

The Late Miocene Mammal Faunas of the Mytilinii Basin, Samos Island, Greece: New Collection

16. Biochronology

by

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KOUFOS, G.D., KOSTOPOULOS, D.S. & VLACHOU, Th.D. 2009. The Late Miocene Mammal Faunas of the Mytilinii Basin, Samos Island, Greece: New Collection. 16. Biochronology. — Beitr. Paläont., 31:397–408, Wien.

Abstract

The limited correlation of the old collections to the fossiliferous sites and to the local stratigraphy prevented safe dating of the Samos mammal fauna for a long time. Two main approaches are known: that supporting the presence of two faunal assemblages and that of a single homogeneous and isochronous fauna. The collected new material, and its detailed study and comparison allow the separation of three chronologically succeeding faunal assemblages MLN, MYT, MTL, ranging from the uppermost early Turolian to late middle Turolian. The updated correlation of the old collections with the local stratigraphy and their comparison with the new collection, as well as the magnetostratigraphic study of the fossiliferous Mytilinii Fm allow the precise dating of all fossil sites: a. Q5-? Limitzis, lowermost MN 13, 6.9–6.7 My; b. Q1, QA, S3,4, Adrianos, MTL, MN 12, ~7.1 My; c. Q3, S2,3, Potamies, MYT, MN 12, ~7.3 My; d. Q2, Stefano, MLN, lowermost MN 12, ~7.5 My; e. Qx, Vryssoula, upper part of MN 11, 8.0–7.6 My. The combination of old and new data concerning the Samos Turolian mammal faunas implies the establishment of four stages of evolution and refutes the “single fauna” approach.

Keywords: Late Miocene, Samos, Greece, Mammalia, Chronology.

Zusammenfassung

Die eingeschränkte Korrelation der alten Aufsammlungen mit den Fossilfundstellen einerseits und der lokalen Stratigraphie andererseits verhinderte eine sichere zeitliche

Zuordnung der Säugetierfunde von Samos für lange Zeit. Zwei Interpretationen sind bekannt: bei der ersten handelt es sich um die Möglichkeit zweier Faunenvergesellschaftungen und die andere wäre eine homogene, isochrone Fauna. Neu aufgesammeltes Material und die detaillierte Studie dazu erlauben eine Trennung in drei aufeinander folgende Faunenhorizonte (MLN, MYT, MTL), die vom obersten Frühturolium bis zum späten Mittelturolium reichen. Die Aufarbeitung der alten Sammlungen mit der lokalen Stratigraphie und der Vergleich mit den Neufunden, sowie die Miteinbeziehung der magnetostratigraphischen Ergebnisse der fossilen Mytilinii Formation führte zu einer präzisen Datierung aller Fundstellen: a. Q5-? Limitzis, unterstes MN13, 6.9–6.7 Ma; b. Q1, QA, S3,4, Adrianos, MTL, MN12, ~7.1 Ma; c. Q3, S2,3, Potamies, MYT, MN 12, ~7.3 Ma; d. Q2, Stefano, MLN, unterstes MN12, ~7.5 Ma; e. Qx, Vryssoula, upper part of MN11, 8.0–7.6 Ma. Die Kombination der alten und neuen Daten der turolichen Säugetierfundstelle von Samos erlaubt eine Aufstellung von vier Evolutionsstadien und verwirft damit den alten „single fauna“-Ansatz.

Schlüsselworte: Obermiozän, Samos, Griechenland, Säugetiere, Chronologie.

1. Introduction

The Late Miocene fossiliferous deposits of Samos Island, Greece, have been known since the second half of the 19th century, when Forsyth-Major discovered them and collected the first fossils. Then afterwards, several scientists, as well as fossil collectors and dealers visited Samos and gathered fossils for various museums and institutions (Koufos, this volume-a). There is a great number of publications concerning the Samos fauna, referring either to vertebrate paleontology or to chronology (Major, 1888, 1891, 1894; Andrews, 1896; Schlosser, 1899, 1906; Osborn, 1898; Studer, 1911; Andree, 1926; Brown, 1927; Colbert, 1941; Wehrli, 1941; van Couvering & Miller, 1971; Gentry, 1971; Sondaar, 1971; Heissig,

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1975; MEISSNER, 1979; BLACK et al., 1980; SOLOUNIAS, 1981; KOUFOS & MELENTIS, 1982, 1984; WEIDMANN et al., 1984; SEN & VALET; 1986; BERNOR et al., 1996; and literature cited in these articles). In these studies, a great number of fossils has been described, numerous species established and several opinions about the age of the Samos fauna have been proposed. Nevertheless, the absence of accurate locality descriptions from the old collections and the uncertainties about the local stratigraphy continued to plague biostratigraphic and age determinations and left vague taxonomic definitions. Exceptions are Forsyth-Major's collection in Lausanne (MGL) and B. Brown's collection at AMNH. Forsyth-Major marked the fossils he collected as originating from 'Stefano', 'Potamies' and 'Adriano', all referring to local place-names, whereas Brown used a register code of seven "quarries" (Q_x, Q1-6), corresponding to precise fossil sites. A first serious effort towards the relocation of the localities and their correlation with the various museum collections has been undertaken by SOLOUNIAS (1981). The author combined personal field and laboratory observations with information from the available field books of B. Brown, the museum archives and the local people of Samos. But, as he realized, it is hard to give a definite answer about the provenance of the entire fossil collections as most of them were made by amateurs, sometimes including specimens purchased from villagers (KOUFOS, this volume-a). In the early 1970ies, absolute chronological methods were also used for the chronology of the Samos fauna, but again, due to the problems did not result in a final solution as the correlation of the faunas with the stratigraphic and sampling horizons remained questionable.

With the aim to solve the Samos puzzle and its negative impact on European biochronology and mammalian systematics, a team of palaeontologists from the Laboratory of Geology and Palaeontology, University of Thessaloniki, led by G.K., started a new series of excavations in 1993 (KOUFOS et al., 1997, 2004). The main goal of this new campaign was the relocation of the fossiliferous sites, their arrangement in a precise stratigraphic order, the collection of new fossils and the dating of the faunas using biochronology and magnetostratigraphy. The results of the first 12 years of this campaign are included in this volume.

