CHAPTER III. VERTEBRATE PALEONTOLOGY

III.1. Vertebrate Biostratigraphy of Java

The Quaternary mammal fauna in Java is composed of a rather constant set of mammal groups encompassing several bovids, cervids, hippopotami, rhinoceros, and proboscidean (Hertler and Rizal, 2005). Since 1930s, von Koenigswald (1933, 1934, and 1935) had been proposed the widely used classical biozonation scheme for Quarternary sediment of Java. Afterward, in the 1980s a new biostratigraphic scheme has been proposed for the Quaternary terrestrial deposits of Java (de Vos et al., 1982, Sondaar, 1984, de Vos, 1983, 1985). These new biostratigraphic schemes for the Pleistocene of Java proposed by de Vos et al. (1982) and Sondaar (1984) is based on the faunal contents from single localities or composite faunas from localities that are closely superposed in thick stratigraphic sequences (van den Bergh, 1999).

The oldest, Early Pleistocene, Satir Fauna is characterized by poor amount taxa. The fauna was obtained from five excavations (excavations 1-4 and 8) carried out by C. ter Haar and J. Zwierzycki of the Dutch East Indies Geological Survey. The excavations were carried out near Satir village at the base of the Kali Glagah Series near Bumiayu (van den Bergh, 1999). The composition of fauna clearly differs from younger faunal assemblages which are considered as Early Pleitocene in Java. It is contains of *Sinomastodon bumiajuensis*, remarkably small hippopotamus (*Hexaprotodon simplex*) and giant tortoise of *Geochelone* also some cervids. Due to the occurrence of *Geochelone*, the faunal assemblage is representeing swampy or mangrove condition. Outside of Western part of Java, the Satir faunal assemblage also found in Sangiran. As reported by Matsu’ura et al. (1985), Leinders et al. (1985), by analyzing the fluorine content of a *S.*

bumiajuensis mandible originating from the Sangiran area and comparing it with fluorine data from excavated fossils from several stratigraphic levels, were able to show that it most likely originated from the so-called “black clays”, also known as the Sangiran (=Pucangan) Formation (van den Bergh, 1999). The age of this faunal assemblage is considered from fission track ages of volcanic ash layers (T5 and T6) in the Sangiran area as reported by Suzuki et al. (1985) proposed an age of 1.5 Mya (Million years ago).

The Cisaat Faunal assemblage is also insufficiently known and was originally proposed on hypothetical grounds by Sondaar (1984). It differs from the Satir Fauna by the replacement of *S. bumiajuensis* by well-known *Stegodon trigonochepalus*, and perhaps by the occurrence of the first felids (van den Bergh, 1999). Other than that, an endemic pig called *Sus stremmi*, *Hexaprotodon simplex* and undescribed cervid and bovid occurred in this assemblage. It is commonly understood as an open woodland environment (Hertler and Rizal, 2005). The latter publication by Suzuki, et al. (1985) by means of fission-track dating of Sangiran Formation sediment results an age of 1.16 ± 0.24 Mya.

The next stage of fauna called Trinil HK (“Haupt-Knochenschicht”) it is named based on type locality of Trinil in East Java. This faunal assemblage is well known due to Dubois and Selenka’s excavation in 1908. Trinil HK fauna includes small mammal porcupine *Hystrix* (*Acanthion*) *brachyuran*, *Rattus trinilensis* and fifteen large mammal species. Most abundant are cervids and bovids such as *Muntiacus mintjak, Axis lydekkeri,* some undescribed cervids, *Bubalus paleokarabau, Bibos paleosondaicus,* and *Duboisia santeng*. Besides, there are new species occurring for the first time in Java such as *Rhinoceros sondaicus, Trachypithecus cristatus, Macacca fascicularis, Mececyon trinilensis, Panthera tigris trinilensis,* and *Prionailurus bengalensis. Stegodon trigonocephalus* is the only Proboscidean species known from this fauna stage. Since the older faunal assemblage are not well known, Trinil HK fauna does not provide reliable first appearance datum (FAD) for each species (Hertler and Rizal, 2005).

Originally, Dubois (1908) considered the Trinil Fauna and the Kedung Brubus Fauna to be contemporaneous, explaining the relative poorness in species of the Trinil Fauna as due to palaeoenvironmental differences. Von Koenigswald (1934) basically followed this view and lumped the fossil assemblage from the locality Kedung Brubus with that from Trinil and considered this composite fauna as his Trinil Fauna. His Trinil Fauna is not to be confused with the Trinil H.K. Fauna sensu de Vos et al. (1982), which includes only those species originating from a single layer at Trinil, the so-called “Haupt-Knochenschicht”. According to these authors, the difference in faunal composition between Trinil H.K. and Kedung Brubus is due to the higher age of the Trinil H.K. Fauna and the relatively isolated circumstances of Java at the time of its accumulation. Others have maintained that the Trinil mammalian assemblage is incomplete (Heaney, 1984), which is certainly true with respect to the small mammals.

