the structurally deformed gypsum beds of the intra-Messinian tectonic phase. Italian MN 13 localities are, in biostratigraphic order, Baccinello V 3 and Brisighella above.

MN 13

Age: late Miocene
Locality: Baccinello V 3, Grosseto, Italy
Lithostratigraphic Position: overlain by marine beds
Mammal Correlation: Bacinello V 3 is correlative with medial MN 14 (de Bruijn et al. 1992); alternatively MN 13 (Torre, pers. comm.; see below); alternatively MN 13/14 boundary (Mein et al. 1993).
Correlation Tie Points: overlying marine beds with *Globorotalia margaritae*
Inferred Age: (Torre, pers. comm., 1990) intra Messinian (i.e., between 7.1 to 5.25 Ma; see discussion with the locality of Brisighella)
References: de Bruijn et al. 1992; Engesser 1989; Hürzeler and Engesser 1976; Rook et al. (in press); Torre 1987
Remarks: Torre (pers. comm., 1990) states that in the past this faunal assemblage was correlated with the transition between MN 13 and MN 14 because it included *Dicerorhinus* cf. *megarhinus* and *Tapirus arvernensis*. New elements demonstrate that the assemblage is best correlated with MN 13 and with the pre–intra-Messinian tectonic phase (Rook et al., in press). This correlation is made based upon the structural deformation of the fossiliferous sediments and by the presence of a more primitive *Apodemus* than found from the Cava Monticino (Brisighella; re: Engesser 1989).

MN 13

Age: late Miocene
Locality: La Hornera, Spain
Mammal Correlation: MN 13 (Agusti 1987).
Correlation Tie Points: overlies third Messinian evaporitic series and *Globorotalia conomiozea* Zone
Inferred Age: (Gaultier et al. 1994) Messinian evaporitic series: 5.8 to 5.32 Ma
References: Agusti in Steininger et al. 1989

MN 13

Age: late Miocene
Locality: Rema Marmara, Greece
Mammal Correlation: MN 13 (Benda and Meulenkamp 1989, 1990)
Correlation Tie Points: uppermost Kizilhisar E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989; Steininger et al. 1989

MN 13/14

Age: late Miocene/early Pliocene
Locality: Molina de Segura, Horizon E to 10, Spain
Mammal Correlation: MN 13/14, according to Agusti (1987)
Correlation Tie Points: overlies the third Messinian series in a continous section containing MN 12/13 faunas (see above).
Inferred Age: (Gaultier and al. 1994) Messinian evaporitic series from 5.8 to 5.32 Ma
References: Agusti in Steininger et al. 1989

European Mammal Faunal Unit: Ruscinian

European Mammal Faunal Zone: MN 14

MN 14

Age: early/late Pliocene
Locality: Villalba Alta Rio 1, Teruel graben, Spain
Mammal Correlation: uppermost MN 14 (de Bruijn et al. 1992)
Correlation Tie Points: Lower Alfambrian Stage, AF 1c
Paleomagnetic Calibration: normal polarity interval, interpreted to be the Cochiti Subchron (Mein et al. 1983); = Chron C3n.1n
Inferred Age: (Berggren et al. 1995) C3n.1n: 4.29 to 4.18 Ma
References: Adrover 1987; de Bruijn et al. 1992

MN 14

Age: early Pliocene
Locality: Celleneuve, France
Mammal Correlation: Mammal Zone F 1 (Aguilar); alternatively Zone G1 (Aguilar and Michaux); alternatively MN 14 (Mein 1975, 1989); alternatively basal MN 14 (Steininger et al. 1989 and de Bruijn et al. 1992)
Correlation Tie Points: marine influence proven by shark-teeth

and cysts of hystrichospaerids. NW-Mediterranean pollen zone P II

Paleomagnetic Calibration: reverse polarity in Gilbert (Lindsay 1985), base of Gilbert (Aguilar and Michaux 1984) = base of Chron C3r

Inferred Age: (Berggren et al. 1995) Chron C3r: 5.89 to 5.23 Ma

References: Aguilar and Michaux 1984; Aguilar et al. 1989; de Bruijn et al. 1992; Mein and Michaux 1970; Michaux 1966; Lindsay 1985; Suc and Zagwijn 1983

Remarks: The rodent-fauna indicates an early Pliocene age, not a middle Pliocene age.