Abbreviations:

AMNH = American Museum of Natural History, New York
 ELMZ = European Land Mammal Zones
 MGL = University of Lausanne, Samos Collection
 PMMS = Melentis collection, Aegean Museum of Natural History (NHMA), Samos
 MLN = Mytilinii-4, Samos, Greece
 MYT = Mytilinii-3, Samos, Greece
 MTL = Mytilinii-1, Greece
 MTLA = Mytilinii-1A, Samos, Greece
 MTLB = Mytilinii-1B, Samos, Greece
 MTLC = Mytilinii-1C, Samos, Greece
 MTLD = Mytilinii-1D, Samos, Greece
 NOW = Neogene Old World database
 QA = Quarry-A, Samos, Greece

Q1-6 = Quarry1-6, Samos, Greece

Q_x = Quarry x, Samos, Greece

S = Stefano, Samos, Greece

A = Adriano, Samos, Greece

S2-4 = Solounias collection from Samos, Greece

L = Limitzis site, Samos, Greece

G = German quarries, Samos, Greece

2. Historical Overview

The Samos vertebrate fauna was considered equivalent to that of Pikermi for a long time as and was referred to as Pontian (Late Miocene/Early Pliocene), with the old-fashioned use of this term. At first sight, the faunal assemblages provided from these two Greek localities look similar, but a thorough study indicates several differences. The first serious efforts concerning age determination of the Samos mammal fauna started in the 1970ies. At that time VAN COVERING & MILLER (1971), using Argon Isotope Analysis, provided absolute radiometric datings for Samos Neogene volcanoclastic deposits, influencing various palaeontologists dealing with museum collections to comment on the biochronological meaning of the Samos fauna.

SONDAAR (1971) studied the hipparion assemblage (mainly skulls and metapodials) of Samos, housed at AMNH, and although he stated that "the phylogeny of the Samos Hipparion remains speculative" he realized that different *Hipparion* species from the various fossiliferous sites might represent chronologically distinct assemblages (Table 1). The same author tried to check if there were differences in other animal groups of the Samos fauna and he studied the aardwark *Orycteropus gaudryi* from the Brown quarries (SONDAAR, 1971). Comparing the length of the upper and lower molar row versus M2 or m2, he found that *O. gaudryi* from Q5 is larger than that from Q1-4 (SONDAAR, 1971:figs. 4, 5). Thus, he supposed an age difference between the two faunas, accepting that the size increase in this genus is an evolutionary trend, as the recent *O. eriksoni* is much bigger. GENTRY (1971) arrived at a similar conclusion, studying "*Pachytragus*" samples at AMNH from Q1-4 and Q5, whereas HEISSIG (1975) distinguished four rhinocerotid assemblages on Samos and later also indicated a time-distance between Q1-4 and Q5 mammal faunas (Table 1).

All this data failed, however, to reliably correlate with the radiometric datings of VAN COVERING & MILLER (1971), that gave unexpectedly high values, ranging from 20.8±1.7 My to 7.4±0.6 My (Table 1). As the authors mentioned, "...there is nothing in the geology of the basin to suggest that the pumice-breccia to which this date refers (i.e., the sample GM-101 dated at 20.8±1.7 Ma and 18.5±1.5 Ma) should be as much as 10 m.y. older than the others". Based on the three best ages VAN COVERING & MILLER (1971) suggested an age of 9.3 My for Q1-4.

Later, BERNOR (1980) studied the hipparions from Maragheh (Iran) and compared them with the Samos ones. Using the chronological data from Maragheh he also suggested two

Stratigraphic Unit	VAN COUVERING & MILLER (1971)	GENTRY (1971) SONDAAR (1971) HEISSIG (1975)	SOLOUNIAS (1981)	WEIDMANN et al. (1984)	BERNOR et al. (1996)	SWISHER III (1996)	PRESENT CHRONOLOGY		My	GPTS	ELMA						
							OLD LOCALITIES	NEW LOCALITIES									
Marker Tuffs	GM105 { 9.6±0.8 9.0±0.7			SK1=6.14±0.19 SK2=6.14±0.04 R105=6.74±0.11 SK19=5.41±0.17				?Limitzis			C3A MN 13 LATE						
Main Bone Beds	GM106 { 8.9±0.9 8.0±0.8	? Q5	L, A Q1 Q5	Q1 Q5 L, A	Q3	Q1, Q5 L, A	Q1, Q5 L, A	SK17 { 7.23±0.14 6.98±0.15 R106=6.89±0.06 SK5=7.75±0.08	7.0		Q5	Q1, QA Adriano	MTLA, B, C, D				
Old Mill Beds	GM102=9.2±0.7	? Q1-4		Q2,3 R102 { 7.55±0.11 7.42±0.06 S2-4 SK18A=7.52±0.16 St		A, Q1,2,3,5		?SK5=8.580±0.010 Q4 Q3 S3,4 Potamies Q6	7.5				MYT				
Stratigraphic Unit			Q4	Q4		Q4		R102=7.660±0.010				Q2 Stefano	MLN				
Old Mill Beds	GM103 { 9.1±0.8 9.0±0.7 GM103 { 8.4±0.7 7.4±0.6		G Q6	Q6		G Q6		SK3=8.26±0.08 SK6=7.80±0.40									
Stratigraphic Unit			Qx	Qx		Qx		SK3=8.26±0.008 SK16=8.38±0.07				Qx, Vryssoula					

Normal= ⁴⁰Ar/³⁹Ar date; Italics=K-Ar date

Table 1: Chronostratigraphic position of Samos fossiliferous sites according to several authors associated by radiometric dating and magnetostratigraphy. (1): lithostratigraphic division according to WEIDMANN et al. (1984) and KOSTOPOULOS et al. (this volume).

fossiliferous levels for Samos, in agreement with SONDAAR (1971) and GENTRY (1971). The first level was considered as being early and the other middle-late Turolian.

One year later SOLOUNIAS (1981) published a thesis on the history of the Samos fossil sites and collections and studied the carnivores and bovids (Table 1). He also provided revised faunal lists for the various Samos sites, but the number of registered taxa was extremely high, not only significantly exceeding the usual number of mammals ever recorded in the late Miocene European faunas but also in recent ones. Even more surprisingly, the author diverged from all known approaches at that time and he proposed that the fossiliferous horizons of Samos were deposited during a short-timed interval and consequently the included mammal faunas represent an isochronous and homogeneous assemblage. This idea was going to radically affect most of the following works.

WEIDMANN et al. (1984) gave new absolute datings for the Neogene deposits of the Mytilinii Basin (Table 1). Using the K/Ar-method and the stratigraphy proposed by SOLOUNIAS (1981), they dated the base of the Mytilinii Formation at ~8.5 My, the main fossiliferous beds at ~7.35 My and the uppermost part of the Mytilinii Formation at ~6.18 My. The authors stated that it was incorrect to separate the Samos mammal fauna into two associations (Q1-4 and Q5), and concluded that all bone-bearing beds had been deposited between 7.0 and 8.5 My (WEIDMANN

et al., 1984) in accordance with SOLOUNIAS (1981) "single-fauna" hypothesis.