Perspectively, in Sangiran, The fossil fauna from the “Grenzbank” can be correlated with the Trinil H.K. faunal stage (Leinders et al., 1985). This could mean that the Trinil H.K. fauna, which lacks the genera *Elephas*, *Tapirus* and *Hyaena*, has an age of approximately 0.9 Mya, which is slightly younger than the 1 Ma originally proposed by Leinders et al. (1985 in van den Bergh, 1999).

The Kedung Brubus fauna is defined based on Dubois’ finds from Kedung Brubus. Although it contains smaller total number of specimens compared to Trinil collection, the number of species indicates a well-balanced representation. This stage characterized by the occurrence of *Manis palaeojavanica* as well as the simultaneous co-occurrence of *Stegodon* and *Elephas*. The large tiger still present and *Hyaena brevirostris* occurs for the first time, also the only otter fossil from Java, *Lutrogale palaeoleptonyx*. Besides, *Tapirus indicus*, which is still exist until present days, *Rhinoceros sondaicus* and *R. unicornis, Hippotamus, Sus macragnathus* and *S. brachiatus,* some bovids and cervids, *Epileptobos groeneveldtii,* are also appear (Hertler and Rizal, 2005). The change of species assemblage and the co-occurrence of two different genera of proboscideans considered to indicate an open woodland environment (Hertler and Rizal, 2005). Moreover, the rareness of arboreal primate and forest dwelling species as tapir, and also the occurrence of a grazer like rhino strengthen the rather dry climate and open landscape.

As stated in van den Bergh (1999) the younger age, Ngandong fauna is constructed based on material excavated from the Solo River terrace at Ngandong by Oppenoorth during the 1930's. Bartstra et al. (1988) gives a preliminary U-series age of 50-100 ka for fossil bone samples collected from an excavation in a terrace remnant at Ngandong. As they state, this age should be considered a minimum, yet it is presumably the maximum age is approximately 135 kya corresponds with the last glaciations. The faunal composition of the Ngandong fauna is very similar to that of the Kedung Brubus Fauna but very different from the younger Punung Fauna. Many taxa in the Ngandong fauna, including *Homo erectus*, differ on subspecies level from those of the Kedung Brubus Fauna (deVos et al., 1994), both faunas being characteristic of an open woodland environment. On the other hand, the Ngandong Fauna should be older than the Late Pleistocene Punung fauna (de Vos, 1983), which is characteristic of a tropical rainforest environment.

The presumably Late Pleisotocen Punung Fauna contains only such species extant today or at least from historic report of fauna in Java. Since a number of primates occur, i.e. orangutan, Punung Fauna considered to represent forested environment (Hertler and Rizal, 2005).

The sequences of Mammal biostratigraphic from Java runs from young to old can be seen in Figure III. 1 below. The shaded animals represent extinct species and colored animals represent extant species.

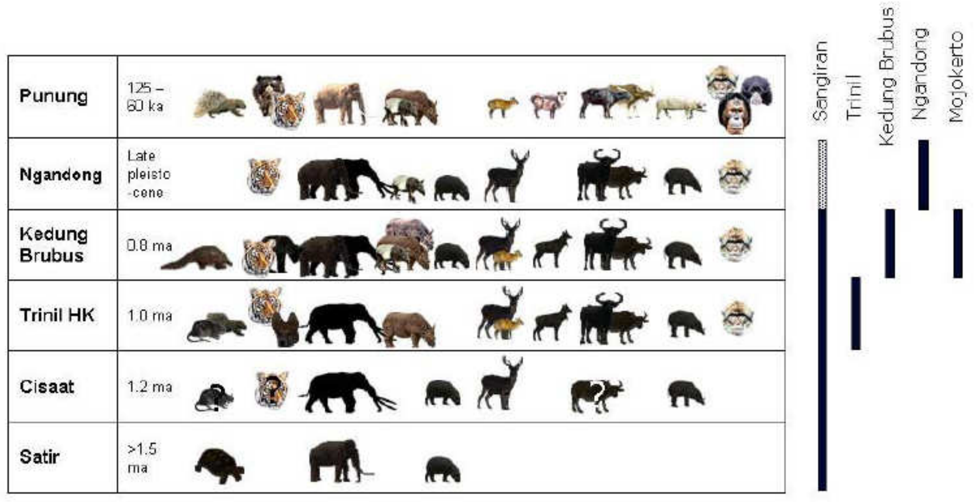

Figure III.1. Schematic composition of Mammalian fauna in the Pleistocene of Java and occurrence at different fossil sites (Hertler and Rizal, 2005).