MN 14

Age: early Pliocene

Locality: Ptolemais 1, Greece.

Mammal Correlation: medial MN 14 (Steininger et al. 1989; de Bruijn et al. 1992)

Correlation Tie Points: lower Akça E-Mediterranean pollen zone

References: Benda and Meulenkamp 1989, 1990; de Bruijn et al. 1992; Meulen and Kolfschoten 1986; Steininger et al. 1989; Van de Weerd 1979

MN 14

Age: early Pliocene

Locality: Terrats, France

Lithostratigraphic Position: the micromammal fauna was recovered from lignitic marls within a continental sequence.

Mammal Correlation: mammal Zone F 2 (Aguilar); alternatively MN 14 (Mein 1975, 1989), upper MN 14 (de Bruijn et al. 1992)

Correlation Tie Points: NW-Mediterranean pollen zone P II

Paleomagnetic Calibration: reverse and normal polarity in Gilbert (Lindsay 1985); base of Gilbert (Aguilar and Michaux 1984) = Chron C3r to C3n.4n

Inferred Age: (Berggren et al. 1995) Chron C3r to C3n.4n: 5.89 to 5.23 Ma

References: Aguilar and Michaux 1984; de Bruijn et al. 1992; Clauzon et al. 1989; Mein and Michaux 1970; Michaux 1976; Lindsay 1985

Remarks: drillings indicate marine Pliocene below the continental formation.

MN 14

Age: early Pliocene

Locality: Vendargues, France

Lithostratigraphic Position: the mammal fauna from Vendargues was recovered from a continental sequence of about 30 m at the quarry of Pioch Palat discordantly above sandy marls.

Mammal Correlation: Mammal Zone F 2 (Aguilar); alternatively MN 14 (Mein 1975, 1989); alternatively MN 14b (Fejfar and Heinrich 1989); upper MN 14 (de Bruijn et al. 1992)

Correlation Tie Points: NW-Mediterranean pollen zone P II (base)

Paleomagnetic Calibration: reversed polarity of the Gilbert Chron (Lindsay 1985); base of the Gilbert (Aguilar and Michaux 1984; = Chron C3r)

Inferred Age: (Berggren et al. 1995) Chron C3r: 5.89 to 5.32 Ma

References: Aguilar and Michaux 1984; de Bruijn et al. 1992; Lindsay 1985; Mein and Michaux 1970; Suc and Zagwijn 1983

MN 14

Age: early Pliocene

Locality: Spilia 1, Greece

Mammal Correlation: MN 14b according to Fejfar and Heinrich (1989)

Correlation Tie Points: lower Akça E-Mediterranean pollen zone

References: Benda and Meulenkamp 1989, 1990; Fejfar and Heinrich 1989

MN 14

Age: early Pliocene

Locality: Vivès 2, France

Mammal Correlation: Mammal Zone F 1 (Aguilar), MN 14, according to Aguilar and Michaux (pers. comm., 1990).

Paleomagnetic Calibration: reverse event in Gilbert.

Inferred Age: (Berggren et al. 1995) if actually the reversed zone at base of Gilbert, then this would correlate with Chron C3r: 5.89 to 5.23 Ma.

References: Clauzon et al. 1985, 1987; Aguilar et al. 1989

Remarks: the fossiliferous continental deposits follow above marine early Pliocene deposits.

MN 14

Age: early Pliocene

Locality: Elbistan, Turkey

Mammal Correlation: MN 14 (Benda and Meulenkamp 1989, 1990)

Correlation Tie Points: lower Akça E-Mediterranean pollen zone

Isotopic Age: radiometric date of 3.7 Ma

References: Benda and Meulenkamp 1989, 1990; Sickenberg et al. 1975

MN 14

Age: late Pliocene

Locality: Mesas de Asta section, Guadalquivir Basin, Cadiz, Spain

Lithostratigraphic Position: 60 m of section with two lithostratigraphic units. Unit 1 (approximately at 25 m) is a marine offshore-to-lower shoreface deposit with hardground on top separated by an angular and erosive unconformity from overlying Unit 2 (approximately 35 m). Fluviatile and lacustrine deposits with a micromammal fauna at 40 meter mark of the section.

