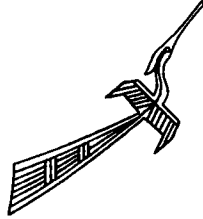# The Environmental Background:
Present and Past

The Indo-Malaysian Archipelago (Fig. 1.1) demonstrates a certain unity in human terms today, in the sense that all its indigenous populations (with restricted exceptions in the Malay Peninsula and the far east of Indonesia) belong to the same major Austronesian-speaking ethnolinguistic group of mankind. The majority belong also to the Southeast Asian branch of the Mongoloid physical stock of mankind, although as I hope to indicate in the course of this book there is no simple one-to-one correlation between biology and language throughout the region. The reality is much more interesting.

However the picture of Indo-Malaysian humanity might appear now, there can be no doubt that it has changed in complex ways in the past. It is first necessary to introduce the archipelago itself from a basically geographical and environmental viewpoint in order to understand some of these changes. The object here is not to duplicate the numerous standard geographical treatises on the region, but rather to emphasize aspects of the environment, past and present, that are likely to have direct interpretative value for the human prehistoric record of the last two million years.

I. THE INDO-MALAYSIAN ARCHIPELAGO

The main area of interest includes all the islands of Indonesia and Malaysia (including the Malay Peninsula south of Thailand). The Philippines represent a direct extension northward of the Indo-Malaysian Archipelago, and although they lie outside the main area of concern of this book they will merit extended comment in later sections. Indeed, the prehistory of Indonesia in particular is very closely tied with that of the Philippines, especially in its later stages during
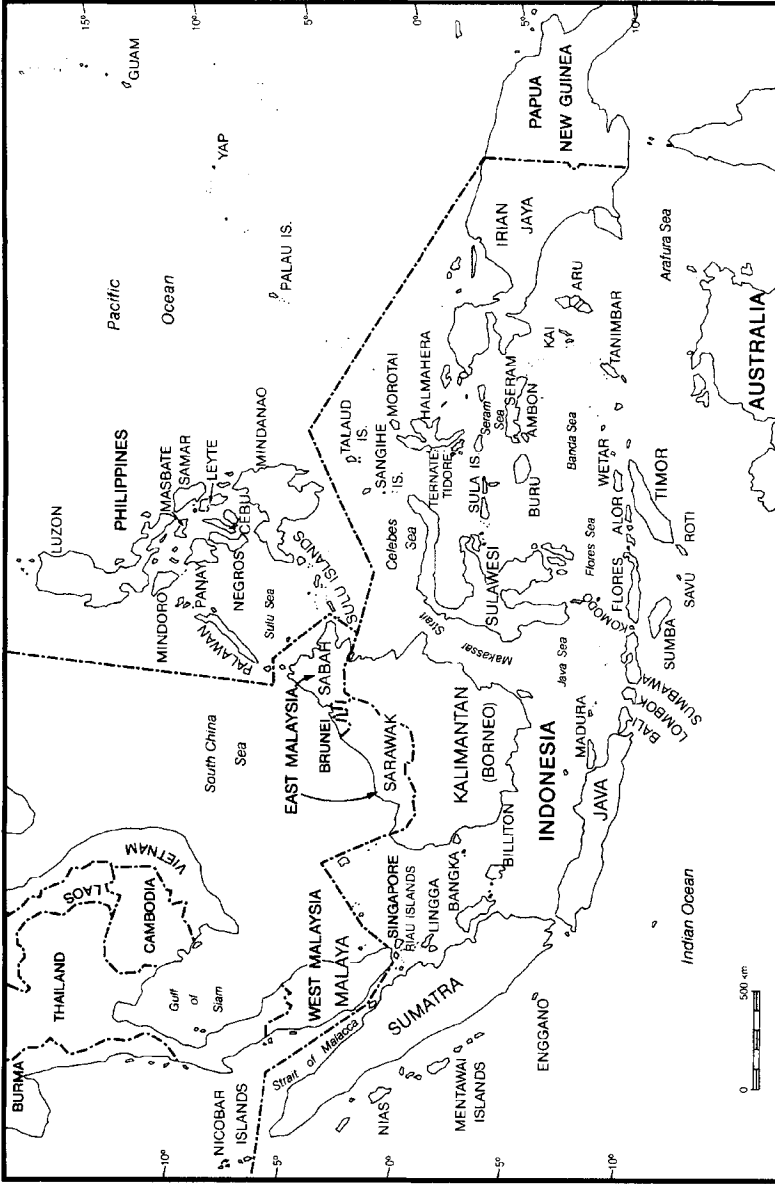
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Fig. 1.1 The Indo-Malaysian Archipelago (Malaysia and Indonesia), together with adjacent regions.

the period of expansion of the Austronesian-speaking peoples. Adjacent regions that will also require extended comment in some following sections include Taiwan, the countries of mainland Southeast Asia (especially Thailand and Vietnam), China (especially the southern half), and the Greater Australasian continent comprising Australia and New Guinea. The latter island, the western half of which is politically now a part of Indonesia, is not included in the Indo-Malaysian Archipelago as here defined.

As defined for the purposes of this book, therefore, the "core region" of the Indo-Malaysian Archipelago extends from about 7° north latitude (northern Peninsular Malaysia and Borneo[1]) to 11° south (Sumba and Timor), and from the western tip of Sumatra to the Moluccas. The region is about 4,200 kilometers long from west to east, 2,000 kilometers from north to south, and supports about 1.8 million square kilometers of dry land, of which about 80 percent lies in Indonesia, with the remainder being in Malaysia (Peninsular Malaysia, plus the states of Sarawak and Sabah on Borneo) and Brunei.

The islands of this region differ greatly in size: Borneo covers 736,000 square kilometers (only slightly smaller than New Guinea), Sumatra comes next with 435,000 square kilometers, then Sulawesi (172,000), the Malay Peninsula (138,000 within Malaysia), and Java (127,000). The islands of western Indonesia are in general larger than those of eastern Indonesia (except for Sulawesi), and the reasons for this lie in the structure of the archipelago.

A. The Shelves and Basins

To understand the human prehistory of Indonesia it is necessary to know something of the geological, climatic, and biotic history of the archipelago. I will commence with some geology, referring to the splendid new color map reconstructions of Southeast Asia covering the past 50 million years produced by the Southeast Asia Research Group in London and now available to Internet users (Hall 1995, 1996).

The Indo-Malaysian islands, "the remarkable festoon of islands that swing around the equator in the East Indies" (Umbgrove 1949), fall into three fundamental structural divisions. The first, forming a direct extension of the Asian mainland in the west and north, comprises the Sunda continental shelf. The second, attached to the Indian Ocean edge of the shelf and extending beyond it east into the Moluccas, comprises the volcanic Sunda-Banda arcuate mountain and trench system. The third, in the northeast, comprises the Sulawesi-Philippine and Halmahera volcanic arc systems (Fig. 1.2, 1.3, 2.10).

The Sunda continental shelf (Tjia 1980), which has the largest area of submerged shelf in the world, has an old and fairly stable tectonic core that has had little recent volcanic activity. Much of it today lies beneath the sediments
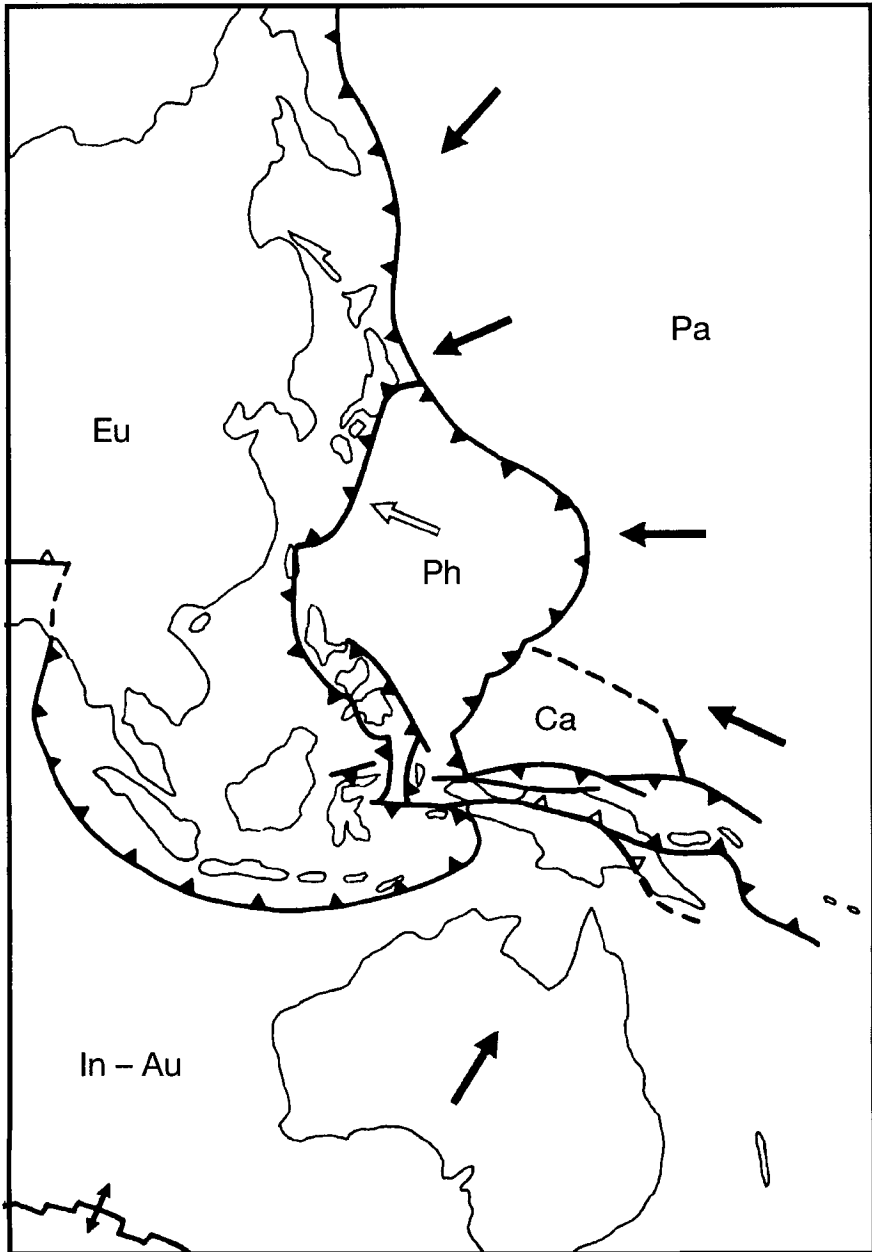
Fig. 1.2 Structural sketch map of eastern Asia, Australasia, and Southeast Asia showing the major plates and subduction zones (thick lines with triangles). Plates are as follows: Eu = Eurasian; Ph = Philippine; Pa = Pacific; Ca = Caroline; In-Au = India-Australia. After Rangin et al. 1990.

