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The presence of fossil mammals in Lesvos Island, NE Aegean Sea, and their paleobiogeographical implications

Dermitzakis, M.D. & H. Drinia, 1999 - The presence of fossil mammals in Lesvos Island, NE Aegean Sea, and their palaeobiogeographical implications - in: Reumer, J.W.F. & De Vos, J. (eds.) - ELEPHANTS HAVE A SNORKEL! PAPERS IN HONOUR OF PAUL Y. SONDAAR - DEINSEA 7: 113-120 [ISSN 0923-9308]. Published 10 December 1999

The study of fossil mammals of Lesvos Island can give us good paleogeographical results. Paleogeographic sketches that indicate the relative positions of various paleogeographic domains during some critical periods will describe the paleogeographic evolution of Lesvos Island during the Late Cainozoic, with emphasis on the Pliocene/Pleistocene period.

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Keywords: Lesvos Island, Late Cainozoic, mammal fossils, paleobiogeography

INTRODUCTION

Under the ancient name 'Aegeis', Phillipson (1898) described a large continent that occupied the Aegean territory from Minor Asia to the Ionian Sea. This region is marked, from a geotectonic point of view, by the collision between the African plate and the Eurasian plate, resulting in successive tectono-orogenetic events, which created the present structure of the Hellenic Arc. Lesvos Island is situated in the Northeastern part of the Aegean Sea, close to West Anatolia, near the coasts of Minor Asia, around the latitude of 39^{o} N and longitude of 26^{o} W (Fig. 1). The maximum length of it is about 70 km and the maximum width is about 45 km. The Neogene of Lesvos consists of carbonate sediments and pyroclastic material. The latter appears in the northern and western part of the island (Fig. 2). The carbonate sediments include marls, marly limestone and, between these beds, there are intercalations of silicified marls containing plant remains.

Figure 1 Map of Lesvos and the surrounding area (after Pe-Piper 1978).

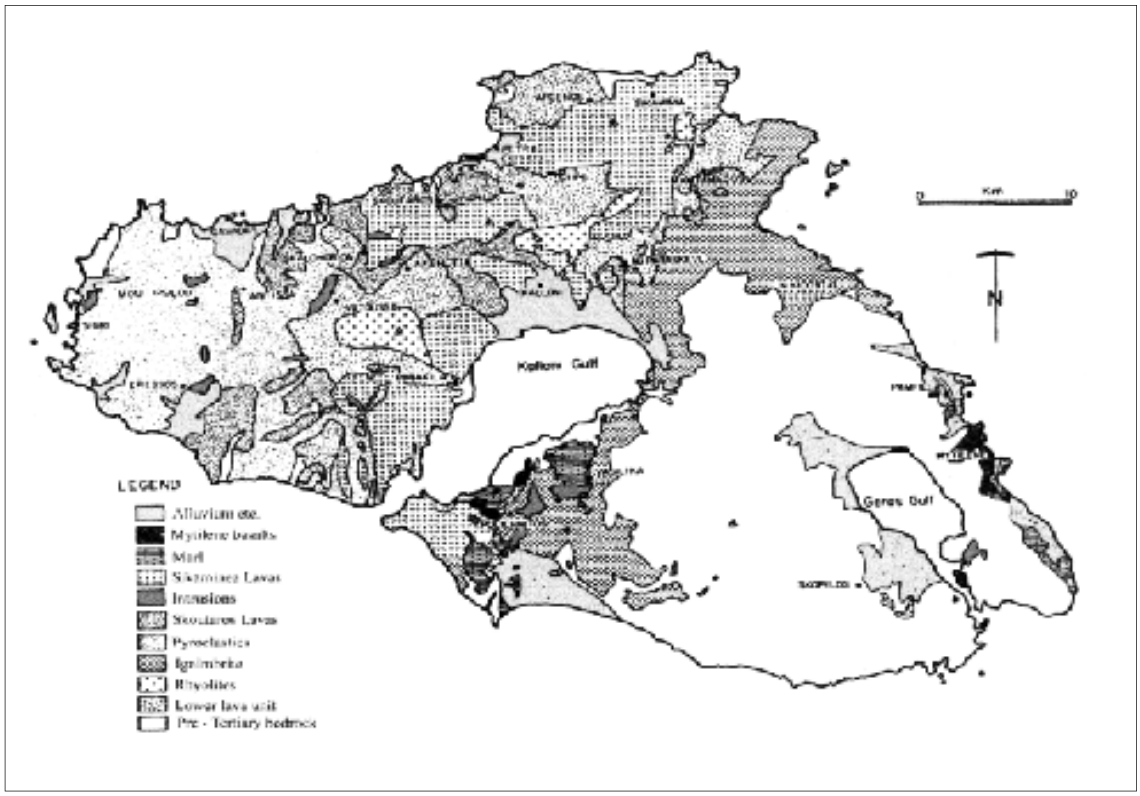

Figure 2 Geological sketch map of Lesvos island.