Mammal Correlation: uppermost MN 14 (Aguirre et al. 1992)

Correlation Tie Points: marine marls in upper part of unit 1 with planktonic foraminifera fauna of P12 Biozone (Berggren et al. 1995).

Inferred Age: (Berggren et al. 1995) Planktonic foraminiferal Biozone P12: 4.2 to 3.55 Ma; mammal horizon younger than 3.55 Ma

References: Aguirre et al. 1992

European Mammal Faunal Zone: MN 15

MN 15

Age: early to late Pliocene
Locality: Villalba Alta Rio 1 and Orrios 1 to Villalba Alta Rio 2 and Orrios 3 section, Spain
Mammal Correlation: upper MN 14 (Orrios 1 and Villalba Alto Rio 1); alternatively lowermost MN 15 (Villalba Alto Rio 2) and medial MN 15 (Orrios 3) (de Bruijn et al. 1992)
Paleomagnetic Calibration: lower Gauss = Chron C2An (Opdyke et al. 1988)
Inferred Age: (Berggren et al. 1995) base Chron C2An, 3.58 Ma
References: Adrover 1978; de Bruijn et al. 1992; Opdyke et al. 1988; Van de Weerd 1976

MN 15

Age: early/late Pliocene
Locality: Villalba Alta Rio 2, Teruel graben, Spain
Mammal Correlation: lowermost MN 15 (de Bruijn et al. 1992)
Paleomagnetic Calibration: in reversed part of the section interpreted as upper Gilbert, above Villalba Alta Rio 1 (Moissenet et al. 1990) = Chron 2Ar
Inferred Age: (Berggren et al. 1995) Chron C2Ar: 4.18 to 3.58 Ma. Inferred age between 3.85 and 3.40 Ma (Moissenet et al. 1990).
References: de Bruijn et al. 1992; Mein et al. 1983; Moissenet et al. 1990
Remarks: Mein (pers. comm., 1992) states that this fauna contains the most archaic *Mimomys* currently known (= *Mimomys vandermeuleni*).

MN 15

Age: late Pliocene
Locality: Dinar-Akçaköy, Turkey
Mammal Correlation: lower MN 14 (Steininger et al. 1989); alternatively lower MN 15 (de Bruijn et al. 1992)
Correlation Tie Points: lower Akça E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989, 1990; de Bruijn et al. 1992; Sickenberg et al. 1975

MN 15

Age: early Pliocene
Locality: Perpignan (= Serrat d'en Vacquer), France
Mammal Correlation: Mammal Zone F3 (Aguilar); MN 15 (Mein 1975, 1989); alternatively medial MN (de Bruijn et al. 1992)
Correlation Tie Points: NW-Mediterranean pollen zone P II
Paleomagnetic Calibration: reverse polarity of Gilbert about 20 m below the fossiliferous level (Lindsay 1985)
References: de Bruijn et al. 1992; Clauzon et al. 1987; Hugueney and Mein 1965; Lindsay 1985; Mein and Aymar 1984; Suc and Zagwijn 1983
Remarks: The mammal locality is 200 m above the boundary between the marine and the continental Pliocene (Mutualité Agricole Drilling). Mein (pers. comm., 1992) states that the presence of *Mimomys* cf. *clavakosi* is a very accurate biostratigraphic marker. This suggests that Perpignan is younger than the localities of Ptolemais 3 and Villalba Alta Rio 2, but older than the locality of Sète.