of the South China and Java Seas as a virtual peneplain worn down by erosion. Present land areas that rise above the old submerged shelf core include the Malay Peninsula, Borneo, and the northern coastal lowlands of Sumatra and Java. The volcanic mountains of Sumatra and Java are actually members of the Sunda-Banda arc system, which has formed along the Indian Ocean rim of the Sunda shelf. It is convenient to refer to the general western Indonesian shelf land mass as *Sundaland* (see Fig. 1.3), an area which of course contains both the Sunda shelf and a large portion of the present Sunda-Banda arc.

The Sunda-Banda arc includes the highland spines of Sumatra, Java, and the Lesser Sundas and forms one of the most remarkable volcanic mountain arcs in the world. It has been formed by subduction of the Indo-Australian Plate beneath the southern boundary of Indonesia (Rangin et al. 1990) (Fig. 1.2) and continues eastward as far as the southern Moluccas. The process of subduction, described briefly for the Sunda-Banda arc by Ollier (1985), has led to the upwarping of two parallel mountain chains, the inner one volcanic and the outer of uplifted sediments without active volcanoes. The inner volcanic chain includes eighty-two active volcanoes that extend in a curve from Sumatra through Java and into the Lesser Sundas and Moluccas. Outside this arc is a deep marine trench, beyond which the other nonvolcanic outer arc rises to support the small islands off the western coast of Sumatra, as well as Sumba, Timor, and Tanimbar.

So far, therefore, we have two major structural regions in Indonesia: the Sunda shelf and the Sunda-Banda mountain arc system wrought against its edge and beyond it. The latter is still in active construction, as witnessed by numerous volcanic eruptions (such as the famous Krakatoa eruption of 1883) and earthquakes. The third region is not so clearly defined and includes the remaining parts of eastern Indonesia. The Philippines and Sulawesi lie on double arcs similar to the Sunda-Banda arc, and other such arcs continue northward around the western Pacific rim through the Ryukyu Islands, Japan, and the Aleutians. Part of a smaller double arc also appears in Halmahera, farther toward the Pacific.

General accounts of the formation through geological time of the whole Indo-Malaysian region have been given by many geologists and earth scientists and this is a particularly difficult topic to summarize. Those who want current views should consult, as a broad sample of views, Katili (1974, 1975, 1991), Audley-Charles (1981, 1987), Hamilton (1979), Rangin et al. (1990), McCabe and Cole (1989), Metcalfe (1996), and Hall (1995, 1996). The field appears to be one of some disagreement between authorities. For instance, during the 1970s Katili regarded Sundaland as the result of a series of successive volcanic arcs that had been forming since Permian times. According to his thesis, the earliest was represented in the older eroded northerly parts of the shelf, and the latest was
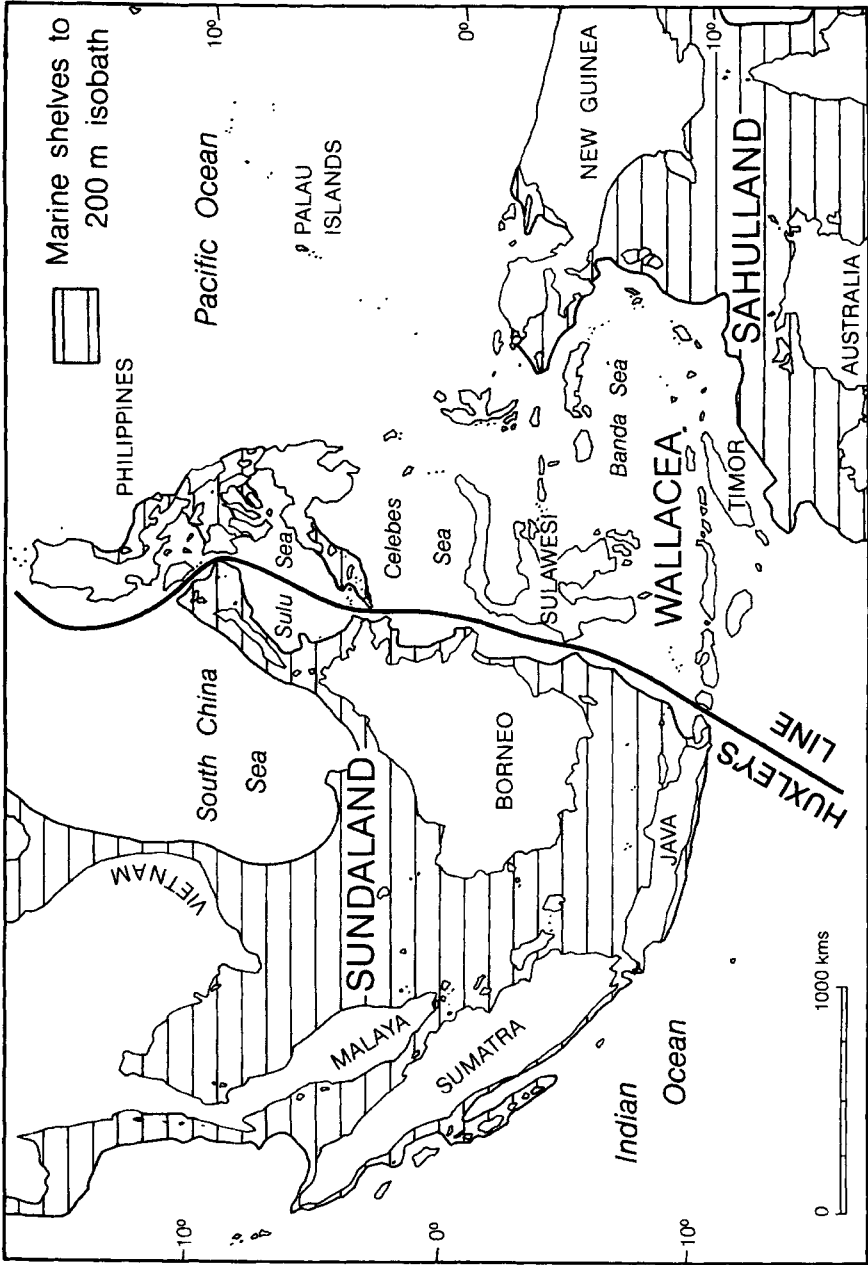
Fig. 1.3 Major biogeographical divisions within the Indo-Malaysian region. Separate Philippine landmasses during glacial periods of low sea level would probably have comprised (a) Greater Luzon; (b) Mindanao, Samar, and Leyte; (c) Masbate, Panay, Negros, and Cebu. Bohol and Mindoro remained separate. Palawan was linked during some glacial maxima with Borneo.

the present Sunda-Banda arc that attained its current configuration during the Pliocene—by which time the emergence of Java was also under way (see also Umbgrove 1949). More recent views, such as those of Metcalfe (1996), consider Sundaland to be a series of fused pre-Cretaceous terranes, some of Gondwana-land origin, rather than purely the creation of a series of volcanic arcs (see also Hutchison 1989). The issue is a complex one and will not be considered in detail; it is not of overall relevance for understanding early human prehistory.