The study of fossil mammals on islands is interesting as they can give information on paleogeography and, in consequence, on tectonic movements (Dermitzakis & Sondaar 1979). For instance, when the fossil fauna of the island consists only of elephants this indicate that the area was an island in the past too. If we find a balanced fauna on the island with carnivores and herbivores, we may be sure that the present island must have been connected with the mainland in the past. This paper deals with the geological evolution of Lesvos Island during the Late Cainozoic.

THE CAINOZOIC VOLCANIC ACTIVITY OF LESVOS ISLAND

The regional setting of the island is important in understanding the Miocene volcanism. Lesvos Island is characterised by the presence of a thick sequence of Miocene volcanic rocks resting on metamorphic basement (Fig. 3). Field observations, petrology, magnetic stratigraphy and radiometric dating have been used to develop a volcanic stratigraphy (Pe-Piper 1978). The main volcanic sequence comprises basalts, andesites and dacites (principally in the upper part of the sequence), developed in a chain of strato-volcanoes extending NE-SW across the centre of the island. Thick acid pyroclastics are found on the flanks of the strato-volcanoes. Late dykes and lava cones are also found in the flank regions. The main volcanic sequence correlates with standard magnetic epochs 16 and 17, around 17-18 My (Borsi *et al.* 1972). The main volcanic sequence of Lesvos Island belongs to the shoshonitic suite. This is related to Miocene subduction in the southern or central Aegean Sea.

In the Mesozoicum and the Palaeocene, one or more small ocean basins were created within the present Aegean and then destroyed by subduction. Palaeocene calc-alkali volcanism is widespread in northern Greece, north-western Anatolia, and the northern Aegean islands, and may be related to subduction of either the

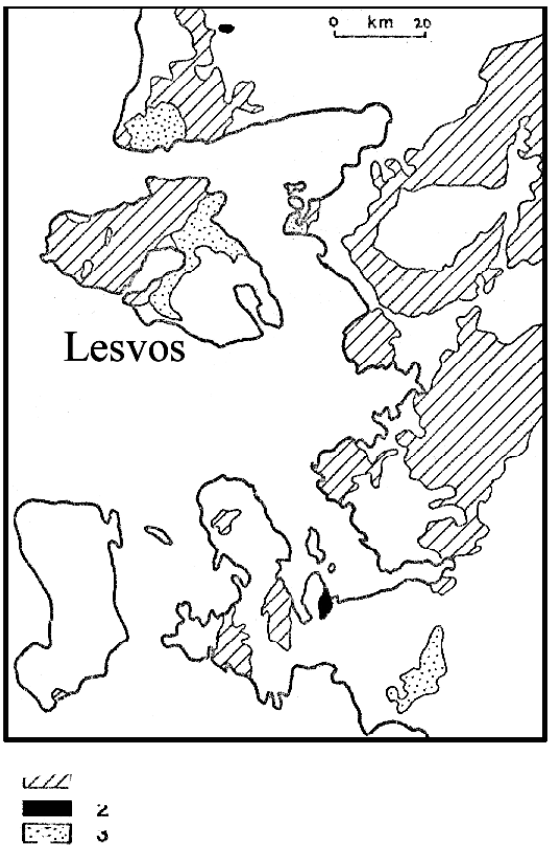

Figure 3 Neogene volcanism of Lesvos Island and West Anatolia (based on Borsi et al. 1972, Jones 1971): **1**. Calc-alkali rocks; **2**. Basic rocks; **3**. Acid rocks.

