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New paleontological data from the continental Plio-Pleistocene of Java

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The results of a preliminary study of some assemblages of Murinae from continental Plio-Pleistocene deposits of Central and East Java, Indonesia are presented and discussed, in order to verify the biostratigraphical scheme worked out by Sondaar and his co-workers. Their correlation of the Grenzbank in the Sangiran Dome with the Trinil H.K. layer, as well as their paleoecological inferences are confirmed. The predominance of *Rattus* indicates a murid fauna that is very unlike the present Sundaic murid fauna and that has a more Indochinese character. The murids from the Satir fauna differ from the murids of the Trinil H.K. faunal unit, which may be due to difference in age as is indicated by Sondaar and colleagues' biostratigraphical scheme. The subgenus *Mus* (*Mus*) has been encountered on the Sunda Shelf area for the first time as a native inhabitant.

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INTRODUCTION

In this paper we will discuss the results of a preliminary study of the first assemblages of Murinae (Muridae, Rodentia) from continental Plio-Pleistocene deposits of Central and East Java, Indonesia. Murinae is the rodent subfamily comprising rats and mice (Carleton & Musser 1984, Musser & Carleton 1993). The study forms part of the project 'Faunal Evolution and Paleobiogeography of the Indo Australian Archipelago', initiated in 1980 by Dr J.J.M. Leinders (Open University, Heerlen), Dr J. de Vos (Naturalis, Leiden) and Dr P.Y. Sondaar (Natuurmuseum Rotterdam) and their Indonesian counterparts Dr M. Untung (Director), Dr D. Kadar, Dr F. Aziz and Dr Sudijono of the Geological Research and Development Centre in Bandung (Indonesia). A major result of the project has been the establishment of a new

biostratigraphical scheme based on sound evidence from revised lists of the various Plio-Pleistocene mammal faunas of Java (De Vos & Sondaar 1982, De Vos *et al.* 1982, Sondaar 1984, Leinders *et al.* 1985).

The fossils they used are those of large mammals only, for the simple reason that, with exception of the porcupine and a few *Rattus* sp. molars from the Sangiran area, no rodent material was available. The first described Pleistocene murid species from Indonesia, *Rattus trinilensis* MUSSER, 1982 (Musser 1982a), is based on a lower jaw in the Dubois collection of the famous locality Trinil, where he found the first *Homo erectus*. The here discussed rodent material is the result of the first two campaigns which were specifically intended to explore and sample Plio-

Pleistocene sediments of Java for rodents, in order to verify the biostratigraphical scheme worked out by Sondaar and his co-workers. Although there are no Plio-Pleistocene rodents from Java and adjacent areas with which we can compare our material, there is much information on the systematics and biogeography of the recent Muridae from the Sunda Shelf and adjacent areas (e.g. Taylor & Horner 1973, Musser 1981a, 1981b, 1982b, 1991, Taylor *et al.* 1982, Musser & Newcomb 1983, Musser & Heaney 1985, 1992, Musser & Holden 1991, Corbet & Hill 1992, Musser & Carleton 1993, Flannery 1995). The bearing of our material to some recent distributional patterns will be discussed. The study of the fossil rodents, as an integrated part of the study of the faunal history and paleobiogeography of the Sunda Shelf and adjacent areas, contributes to different but interrelated general themes of interest: the inquiry into climatic changes in the past, and into the changing environment of fossil humans in this part of the world.

REMARKS ON THE RODENT LOCALITIES

The here discussed rodents have been collected in the Sangiran and Trinil areas in Eastern Java and in the Bumiayu area in Central Java. Detailed descriptions of the successions in Sangiran and Trinil are given in Watanabe & Kadar (1985). In 1984 Situmorang and the other sedimentologists of the Snellius II Solo River Project measured and described the 700 stratigraphical meters of the marine Kalibiuk and continental Kali Glagah Formations along the Ci Saat (Bumiayu area). In all three sections deposits are exposed that document the Late Neogene regression, already described in the older literature (e.g. Van Bemmelen 1949). In our first field-campaigns we concentrated prospecting and sampling on the lower parts of the continental deposits.

The Kalibiuk Formation (Bumiayu area) consists mainly of dark gray clays with foraminifera. In its upper part molluscs (amongst

which thin-walled *Ostrea*) become more and more frequent, and some 10 meters below the top a *Turritella* bed is present. In the top of the formation a black, lignitic clay with freshwater molluscs has yielded a few rodent molars (sample CS.1). The Kali Glagah Formation consists of an alternation of fluvial sands, gravel and clay. According to Dr P.L. de Boer (Utrecht) and his team this formation has a thickness of nearly 500 meters. In the lower half the channel fills indicate a braided river regime, in the upper half indications of meandering systems have been found. Tidal influence is frequently indicated, in the lower half of the formation in particular. Samples CS.2A and CS.2B have been taken some 150 meters above the base of the Kaliglagah Formation from the clayey parts of a mollusc-rich alternation of thin beds of gravel, sand and clay. Sample CS.3 (270 meters above the base) has not yielded rodent molars. Sample CS.5 was taken from a sandy clay with some large mammal remains, 400 meters above the base, and some 50 meters higher a black clay yielded sample CS.4. In 1983 a cervid bone has been found in this bed.