MN 15

Age: late Pliocene
Locality: Escorihuela B, Teruel graben, Spain
Mammal Correlation: MN 15 (Moissenet et al. 1989); alternatively uppermost MN 15 (de Bruijn et al. 1992)
Paleomagnetic Calibration: reversed polarity of the uppermost Gilbert, just before the Gauss lowermost normal (Moissenet et al. 1990), i.e., the upper part of Chron C2Ar/lower part of Chron C2An.
Inferred Age: (Berggren et al. 1995) Chron C2Ar/C2An boundary, ca. 3.58 Ma. Inferred age is 3.4 Ma (Moissenet et al. 1989).
References: de Bruijn et al. 1992; Mein et al. 1983; Moissenet et al. 1989

MN 15

Age: late Pliocene
Locality: Sete, France
Mammal Correlation: uppermost MN 15 (= Aguilar and Michaux Zone G 1) (Steininger at al. 1989; de Bruijn et al. 1992)
Correlation Tie Points: NW-Mediterranean pollen zone P II
References: Aguilar and Michaux 1984; de Bruijn et al. 1992; Steininger et al. 1989; Suc 1980, 1982; Suc and Zagwijn 1983

MN 15

Age: early/late Pliocene
Locality: Villalba Alta Rio 5, Teruel graben, Spain
Mammal Correlation: MN 15 (Moissenet et al. 1989)
Paleomagnetic Calibration: at top of a reversed magnetic zone that is correlative with uppermost Gilbert/Gauss Chron transition (Moissenet et al. 1989); correlative with Chron C2Ar/C2n boundary.
Inferred Age: (Berggren et al. 1995) Chron C2Ar/C2An boundary: 3.58 Ma. Inferred age 3.4 Ma (Moissenet et al. 1989).
References: Mein et al. 1983; Moissenet et al. 1989

MN 15

Age: early Pliocene
Locality: Val di Pugna, Siena, Italy
Lithostratigraphic Position: in sandy marine sediments, macrofaunal assemblage with few biostratigraphic diagnostic elements
Mammal Correlation: MN 15 (Torre, pers. comm., 1990)
Correlation Tie Points: the sandy marine sediments are referred to the *Globorotalia puncticulata* Zone.
Inferred Age: (Berggren et al. 1995) *Globorotalia puncticulata* Zone, 4.6 to 3.6 Ma
References: Azzaroli et al. 1988

MN 15

Age: late Pliocene
Locality: "Karaburun" = Megalo Emvolon, Macedonia, Greece

Mammal Correlation: MN 14 (Benda and Meulenkamp 1989); alternatively MN 15 (Stefens et al. 1979 and de Bruijn 1984)
Correlation Tie Points: lower E-Mediterranean Akça pollen zone; Blow Zone N 19 (Koufos, pers. comm., 1990)
Inferred Age: (Berggren et al. 1995) Blow Zone N 19 (= Berggren et al. 1995 uppermost Planktonic Foraminifera Zone PL 1a and PL 1b): 4.7 to 4.2 Ma
References: Arambourg and Piveteau 1929; Benda and Meulenkamp 1989; de Bruijn 1984

European Mammal Faunal Unit: Villafranchian (Villanyian)

European Mammal Faunal Zone: MN 16

MN 16

Age: late Pliocene
Locality: Escorihuela, Teruel graben, Spain
Mammal Correlation: MN 16 (Moissenet et al. 1989); lowermost MN 16 (de Bruijn et al. 1992)
Paleomagnetic Calibration: normal polarity of lowermost Gauss (Moissenet et al. 1989); correlative with Chron C2An.3n
Inferred Age: (Berggren et al. 1995) Chron C2An.3n: 3.58 to 3.33 Ma. The inferred age is 3.4 Ma (Moissenet et al. 1989).
References: de Bruijn et al. 1992; Moissenet et al. 1989; Van de Weerd 1976