One aspect of continental movement is of relevance, however, because it has allowed some degree of mixing of floras and faunas of very different Asian and Australasian origins. The northward drift of Australia has apparently been continuing at a rate of about 80 kilometers per million years since this landmass began its northward migration from Gondwanaland early in the Tertiary. The eventual result of this was that the Australian continent, or at least some drifting crustal fragments of it, began to collide with the Banda arc and the eastern part of Sulawesi from possibly 20 million years ago and onward. The geological structure of the eastern region of Indonesia is particularly complex owing to the long history of plate collision and the movement into the region of many small island fragments derived from both the Asian and Australian plate margins (the latter including some portions of the two eastern arms of Sulawesi, plus Timor, Seram, Buru, and the Sula Islands; Metcalfe 1990; Hutchison 1989; Burrett et al. 1991). According to Audley-Charles (1987), the two arms of Sulawesi fused together during the Miocene, about 15 million years ago, although Hall's reconstructions show them as essentially separate until within the past 5 million years.

Whatever the underlying geological sources of the islands of the archipelago, it is clear that it had reached its present basic shape by the time humans first entered it. In terms of human and biotic developments, the major structural divisions can be rearranged to make two basic divisions of more relevance for prehistory. These are *Sundaland* and *Wallacea*, with a third area, *Sahulland*, to the east (Fig. 1.3).

B. Sundaland

Sundaland comprises the regions on or attached to the present Sunda shelf: the Malay Peninsula, Sumatra, Java, Borneo, Palawan, and other small groups such as the Riau and Lingga Islands. Its eastern edge is marked by Huxley's Line of biogeographers, not to be confused with its better-known antecedent the Wallace Line, which runs south of the Philippines. Much of this area is now covered by shallow sea, but most of it (2.2 million square kilometers) would have been exposed as dry land by low sea levels for long periods during the Pleistocene and especially at the peak of the last glaciation about 20,000 years ago. Drowned

river channels and sediments in the beds of the South China and Java Seas show this very clearly, although two large freshwater lakes, one north of Java and one in the Gulf of Thailand, would always have existed according to depth contours of the seabeds (Butlin 1993:Maps 8a, 8b). Huxley's Line runs between Bali and Lombok, Borneo and Sulawesi, Borneo and the Sulu Archipelago, then up to include the Calamianes and Palawan, and finally off into the Pacific between Luzon and Taiwan. The eastern edge of Sundaland between Borneo and Sulawesi is partially marked by the remarkable Great Sunda Reef—a partly drowned coral reef extending out from Borneo into the Strait of Makassar to within 44 kilometers of Sulawesi (Bemmelen 1949:Fig. 4) that must originally have grown from the old emergent coastline.

C. Wallacea

The term *Wallacea,* after nineteenth-century naturalist Alfred Russel Wallace, was first introduced into the zoogeographical literature by Dickerson in 1928. Dickerson defined the region as that between Huxley's Line and Weber's Line—a line in eastern Indonesia that is believed to mark a fifty-fifty balance between the Oriental and Australian faunas. In this book, however, I will adopt a definition more relevant for prehistory: Wallacea includes all those islands lying between the continental shelves of Sundaland and Sahulland, namely the Lesser Sundas from Lombok eastwards, Sulawesi, the Moluccas, and the Philippines (with Sulu, but not Palawan).

Wallacea has evolved as a zone of enormous crustal instability and now exists as a number of islands separated by deep ocean basins (particularly the Sulu, Sulawesi, and Banda Seas), the whole formed by rapid processes of uplift and downfaulting. This area has never formed a continuous land bridge between Asia and Australia and all faunal, floral, and human dispersals through it must have involved water crossings. Some of the enclosed seas have particularly impressive features; for instance, the Sulu Sea is 4,633 meters deep and yet is totally enclosed by high ridges that never sink more than 380 meters below sea level. This means that the temperature of this sea remains fairly even from top to bottom, without the rapid cooling with depth found in the great oceans (Molengraaff 1921). The islands of Wallacea rise from the continuous undersea ridges of the region, and the rate of uplift has been very rapid in places; corals of presumed Pleistocene date have been reported from an altitude of 1,300 meters in Timor, and many islands have series of raised coral coastal terraces. Those at Cape Laundi on the north coast of Sumba have recently been calculated to be rising at a rate of 0.5 meters per 1,000 years (Pirazzoli et al. 1991). On the other hand, corals have been found to depths of 1,633 meters in the bed of the Seram Sea, so downfaulting of great magnitude has also occurred.

D. Sahulland

The Sahul shelf forms a shallow, drowned, and tectonically stable link between the Australian continent and the massive island of New Guinea—it is the Australasian equivalent of the Sunda shelf. The term *Sahulland* may be used to denote the New Guinea–Australian land masses when both were joined together during periods of low sea level. Environmental changes in northern Sahulland, particularly during the later Pleistocene and Holocene, are of particular significance for an understanding of similar events in Sundaland.

II. THE INDO-MALAYSIAN ENVIRONMENT

A. Climate

As the whole region lies well within the tropics, temperatures are uniformly hot and vary little throughout the day or from season to season. The only major variation in temperature occurs with altitude (average temperature drops 1° Celsius every 160 meters), but even on the highest peak in Southeast Asia (Mt. Kinabalu in Sabah, 4,104 meters) the temperature never gets colder than an occasional nighttime frost. The only permanent glaciers occur to the east in New Guinea, but only 8 square kilometers of the total 805,000 square kilometers of this island are so covered.

The crucial climatic feature in the region is the rainfall, and for general purposes it is useful to recognize two major zones (Fig. 1.4).

a. The zone within approximately 5° of the equator, where rain occurs all year round. Most regions do have two slight rainfall peaks, but for practical purposes the rainfall is frequent, heavy, reliable, and the evergreen rain forest grows luxuriantly in constantly damp or wet soils. Peninsular Malaysia, Sumatra, western Java, Borneo, central Sulawesi, the southern and eastern Philippines, and parts of the Moluccas fall generally in this zone, which I will henceforth term *equatorial*.

b. The zone that extends beyond the equatorial zone both north and south of the equator and is characterized by clearly differentiated wet and dry seasons. Within the Indo-Malaysian Archipelago, this zone forms the warmer equatorward part of a worldwide intermediate tropical zone (Harris 1980) characterized by winter dry seasons of between 2.5 and 7.5 months in length. Within Southeast Asia the intermediate tropical zone includes the mainland north of the Malay Peninsula, the western and northern Philippines, southern Sulawesi, and the Sunda islands from central Java eastwards. The zone ultimately fades into the temperate climates of China and the deserts of central Asia and Australia. Because of the presence of
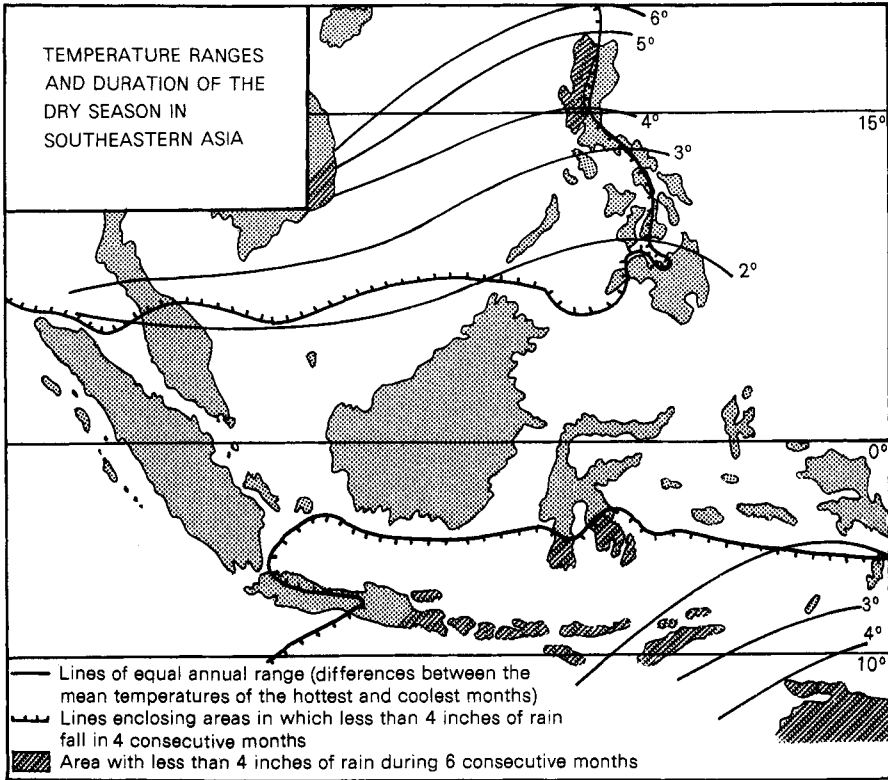
TEMPERATURE RANGES
AND DURATION OF THE
DRY SEASON IN
SOUTHEASTERN ASIA

Lines of equal annual range (differences between the
mean temperatures of the hottest and coolest months)
Lines enclosing areas in which less than 4 inches of rain
fall in 4 consecutive months
Area with less than 4 inches of rain during 6 consecutive months

Fig. 1.4 Climatic regimes in the Indo-Malaysian Archipelago. After Robequain 1954. Courtesy:
Editions Payot.

the dry season and occasional severe droughts, forests tend to be more
open and have a deciduous tendency.