RESULTS

Except for a single undetermined squirrel (Sciuridae) p4 from sample SW4 from the Grenzbank in the Sangiran area, all rodent material represents species of rats and mice (Murinae, as defined by Carleton & Musser 1984; Musser & Carleton 1993). These specimens have been preliminary identified by comparing them with samples of *Rattus trinilensis* and all relevant species of extant murine genera from the Indomalaysian and Australian regions. The results are listed in Table 1. The total number of the studied molars is 74(24).

The m1 of *Chiropodomys* from sample 84.CS.1 from the very base of the Kali Glagah Formation is very similar to certain variants of the living *C. gliroides*. This arboreal species occurs today in tropical forests

Table 1. The first assemblages of Murinae from continental Plio-Pleistocene deposits of Central and East Java, Indonesia. The numbers in brackets refer to the molars that are damaged. Capital 'M' and lowercase 'm' refer to upper and lower molars, respectively.

TRINIL H.K. FAUNAL UNIT		
Sangiran (Brangkal, Grenzbank, SW4)		
(1) <i>Moschus</i> sp.	1M1	= 1
(2) <i>Rattus trinilensis</i>	2M1, 2M2, 2M3, 2m1(1), 1m2, 1m3	= 10(1)
(3) <i>R. aff. thomomys</i>	3M1(2), 1M2, 2m1(2), 1m2, 1m3	= 8(4)
(4) <i>Rattus</i> sp. A	4M1(1), 4M3, 3m1(3), 2m2, 3m3	= 16(4)
(5) <i>Rattus</i> sp. B	3M1(1), 2m1(1), 3m2(1), 3m3	= 11(3)
(6) <i>Rattus</i> sp. C	2M1(1)	= 2(1)
(7) <i>Rattus</i> sp. indet.	1m3	= 1
Total: 49(13)		
Sangiran (Grenzbank, SW5)		
(1) <i>R. aff. thomomys</i>	1m1(1)	= 1(1)
(2) <i>Rattus</i> sp. B	1M3	= 1
Total: 2		
Sangiran (Black Clays, SW6)		
(1) <i>R. tritileusis</i>	1M1(1)	= 1(1)
(2) <i>Rattus</i> sp. A	1m2	= 1
Total: 2(1)		
Trinil, a few meters above Trinil H.K. of Duhois		
(1) <i>R. tritileusis</i>	mand. with m1 and m2	= 2
(2) <i>Rattus</i> sp. B	1M2	= 1
Total: 3		
SATIR FAUNAL UNIT		
Kali Glagah (84.KG.3), Lower part of the Kali Glagah Formation		
(1) <i>Mus (Mus)</i> sp.	4M1, 2M2(2), 1m1(1), 1m2(1)	= 8(4)
(2) <i>Rattus</i> sp.	1M1(1), 2M2(1), 2m2(2)	= 5(4)
Total: 13(8)		
Ci Sant (84.CS.1), Basis of the Kali Glagah formation		
(1) <i>Chiroptulomys glabridens</i>	1m1	= 1
(2) <i>Rattus</i> sp.	3M2(2)	= 3(2)
Total: 4(2)		
FAUNAL UNIT AS YET UNKNOWN		
Ci Sant (84.CS.4=CW.1), Upper part of the Kali Glagah Formation		
(1) <i>Mus</i> sp.	1m2	= 1
(2) <i>Rattus</i> spp.	2m3	= 2
Total: 3		

throughout Indochina, the Malay Peninsula and the Sunda Shelf (Musser 1979). As the sample was taken from the very base of the Kali Glagah Formation *C. gliroides* probably was a member of the Satir fauna, the oldest (approx. 1.5 My) faunal unit recognised on Java (Sondaar 1984, Leinders *et al.* 1985).

The genus *Mus* has been recognised in sample 84.KG.2 from the basal part of the Kali Glagah Formation in the Kali Glagah section, and in sample 84.CS.4 from the upper part of the Kali Glagah Formation in the Ci Saat section. It cannot be established on the basis of the present material whether or not the molars from the two localities belong to the same species. The M1 from 84.KG.2 have the characteristics of Misonne's *booduga* section of *Mus*. The distortion of M1 is less strong than in *Mus musculus* and *M. booduga*, but it is comparable to that found in other *Mus* (*Mus*) species. The M1 from 84.KG.2 resemble in particular the living *Mus caroli* (except those seen from China), with which they share the reduction of t9. *Mus caroli* occurs today in a few areas on the Sunda Shelf, but is considered to be introduced by man from mainland SE Asia (Marshall 1977, Musser 1982b). According to the former author it inhabits rice fields and other agricultural grassy areas. In Thailand it has been found in pine grass savannah and in grass areas in deciduous forest.