The first magnetostratigraphic data for the late Miocene deposits of Samos was published during the mid-1980ies by SEN & VALET (1986). The authors sampled a 132 m thick section, covering the upper part of the fossiliferous Mytilinii Fm, without, however, any reference to precise fossil sites. The authors estimated a 6.4-6.1 My age for the Q5, Q1, L and A sites. The old radiometric samples of WEIDMANN et al. (1984) were lately re-dated with the ⁴⁰Ar/³⁹Ar-method (SWISHER III, 1996). The proposed age for the basal part of the Mytilinii Fm (Old Mill Beds of WEIDMANN et al., 1984) ranges between 8.38±0.07 and 8.26±0.08 My, for the lower part of the main fossiliferous beds (Main Bone Beds) from 7.66±0.01-7.28±0.01 My, for the upper part of the main fossiliferous beds from 7.09±0.01 My and for the uppermost part of the Mytilinii Fm (Marker Tuffs) between 5.41±0.17 and 6.74±0.11 My. Based on these datings, BERNOR et al. (1996) tried to correlate the Maragheh, Samos and Pikermi faunas, combining faunal and chronological data. Concerning Samos, the authors suggested (Table 1) that the lower part of the Mytilinii Fm can be correlated to MN 11 with an age of ~8.34 My, the main fossiliferous level to MN 12 with an age > 7.1 My and the uppermost part of the Mytilinii Fm (Marker Tuffs) to MN 13. In spite of opposing evidence, the "single-fauna" hypothesis was not explicitly abandoned.

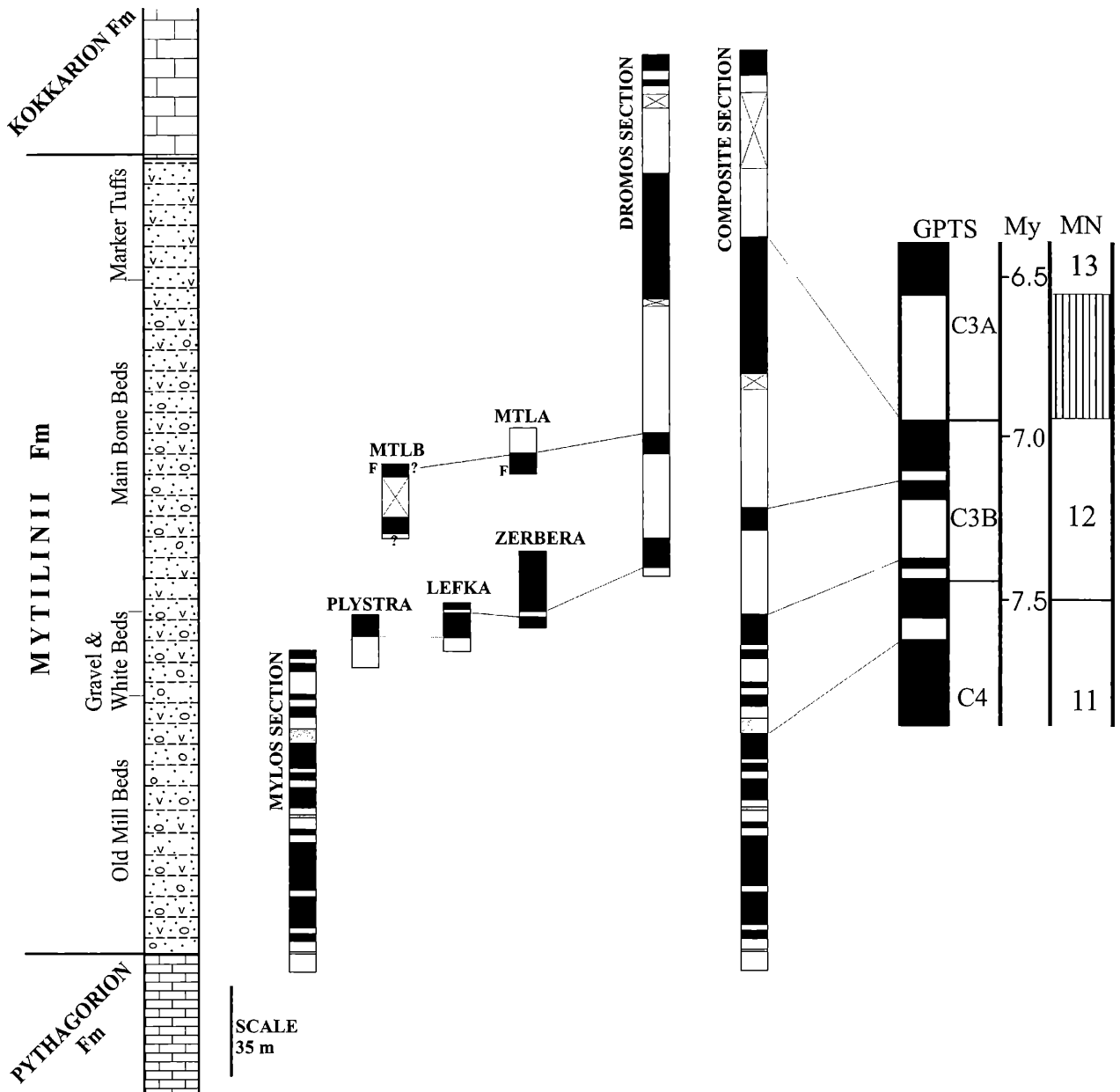


Figure 1: Magnetostratigraphic correlation between the sampled sections of Mytilinii basin, Samos and correspondence of the composite magnetostratigraphic section with GPTS and MN-zones (after KOSTOPOULOS et al., 2003, modified). F = fossil levels. MN boundaries according to AGUSTI et al. (2001), GPTS according to BERGGREN et al. (1995)

3. Magnetostratigraphy

As it was already mentioned, the magnetostratigraphy of the fossil-bearing Mytilinii Fm was partially studied earlier by SEN & VALET (1986), whose results allowed them to choose between the 8.7-7.4 My and the 6.8-5.7 My intervals. Based on the available radiometric data by WEIDMANN et al. (1984), and on the HARLAND et al. (1982) polarity time scale, both sources of evidence being extensively reviewed during the last decade, the authors suggested a 6.8-5.7 My age for the upper part of the Mytilinii Fm (KOSTOPOULOS et al., 2003). During the end of 1990ies we decided to re-study the magnetostratigraphy of the Mytilinii Fm and the results were presented by KOSTOPOULOS et al. (2003). In the present article we will

give a short review of this work in order to correlate the bio- and magneto-chronological data. 178 horizons from two main and five secondary sections, including the whole Mytilinii Fm, as well as part of the underlying Hora Fm, and the overlying Kokkarion Fm have been sampled and analysed (KOSTOPOULOS et al., 2003). The correlation of magnetostratigraphic data from individual sections led to a composite magnetostratigraphic column on which the new mammal sites were correctly placed. We also successfully coped with the problem of the stratigraphic location of the old quarries, using all the available information given by the previous researchers, mainly SOLOUNIAS (1981), as well as field and personal observations of old collections (KOSTOPOULOS et al., 2003). The correlation of the composite magnetostratigraphic section with GPTS (Fig. 1)

suggested the following age determinations (KOSTOPOULOS et al., 2003):

Basal part of Mytilinii Fm. It includes the localities Q_x and Vryssoula (probably a single site), situated at the NE border of Mytilinii village inside an army campus (SOLOUNIAS, 1981; pers. obs). This part of the Mytilinii Fm can be correlated with Chron C4n.2n, corresponding to 8.0–7.6 My, implying that Q_x and Vryssoula correspond to the upper part of early Turolian (MN 11). As the localities are situated above the middle of the basal part of Mytilinii Fm it is clear that the deposition of the formation started within the Turolian.