MN 16

Age: late Pliocene
Locality: Triversa sites, Asti, Italy
Mammal Correlation: MN 16a (early Villafranchian; Torre, pers. comm., 1990); alternatively lowermost MN 16 (Steininger et al., 1989 and de Bruijn et al. 1992)
Correlation Tie Points: indirect correlation to the *Globorotalia puncticulata/Globorotalia crassaformis* transition (see remarks).
Paleomagnetic Calibration: reversed-normal-reversed polarity pattern in Fornace RDB quarry assigned to the interval between Kaena and Mammoth of the Gauss Chron (Lindsay et al. 1980) and *not* as indicated in Steininger et al. (1989:36) to the Matuyama.
Inferred Age: (Berggren et al. 1995) The geomagnetic sequence described above can be correlated with either Chron C2Ar/C2An.3n/2r or Chron C2An.2r/2n/1r, with a time interval of 4.18 to 3.0 Ma. Because the *Gt. punticulata/Gt. crassaformis* Zone transition is recognized, the more likely geomagnetic correlation is Chron C2Ar/C2An.3n/2r, 4.18 to 3.22 Ma.
References: Azzaroli et al. 1982; de Bruijn et al. 1992; Giulio et al. 1988; Lindsay et al. 1980; Steininger et al. 1989; Torre 1987
Remarks: (Torre, pers. comm., 1990) The *Mimomys stehlini* from San Giusto (a species also present at Arondelli, Triversa) and a small Villafranchian cervid from Ponte a Elsa were both found in sediments of transitional environments containing pollen that allows their referral to the base of the early Villafranchian. The foraminifera present are commonplace, but a rich molluscan fauna indicates that the sediments can be no younger than the beginning of the Mediterranean's cooling (ca. 3.2 to 3.0 Ma), and therefore are correlative with the upper part of the *Globorotalia puncticulata* Zone (Valleri et al., in press).

MN 16

Age: late Pliocene
Locality: Arcille, Grosseto, Italy
Lithostratigraphic Position: the fossiliferous strata overlie marine sediments of the *Globorotalia puncticulata* Zone.
Mammal Correlation: MN 16a (Torre, pers. comm., 1990); lowermost MN 16 (de Bruijn et al. 1992), below the Triversa locality
Correlation Tie Points: above marine sediments of *Globorotalia puncticulata* Zone
Inferred Age: (Berggren et al. 1995) younger than 3.6 Ma
References: de Bruijn et al. 1992; Hürzeler and Engesser 1976; Torre 1987; Masini and Torre 1989

MN 16

Age: late Pliocene
Locality: Vialette, France
Lithostratigraphic Position: the mammal fauna from Vialette is found in a sequence with white marls at the base, overlain by a volcanic sedimentary sequence containing a volcanic block dated 3.3 Ma, overlain by a basalt flow dated 3.33 ±0.11 Ma (5 samples). The fauna rests on top of this flow. The basalt flow of d'Azanières to the NW is dated 2.18 ±0.15 (2 samples) and 2.60 ±0.20 (1 sample) and is thought to overly prior to its ersosion the faunal horizon of Vialette.
Mammal Correlation: lower part of MN 16 (Steininger et al. 1989; de Bruijn et al. 1992)
Isotopic Age: basalt flow below mammal horizon dated at 3.33 Ma
References: Alberdi and Bonadonna 1987; Azzaroli et al. 1988; Bandet et al. 1978; de Bruijn et al. 1992; Heintz et al. 1974; Ly Meng Hour et al. 1983; Steininger et al. 1989

MN 16

Age: late Pliocene
Locality: Poggio Mirteto, Rome, Italy
Mammal Correlation: lower part of MN 16 (Steininger et al. 1989)
Correlation Tie Points: intertonguing with *Globorotalia aemiliana* (= *crassaformis*) Zone.
Paleomagnetic Calibration: reversed magnetic polarity
Isotopic Age: ash bed dated at 3.32 ±0.3 Ma
References: Alberdi and Bonadonna 1987

MN 16

Age: late Pliocene
Locality: Valdeganga 9, 9b and 16a (like Rincon 2); Valdeganga 4a and 10b (Valdeganga inf.); Júcer Basin, Spain
Mammal Correlation: medial MN 16 (Mein et al. 1990), like Rincon 2; MN 16 (= "Valdeganga inf.") (de Bruijn et al. 1992)
Paleomagnetic Calibration: lowermost part of the reversed polarity interval of the Matuyama (Opdyke et al. 1989), equal to Chron C2r.2r

Inferred Age: (Berggren et al. 1995) Chron C2r.2r: 2.6 to 2.2 Ma
References: Alberdi et al. 1982; de Bruijn et al. 1992; Mein et al. 1989