Vardar zone or the Black Sea. Miocene volcanism is extensive in West Anatolia, and may extend to some of the central Aegean islands where the volcanism has not been dated. Plio-Quaternary trachytic volcanism is also common in northern Greece. The Plio-Quaternary Hellenic Arc has an outer series of calc-alkali volcanoes and an inner potash-rich series. They are related to subduction of the African plate beneath the Aegean plate. This plate tectonic system was established in the Miocene. The immediately preceding plate distribution is disputed. A Miocene blue schist metamorphic zone runs through Crete; its role in Miocene and Pliocene volcanism of the Aegean is unclear.

PALEOGEOGRAPHICAL EVOLUTION OF LESVOS ISLAND

Fundamental changes took place in the basin configurations and paleogeography during the Late Cainozoic and especially in the Late Burdigalian, the Serravallian, the Serravallian-Tortonian boundary interval, the Late Miocene and the Early Pliocene. Rögl & Steininger (1983) suggest that some of these changes were related to major plate reorganisations (Dermitzakis 1988, 1990, 1996). Moreover, it must be noted that an essential role in the basins configuration and their paleogeographic evolution was played by dominant volcanism during that period. The volcanic activity of the islands of the Aegean Sea has not been dated accurately, yet it is likely that it is of Miocene to Pliocene age. Paleogeographic sketches, indicating the relative positions of various paleogeographic domains during some critical periods, will describe the paleogeographic evolution of Lesvos Island during the Late Cainozoicum.

Late Oligocene-Early Miocene (Fig. 4)

For this time span, we can make a reconstruction with a relative accuracy for the external Hellenides only. Less is known for the southern Aegean Arc. The Hellenic molassic trough is more or less connected with the external area of the Ionian Sea, through eastern Peloponnesus and the Cretan basin, to the SW Minor Asia. The Pelagonian cordillera, consisting mainly of metamorphic rocks, is extending from western Macedonian, through Eastern Thessaly, Attica and the Cyclades to the area of Minor Asia. In the Northern Aegean Sea, along the southern margin of Rhodopes, another molassic basin of Upper Eocene-Oligocene age might still locally exist and extend in a north-eastern direction. A volcanic zone from Eastern Thrace to the North of Samos Island, going parallel to the present coastline of Minor Asia, is also evident. Volcanic rocks of Late Eocene or Oligocene age are well extended in the North Aegean region. In Lemnos Island (Davis 1960) there are trachytes and dacites of Late Oligocene-

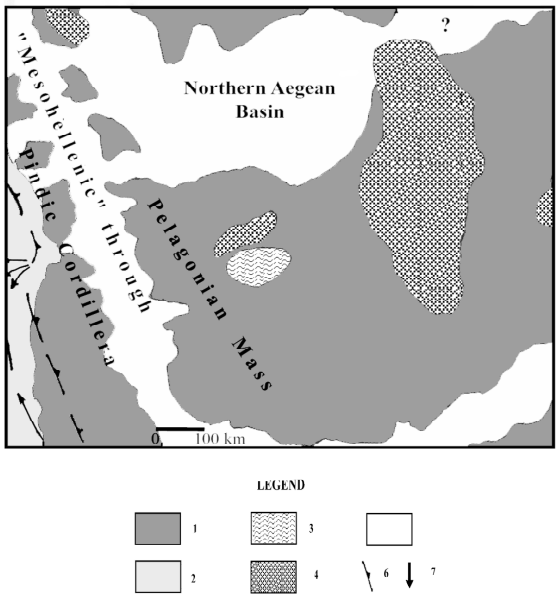

Figure 4 Paleogeographical reconstruction of Lesvos Island during the Late Oligocene-Early Miocene: **1**. Continental areas; **2**. Preapulian platform; **3**. 'island' freshwater or brackish water basins; **4**. Volcanic zone; **5**. Marine environment; **6**. The front of the Hellenides; **7**. Vertical tectonic movements.

Early Miocene age. In Imbros Island there are andecites whereas in Samothraki Island (Davis 1963) volcanic rocks of the same age are overlying beds of Eocene age and underlying Pliocene ones. These volcanic rocks comprise andesites, tranchy-andesites and tuffites. Late Eocene andesites have been also described in Northwest Anatolia (Erk 1942), in the Gemlik-Bursa region (Diller 1892) and in Dardanellia (Van der Kaaden 1952).