Lower part of the main fossiliferous beds. It includes the new locality MLN, as well as ‘Stefano’ of Forsyth-Major (Tab. 1). Following the topographic re-location of the old quarries by SOLOUNIAS (1981) we have directly but erroneously correlated MLN with Brown’s Q₄ (KOSTOPOULOS et al., 2003). New data (KOSTOPOULOS, this volume-a) allows us to realize that for inexplicable reasons, the location of Q₄ has been confused with that of Q₂ and vice versa. Correcting this mistake, we now suggest correlating MLN with Q₂, both placed in the same fossil horizon with ‘Stefano’. This part of the section can be correlated to Chrons C3Br.2n–C4n.1n (between 7.45 and 7.65 My) with an average 7.5 My of age for MLN, Q₂ and ‘Stefano’. This age corresponds to the end of early Turolian, MN 11.

Upper part of the main fossiliferous beds. The old locality Q₆ is now placed near its base (Tab. 1). It is situated at the northern border of the Mytilinii basin, near the village of Kokkarion, and at the beginning of Tholoremma ravine. Although the locality has been relocated, we did not yet excavate there. Brown’s Q₆ site was indirectly correlated with the radiometric samples SK3 (8.26±0.8 My) and SK6 (7.8±0.4 My) of WEIDMANN et al. (1984), and used to be placed together with Q_x into the lowermost fossil-level (BERNOR et al. 1996). However, the collected poor fauna from this site undoubtedly includes *Samotherium major*, which certainly implies an age no older than 7.4 My, i.e. younger than Q_x and even younger than MLN, Q₂ and ‘Stefano’, and maybe older than MYT (KOSTOPOULOS, this volume-a).

The new locality MYT is identical with Brown’s Q₃ placed in the middle of the main fossiliferous part of Mytilinii Fm (Tab. 1); S2-3 of SOLOUNIAS (1981) are on the same level, whereas ‘Potamies’ of Forsyth-Major would also be contemporaneous. This part of the section is correlated to Chron C3Br.2r, suggesting an age of ~7.3 My for the MYT fauna, which should, therefore, be placed in the middle Turolian, MN 12. According to the updated faunal data (KOSTOPOULOS, this volume-a, b; VLACHOU & KOUFOS, this volume), the Q₄ site of Brown should be slightly younger.

The new locality MTL (including the sites MTLA, MTLB, MTL C), as well as the old localities ‘Adriano’ of Forsyth Major, ‘Adrianos’ of Melentis and Q₁ of Brown, are located in Adrianos ravine, in the upper levels of the main fossiliferous beds. This fossil level is correlated to Chron C3Br.1n with an estimated age of 7.13–7.17 My, corresponding to the end of middle Turolian, MN 12.

Uppermost part of Mytilinii Fm. It includes the old locality Q₅ of Brown (Tab. 1). According to our magnetostratigraphy, this part of the formation should be correlated with Chrons C3Ar–C3Bn, corresponding to an age between 7.1–6.5 Ma; an age estimation for Q₅ should be 6.9–6.7 My.

Figure 1 and Table 1 summarize the chrono-stratigraphic distribution of the old and new Samos sites, updating data by KOSTOPOULOS et al. (2003).

4. Biochronology – Correlation with ELMZ

Two main issues concern the biochronology of the Samos fauna: a) its relations with the European Land Mammal Zones (ELMZ; STEININGER, 1999), and b) the internal structure of the Samos mammal assemblages and their possible discrimination into chronologically succeeding stages. The study of the new collection from the mammal localities of Samos led to the determination of a quite rich fauna. The available material was collected from the localities MLN, MYT and MTL; the last locality includes three fossiliferous sites, MTLA, MTLB and MTL C (details about the localities are given in KOSTOPOULOS et al., this volume). The faunal composition of MTL is the richest one and gives accurate biochronological data. Although the faunas of MLN and MYT are poor, they give some biochronological evidence, which together with magnetostratigraphy allow certain age determinations. The biochronology of each locality will be given separately, beginning with the oldest fauna.

Biochronology of Mytilinii-4 (MLN). The locality MLN is situated at the base of the main fossiliferous beds of Mytilinii Fm in Potamies ravine (KOSTOPOULOS et al., this volume). The determined fauna is relatively poor, including the following taxa: *Hyaenictitherium cf. wongii*, *Protictitherium crassum*, *Hipparion* aff. *proboscideum*, *Hipparion* aff. *prostylum*, “*Diceros neumayri*”, *Palaeotragus rouenii*, *Palaeotragus* sp., *Samotherium boissieri*, *Gazella pilgrimi*, *Tragoportax* sp., *Miotragocerus* sp., ?*Palaeoryx* sp. (KOSTOPOULOS, this volume-a, b; KOUFOS, this volume-b; VLACHOU & KOUFOS, this volume).

Most of the available taxa indicate Turolian age. *Protictitherium crassum* is known from several Eurasian localities and has a long stratigraphic range from middle Miocene MN 6 up to late Turolian MN 13 (KOUFOS, this volume-b). The MLN *Protictitherium* sample belongs to the large forms of the species, like that found in Dytko (Axios valley, Greece), suggesting a Turolian age.

The hipparion sample from MLN is poor and indicates the presence of two species: a medium-sized species resembling *H. prostylum* and a large-sized one, known only by postcranials, that could be ascribed to *H. proboscideum* by their size. The type locality of *H. prostylum* is Mont Luberon, (France) dated to middle Turolian, MN 12 (BERNOR et al., 1996; NOW 2007). The species is also known from the middle Maragheh and Pikerimi (BERNOR et al., 1996), dated from early to middle Turolian (KOUFOS, 2006; NOW, 2007). The type of the large-sized *H. probos-*

cideum comes from Samos but from an unknown locality (SONDAAR, 1971); nonetheless, its presence in Brown's Q_x indicates that the species probably originates from the lower fossil levels (VLACHOU & KOUFOS, this volume). *H. proboscideum* is certainly known from the locality Ravin des Zouaves-5 of Axios valley (Macedonia, Greece) dated to MN 11, more precisely at ~8.2 My by magnetostratigraphy (KOUFOS, 1987, 2006). A large-sized hipparion from the Turkish locality of Kemiklitepe-A, B, dated to middle Turolian, at ~7.2 My (KOUFOS & KOSTOPOULOS, 1994; SEN et al., 1994), resembles *H. proboscideum*, too. The MLN *H. aff. proboscideum* sample is distinguished from the Q₁ sample of the species by its more slender postcranials that indicate a more primitive stage (VLACHOU & KOUFOS, this volume). "*Diceros*" *neumayri* is a wide-spread rhinoceros with a very long range from MN 9 to the end of MN 12 and with a clear tendency of size-increase through time (HEISSIG, 1975; GIAOURTSAKIS, this volume). The MLN rhinocerotids are, however, too poor for certain chronological suggestions.