MN 16

Age: late Pliocene
Locality: Valdeganga I and II, Júcer Basin, Spain
Mammal Correlation: uppermost MN 16 (Mein et al. 1989), together with Rincon 1; MN 16 (= "Valdeganga inf.") (de Bruijn et al. 1992)
Paleomagnetic Calibration: lower, reversed part of Matuyama = Chron C2r.2r
Inferred Age: (Berggren et al. 1995) Chron C2r.2r: 2.6 to 2.2 Ma.
References: Alberdi et al. 1982; de Bruijn et al. 1992; Mein et al. 1990

MN 16

Age: late Pliocene
Locality: Casa del Rincon (= El Rincon 1), Spain
Mammal Correlation: medial MN 16 (Steininger et al. 1989); alternatively upper MN 16 (de Bruijn et al. 1992)
Paleomagnetic Calibration: in a normal magnetic polarity zone
References: Alberdi et al. 1982; Azzaroli 1988; de Bruijn et al. 1992; Leone 1985; Steininger et al. 1989; Torre 1987

MN 16

Age: late Pliocene
Locality: Villaroya, Spain
Mammal Correlation: lowermost MN 17 (Steininger et al. 1989); alternatively medial MN 16 (de Bruijn et al. 1992)
Correlation Tie Points: NW-Mediterranean pollen zone P III
References: Azanza et al. 1989; Aguirre and Morales 1991; de Bruijn et al. 1992; Suc and Zagwijn 1983; Steininger et al. 1989

MN 16

Age: late Pliocene
Locality: El Carasco, Júcer Basin, Spain
Mammal Correlation: MN 16 above the faunal horizons of Valdeganga; alternatively MN 14 and 15 (Mein 1989)
Paleomagnetic Calibration: uppermost part of the Gauss normal polarity the Gauss at the transition to Matuyama, according to Mein et al. (1990) = within Chron C2An.1n
Inferred Age: (Berggren et al. 1995) Chron 2An.1n: 3.0 to 2.6 Ma.
References: Mein 1989; Mein et al. 1990

MN 16

Age: late Pliocene
Locality: Rhodos, Greece
Lithostratigraphic Position: Kritka Formation
Mammal Correlation: MN 16 (Benda and Meulenkamp 1977)
Correlation Tie Points: lower part of *Globorotalia inflata* Zone; upper NN 16 Nannoplankton Zone; upper NN 16; medial Akça E-Mediterranean pollen zone
Inferred Age: (Berggren et al. 1995) approximately 3.0 to 2.4 Ma
References: Benda et al. 1977; Benda and Meulenkamp 1989, 1990

MN 16

Age: late Pliocene
Locality: Montopoli, Pisa, Italy
Lithostratigraphic Position: the fossiliferous mammal horizon is found within marine littoral sands.
Mammal Correlation: MN 16b (Torre pers.comm., 1990); upper MN 16 (de Bruijn et al. 1992)
Correlation Tie Points: the littoral marine sands cap the marine cycle of the Valdarno Inferiore Basin and are still referable to the *Globorotalia crassaformis* Zone.
Paleomagnetic Calibration: the mammal fossils were found above the Gauss/Matuyama palaeomagnetic boundary (Lindsay et al. 1980) = Chron C2An.1n/C2r.2r boundary.
Inferred Age: (Berggren et al. 1995) younger than 2.6 Ma
References: Azzaroli 1988; Bonadonna and Alberdi 1987; de Bruijn et al. 1992; Giulio et al. 1988; Lindsay et al. 1980; Torre 1987

MN 16

Age: late Pliocene
Locality: De Meern drill-site, Netherlands
Mammal Correlation: upper MN 16 (Steininger et al. 1989)
Correlation Tie Points: NW-Mediterranean pollen zone P III/P IV-Pl 1
References: Suc and Zagwijn 1983; Steininger et al. 1989