III.2. Elephantoid and Quaternary Environment Evolution in Java

The evolution of Java environment in the Quaternary Period from time to time could have seen from the succession Elephantoidea (Figure III.2). In the graphic, species present in the type faunas of the faunal stages have been underlined. Lineages, which are thought to be continuous, are connected with dashed lines. Arrows indicate immigration events.

The evidence of large mammals lived in Java until the Pliocene at 2.4 Mya (million years ago) have not been found until now. Following the emergence of Java above sea level from the Late Pliocene until ca. 1.5 Mya, mammalian dispersal to Java was limited. Impoverished faunal assemblages and the occurrence of various dwarfed elephantoids in this time interval, indicating isolation of the islands, illustrate this condition. The earliest known well-documented fauna from Java, the Satir fauna (2-1.5 Mya) contains a mastodon of Chinese origin, *Sinomastodon bumiajuensis*. There are no predatory mammals known from this fauna (van den Bergh, 2001).

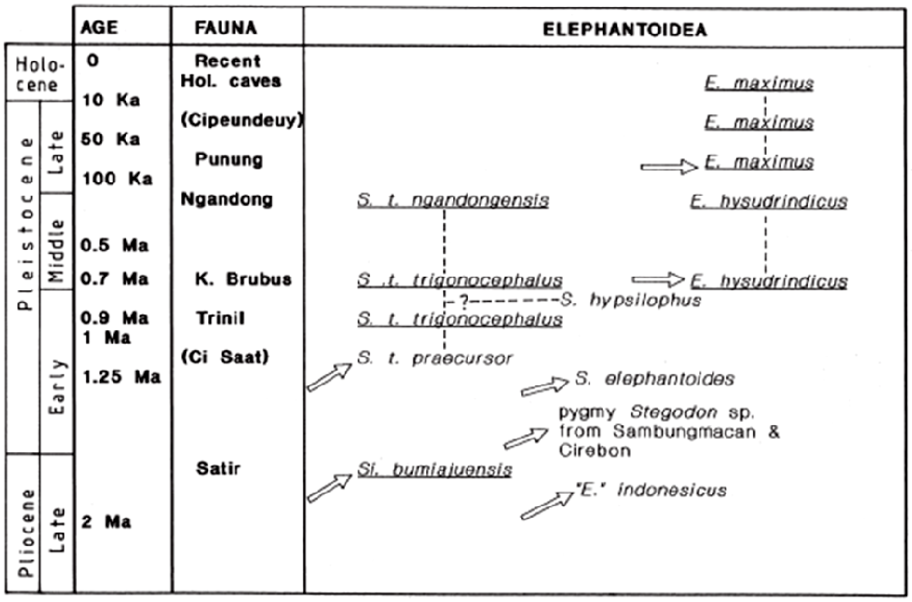

Figure III.2. Ranges of Elephantoidea species from Java relative to time (van den Bergh, 1999).

Further uplift and volcanic activity in combination with episodes of low sea level led to an increasing accessibility of the Java region between 1.5 and 0.8 Mya. *Stegodon* (*S. elephantoides* and *S. trigonocephalus*) appears to be the only Elephantoid genus present on Java around that time. The associated faunas (Ci Saat and Trinil Faunas, the latter including *Homo erectus*) are somewhat impoverished, suggesting filter dispersal (van den Bergh, 1999).

Corridor dispersal to Java occurred for the first time between 0.8-0.7 Mya (van den Bergh, 2001). At this time, the sea level experienced the greatest decline, by a minimum of 170 meters above sea level today, with an average decline across the world at 90 meters (Vrba, 1990), fauna from mainland Asia will be easily crossed the Java Sea. The condition was reflected in the composition of the species-rich Kedung Brubus fauna (de Vos, et al., 1982; Sondaar, 1984). Based on the palinologi analysis, this time is when the conditions in Java tend to dry. The abundance of pollen-pollen shrubs and herbaceous plants, and least arboreal pollen of plant species are proofed the typical environment (Semah, 1986). This time interval concurs with the arrival of the first modern, high-crowned Elephas (*E. hysudrindicus*) on Java. Only during the Late Pleistocene does *Elephas maximus* enter Java, associated with the first recorded rainforest fauna. *Stegodon* becomes extinct around that time (van den Bergh, 1999).