To explain these rainfall variations, I will attempt to summarize this complex
topic (see Mizukoshi 1971; Dobby 1976). A major feature of global air circula-
tion concerns the constant exchange of air (which flows as winds) between the
equator and the poles. In the tropics, warm air is constantly rising and flowing
poleward at intermediate altitudes. It cools, sinks in the latitudes of about 20 to
30°, and flows equatorward again as the trade winds (these blow from the north-
east in the northern hemisphere and from the southeast in the southern hemi-
sphere). The tropical zone where the trade winds meet and where air convec-
tion is strongest is termed the Intertropical Front, or Intertropical Convergence
Zone. This front is not fixed in position, but moves seasonally according to
temperatures in the continental interiors of Asia and Australia.

In January the Asian interior is cold, the Australian interior hot. The resulting pressure gradient outward from Asia deflects the Intertropical Front southward into the southern part of Indonesia and the northern tip of Australia (to about 10 to 12° south). These areas then receive their rainy season (southern summer) because the front is a constant formation zone of depressions and squalls. In the northern summer (July) the front is pushed far to the north (up to 32° north) and Mainland Southeast Asia and the northern Philippines then get their wet seasons. The equatorial regions proper tend to have a double wet season because the front passes over them twice in each year.

The Intertropical Front is not the only condition affecting rain in the intermediate tropical regions. When it lies in the northern hemisphere in the northern summer, the southern hemisphere trade winds are sucked across the equator and bring additional moisture from the seas that they cross. The same happens in reverse in January, when the northern trades tend to flow farther south (although they do not get deflected so far because Australia, as a smaller continent, has a much weaker influence than Asia). These extended trade winds become the monsoons, which are usually named after their directions. These directions vary from place to place by deflection across the equator, and their effects can be varied locally by topography and position. For instance, the northeast coast of Peninsular Malaysia, in the northern hemisphere, has its wet season in November–January, actually the southern summer. This is because wet trade winds blow directly onto the coast at this time of the year from the South China Sea.

These climatic variations are of great importance for recent prehistory, and postulated changes in them are also of great importance in the Pleistocene. Typhoons and hurricanes also form in the intermediate tropical zone, but generally occur outside our area of interest. They are common in the northern Philippines, where they blow in from the Pacific Ocean, and likewise in northern Australia and the islands of Melanesia and Polynesia. They are almost unheard of in Indonesia and Malaysia.

B. Landforms and Soils

Humans, animals, and plants depend not only on climate for their existence, but also on the nature of the ground upon which they live. In the Indo-Malaysian Archipelago there are some very important variations in landforms and soils. These variations lie at the base of the enormous differences in population density seen today between such islands as Java and Borneo. It is my suspicion that they were equally important in prehistoric times.

The main soils of the equatorial ever-wet region are yellow to red leached lateritic formations, often called latosols. These soils are rich in iron and alumin-

ium, are generally acidic, tend often to be heavy sticky clays, and are generally low in plant nutrients and organic matter. They do, indeed, support dense and luxuriant forests, but these are products of long evolution whereby 50 to 80 percent of the nutrients are accumulated in the biomass and constantly recycled in the upper layers of the soil as vegetation grows, dies, and decays. Once these forests are cleared the cycle is broken, as the nutrients simply leach away through the exposed soil—often with disastrous results.

These lateritic soils are generally characteristic of the equatorial and nonvolcanic lowlands of Sumatra, the Malay Peninsula, Borneo, Sulawesi, and western New Guinea. Today they support low populations because they are fairly infertile, unsuited in traditional cultivation systems to anything but shifting agriculture, and difficult—for reasons of structure and excessive rainfall—to bring under irrigated and terraced rice. Furthermore, the forest itself is ever-wet, hard to clear and burn with simple equipment, and subject to rapid regrowth of weeds and secondary vegetation. In addition, many coastal regions of the Malay Peninsula, eastern Sumatra, and southern and western Borneo have extensive areas of lowland peat soils (Polak 1975), which are very difficult for any simple economy apart from sago management.

The soil patterns change, however, when we move into southeastern Indonesia, from central Java through the Lesser Sundas. Here the soil is constantly enriched by the fertile outpourings of the many volcanoes, particularly where the products are of basic rather than acidic composition, as they are in central and eastern Java, Bali, Lombok, and the Minahasa Peninsula of northern Sulawesi. Most (but not all) of the Sumatran volcanoes are more acidic in this respect and consequently produce soils less favorable for agriculture.

This volcanic replenishment means that the normal tropical trends of leaching and nutrient loss in soils are constantly reversed. The resulting volcanic ashes are often firm and ideally suited for purposes of rice terrace construction, as any visitor to Bali or eastern Java will observe. This lucky combination does not cease here, for these regions have a climate with a definite dry season; this lessens the rate of soil leaching and also promotes a partially deciduous and more open vegetation, which is an easier target for agricultural societies than the ever-wet equatorial rain forest. However, this monsoon vegetation is fragile when subjected to clearance, perhaps more so than the equatorial rain forest, and degraded lands in these regions tend to degenerate to extensive grasslands, particularly where droughts are common.

The present-day results of these differences were very clearly pointed out by Mohr in 1945. From a census taken in 1930 he was able to show that Java and Madura had average densities of over 300 persons per square kilometer, Bali and Lombok about 175, Sulawesi 22, Borneo 4, and Irian Jaya only 0.73. These figures, even if now outdated (Java had a density of 733 persons per square kilometer in 1983), still tell an important tale. The high Javanese densities are large-

ly the result of the Dutch introduction of intensive agricultural techniques, including permanent dry-field cultivation after 1830. Nevertheless, Mohr was able to show very convincingly how high population densities in Indonesia depend on a combination of basic volcanic soils, a nonexcessive rainfall (with a good dry season for cereal ripening and harvest), and a dependence on rice cultivation in permanent irrigated fields. He concluded: "In the Netherlands Indies the population density is a function of the nature of the soil and this is a function of the presence of active volcanoes" (Mohr 1945:262). These differences in soil qualities, when combined with climate, are important for reconstructing patterns of prehistoric agriculture in the archipelago.

One final point of importance concerns the rate of erosion and landform change in the tropics: Archaeological sites are not only hard to find in dense vegetation, but land surfaces can change rapidly in geomorphological terms. Caves and rock shelters are common in Southeast Asia, but few appear to contain deposits much older than 30,000 years; this circumstance may mean that in many cases the caves were buried and thus not available for habitation until geologically recent times, although the possibility that Pleistocene human occupation in equatorial regions was very sparse will also be discussed in Chapter 6. The prevailing high rates of erosion also affect open sites, causing rapid destruction or burial. Some idea of the sheer power of erosional processes in these latitudes can be derived from geomorphic observations: The Solo River of Java carries fifty times more sediment by water volume than does the Rhine (Robequain 1954:26), and Haile (1968:278) has suggested that surfaces exposed to active erosion in the Baram region of Sarawak could have been eroded by as much as 750 meters in the past 2 million years. In the same vein, Hanbury-Tenison (1980) states that limestone surfaces in the Gunung Mulu region of northern Sarawak are eroding at a rate of 0.5 millimeters per year, or about 1,000 meters in 2 million years.

C. The Flora and Fauna

The Indo-Malaysian Archipelago forms part of the "Malesia" of botanists; in its ever-wet equatorial regions, the evergreen mixed Dipterocarp rain forest forms

> the most complex terrestrial ecosystem in the world. Below about 1000 metres above sea level the forest canopy lies between thirty and fifty metres above the ground and shelters a more or less dense undergrowth of smaller shade-tolerant trees, shrubs and saplings criss-crossed by lianes and studded with epiphytes. (Walker 1980:21)

Botanists are always eager to quote impressive statistics about this vegetation: Within Malesia about 10 percent of all the plant species in the world, 25 percent of the genera, and over 50 percent of the families are represented. Over

25,000 species of flowering plants occur in the region, with 11,000 on Borneo alone. Associated with this variety is a rarity of extensive stands of single tree species. Extreme spatial variation is the rule: No less than 780 species of trees have been recorded from a single 10-hectare plot in northern Sarawak (Hanbury-Tenison 1980).

This equatorial rain forest is characteristic of the lowland regions along the equator that lack dry seasons, but in eastern Java, the Lesser Sunda Islands, and the southern tips of Sulawesi, the longer dry season has favored more open monsoon forests with a deciduous tendency, characterized by stands of casuarina, teak, sandalwood, and eucalypts. In western Java, southern Sumatra, and northern Peninsular Malaysia there is a shorter three- to five-week dry season that also encourages some elements of this type of forest. Local ecological variations also cross-cut the major climatic patterns to create such specialized ecosystems as the coastal mangrove swamps, the limestone forests, and the high-mountain moss forests.