During the same period in the NW part of Lesvos Island a Petrified Forest is buried in tuffites from the nearby volcano. This rather extended Petrified Forest is of autochthonous origin. Its formation is highly connected with the volcanic activity of the surrounding area of Lesvos Island. The flora resembles the Paratethys flora in Southern Germany and other European countries (Velitzelos & Gregor 1990). Apart from the already known species of Lower Miocene Taxodiaceae-woods, *Taxodioxylon gypsaceum*, *Taxodioxylon megalonissum* and *Glyptostoboxylon microtracheidale* have been recently described (Suss & Velitzelos 1997). It is believed that the Forest of Lesvos Island grew during subtropical climatic conditions, which abruptly changed into continental-tropical climatic conditions.

Middle-Late Miocene (Fig. 5)

During this period, volcanism is still present along the same N-S trending zone as before, but extended through the Island of Kos. During the Miocene intense volcanic activity was taking place in West Anatolia (Gumus 1964). The volcanic activity of the islands of the Aegean Sea, which are situated westwards and northwards of Lesvos Island, has not been accurately dated, though it is likely to be of Miocene or Pliocene age. The intra-Serravallian events resulted in the disruption of the hitherto existing connections of the Mediterranean with the Paratethys and the Mediterranean with the Atlantic (Rögl & Steininger 1983). During this time span a

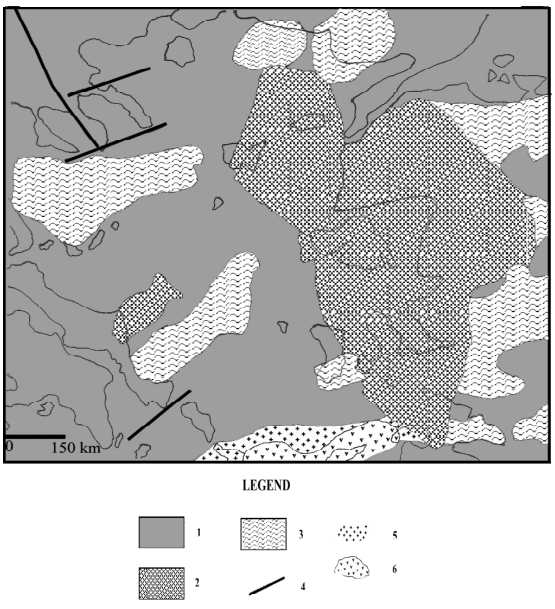

Figure 5 Paleogeographical reconstruction of Lesvos Island during the Middle-Late Miocene: **1**. Continental areas; **2**. Volcanic zone; **3**. 'island' freshwater or brackish water basins; **4**. Fault zones; **5**. Acid intrusives; **6**. The Cycladic nappe.

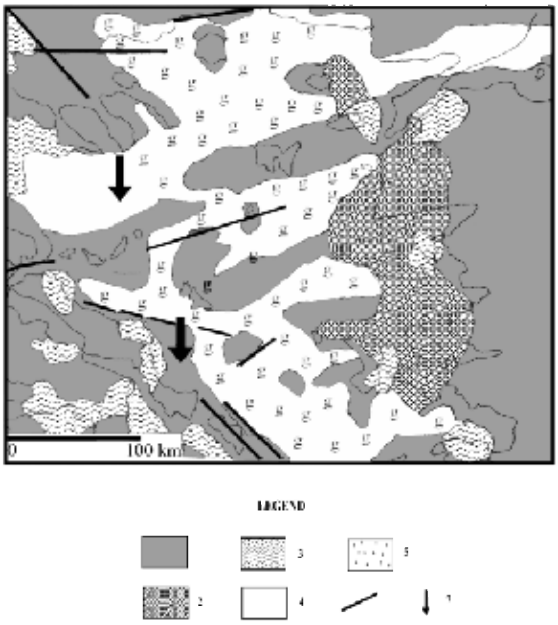

Figure 6 Paleogeographical reconstruction of Lesvos Island during the Messinian: **1**. Continental areas; **2**. Volcanic zone; **3**. 'island' freshwater or brackish water basins; **4**. Marine environment; **5**. Evaporites; **6**. Fault zones; **7**. Vertical tectonic movements.

faunal exchange from Minor Asia took place. The first occurrence of Asiatic immigrants shows a unique presence in MN3 zone, that is to say about 20 My and in MN12-MN13 zones about 6-7 My (De Bruijn & Zachariasse 1979).