III.3. *Stegodon* of Java

Stegodon fossils have been found in a great number of localities all over Java, but mainly in Central and East Java. The *Stegodon* from Java has been given various names and for a full list of synonyms of *S. trigonocephalus* is referred to Hooijer (1955). Martin (1884, in van den Berg, 1999) figured a molar of *Stegodon* sp. indeterminate, and three years later described a skull from the Raden Saleh's collection and identified it *Stegodon trigonocephalus* Martin, after the triangular outline of the (juvenile) skull. This skull, and a lower M_2 described in the same paper as a second species, *Stegodon airawana*, were reportedly collected in the surroundings of Surakarta (Solo), which is not far from the Sangiran (van den Bergh, 1999).

As expressed by the names *Stegodon javanoganesa* and *S. ganesa* var. javanicus, Dubois (1908 in van den Bergh, 1999) noted the close affinity between the *Stegodon* remains excavated by him at Trinil and *S. ganesa* from the Siwaliks. According to Dubois (1908), there was a single species present on Java. This conclusion was later also supported by Dietrich (1926), von Koenigswald (1933) and Hooijer (1955). The latter author treated extensively the large collection of Elephantoid fossils collected by Dubois at various localities on Java. With the exception of the lower dP_2, he described the full set of molars of *S. trigonocephalus*, besides various skulls and numerous postcranial elements (Hooijer, 1955). Most fossils in the Dubois collection originate from the famous locality Trinil HK, type locality of Homo erectus. *Stegodon* fossils had also been collected at Trinil during the Selenka expedition. Janensch (1911) attributed them to *S. airawana*, which is generally considered a junior synonym of *S. trigonocephalus* (Hooijer, 1955). From the localities Trinil H.K. and Kedung Brubus there are dozens of molars besides well preserved mandibles and skulls present in the Dubois Collection (DC) at the National Museum of Natural History, Leiden, Netherland (NNM). In addition, the DC contains numerous molar remains, various mandibles and skulls originating from a wealth of other fossil localities on Java. Janensch (1911) described of the well preserved material collected by the Selenka expedition at Trinil, but the collection was largely destroyed during World War II. Hooijer (1955) lumped all this material into a single species: *S. trigonocephalus* Martin (van den Bergh, 1999).

The only other *Stegodon*t on Java recognized by Hooijer (1954, 1955) was the small sized, subhypsodont *Stegodon hypsilophus* Hooijer, based on a pair of third lower molar (M_3) fragments from the surroundings of Jetis in East Java. He also attributed a molar fragment earlier described by von Koenigswald (1934) as *Elephas* sp. to this dwarf *Stegodon*t. Maglio (1973) considered *S. hypsilophus* a synonym for *Elephas celebensis* from South Sulawesi. This opinion was contested by van den Bergh et al. (1992), who argue that the unworn Jetis molars show clearly *Stegodon*t affinities, such as the thick, double-layered enamel consisting of two layers of approximately equal thickness and the absence of median pillars. The h/w indices of the ridges vary between 73-92, indices normally encountered in dwarfed insular *Stegodon*ts but never in large-sized *Stegodon*ts (van den bergh, 1999).

Though von Koenigswald (1934) distinguished only one *Stegodon* species on Java, he erected a subspecies, *S. trigonocephalus praecursor*, which was thought to be slightly more primitive as *S. trigonocephalus trigonocephalus* from Trinil. This primitive subspecies was based on a left mandible with complete M_3, reportedly originating from the lower layers of the Kali Glagah Formation at Bumiayu and served to indicate the older age of von Koenigswald’s (1934) Kali Glagah Fauna. The Kali Glagah subspecies was regarded as more primitive than

S. t. trigonocephalus from Trinil because of its small size and because it had only 11 fully developed ridges in the lower M_3, whereas the Trinil variety had typically 13 ridges. Von Koenigswald (1934) also included a lower jaw from Cipanaruban near Subang, West Java, in this subspecies. Hooijer (1955), who considered that the number of ridges in the lower M_3 of *S. trigonocephalus* is variable between 11 and 13 refuted the idea of subspecific distinction. As an example, he mentioned a lower M_3 from Lepen Alit near Tinggang, figured by van der Maarel (1932), which also bears 11 ridges and which was regarded by von Koenigswald (1934) as belonging to the typical Trinil subspecies *S. t. trigonocephalus*. With the lack of detailed stratigraphic data and age assessments of these isolated findings it is hard to decide whether the noted differences for ridges are due to intraspecific variability or due to differences in evolutionary stage (van den Bergh, 1999).