MN 16

Age: late Pliocene
Locality: Valdeganga 14, 15 (Valdeganga inf.), Júcar Basin, Spain
Lithostratigraphic Position: lacustrine limestones and carbonated silts; Jucar River Formation
Mammal Correlation: lower MN 16; alternatively uppermost MN 16 (= "Valdeganga inf."; de Bruijn et al. 1992)
Paleomagnetic Calibration: normal polarity in uppermost Gauss = Chron C2An.1n
Inferred Age: (Berggren et al. 1995) Chron 2An.1n, 3.0 to 2.6 Ma
References: Alberdi et al. 1982; de Bruijn et al. 1992; Mein et al. 1989

MN 16

Age: late Pliocene
Locality: Les Etouaires, France
Lithostratigraphic Position: the Etouaires local fauna is directly underlain by a sanidine and quartz bearing ash that has been dated.
Mammal Correlation: uppermost MN 16 (Steininger et al. 1989; de Bruijn et al. 1992); alternatively, medial MN 16
Paleomagnetic Calibration: approximately Gauss/Matuyama boundary

Isotopic Age: ash bed below mammal horizon dated at 3.6 and 2.4 Ma by several authors.
References: Alberdi and Bonadonna 1987; Azzaroli 1988; de Bruijn et al. 1992; Heintz et al. 1974; Lindsay et al. 1980; Steininger et al. 1989

MN 16

Age: late Pliocene
Locality: Stranzendorf (sportfield): horizon A and C, Molasse Zone, Lower Austria
Lithostratigraphic Position: Entire sequence about 31 m thick. Lower part to horizon C about 5 m. Horizons A, B and C red loams (= paleo intercalated into the löss sequence).
Mammal Correlation: fauna from Horizon A uncharacteristic for correlation; fauna from Horizon C an upper MN 16 characteristic fauna. Uppermost MN, according to Steininger et al. (1989) and de Bruijn et al. (1992).
Paleomagnetic Calibration: normal from base to Horizon C, equal to the uppermost part of the Gauss (= Chron C2An.1n).
Inferred Age: (Berggren et al. 1995) Chron C2An.1n: 3.04 to 2.58 Ma. Horizon C in uppermost C2An.1n just below boundary to C2r.2r.
References: de Bruijn et al. 1992; Rabeder 1981; Steininger et al. 1989

MN 16

Age: late Pliocene
Locality: Slatina 1, Romania
Mammal Correlation: MN 16 (Andreescu 1981)
Correlation Tie Points: molluscs characteristic for Romanian Stage
Paleomagnetic Calibration: in Lower Matuyama = Chron C2r.2r
Inferred Age: (Berggren et al. 1995) correlative with Chron C2r.2r; 2.6 to 2.2 Ma
References: Andreescu 1981

European Mammal Faunal Zone: MN 17

MN 17

Age: Pliocene
Locality Rocca Neyra (= Roccaneyra), Italy
Mammal Correlation: MN 16 (Azzaroli et al. 1988); alternatively lowermost MN 17 (Steininger et al. 1989 and de Bruijn et al. 1992)
Isotopic Age: radiometric dates are 2.5 to 2.4 Ma
References: Azzaroli et al. 1988; de Bruijn et al. 1992; Heintz et al. 1974; Steininger et al. 1989; Torre 1987

MN 17

Age: late Pliocene
Locality: Gülyazi, Turkey
Mammal Correlation: medial MN 16 (Steininger et al. 1989); MN 16 lower part according to de Bruijn et al. (1992); MN 16b, correlative with Gauss/Matuyama boundary due to cooccurrence of *Equus* and a hipparionine horse ("*Plesiohipparion*" cf. *huangheense*; Bernor and Tobien 1991)
Correlation Tie Points: middle Akça E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989, 1990; Bernor and Tobien 1991; de Bruijn et al. 1992; Van der Meulen and Kolfschoten 1986; Sickenberg et al. 1975; Steininger et al. 1989