From a human prehistoric perspective, it is the broad distinction between the equatorial and the monsoon forests that is likely to be of the greatest significance on a large scale. Modern plant geography also reflects factors concerning the geological history of the Indonesian region that are of importance for human prehistory. The floras of Sundaland are of Asian origin and are rich in species, a reflection partly of the frequency of dryland connections across the subcontinent in the past. The floras of Wallacea, on the other hand, have fewer species, higher proportions of endemic species, and a larger Australian element; some species of eucalypts extend as far as Sulawesi and the southern Philippines, and *Agathis* species have spread from New Guinea through equatorial Indonesia as far as Peninsular Malaysia. Wallacea may be regarded as a transition zone between two ancient continental areas with quite different floras.

The differences between Sundaland and Wallacea in terms of flora are also reflected in the distribution of animal species—particularly the large mammals that have a fairly prolific fossil record. Basically, Sundaland has an Asian placental mammal fauna that includes many species ranging in size from the elephant downward. Wallacea, on the other hand, has fewer species and a greater proportion of endemic ones, with an increasing Australian marsupial element in the east (Fig. 1.5). (For general surveys see Jacobs 1974, Whitmore 1975, 1981, 1987).

D. Biogeographical Boundaries

The sluggishness or absence of faunal dispersal across Huxley's Line into the eastern part of the archipelago is clearly of importance for human dispersal. There have been no Wallacean land bridges of anything more than a very local
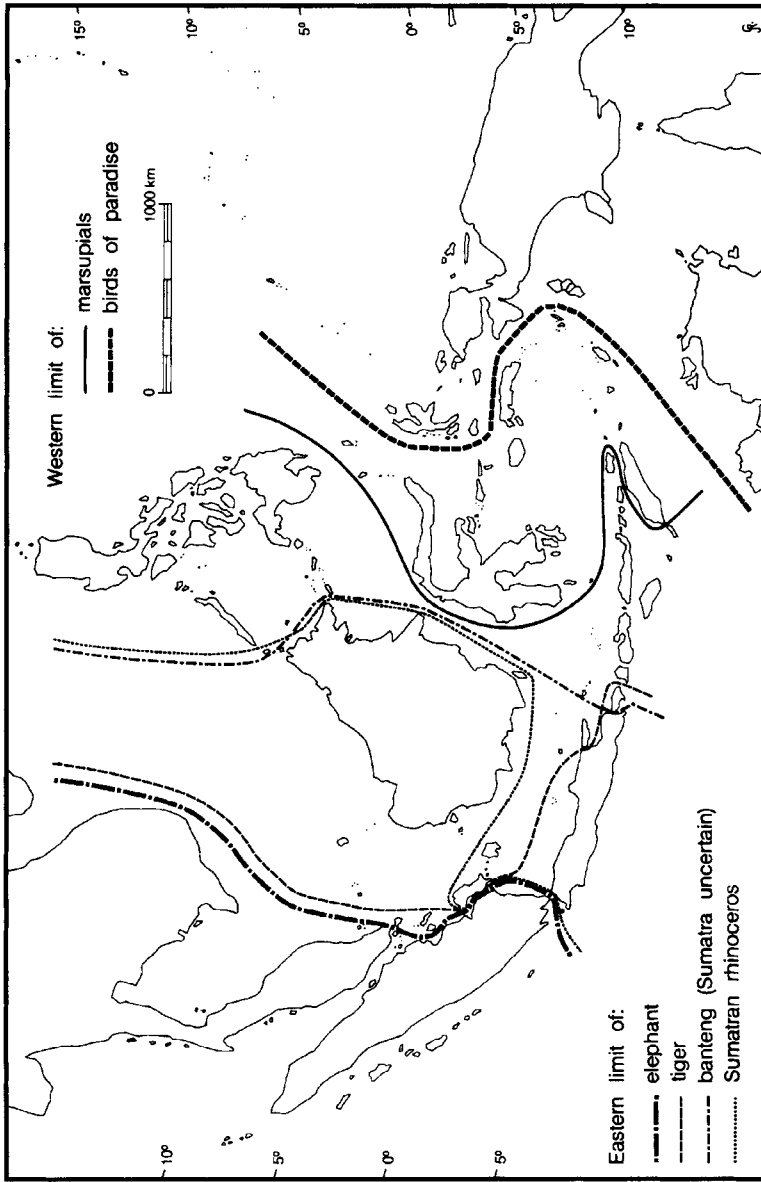
Fig. 1.5 The boundaries of some selected animal species in the Indo-Malaysian Archipelago. The Javan rhinoceros *(Rhinoceros sondaicus)* occurs on Sumatra and Java but not Borneo, where the Sumatran rhinoceros *(Dicerorhinus sumatrensis)* occurs alone today (but see Chapter 6, Section IIB). After Atlas 1938, Blad 7b.

nature within the past 2 million years, an observation underlined by biogeographical as well as geological considerations.

The most important of the biogeographical boundaries is Huxley's Line, the eastern edge of Sundaland (see Fig. 1.3). This is the line beyond which the Sundaland fauna drops off markedly into endemicity and species depletion. Sundaland and Australia have never been joined by continuous dry land, and all faunal dispersals into Wallacea have involved sea crossings with the exception of the few land-bridge cases reviewed below. Of placental mammals, only rats and bats are distributed from Sundaland right through to Sahulland, and of marsupials a number have spread into the Moluccas (Flannery 1995), but only phalangers (cuscuses) ever reached Sulawesi (Groves 1987) and Timor, in the latter case perhaps by human translocation. However, both wallabies and bandicoots were once widely distributed in the northern Moluccas before their extirpation in the Holocene (Flannery et al. 1995) (see Chapter 6, Section IIE). The zone defined as Wallacea (between the Sunda and Sahul shelves) is in fact a zone with a partly endemic fauna of mixed Asian and Australian elements.

Discussions of the significance of Huxley's Line have been numerous and there is still much disagreement about how to subdivide the Wallacean region in zoogeographical terms (see Scrivenor et al. 1942–1943; Mayr 1945; Darlington 1957:462–472; Simpson 1977). The line works quite well for freshwater fish, mammals, and birds (in that order), but is less marked for insects and plants. It also works well between Borneo and Sulawesi, but the Philippine and Lesser Sunda boundaries are hazy. Although Oriental bird faunas drop off sharply down the Lesser Sunda chain from Java, it appears that the reasons are more to do with changing ecology than with the mere presence of sea gaps (Lincoln 1975). Furthermore, there is no sharp break in plant distribution down the Lesser Sundas (Jacobs 1974; Flenley 1979), while the break is sharper from Borneo (with 280 species of Dipterocarps) to Sulawesi (with only 45). In general, it is best to regard Wallacea as a zone of transition rather than as a zone of barriers.

III. THE PLEISTOCENE AND WORLDWIDE CHANGES IN ENVIRONMENT

Having discussed some elements of the natural environment in remote geological time and at the present day, I will now turn to the fundamental question of variations in climate, land-sea distribution, and flora and fauna in the archipelago during the Pliocene and Pleistocene periods. In order to document environmental changes in the Pleistocene, it is necessary to search the literatures of a number of complex and rapidly expanding disciplines in the earth sciences and the natural sciences. There are many viewpoints to explain any given set of phenomena, and rapid obsolescence of any bright new idea

seems to be an occupational hazard. I hope my scientific colleagues will bear with me while I try to set their data in a perspective relevant for human prehistory.

A. The Pleistocene Period: Definition and Chronology

Concerning overall chronology, the boundary between the Pliocene and Pleistocene periods has been dated in the past according to three different criteria (Goudie 1983): the onset of mid-latitude glaciation, changes in marine faunas, and changes in terrestrial faunas. The present cycle of mid-latitude glaciation started about 2.5 to 3.2 million years ago (Shackleton and Opdyke 1977), and earlier cycles can be traced back into the Tertiary. But most scholars today accept a Plio-Pleistocene boundary based on the appearance of certain new species of cool-temperature foraminifera in the oceans between about 1.5 and 2 million years ago; this change is marked at 1.6 million years ago by the Calabrian fauna of the Mediterranean (Haq et al. 1977). A similar change also occurs in the Pacific. The Villafranchian land mammal fauna, once considered to appear in the early Pleistocene, is now known to go back well into the Pliocene and is no longer acceptable as a boundary marker.

It is, of course, apparent that both the Pliocene and the Pleistocene are rather artificial divisions of convenience—there are no indications of any major worldwide environmental changes that took place in this particular boundary time span, and hence there is no clear worldwide boundary. This is especially true of Southeast Asia, where it is perhaps not justifiable to separate a Pleistocene from a Pliocene at all. The terminology, however, is too deeply rooted to tamper with at this stage, and I will follow the international chronology adopted for Java by Orchiston and Siesser (1982) and place the Pliocene-Pleistocene boundary at 1.6 million years ago (while noting that a date of 1.8 million years ago is also widely accepted; Howell 1994:254).