At the boundary interval from the Serravallian to the Tortonian, about 10.6 My, the palaeogeographic configuration changed completely. Intra-Tortonian tectonics (between 8 and 9 My ago) resulted in the fragmentation of the existing landmass. In general, the late Tortonian was characterised by a flattening of relief. Several brackish and fresh-water lakes were formed at that period. E.g., during the Tortonian there was a fresh water basin in Rhodes Island, whereas at the same time we can observe an interfingering of marine and fresh-water deposits in Kythera Island.

Intra-Messinian tectonics about 5-6 My ago (Fig. 6) are more difficult to unravel. We are nevertheless able to demonstrate that a major tectonic reorganisation occurred in Messinian times. Throughout the Middle Tortonian and the Messinian, temporary connections between the Mediterranean and the Northern Aegean existed, without however creating 'barriers' preventing mammal migrations from Minor Asia. During this part of the Late Miocene, the former Aegean mainland formed an archipelago, in which landbridges between Minor Asia and Greece facilitated the arrival of a large number of Asiatic steppe immigrants and African elements to the present Greek mainland.

Pliocene (Fig. 7)

From this period onwards the volcanic Aegean Arc has been developed. Pliocene localities with macro-mammals are few in the eastern Mediterranean and the faunas of this age are not well known. However, recent investigations have extended our knowledge and new data have been appeared. Mammal faunas of Pliocene (Ruscinian) zones MN14 and MN15 occur either in eastern Aegean islands or in the northern mainland of Greece. During Pliocene/Pleistocene times, Lesvos Island was part of continental Minor Asia (Sondaar & Dermitzakis 1985, Sondaar *et al.* 1986, Dermitzakis 1989). During that time, the mammals of Lesvos continued to spread over the island; new mammalian species started to invade. The transient volcanic activity in the island, the changes of the shape and size of Lesvos due to glacier alternations and tectonic movements, played a crucial role to the spreading of these mammals. The dispersal route of most of the mammals of Lesvos was a land corridor.

A thick succession of Late Pliocene-Early Pleistocene terrigenous fluviatile and lacustrine deposits has been observed in Lesvos Island (Vatera Formation, SE Lesvos), in particular the Vatera lake deposits, containing

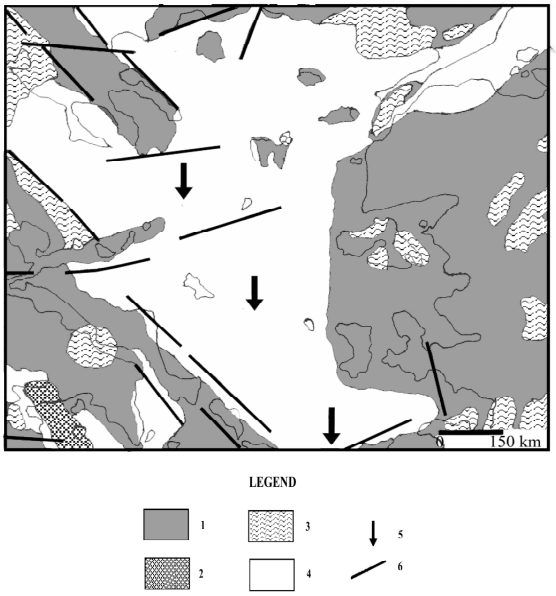

Figure 7 Paleogeographical reconstruction of Lesvos Island during the Pliocene: **1**. Continental areas; **2**. Volcanic zone; **3**. 'island' freshwater or brackish water basins; **4**. Marine environment; **5**. Vertical tectonic movements; **6**. Fault zones.

ostracodes, plant remains and fishes (Dermitzakis *et al.* in press a). These lake deposits are composed of greenish marls, marly limestones and diatomites, which are bearing huge concretions and traces of mammal footprints. Dermitzakis *et al.* (in press a,b) describe Late Pliocene-Lower Pleistocene fluviatile deposits that contain a fauna, the composition of which indicates that Lesvos must have been a part of the mainland and that it contains Asiatic and European elements. The possible dispersal route of the mammals was a corridor where the dispersal took place in both directions.