The MLN giraffids and bovids are rather point to an early Turolian age. *Palaeotragus rouenii* has a wide chronostratigraphic range from late Vallesian (MN 10) to latest Turolian (MN 13) but its coexistence with a sturdier palaeotragine, *Palaeotragus* sp. in MLN is rather indicative of an early Turolian, MN 11 age (KOSTOPOULOS, this volume-a). A robust *Palaeotragus* is usually present in latest Vallesian-early Turolian faunas from Turkey, Greece and the Black Sea region, while it is much more uncommon in middle Turolian faunas. *Samotherium boissieri* is originally known from Samos, but is also documented at Kemiklitepe D, dated at ~7.7 My (SEN et al., 1994). *Gazella pilgrimi* also implies chronological similarities with early Turolian faunas from continental Greece. On the other hand, *Palaeoryx* is a common element in the middle Turolian faunas of the Greek mainland. Hence, the combination of early Turolian elements with some middle Turolian ones suggests a late early Turolian age (late MN 11) for MLN, in accordance with the available magnetostratigraphic data.

Biochronology of Mytilinii-3 (MYT). The locality MYT is situated at the basal part of the main fossiliferous beds of Mytilinii Fm, in Potamies ravine (Tab. 1). The determined fauna is poor in identifiable specimens but includes an important number of taxa: "*Diceros*" *neumayri*, *Diboplus pikermiensis*, *Ancylotherium pentelicum*, *H. cf. proboscideum*, *H. cf. forstenae*, *H. prostylum*, *H. cf. matthewi*, *Samotherium major*, *Sporadotragus parvidens*, *Gazella pilgrimi*, *Skoufotragus zemalisorum* n. sp., *Palaeoryx* sp., ?*Majoreas* sp. (GIAOURTSAKIS, this volume; GIAOURTSAKIS & KOUFOS, this volume; KOSTOPOULOS, this volume-a, b; VLACHOU & KOUFOS, this volume).

"*Diceros*" *neumayri* continues its presence in MYT. *Ancylotherium pentelicum* is a rare taxon known from Pikermi, upper Maragheh and Akkaşdağı, suggesting a middle Turolian age; its record in MYT most probably corresponds to the appearance of the species and its first occurrence in the Samos faunal succession. HEISSIG (1996) lists *Diboplus pikermiensis* from Samos and Pikermi whereas FORTELIUS

et al. (2003) register the species in locality 26 of Middle Sinap (Turkey), dated at 8.1 My. Thus, the co-existence of "*Diceros*" *neumayri*, *Diboplus pikermiensis* and *Ancylotherium pentelicum* is rather indicative of an early middle Turolian age.

The identified hipparions from MYT are slightly different than those from MLN. *H. prostylum* is probably still present in MYT, whereas *H. cf. proboscideum* is known only by a few postcranial elements (VLACHOU & KOUFOS, this volume). *H. matthewi* is originally described from an unknown locality of Samos (ABEL, 1926) but is well-known from the middle Turolian sites of Kemiklitepe, Turkey (KOUFOS & KOSTOPOULOS, 1994). *H. forstenae* was originally described from Loc. 30 of Shanxi, China, and it seems to be a time-spread species ranging from Vallesian to Turolian. A similar form is known from Gülpınar, Turkey (recorded as *H. matthewi*) and Titov-Veles, FYR of Macedonia (recorded as *H. verae*), both dated to middle Turolian, MN 12 (FORSTÉN & GAREVSKI, 1989; FORSTÉN & KAYA, 1995). *H. cf. forstenae* from MYT represents the first appearance of the species in the Samos faunal succession.

The large palaeotragine *Samotherium major* replaces its forerunner *S. boissieri* at about 7.35 My, appearing for the first time in the Q₆-level (KOSTOPOULOS, this volume-a). *S. major* is well-documented in MYT by a form of slightly smaller size than that occurred in the overlying Samos fossil levels, suggesting an earlier age.

Gazella pilgrimi is the predominant gazelle species in the early Turolian localities of Macedonia, Greece, where it fades out at the beginning of middle Turolian (KOSTOPOULOS, 2006). The species occurs in the lower fossil levels of Samos probably together with *G. cf. ancycensis* but it is still present in MYT, MTLA/B and Q₅, suggesting a much wider time-distribution than in continental Greece (KOSTOPOULOS, this volume-b). *Palaeoryx* sp. and *Sporadotragus parvidens* are typical middle Turolian bovids of continental Greece, originally known from Pikermi, but they seem to have a wider time distribution in the East, going down to early Turolian (KOSTOPOULOS, this volume-b). *S. parvidens* is already well-known from Kemiklitepe D, dated at ~7.7 My (SEN et al., 1994). *Skoufotragus zemalisorum* is a possible forerunner of *Skoufotragus laticeps* (= *Pachytragus laticeps*) from the main Samos fossil levels (KOSTOPOULOS, this volume-b).

In summary, a few early Turolian mammal taxa persist in the MYT fauna, which is basically characterized by the first appearance of several middle Turolian elements. Thus, an early MN 12 age, totally compatible with the magnetostratigraphic data, is suggested.

Biochronology of Mytilinii-1 (MTL). The locality MTL is situated in Adrianos ravine and includes several fossiliferous sites, from which a rich mammal fauna has been unearthed; the fauna includes both micro- and macro-mammals.

MTLA. *Pseudomeriones pythagorasi*, '*Karminata*' *provocator*, *Spermophilinus cf. bredai*, *Adcrocuta eximia*, *Hyaenictitherium wongii*, *Machairodus giganteus*, *Metailurus parvulus*, *Parataxidea maraghana*, *Zygodolophodon turicensis*, *Orycteropus gaudryi*, "*Diceros*" *neumayri*, *Diboplus pikermiensis*, *Ancyloth-*

erium pentelicum, *Hipparion brachypus*, *Hipparion dietrichi*, *Hipparion* cf. *proboscideum*, *Hipparion* cf. *matthewi*, *Hipparion* cf. *forstenae*, *Microstonyx major*, *Palaeotragus rouenii*, *Samotherium major*, *Helladotherium duvernoyi*, *Gazella pilgrimi*, *Gazella* cf. *capricornis*, *Gazella mytilinii*, *Miotragocerus valenciennesi*, *Sporadotragus parvidens*, *Skoufotragus laticeps*, *Palaeoryx pallasi*, *Urmitherium rugosifrons*.