On Java the situation is expected to have been quite complicated due to periodic isolation of Java as a result of sea level fluctuations and subsequent new immigrations of mainland *Stegodon* populations. The multiple immigration models is supported by the findings of various dwarfed insular *Stegodon*ts on Java (Hooijer, 1954; Aziz & van den Bergh, 1994), and by the recent finding of a primitive *Stegodon* mandible near Bukuran in the Sangiran area, which is clearly distinct from *S. trigonocephalus* and which is attributed to *S. elephantoides*. This large mandible, presently stored in the BPSMP Sangiran, has an elongated symphysis and a very wide ramus, which clearly distinguishes it from *S. trigonocephalus* (van den Bergh, 1999).

III.4. Biometry

For the biometry measurement, only maxilla, mandible and teeth are being used. Other post-cranial fossils were not being measured due to fewer amounts of fossil and incomplete stratighrapic data. The measurements are based on biometry measurement based on Maglio (1973) and Beden (1979). Originally, the method is intended to measure the Elephantoid, yet since the morphology of Elephantoidea and Stegodontidea are closely similar, so the method is applicable for *Stegodon*. Most lettercodes used by Beden (1979) for the biometrical parameters were derived from the French language, and have been altered here. Some modifications are taken from van den Bergh (1999) to the methods referred to above were applied in the present study.

The biometrical parameters used in teeth measurements are: number of ridges (P), Maximum length of the molar, maximum width of the molar (W), width of individual molar ridges (w), maximum height of a molar (H), height of individual molar ridges (h), enamel thickness (ET), Hypsodonty index (HI), ratio between the maximum length (L/W), frequency of the enamel folding (EF), and relative amplitude of the enamel folds (EA). A more complete explanation attached in appendix 3.

The Hypsodonty index, is the height of individual ridges that expressed as a percentage of the width (h*100/w). As the h/w indices of individual ridges may differ slightly within one molar, a range of h/w indices is usually given for single dental elements. This method is preferred above the one in which a single index between the maximum height (H) and width (W) of the molar is given, because in many molar fragments or halfworn molars the H or W values could not be taken. In practice, the range of h/w indices of intermediate ridges includes the value of the H/W index of the same molar. However, at the posterior and anterior extremities of a molar hypsodonty indices tend to show aberrant values, sometimes differing more than 20% from those obtained on intermediate ridges. Therefore, the given ranges for a certain molar or molar fragment, or the h/w ranges given in the various tables with summary measurements, exclude h/w indices of the most anterior ridge and the most posterior ridge (and halfridges), and in case of the posteriorly tapering M3’s, exclude the three most posterior ridges (van den Berg, 1999).

Measurements on incomplete molars or bones are followed by "+" indicating that the value of the original element was larger than the recorded value. If a measurement represents an estimated value (for example the length of a broken molar based on the alveolar outline), that value is succeeded by "e". The h and w values taken on molar ridges completely covered with cementum are succeeded by "c". Specific ridges or lamellae of a molar are indicated with an Arabic number when counted from anterior in posterior direction (Fig. 3.3B), and with a roman number when counted from posterior in anterior direction (in molars that are incomplete in front) (van den Bergh, 1999).

For the nomenclature used in this thesis for molars of Stegodontidae and Elephantidae is referred to Fig. 3.1A-C in Appendix 3. The transverse lophs of Stegodontid molars are wedge-shaped and are referred to as ridges. The shape of the valleys in between the molar ridges or lamellae has often been used to distinguish the Stegodontidae from the Elephantidae. Osborn (1942) states that the bottoms of the valleys in between adjacent lammellae are closed or V-shaped in what he considered as the superfamily Stegodontoidea.

The outer layer of teeth is less resistant to wear, which leads to a stepwise morphology of the enamel at the grinding surface (Fig. 3.2 and 3.3 in appendix 3). Janensch (1911) has called this step-wise morphology 'Stufenbildung'. Characteristic for *Stegodon* molars is also the fact that the inner enamel layer is more heavily wrinkled than the outer enamel layer. Coppens et al. (1978) have called this type of folded enamel 'scalloped' enamel.

The same biometric parameters for elephant skulls used by Beden (1979) were used here for measuring cranial material (Fig. 3.4). For the mandibles the definition of the measurements used here is the same as that of Beden (1979), though van den Bergh (1999) indicated with different letter codes (Fig. 3.5).