The question of subdivisions within the Pleistocene remains. It has been the tradition in the past to place hominid remains, animal faunas, and stone tool assemblages into a framework of early, middle, and late Pleistocene, and there have been a number of strong debates between scholars—particularly with respect to Javanese faunas and stone tools—concerning the division to which a particular fauna or industry belongs. The problem is well illustrated in Bemmelen's geological survey (1949): On page 93, Koenigswald placed the Kali Glagah and Ci Julang faunas of Java in the Pliocene, while on page 99, Bemmelen himself (following Movius) placed these faunas in the Lower (early) Pleistocene. Similarly, Koenigswald (in the above survey) considered the Jetis fauna of Java to be Lower Pleistocene, while Hooijer (1956, 1968) placed it in the middle Pleistocene. The situation is becoming even more confused today with the pub-

lication of conflicting radiometric dates, and it is clear that there are no major pan-Southeast Asian changes in environments, hominids, or faunas that can be recognized as unequivocal boundary markers. I will therefore follow Orchiston and Siesser (1982) and modern African Pleistocene specialists and refer to the period between 1.6 million and 700,000 years ago as early Pleistocene, between 700,000 and 125,000 years ago as middle Pleistocene, and from 125,000 to 10,000 years ago as late Pleistocene. These divisions are for chronological convenience only and it will be noted that they are not of equal duration. The late Pleistocene is the only division with a firm environmental record in Southeast Asia and it equates with the last interglacial and last glacial episodes of the temperate Pleistocene chronologies. Finally, I place the Pleistocene-Holocene boundary at 10,000 years ago following convention; this date falls somewhere toward the end of the worldwide postglacial warming trend.

B. The Consequences of Mid-Latitude Glaciation

According to present theories (Covey 1984; Broecker and Denton 1990), the mid-latitude glaciations of the past 3 million years have been caused by the interaction of a number of phenomena. Cyclical causes may include variations in the intensity of solar radiation and variations in the earth's trajectory around the sun and the slope of its axis. Other less cyclical causes may include the frequency of ash clouds from volcanic activity and periods of continental uplift in high latitudes. At peaks of glaciation, the icesheets covered three times their present area and extended deep into Europe and North America. During interglacials, conditions returned to something like those of the present, and within the glacials themselves there occurred short warm phases called interstadials, when conditions ameliorated to intermediate levels.

The major worldwide effects of glaciation were to lower sea levels and vegetation zones and reduce temperatures. These changes were all felt quite strongly in tropical latitudes (Rind and Peteet 1985). For instance, in the fairly intensively studied highlands of New Guinea (Flenley 1979; Hope 1980; Haberle 1994), ice sheets covered about 2,000 square kilometers (only 8 square kilometers now) at the last glacial peak 18,000 years ago, the snow line was lowered to 1,100 meters below its present altitude, the tree line was lowered by about 1,500 meters, average highland temperatures dropped by 7 to 7.5° Celsius, and 57,000 square kilometers of land below the ice were under grassland (as opposed to only 5,000 square kilometers now).[2] In Southeast Asia the effects of preexisting permanent glaciers are still traceable on the summit of Mt. Kinabalu on Borneo (Flenley and Morley 1978), but any that might have occurred on the high volcanoes of Java and Sumatra will have left no traces owing to subsequent volcanic activity.

As a result of these changes caused by glaciation, tropical climates on large land masses became drier, rain forests shrank in extent, land bridges were exposed in the Indo-Malaysian Archipelago, and humans, animals, and plants were subjected to alternating phases of island contact and island isolation.

C. The Cycles of Glacials and Interglacials

Until the 1960s, Pleistocene climatic cycles were traced mainly from studies of glacial geomorphology in temperate latitudes; the tropics remained rather remote and mysterious. But in the past thirty years, knowledge has been revolutionized by the results derived from deep-sea cores and also from studies on deeply stratified terrestrial gastropod- and pollen-bearing soils. Sediments in the beds of the oceans contain shells of tiny marine microorganisms and these shells contain oxygen in two isotopic forms: ^{16}O and ^{18}O. During glaciations, the vast quantities of water trapped in the ice sheets immobilized large amounts of ^{16}O and the cold seas were thus relatively rich in ^{18}O. In interglacials the ratios were reversed. Fluctuations in these ratios have been plotted from deep-sea cores for the duration of the Pleistocene in several areas, and because they are thought to reflect partly the waxing and waning of continental glaciers, they provide excellent evidence of Pleistocene climatic and sea level cycles.

One exceptional core, drilled in the seas of the Solomon Islands, showed that there had been at least seven full glacial maxima with low sea levels since the Matuyama to Brunhes reversal of the earth's magnetic field about 700,000 years ago (Shackleton and Opdyke 1973; Shackleton 1982). It is now known that there have been about twenty full glacials within the past 2 million years, with the same number of intervening true interglacials, plus periodic intermediate interstadials within the glacials themselves. This record has come from deep-sea cores, from deep pollen-bearing soil profiles, from gastropod faunas in loess deposits, and also from the dating of coral reefs as indicators of past sea levels (Kukla 1977, 1981; Chappell 1983; Chappell and Shackleton 1986; Prentice and Denton 1988; Chappell 1994). There is still some disagreement about the duration of the glacial-interglacial cycles, but present views seem to favor long glacials of about 100,000 years separated by much shorter interglacials of perhaps 10,000 years in duration.

Several other general observations emerge: The glacials have become more severe within the past million years, and the glacial waxing and waning cycles themselves are not totally regular. Glacial retreats appear to have been much more rapid than glacial advances (Fig. 1.6, top) and this high rate of environmental change is important for any consideration of the emergence of the present world environmental regime at the end of the last glaciation. It is
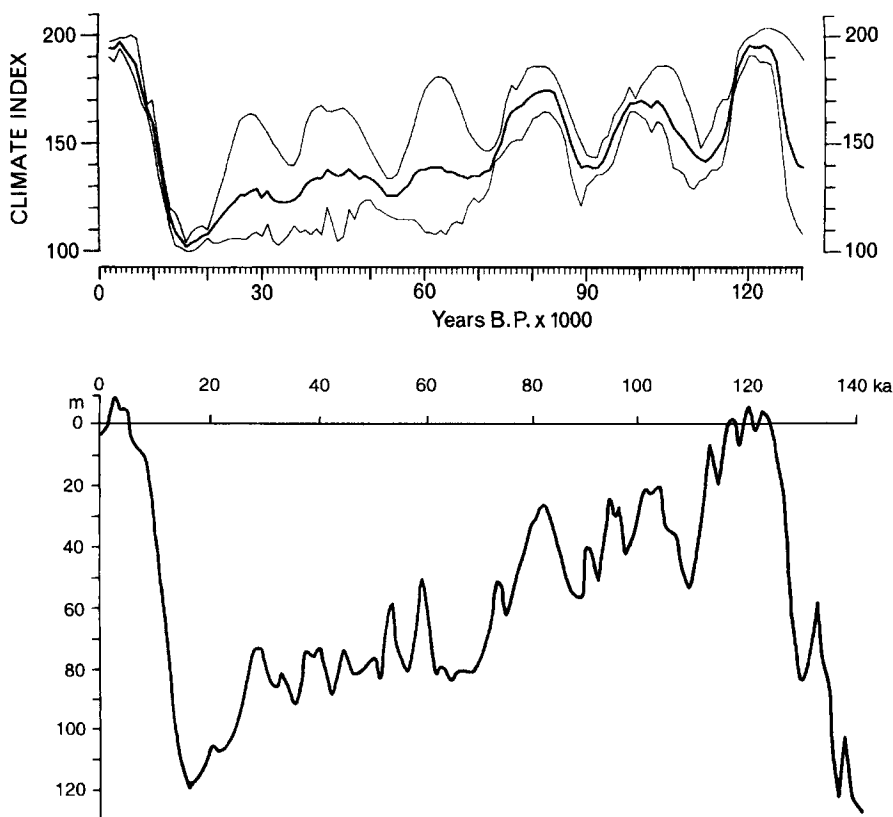
Fig. 1.6 *Top:* climatic severity index for the past 130,000 years derived from pollen, sea level, and oxygen isotope data. The vertical scale is relative: 100 units correspond to peak glacial conditions, 200 units to the climatic optimum of the mid-Holocene. Uncertainty ranges are also indicated. After Kukla 1981. Courtesy: D. Reidel Publishing Company. *Bottom:* a sea level curve for the past 140,000 years based on isotopic data from deep-sea cores and supported by data from raised coral reefs on the Huon Peninsula, northeast Papua New Guinea (Shackleton 1987; Chappell et al. 1996). Courtesy: John Chappell. (*Note:* Although the isotopic curve suggests a level higher than now about 3,000 to 6,000 years ago, evidence from stable regions indicates only minor variation from the present level during this interval.)

also becoming apparent that interglacials are periods of long-term stability of climate, whereas the glacial periods themselves could have witnessed rapid temperature fluctuations owing to changes in ocean circulation patterns (Broecker 1995). This suggests that the close chronological correlation between the relative warmth and climatic stability of the Holocene and the contemporary growth of human cultural complexity may not be entirely coincidental.

D. World Sea Level Changes during the Pleistocene

Large-scale glaciation implies a lowering of world absolute sea level owing to the immobilization of vast quantities of water in the ice sheets. If it is accepted from the oxygen isotope record that there have been twenty glacial-interglacial cycles within the past 2 million years, then world sea levels must have gone through twenty major cycles of glacial falling and interglacial rising—not to mention interstadial fluctuations. Magnitudes of these absolute fluctuations have always been hard to estimate; the most direct indicators come from observations of drowned shelf topography and the dating of old coastline markers such as coral reefs and mangrove timbers.