MTLB. *Pseudomeriones pythagorasi*, *Spermophilinus* cf. *bredai*, *Pliospalax* cf. *sotirisi*, *Pliovivverrops orbigny*, *Hyaenictitherium wongii*, *Choerolophodon pentelici*, *Orycteropus gaudryi*, “*Diceros*” *neumayri*, *Ancylotherium pentelicum*, *Hipparion brachypus*, *Hipparion dietrichi*, *Hipparion* cf. *proboscideum*, *Hipparion* cf. *matthewi*, *Hipparion* cf. *forstenae*, *Palaeotragus rouenii*, *Palaeotragus* sp., *Samotherium major*, *Gazella pilgrimi*, *Gazella* cf. *capricornis*, *Gazella mytilinii*, *Miotragocerus valenciennesi*, *Tragoportax rugosifrons*, *Skoufotragus laticeps*, *Palaeoryx pallasi*, *Palaeoryx majori*.

MTLC. *Hyaenictitherium* cf. *wongii*, *Pliohyrax graecus*, *Samotherium major*, *Miotragocerus valenciennesi*, *Gazella* cf. *capricornis*, *Palaeoryx majori*.

(GIAOURTSAKIS, this volume; GIAOURTSAKIS & KOUFOS, this volume; KONIDARIS & KOUFOS, this volume; KOSTOPOULOS, this volume-a, b; KOUFOS, this volume-b; SYLVESTROU & KOSTOPOULOS, this volume; VASILEIADOU & SYLVESTROU, this volume; VLACHOU & KOUFOS, this volume).

The rodent *Pseudomeriones pythagorasi* was found in MTLA and MTLB, but BLACK et al. (1980) had already recorded the species in S3 site, i.e. near the MYT fossil level. Recent data about the phylogeny of the genus suggests that it is a descendant of *Pseudomeriones latidens*, known from the late Vallesian - early Turolian of Turkey, whereas *P. pythagorasi* is classified as middle Turolian, MN-12 (SYLVESTROU & KOSTOPOULOS, 2007). Apart from Samos, *P. pythagorasi* is also known from the locality Düzyayla, Turkey, dated to MN 12 (FAHLBUSCH, 1996). “*Karminata*” *provocator* shares several morphological characteristics with that from Pikermi (VASILEIADOU & SYLVESTROU, this volume), implying a similar middle Turolian age.

The mastodonts found in MTL are few and include two species, *Choerolophodon pentelici* and *Zygodon turicensis*. The late Miocene choerolophodonts are separated into three species: *C. corrugatus*, *C. anatolicus* and *C. pentelici*. *C. anatolicus* is Vallesian and the other two Turolian (SANDERS, 2003). The similarity of the MTL choerolophodont with *C. pentelici* suggests Turolian age (KONIDARIS & KOUFOS, this volume). The *Zygodon turicensis* specimen belongs to the PMMS collection and possibly originates from MTLA. This taxon has a wide time-distribution in Eurasia covering middle-late Miocene (NOW, 2007). The sole known dp4 is similar to those from the Greek localities of Ravin de Zouaves-5 (Axios Valley) and Pikermi, dated to early and middle Turolian respectively.

The carnivores from MTL are relatively abundant and offer some additional biochronological data. *Hyaenictitherium wongii* has a wide chronostratigraphic range, covering the whole late Miocene. *Adcrocuta eximia* also shows a long time-distribution but it is known by two subspecies, the Vallesian *A. eximia leptoryncha* and the Turolian *A. eximia*

eximia (BONIS & KOUFOS, 1981). The resemblance of the studied material from MTL to that of the Turolian subspecies *A. e. eximia* indicates a Turolian age for MTLA. *Machairodus giganteus* is possibly known from MTLA by a fragment of an upper canine in the PMMS collection (KOUFOS, this volume-b). Its resemblance to the material from Vathyakkos and Halmyropotamos (Greece) suggests a middle Turolian age (KOUFOS, this volume-b). The MTLB *Pliovivverrops orbigny* is similar to that from early middle Turolian localities of Axios valley and Thessaly (Greece), as well as to the middle Turolian sample from Pikermi (KOUFOS, this volume-b). The felid *Metailurus parvulus* is mainly known from middle-late Turolian, although there is a single mention of its presence in the late Vallesian locality of Montredon, France (KOUFOS, this volume-b). The similarity of the studied material from MTLA to that from the Greek localities Pikermi, Chomateres, Halmyropotamos and Kerassia suggests late middle Turolian (MN 12) age. The mustelid *Parataxidea maraghana* from MTLA establishes chronological relations with middle Maragheh (SOLOUNIAS, 1981; BERNOR et al., 1996).

The rhino assemblage of MTL is identical to that of MYT, including “*Diceros*” *neumayri*, *Dihoplus pikermiensis* and *Ancylotherium pentelicum*, indicating middle Turolian, MN12 age. Furthermore, the rich material of “*D.*” *neumayri* from MTL shows a more advanced morphology than Pikermi and a lesser one than Akkaşdağı, Turkey, being closer to the Turkish samples from Mahmutgazi and Kinik, indicating a late middle Turolian age (GIAOURTSAKIS, this volume; GIAOURTSAKIS & KOUFOS, this volume).

Five different hipparions have been recognized in MTL. As already mentioned *Hipparion proboscideum* and *H. forstenae* suggest an early-middle Turolian age. *H.* cf. *matthewi* from MTL is characterized by a larger size than MYT, suggesting a younger age (VLACHOU & KOUFOS, this volume). *H. dietrichi* is a medium- to large-sized form, the holotype of which originates from an unknown locality on Samos (SONDAAR, 1971). Although *H. dietrichi* is known from early-middle Turolian sites of continental Greece (KOUFOS, 1987a, b, 1988; VLACHOU & KOUFOS, 2002, 2006), new data suggests that the mainland form might represent a distinct taxon (VLACHOU, in prep). *H. dietrichi* probably derives from Q6 and the MYT *H. prostylum* (VLACHOU & KOUFOS, this volume) and it represents the first occurrence of the species in the Samos faunal succession. A more advanced form of *H. dietrichi* is also recorded in Akkaşdağı, Turkey, dated to 7.0 My (KOUFOS & VLACHOU, 2005; KARADENIZLI et al., 2005). The type of *H. brachypus* is known from Pikermi, Greece, while the species is also documented in Hadjidimovo, Bulgaria, both evidences implying a MN 12 age (HENSEL, 1862; KOUFOS, 1987; HRISTOVA et al., 2002). The presence of *H. brachypus* in MTL represents the first certain occurrence of the species in the Eastern Mediterranean and its first appearance in the Samos faunal succession.