MN 17

Age: Pliocene/Pleistocene
Locality: Stranzendorf (sportfield) horizons D, F, G, H, I, L and M; Molasse Zone, Lower Austria
Lithostratigraphic Position: The total thickness of the loess and paleosol sequence is approximately 31 m. From horizon D to top is about 26 m. Horizons D, F, G, H are in brown loams (= paleosols); horizons I, L are in red loams (= paleosols); horizon M is in brown loam (= paleosol).
Mammal Correlation: Horizons D, F, G, and L with characteristic faunas, horizons H and I with smaller faunas. MN 17, according to Rabeder (pers. comm., 1989); MN 17 lowermost faunal level, according to de Bruijn et al. (1992).
Paleomagnetic Calibration: Horizons D, F, G in a lower reversed part, followed by a short normal (this normal is split into two reversed portions). Above this normal a longer reversed portion is found. This reversed portion is followed by a longer normal, which is continuous to the top of the section. Faunal-horizon L begins in the uppermost part of the reversed zone and is continuous to the lowermost part of the following normal. Geomagnetic interpretation: faunal horizon D to G is in the lower reversed part (= Chron C2r.2r). Faunal horizons H and I are within Chron C2r.1n (? Reunion I and II). Faunal horizon L is within uppermost Chron C2r.1r and Chron C2n (= Olduvai Event).
Inferred Age: (Berggren et al. 1995) Faunal horizon D is at the boundary between Chron C2An.1n/C2r.2r, 2.58 Ma. Faunal horizon F is correlative with upper-middle Chron C2r.2r, 2.35 Ma. Faunal horizon G is correlative with uppermost C2r.2r, 2.25 Ma. Faunal horizons H and I are below C2r.1n, 2.15–2.14 Ma. Faunal horizon L is within the boundary of Chron C2r.1r/C2n, ca. 1.95 Ma.
References: de Bruijn et al. 1992; Rabeder 1981

MN 17

Age: Pliocene/Pleistocene
Locality: Chiliac, France
Mammal Correlation: lower MN 17 (de Bruijn et al. 1992)
Paleomagnetic Calibration: basaltic flow below mammal horizon with reversed magnetization
Isotopic Age: this basalt flow is dated at 1.9 Ma
References: Azzaroli et al. 1988; Boeuf 1983; Alberdi and Bonadonna 1987; de Bruijn et al. 1992

MN 17

Age: Pliocene/Pleistocene
Locality: Slatina 2, Romania
Mammal Correlation: lower MN 17 (Steininger et al. 1989)

Paleomagnetic Calibration: lower part of Matuyama
Inferred Age: (Berggren et al. 1995) Matuyama = Chron C2r, 2.6 to 1.95 Ma
References: Andreescu et al. 1981; Steininger et al. 1989

MN 17

Age: late Pliocene
Locality: Valdeganga 7 and 10, Valdeganga 2, 3 and 6 Valdeganga sup., Júcer Basin, Spain
Mammal Correlation: lower MN 17 (Mein et al. 1989); alternatively medial MN 17 (= "Valdeganga sup."; de Bruijn et al. 1992)
Paleomagnetic Calibration: lower reversed part of Matuyama Chron (Mein et al. 1989), = Chron C2r.2r.
Inferred Age: (Berggren et al. 1995) Chron 2r.2r: 2.6 to 2.25 Ma
References: Alberdi et al. 1982; de Bruijn et al. 1992; Mein et al. 1989

MN 17

Age: Pleistocene
Locality: Tiglian C (= Tegelen), Netherlands
Mammal Correlation: MN 17 uppermost faunal level (Steininger et al. 1989 and de Bruijn et al. 1992)
Correlation Tie Points: NW-Mediterranean pollen zone P IV to Pl 1
References: de Bruijn et al. 1992; Kolfschoten and Van der Meulen 1986; Suc and Zagwijn 1983; Steininger et al. 1989

MN 17

Age: late Pliocene
Locality: Kos, Greece
Mammal Correlation: MN 17 (Benda and Meulenkamp 1990)
Correlation Tie Points: upper part of Akça E-Mediterranean pollen zone
References: Benda and Meulenkamp 1989; 1990

MN 17

Age: early Pleistocene
Locality: Megalopolis, Greece
Mammal Correlation: MN 17 (Benda and Meulenkamp 1990)
Correlation Tie Points: lower part of Megalopolis E-Mediterranean pollen zone
Reference: Benda and Meulenkamp 1989; 1990