This faunal assemblage is characterised by abundant *Gazella borbonica*, an *Equus* of large size resembling *Equus stenonis*, an elephantoid that could be determined as *Anancus arvenensis*. Further *Nyctereutes megamastoides*, giraffids, deer, rhinoceros and a sabre tooth cat. The presence of a dwarf antelope, a giant tortoise and a large terrestrial monkey (*Paradolichopithecus*) makes it unique (Dermitzakis *et al.* in press b). Such a mammal association is common in Late Pliocene (2.5-1.8 My) Eurasia and has also been found in many localities of Northern Greece. The discovery of this balanced fauna supports the conclusion that the island of Lesvos was connected with Minor Asia. This paleobiogeographical interpretation is in accordance with the geomorphological, lithostratigraphical and tectonic observations, which show that Lesvos became an island during Holocene.

The floral association is characterised by a long interval with temperate flora. The beds are reversely magnetised with a short normal episode at the base. Von Vugt (pers. comm.) correlates the short normal interval with the older Reunion event (2.18-1.942 My). In addition, the presence of *Nyctereutes* and *Paradolichopithecus* points to a Late Pliocene age. The Vatera fossil site is of great scientific importance as it gives new important information about the environment in the period just before the beginning of the Ice Age. The abundance of the *Gazella*, horses and antelope fossils indicates an open and dry environment, which corresponds to dry savannah or open forests. The sediments indicate a river system with the possibility of forest on the banks. The Vatera large monkey had a terrestrial way of life, in this respect it resembles the African baboon.

Pleistocene (Fig. 8)

In general it can be said that the land-sea configuration of the Aegean Archipelago did not differ essentially in the Pleistocene from the present time. The Pleistocene of Lesvos is characterised mainly by breccia-conglomerates and a high percentage of arenaceous material, which is presented either as the matrix of breccia-conglomerates or as particular interbeds between the above formations

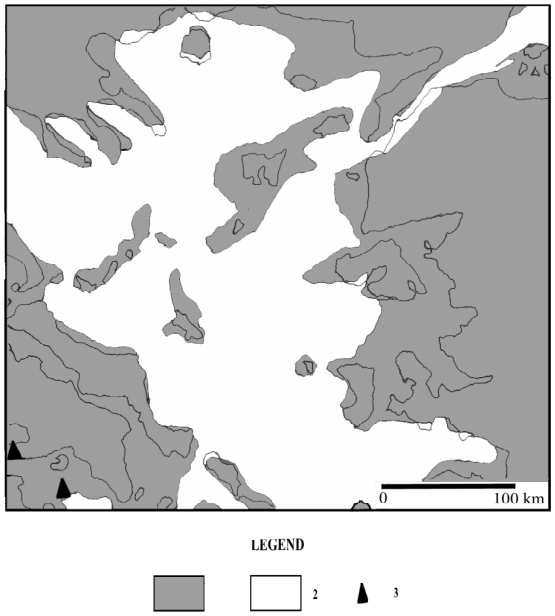

Figure 8 Paleogeographical reconstruction of Lesvos Island during the Pleistocene: **1**. Continental areas; **2**. Marine environment; **3**. Volcanoes.

or even between beds of clay. Pebbles are coming from the tuffs, the lava and the Neogene silicified marls. The main occurrence of this formation is between Vrissa and the Vatera area. Sedimentological features indicate that the island of Lesvos was connected with the mainland during the Late Pleistocene period. The interpretation of the scanty faunal remains that show no endemic character, does not exclude a land connection of Lesvos Island with the landmass of Minor Asia during the Late Pleistocene. Lesvos became an island again in the Holocene. However, more fieldwork and fossil collecting need to be done, to get better insight in combination with tectonics and eustatic sea level changes in the area of Lesvos. During the Pleistocene, the Meganisi region did not constitute an island, but it was connected to the mainland of Lesvos.

Lemnos Island and Ag. Efstratios Island are likely to have been connected once; it seems, however, rather unlikely that they were connected with Lesvos during the Pleistocene (Böger & Dermitzakis 1987). During the Early-Middle Pleistocene, Lesvos was connected with the opposite mainland of Minor Asia. After the elevation of the island, during the Middle Pleistocene, new species of mammals invaded Lesvos, without excluding the existence of a land bridge between Lesvos and Lemnos (Dermitzakis & Goetige 1977). This possibility is based on the resemblance of the Pleistocene mammal fauna found in both islands. Till the Middle Pleistocene, Inouses Island was still connected with the mainland of Minor Asia (Dermitzakis 1996). As far as Chios Island is concerned, it is clearly demonstrated that it became an island only recently (Late Pleistocene-Holocene?) and was before that connected with Minor Asia and Lesvos Island.

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received 25 January 1999

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