The large morphotype of *Microstonyx major* from MTLA is indicative of a late middle Turolian age, analogous to that of Pikermi, Greece, and Kalimantsi, Bulgaria (SYL-

VESTROU & KOSTOPOULOS, this volume). *Palaeotragus rouenii* continues its presence in MTL. *Samotherium major* from MTL appears to be larger than that from MYT, suggesting a younger age (KOSTOPOULOS, this volume-a). The species characterizes middle Turolian faunas, being present in Vathylakkos (Greece), Kemiklitepe A/B, Akkaşdağı and Taskınpaşa (Turkey), dated to middle-late Turolian (KOSTOPOULOS, this volume-a). The first appearance of *Helladotherium duvernoyi* in MTLA is also in favor of a late middle Turolian age. Although the species shows a wide time-distribution from late Vallesian to latest Turolian, its signal significantly increases in the upper part of middle Turolian, documented in Pikermi, Kerassia, Perivolaki (Greece), Hadjidimovo, Kalimantsi (Bulgaria) and Akkaşdağı (Turkey) (KOSTOPOULOS & KOUFOS, 2006; KOSTOPOULOS, this volume-a).

Gazella pilgrimi and *Sporadotragus parvidens*, already known from earlier Samos levels, persist in MTL. *Miotragocerus valenciennesi* shows a wide time-distribution, covering the entire Turolian. *Tragoportax rugosifrons* is considered to be an early Turolian element, disappearing in the Balkans at the beginning of MN12. Nevertheless, it seems to last longer in the East (KOSTOPOULOS, this volume-b). *Palaeoryx pallasii* and *Gazella capricornis* are typical middle Turolian bovids, originally known from Pikermi. *Gazella* cf. *capricornis* from MTL marks the first appearance of the species in the Samos faunal succession and shows a great resemblance to the predominant Akkaşdağı gazelle, suggesting a late middle Turolian age (KOSTOPOULOS this volume-b). *Palaeoryx majori* is also traced in the Samos fauna for the first time. Although its holotype and the rest of the Samos specimens ascribed to this species have an unknown origin, *P. majori* is known from Akkaşdağı, Turkey, dated at ~7.0 My. *Skoufotragus laticeps*, also originally known from Samos, replaces *Sk. zemalisorum* from MYT, and becomes the predominant bovid in the MTL fauna (KOSTOPOULOS this volume-b). The species is also known from Kemiklitepe A/B, dated at ~7.2 My (SEN et al., 1994), suggesting a middle Turolian age (MN 12).

Hence, the mammal assemblage of MTL is rather indicative of a late middle Turolian age (late MN 12), such as suggested by magnetostratigraphy. It is worth mentioning that small compositional differences between the faunal assemblage of the two MTL fossil levels, i.e. MTLA-MTLC from the one site and MTLB-MTLD from the other, do not signify a faunal discrepancy, even though the short stratigraphic distance between them certainly reflects a restricted time-lapse.

5. Internal Structure of the Samos Mammal Fauna

Despite remaining minor inconsistencies concerning the correlation of the Samos old fossil collections with specific chrono-stratigraphic horizons, the fossil assemblage of Samos offers an unprecedented panoramic aspect of the evolution of middle Turolian mammal faunas, which was neglected for a long time by the “single-fauna” hypothesis.

The reader should already have realized from the thorough study of the new collection that the Samos mammal fauna is in no case homogeneous and isochronous. Originally based on bovid data (KOSTOPOULOS, this volume-b) we tried to restore this unfortunate misinterpretation and to credit the Samos fauna with its real meaning and importance. Thus, we combined information from old and new collections in order to create a time-distribution table of Samos taxa (Fig. 2), illustrating the changes in the internal structure of the Samos mammal assemblage through time. Four chronologically succeeding mammal assemblages can be made out, reflecting a “four stages-of-evolution” scheme.

Primary Mammal Assemblage of Samos (PMAS), 7.8-7.4 My, late MN 11.

PMAS (Fig. 2) is characterized by the presence of *Protictitherium crassum*, *Promephitis lartetii*, “*Diceros*” *neumayri*, *Hipparion prostylum*, *Hipparion proboscideum*, *Microstonyx major*, *Samotherium boissieri*, *Palaeotragus rouenii*, *Palaeotragus quadricornis*, *Miotragocerus valenciennesi*, *Tragoportax rugosifrons*, *Sporadotragus parvidens*, *Gazella pilgrimi*, *Gazella* cf. *ancyrensis*, *Majoreas woodwardi*, *Criotherium argalioides*, *Tragoreas oryxoides*, *Prostrepsiceros fraasi*, *Gazella mytilinii*, *Protoryx capricornis* and *Palaeoryx* sp. According to data from Turkish sites (HEISSIG, 1996) *Chilotherium samium* known from non-stratigraphically controlled old Samos collections, should also be credited to this assemblage. At the end of this period, *Majoreas woodwardi*, *Tragoreas oryxoides* and *Protoryx capricornis* probably disappeared.

Intermediary Mammal Assemblage of Samos (IMAS), 7.4-7.2 My, early MN 12.

IMAS (Fig. 2) is characterized by an enormous renewal of the mammal fauna. *Promephitis lartetii*, “*Diceros*” *neumayri*, *Pliohyrax graecus*, *Microstonyx major*, *Palaeotragus rouenii*, *Miotragocerus valenciennesi*, *Tragoportax rugosifrons*, *Gazella pilgrimi*, *Criotherium argalioides* and *Sporadotragus parvidens* continue in this interval together with *Hipparion prostylum* and *Hipparion proboscideum*. Simultaneously, *Pliospalax* cf. *sotirisi*, *Pseudomeriones pythagorasi*, *Byzantinia hellenicus*, “*Karnimata*” *provocator*, *Spermophilinus* cf. *bredai*, *Adcrocota eximia*, *Hyaenictitherium wongii*, *Orycteropus gaudryi*, *Dihoplus pikermiensis*, *Ancylotherium pentelicum*, *Hipparion* cf. *matthewi*, *Hipparion* cf. *forstenae*, *Palaeoryx pallasii* and *Skoufotragus zemalisorum* appear. *Samotherium major* replaces *Samotherium boissieri* and *Prostrepsiceros zitteli* probably takes the place of *Prostrepsiceros fraasi*. *Chilotherium kowalevskii* from Samos should also be credited in this assemblage, probably coexisting with *Chilotherium samium*.

Dominant Mammal Assemblage of Samos (DMAS), 7.2-6.9 My, late MN 12.

The end of the previous period is characterized by the last occurrences of *H. prostylum* and *Criotherium argalioides* and the first appearance of *Hipparion brachypus*, *Hipparion dietrichi*, *Skoufotragus laticeps* and probably *Chilotherium schlosseri*.