The calculations are not simple, however, because the earth's surface is not a rigid, unmoving formation washed by fluctuating water levels. It can move in quite a dynamic fashion itself, partly through the mechanism of isostasy, which compensates for the imposition of variable loads such as ice sheets and oceans at changing times and places on its surface. In general, water, ice, or sediment loads promote sinking, while relief from such loads will allow slow upward rebound. These processes are complicated and details need not be of further concern, except to note that isostatic adjustment processes will have operated mainly in the intermittently drowned Sunda and Sahul shelf regions, while many of the Wallacean islands are subject to other kinds of tectonic instability, so that they themselves can rise and fall independently of sea level changes at quite rapid rates. Northern Timor and Sumba, for instance, seem to be rising at the fairly rapid rate of 0.5 meters per thousand years, and northeast New Guinea is rising at up to 4 meters per thousand years (Pirazzoli et al. 1991; Chappell and Thom 1977). As Chappell (1982) has pointed out, each region of the earth must be studied independently with respect to local correlations between the surfaces of land and sea over time.

At present the sea is at a high absolute level in terms of Pleistocene fluctuations, a level previously attained during the last interglacial about 120,000 years ago (Fig. 1.6, bottom). At the last glacial maximum 18,000 years ago, the sea level is widely estimated to have been between 100 and 130 meters below that of the present (Chappell and Thom 1977; Batchelor 1979; Chappell 1994). A high-to-low overall swing of about this magnitude may have occurred approximately every 100,000 years, going back to a million years ago. The swings before a million years ago seem to have been of slightly decreasing vertical magnitude.

When we come to consider more detailed aspects of these fluctuations, we find ourselves confined largely to the last 120,000 years, for which there are obviously more data than for previous cycles. The last interglacial had a fairly short duration—between about 130,000 and 120,000 years ago (Kukla 1981;

Chappell 1983)—and the seas were at around present absolute levels at this time. Following this, according to the data derived from isotopic analysis of deep-sea cores and from uplifted and dated Pleistocene coral reefs on the Huon Peninsula of New Guinea (Chappell 1982, 1983; 1994; Chappell et al. 1996), sea levels fluctuated many times between relatively high and low points (Fig. 1.6, bottom), although none of these intervening highs appear to have attained the level of the present. The "high" of 28,000 years ago may have reached only 70 meters below present. The implications of these figures are that high stands like that of the present and low stands like that of 18,000 BP were relatively short-lived events during the Pleistocene. Average absolute levels would have been between 30 and 90 meters below present for much longer periods.

These fluctuations in sea level are of great potential importance for prehistory, since low levels make islands larger and also tend to produce land bridges. Shortened sea crossings are particularly important when considering the first settlement of Australia, and this could relate to one of the low points from 35,000 years ago or before (cf. Birdsell 1977). One major problem is that there is still no real agreement on a precise absolute sea level curve; results from other parts of the world are often in conflict (Marcus and Newman 1983), probably owing to local tectonic and isostatic movements. Even within the Indo-Malaysian Archipelago itself, the magnitude of sea level lowering proposed by Linsley (1996) for Sulu is considerably less than that presented in Figure 1.6, and favors a drop to only 40 to 50 meters below present between 58,000 and 23,000 years ago, rather than the 50 to 90 meters suggested here. It would be unwise for archaeologists to demand a universal curve applicable to all regions.

One final matter concerns the disputed question of a world sea level slightly above that of the present during the Holocene. There are raised marine deposits in Sundaland (Tjia 1987; Thommeret and Thommeret 1978), which suggest that sea levels could have been up to 6 meters above present during a warm phase of the Holocene between about 6,000 and 3,000 years ago. These deposits may reflect tectonic or isostatic movement rather than an actual rise in absolute sea level (Chappell 1982, 1994), but they do still indicate that parts of Sundaland may have been *relatively* more drowned then than they are now. The magnitude of the difference is very small, although the potential here for the destruction of early Holocene archaeological sites on coastlines is clearly of great importance (see Chapter 6).

IV. THE ENVIRONMENTAL HISTORY OF THE INDO-MALAYSIAN ARCHIPELAGO DURING THE PLIOCENE AND PLEISTOCENE

During the Miocene period (23 million to 5 million years ago) and the Pliocene (5 million to 1.6 million years ago), the archipelago gradually took on its present

shape as a result of continuing island arc formation and the increasing close-ness of the Australian continental plate in the east. By the end of the Pliocene, Sundaland already formed a large emerging continent some 2,000 kilometers from east to west, incorporating much of the present land masses of Peninsular Malaysia, Sumatra, and Borneo (Batchelor 1979), possibly with western Sulawesi still attached (Hall 1996). Some parts of Java had also emerged, although there is current debate on the precise geography of the island at this time (Braches and Shutler 1983–1984).

A. The Pliocene and Early Pleistocene in Java, the Lesser Sundas, and Sulawesi

In the later Pliocene, about 2 million years ago, a mammal fauna with strong Indian affinities (called "Siva-Malayan" by Koenigswald and related to the Eurasian Villafranchian) gained a footing in the newly emerging western and central Java. It is known from coastal estuarine deposits. Animals present include extinct species of elephant, *Stegodon* (a proboscidean distantly related to the elephants; Fig. 1.7), hippopotamus, and deer, but apparently no hominids
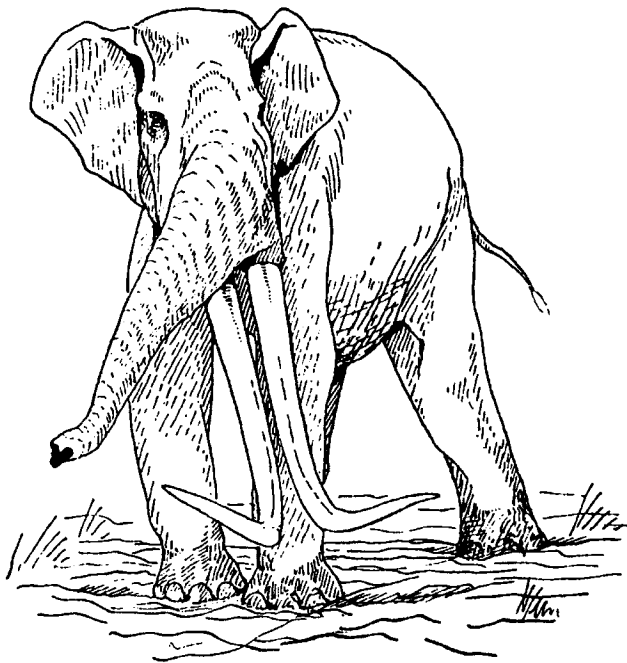

Fig. 1.7 A male *Stegodon*. In females the tusks were shorter and more widely spaced. From Kurten 1971. Courtesy: Weidenfeld Ltd.

or forest primates (van den Bergh et al. 1995a). The whole assemblage, with its numerous browsing animals, seems to have been well suited to both forested and more open parklike landscapes.

Although there can be no real certainty with respect to date, it appears that the late Pliocene to early Pleistocene was also a time of three important faunal dispersals eastward, none on present evidence involving early hominids. One of these took place across the Strait of Lombok, from Java and Bali along the Lesser Sundas to Flores and Timor; the other two were from Borneo to Sulawesi and from Borneo to the Philippines (Groves 1985). The Philippines appear never to have had a land bridge to the Asian mainland (Heaney 1985, 1986), but it is possible that western Sulawesi was still attached structurally to Sundaland during the Pliocene (Hall 1996), although not necessarily by continuous dry land.

The link to Sulawesi is documented by the Cabenge fauna from several localities in the Walanae Valley in the southwestern part of the island (Bartstra et al. 1991–1992; Bartstra and Hooijer 1992). Like the oldest fauna on Java, this has Siva-Malayan affinities and contains species of *Stegodon* and elephant (a small species derived from a larger Pliocene population on Sundaland: Maglio 1973), together with the piglike babirusa and an extinct species of pig. Macaque monkeys and buffalo-like anoas possibly arrived on Sulawesi at the same time, but have not so far been found in the Walanae fauna. A significant chronological marker in this fauna is a giant land tortoise *(Geochelone atlas)*, which appears to have disappeared from Java by about 1.2 million years ago (Bergh et al. 1995a). It was once thought that the Cabenge fauna arrived in Sulawesi via a land bridge through the Sangihe Islands from the Philippines and China, but it is now agreed that it is of Sundaland origin (Groves 1976; Bartstra 1977; Sartono 1979a). The marsupial phalangers presumably rafted from New Guinea to the eastern part of the island during the Miocene, long before the arrival of the Cabenge fauna.

How did the Cabenge placental mammal fauna get to Sulawesi? The biogeographical record suggests that any late Pliocene land bridge would have been short lived, if one ever existed at all (Audley-Charles 1987; Musser 1987). Large mammals can swim, and the absence of a land bridge throughout the following Pleistocene period is agreed upon by all authorities.