The single m2 of 84.CS.4 is most similar to that of the Indian Pygmy Field Mouse, *Mus booduga*, in size and morphology. It is remarkable that the fossil *Mus* from Java seem to belong to the subgenus *Mus* (*Mus*), because it is the first record of this subgenus as a native on the Sunda Shelf. In the present fauna only the *Mus* (*Coelomys*) species from the mountains of West Java and Sumatra are considered to be native (Musser 1982b).

The presence of the genus *Maxomys* in the Brangkal sample is based on a single M1. This molar is more elongated than it is in

living *Maxomys* species; in this respect it better resembles the monospecific *Srilankamys* from Ceylon, and *Niviventer* species. However, it seems that the fossil M1 lacks a well developed posterior cingulum, which is present in *Srilankamys*, and it lacks a t3 and the strongly arched chevrons with pointed central cusps, features that characterise *Niviventer* species. The fossil *Maxomys* sp. differs morphologically from all living species of this genus. According to Musser *et al.* (1979) *Maxomys* is basically a Sundaic genus. Its presence in the Grenzbank shows that it occurs in the Sunda Shelf province for at least one million years. It also shows that *Maxomys* and *Rattus* dentitions had already well diverged in morphology during the Early Pleistocene. This observation complements results of recent morphological and biochemical studies demonstrating that recent species of *Maxomys* and *Rattus* are phylogenetically well separated from one another in different clades (Musser & Newcomb 1983, Watts & Baverstock 1994, Ruedas & Kirsch 1997).

The greatest surprise of the fossil material is the high number of *Rattus* species present. Today a single species, *R. tiomanicus*, is present on Java (accepting that *R. rattus diardi*, *R. argentiventer*, *R. exulans*, and *R. norvegicus* are introduced). The whole of the Sunda Shelf area shows five native *Rattus* species (Musser 1986); the same number is present in the Brangkal sample alone. In the view of Musser & Newcomb (1983) *Rattus* forms a minor part of the species and generic diversity of the Sundaic murid fauna, which to date comprises 41 species in 14 genera. Because of this they concluded that 'the genus, at least subgenus *Rattus*, is turning out to be primarily Indian and Indochinese in geographic distribution, not Malaysian' (op.cit., p.589).

We started our determinations of the rats with the distinction of morphotypes of the first upper molars of Brangkal. One complete

molar and two molar fragments are clearly larger, two other M1's are clearly smaller than the bulk of these elements. The former are assigned to *R. aff. tiomanicus*, the latter, after the study of the lower first molars, to *R. trinilensis*. Amongst the remaining M1's, which are all medium sized, three more morphotypes were distinguished: Species A is characterised by wide molars and straight laminae; species B by somewhat shorter but equally wide molars in which the laminae are curved and a connection is present between cusps t6 and t9; species C is characterised by its slenderness of M1 compared to A and B and its *Rattus rattus* like molar outline.

Further detailed comparisons will have to be carried out in order to establish whether or not *R. aff. tiomanicus* from the Grenzbank can be included in the living species. The fossil molars are very similar to samples of *R. tiomanicus* studied on this first occasion, and we have no doubts about the close relationship between the fossil and living species. *R. tiomanicus*, the white bellied rat, lives in secondary forest, scrub, gardens, agricultural fields, and sometimes human dwellings (Musser & Calafia 1982). It does not occur North of the Isthmus of Kra, nor East of Wallace's line, and is therefore a truly endemic, widespread Sundaic species (op. cit.). The interest of the presence of *R. aff. tiomanicus* in the Lower Pleistocene of Java may appear from the following citations from Musser & Heaney (1985) discussing the native *Rattus* from Tawitawi Island in the southern Sulu Islands of the Philippines: 'In morphology, the Tawitawi rat is most similar to species of *Rattus* living on islands rimming the Sunda Shelf beyond the 180 m bathymetric line. These peripheral isolates appear to be most similar to *Rattus tiomanicus* among the extant fauna of the Sunda Shelf' (op. cit., p.1). Talking about *R. trinilensis* from the Pleistocene of Trinil, the only fossil species from the Sunda Shelf known at the time, but not related to *R. tiomanicus*, they continue: 'We wonder what other species of *Rattus* may

have been on the Sunda Shelf in the past when Sundaland consisted of islands and peninsula during times of high sea levels and a large continental expanse above the water at times of lower sea levels. Perhaps an ancestral species occurred there that is absent from the Recent fauna and now represented by *R. stoicus* in the Andaman Islands, *R. palmanum* and *R. burrus* in the Nicobars, *R. simularensis* in the Simular Islands, *R. lugens* in the Mentawais, *R. adustus* on Pulau Enggano, *R. hoffmanni* on Sulawesi, and *R. tawitawiensis* in the Sulu Archipelago' (op. cit., p.30). The fossil species from Brangkal may be just that ancestral species.