DMAS (Fig. 2) represents an advanced stage of IMAS characterized by a similar faunal composition but with

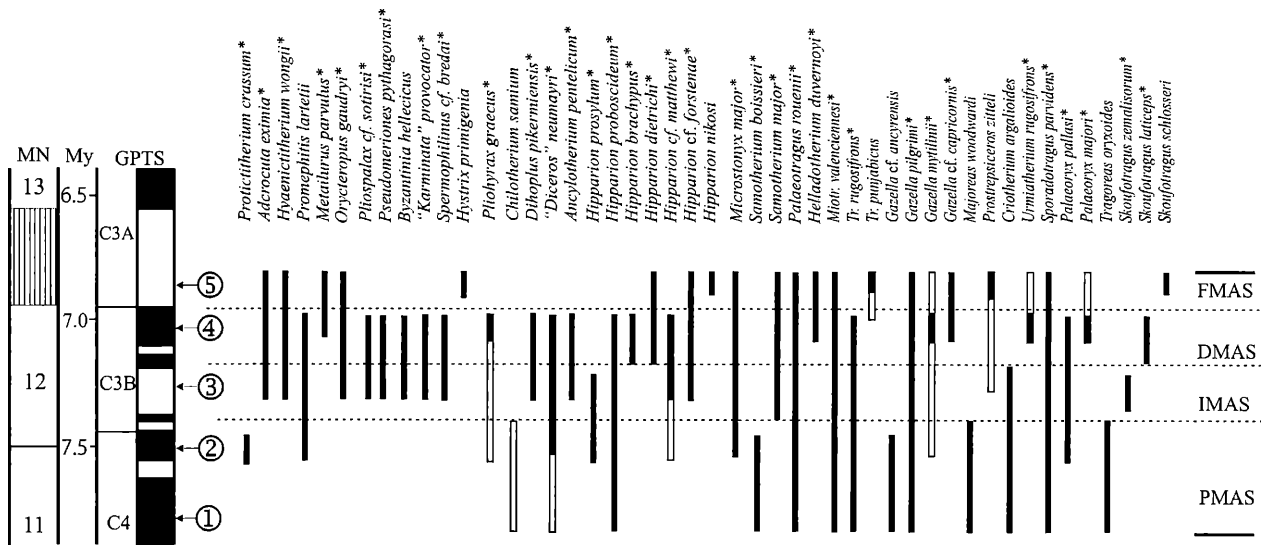


Figure 2: Time distribution of Samos small and large mammal taxa and correlation with MN-zones and GPTS.

(1): Q_x, Vryssoula fossil level; (2): MLN, Q₂, Stefano fossil level; (3): MYT, Q₃, fossil level; (4): MTLA/B/C, Q₁, Adriano fossil level; (5): Q₅ fossil level: Q₆ is in between (2) and (3) and Q₄ in between (3) and (4). Taxa marked with an asterisk are included in the new collection and described in the present volume. PMAS, IMAS, DMAS and FMAS represent primary, intermediary, dominant and final Samos mammal assemblage (for details see text).

a clear trend towards larger and/or more specialized ungulates and an enrichment in carnivores. Most IMAS taxa continue to be present, but “*Diceros*” *neumayri*, *Hipparion* cf. *matthewi*, *Samotherium major* and *Microstonyx major* appear with larger morphotypes than previously, whereas *Skoufotragus zemalisorum* is replaced by the larger *Skoufotragus laticeps* and *H. prostylum* by *H. dietrichi*, both predominating among ungulates. New taxa also appear: *Metailurus parvulus*, *Promeles palaeattica*, *Parataxidea maraghana*, *Plioviverrops orbignyi*, *Ictitherium viverrinum*, *Choerolophodon pentelici*, *Zygalophodon turicensis*, *Chilotherium schlosseri*, *Helladotherium duvernoyi*, *Gazella capricornis*, *Urmitherium rugosifrons* and *Palaoryx majori*. The first occurrence of *Oioceros wegneri*, *Tragoptax punjabicus* and *Samokeros minotaurus* could also be also credited in this assemblage. At the end of this period *Promeplitis lartetii*, *Pliohyrax graecus*, *H. proboscideum*, *H. brachypus*, *Tragoptax rugosifrons* and *Palaoryx pallasii* fade out.

Final Mammal Assemblage of Samos (FMAS), 6.9–6.7 My, latest MN 12–early MN 13.

FMAS (Fig. 2) is characterized by the reduction of the overall number of mammal taxa and the replacement of some of them by others. *Adcrocuta eximia*, *Hyaenictitherium wongii* and *Metailurus parvulus* are still present, as are *Chilotherium schlosseri*, *Hipparion dietrichi*, *Hipparion* cf. *forstenae*, *Microstonyx major*, *Samotherium major*, *Palaeotragus rouenii*, *Helladotherium duvernoyi*, *Miotragocerus valenciennesi*, *Gazella pilgrimi*, *Gazella* cf. *capricornis*, *Gazella mytilinii*, *Prostrepsiceros zitteli*, *Palaoryx majori* and *Sporadotragus parvidens*. *Orycteropus gaudryi* from Q₅ appears larger than that from Q₁–Q₄ (SONDAAR, 1971). *Tragoptax amalthaea* could replace *Tr. rugosifrons* together with the entrance of *Tragoptax punjabicus* and an overall increase of the boselaphine signal. The more specialized

Skoufotragus schlosseri substitutes the earlier *Sk. laticeps* and becomes the dominant bovid. The smaller *Hipparion nikosi* with avdeep narial opening replaces *H. cf. matthewi*. *Hystrix primigenia* is traced for the first time.

6. Conclusion

The biochronological analysis of the new Samos mammal collection and its correlation with existing magnetostratigraphic data (KOSTOPOULOS et al., 2003) allows dating the MLN assemblage to the end of early Turolian (late MN 11), the MYT assemblage at the beginning of early Turolian (early MN 12) and the MTL assemblage at the late middle Turolian (late MN 12).

Updated information concerning the chronostratigraphic location of old quarries and their correlation with new ones together with revised taxonomical data, leads us to refute the “single-fauna” hypothesis of SOLOUNIAS (1981) and to propose four stages of evolution in the Samos mammal fauna, representing a chronological succession of ~1.0 My.

The results of our work resolve long-lasting chronological problems concerning one of the classical late Miocene European mammal localities and provide an unequivocal framework for the local and Eurasian biochronology, as well as for the study of mammalian evolution.

7. Acknowledgements

The excavations on Samos have been supported by the Prefecture of Samos and the “Konstantinos and Maria Zimalis” Foundation. The Municipality of Mytilinii provided generous help too. The

Natural History Museum of the Aegean offered us the premises for the preparation and storage of the fossils. Thanks to Prof. F. Steininger for reviewing the original manuscripts.

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