The presence in Brangkal of *R. trinilensis* MUSSER, 1982 is based on the identical morphology and size of a lower first and second molar and those of the holotype from Trinil. The Brangkal molars are the smallest amongst the other respective elements in the sample. The assignment of other molars to *R. trinilensis* could therefore easily be established on size. Now that more is known about *R. trinilensis* the validity of the taxon is further confirmed. It comes closest to the extant *R. exulans* in size but all elements have a different morphology. We have found no other comparable dentitions amongst extant species. The presence of *R. trinilensis* in our Brangkal sample is further evidence for the correlation of Trinil H.K. with the Grenzbank in the basal part of the Kabuh Formation in the Sangiran Dome (Leinders *et al.* 1985).

The morphology of the *Rattus* sp. A M1 is very similar to that of the extant *R. sordidus* from Australia and Southern New Guinea. The size of the fossil molars is, however, much smaller than in this living species. *R. sordidus* is a grassland inhabitant. According to the observations of one of us (Musser) wide upper molars with straight laminae are characteristic of grassland species. Therefore the dental similarity between *Rattus* sp. A and *R. sordidus* may be due to convergence due to similar diet. On the other hand in no case

the morphological resemblance of the fossil molars to an extant species is so striking as with this particular species.

The *Rattus* sp. B and C morphologies have not been encountered (yet) amongst extant species in spite of the fact that virtually all relevant ones have been seen.

Little can be said about the few molars of *Rattus* from the remaining samples, except that we are quite certain that they belong to this genus. Those of sample SW6 from the upper part of the Black Clays of the Pucangan Formation are assignable to species distinguished in the superposed Grenzbank. The level from which SW6 has been taken is close to the tuff layer (T 10) dated 1.60 ± 0.24 My (Suzuki *et al.* 1985). At this time *Rattus trinilensis* was already present on Java. The interest of *Rattus* in samples 84.CS.1 and 84.KG.2 lies in the fact that the genus was already present on Java, in the Satir fauna, approximately 1.5 My ago (Leinders *et al.* 1985). The occurrence of *Rattus* in the very base of the Kali Glagah Formation in the Ci Saat section is one of the oldest records of the genus. Other Early Pleistocene *Rattus* are mentioned in Savage & Russell (1983) from China and Africa.

CONCLUSIONS

- The sample of Brangkal (Grenzbank, which also yielded remains of *Homo erectus*) is the first Pleistocene rodent collection of reasonably large size in the Sunda Shelf region. It leads to some new and interesting additional insights in the biostratigraphy of the continental Pleistocene, in the paleoecology of the Sangiran fauna, and in the paleozoogeography of the Sunda Shelf.
- The predominance of *Rattus* species indicates a murid fauna that is very unlike the present Sundaic murid fauna. The composition of the fossil fauna has a more Indochinese character.

- The correlation of the Grenzbank in the Sangiran Dome with the Trinil H.K. by Leinders *et al.* (1985) is confirmed.
- The open woodland environment induced from the larger mammal association (op. cit.) is likewise confirmed by the predominance in the Brangkal fauna of the wide-toothed murid, *Rattus* sp. A, presumably a grass-land species.
- *Rattus* sp. A may be related to the native Australian-New Guinean *R. sordidus*. If so, Java may have been on the migratory route of this recent species, the origin and relations of which (and of its extant relatives) are hitherto unknown.
- What little is known of the murids of the Satir fauna, indicates that they are different from the murids of the Trinil H.K. faunal unit. The differences may be due to difference in age as is indicated by the biostratigraphical scheme of Sondaar (1984) and Leinders *et al.* (1985). On the other hand the ecological differences claimed by these authors may also play a role, for instance in explaining the absence of *Chiropodomys* in the Brangkal fauna. More material from the lower part of the Kali Glagah Formation is badly needed.
- The first fossil record of the arboreal *Chiropodomys gliroides* from the base of the Kali Glagah Formation is further evidence for the forested environment assumed by Leinders *et al.* (1985) from the larger mammals of the Satir fauna.
- However, the relatively wide-toothed molars of *Mus* sp. from sample 84.KG.2 indicate the existence of grasslands as well, if our inclusion of the faunule in the Satir faunal unit turns out to be correct.
- The subgenus *Mus (Mus)* has been encountered on the Sunda Shelf area for the first time as a native inhabitant.

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