The evidence for a land bridge along the Lesser Sunda chain from Java to Timor is even more tenuous. The Wallace Line, which runs east of Bali down the 30-kilometer-wide Strait of Lombok, seems never to have been land-bridged through all of geological time since the Lesser Sundas show no signs of a Sundaland derivation, being instead autochthonous volcanic arc formations (Hall 1995, 1996). Beyond the Wallace Line the glacial sea level changes would have been insufficient to bridge all the gaps, and even if tectonic movements of the seabed are invoked it seems unlikely that a continuous bridge ever ran all the

way to Timor. The fossil faunas of the Lesser Sundas are very impoverished and consist only of *Geochelone atlas* tortoises (Sondaar, 1981, disputes that these belong to the same species as those from Java), large lizards (ancestral Komodo dragons), sporadic rodent species, and species of *Stegodon* (e.g. Musser 1981; Bergh et al. 1995b for Flores). The latter, however, are of particular importance for the land bridge question because it has been discovered that separate large and dwarfed species, probably derived from *Stegodon trigonocephalus* of Java, once existed in Mindanao, Sulawesi, Flores, and Timor (Hooijer 1975, 1967–1968; Sartono 1969, 1973; Bergh et al. 1995b). One species of uncertain size existed on Sumba as well (Sartono 1979b; Hooijer 1981).

To explain these *Stegodon* distributions, Audley-Charles and Hooijer (1973; see also Hooijer 1975) suggested that Flores and Timor were joined by a land bridge through Alor in the late Pliocene or early Pleistocene, prior to subsidence of the (now 3,000-meter-deep) Timor Sea, and also that Flores was similarly joined to southwestern Sulawesi. Other scholars have been reluctant to accept these postulated land bridges owing to the degree of tectonic movement they demand and the absence of any other faunal similarities. A contrary theory is favored by Sondaar (1981) and Bartstra et al. (1991). As for Sulawesi, they suggest that the *Stegodon* and tortoise species were able to move from Sundaland into the Lesser Sundas independently, perhaps by swimming. *Stegodon* thereafter could have undergone independent dwarfing as a result of restriction to relatively small islands and the tortoises could have undergone separate selection for reptilian gigantism. Both these processes for large mammals and reptiles are known from other islands. However, because Bergh et al. (1995b) suggest that the large *Stegodon* on Flores is actually *younger* than the pygmy species, it is possible that more than one episode of animal migration was involved.

Interestingly, the large *Stegodon* on Flores is now claimed to be contemporary with human activity, at about 700,000 years ago by palaeomagnetic reversal dating (Bergh et al. 1995b). This is discussed in more detail in the next chapter.

B. The Pleistocene in Java

Sometime during the early Pleistocene a new fauna evidently appeared in Java. It was called "Sino-Malayan" by Koenigswald because it shares more species with southern China than did the preceding Siva-Malayan fauna. It is also much richer in species, including many that still exist today. According to many authorities, this fauna developed through three overlapping stages traditionally termed Jetis (the earliest), Trinil, and Ngandong (see Theunissen et al. 1990; and Fig. 1.8 for approximate chronologies). New appearances in the Jetis (Koenigswald 1949; Hooijer 1968; Medway 1972) include rhinoceros, forest primates such as the gibbon and orangutan, and of course hominids. In addition, the

PLEISTOCENE DIVISIONS	MYA	SANGIRAN LITHOSTRATIGRAPHY	SANGIRAN MAGNETO-STRATIGRAPHY	HOMINIDS (CENTRAL & EAST JAVA)	TRADITIONAL FAUNAL DIVISIONS	SANGIRAN VEGETATION
LATE PLEISTOCENE		OLD RIVER GRAVEL EROSION	NORMAL / BRUNHES	WAJAK (*sapiens*) NGANDONG SAMBUNGMACAN	NGANDONG	open woodland
MIDDLE PLEISTOCENE		POHJAJAR (NOTOPURO) VOLCANICS		*Minimum age of Sangiran hominids (Sémah 1986)		humid rainforest (last interglacial?) open woodland
	0.5	BAPANG (KABUH) FORMATION (Gravels, sand, silt, and clay of limnic and fluvial origin, with tuff layers)		*Homo erectus*	TRINIL	
EARLY PLEISTOCENE	1.0	GRENZBANK (*Calcareous conglomerate*) SANGIRAN (PUCANGAN) FORMATION	JARAMILLO TRANSITION / FRESHWATER FACIES	Date range for Sangiran hominids according to Matsu'ura 1982; Watanabe & Kadar (eds)1985 "*Meganthropus*"		open woodland (few trees, mainly herbaceous forms) open woodland and rainforest mosaic
	1.5	(Bluish-grey clay intercalated with silt, sand, diatomite, peat and tuff layers)	REVERSED / MATUYAMA	*Homo erectus*?	JETIS	
			MARINE FACIES	*maximum theoretical age of Sangiran hominids (Sémah 1986)	KALI GLAGAH	wet grassland, *Nipah*, coastal mangroves, estuarine environment, some rainforest inland.
PLIOCENE	2.0	PUREN (KALIBENG) FORMATION (Bluish-grey marine clay intercalated with silt, sand, limestone and tuff layers)	REUNION/OLDUVAI / REVERSED		(marine deposits)	

MYA = millions of years ago

Fig. 1.8 The Sangiran sequence of geological formations, hominids, faunas ("traditional" divisions), and vegetations since the late Pliocene. From Bellwood 1992. Courtesy: Cambridge University Press.

fauna contains a wide range of large herbivores such as elephant, cattle, buffalo, deer, pig, and hippopotamus, and carnivores such as tiger, bear, panther, and dogs of the genus *Cuon*.

In the past decade or so this faunal scheme has been heavily modified by a new and rather different one, illustrated here in Figure 1.9 (Vos et al. 1982; Sondaar 1984; Leinders et al. 1985; Theunissen et al. 1990; Bergh et al. 1995a).

Java fauna list

	SATIR	BUKURAN SITE BELOW TUFF 9	CI SAAT	TRINIL	KEDUNG BRUBUS	NGANDONG	PUNUNG	HOLOCENE CAVES COMPOSITE	RECENT
Mania palaeojavanica					•				
Mania javanica								•	•
Ursus malayanus						•		•	•
Paradoxurus hermaphroditus								•	•
Arctogalidia sp.								•	•
Panthera sp.			+?						
Panthera tigris subsp.				•	•	•		•	•
Prionailurus (=Felis) bengalensis			•	•	---	---	•		•
Aonix (=Amblonyx) cinerea				•					•
Lutrogale palaeoleptonyx				•					
Martes flavigula									•
Hyaena brevirostris				•					
Mececyon trinilensis				•					
Cuon? javanicus				•					
Cuon javanicus (=alpinus)								•	•
Tetralophodon bumiajuensis	•								
Stegodon cf. elephantoides		•							
Stegodon trigonocephalus			•	•					
Stegodon?hypsilophus					+?	•			
Elephas hysudrindicus			•	•	•				
Elephas maximus							•	•	•
Rhinoceros sondaicus				•	•	---	•	•	•
Rhinoceros unicornis kendengindicus				•					
Tapirus indicus				•					
Hexaprotodon simplex	•			•					
Hexaprotodon sivalensis			•	---	---	•			
Muntiacus muntjak	•		•	•		•	•	•	•
Cervids	•		•						
Tragulus javanicus			•						•
Axis lydekkeri				•					
Axis kuhli				•					•
Rusa sp.						•			
Rusa (=Cervus) timorensis					•				•
Duboisia santeng				•					
Capricornis sumatraensis				•		•			
Epileptobos groeneveldtii				•					
Bubalus palaeokerabau				•					
Bubalus bubalus (=arnee)					•				•
Bibos palaeosondaicus				•					
Bibos sp.						•			
Bos javanicus (=Bibos sondaicus)						•			•
Bovids			•						
Sus brachygnathus				•	---	-+?			
Sus macrognathus				•					
Sus scrofa vittatus								•	•
Sus sp.						•			
Sus verrucosus								•	•
Nycticebus coucang								•	•
Presbytis (=Trachypithecus) cristatus				•	•	---	---		•
Presbytis comata									•
Macaca fascicularis				•	•	---	---	•	•
Macaca nemestrina							•		•
Hylobates syndactylus									•
Hylobates moloch									•
Pongo pygmaeus							•		
Homo erectus			+?	•	•	•	•		
Homo sapiens								•	•
Hystrix (=Acanthion) brachyurus				•	•	---	---	•	•
Hystrix javanica				•				•	•

Fig. 1.9 An alternative faunal scheme for Java, as described in Vos et al. 1982 and Bergh et al. 1995a (see text). Dates are approximately as follows: Satir, 2–1.5 mya (million years ago); Ci Saat, 1.2 mya; Trinil, 0.9 mya; Kedung Brubus, 0.8 mya; Ngandong, uncertain; Punung, 110–70 kya. Courtesy: John de Vos.

This scheme places a number of species later in time, especially the rain forest primates (gibbon and orangutan), that are claimed to have appeared in Java only during the last interglacial period. It also includes a major phase of animal immigration into Java about 800,000 years ago—during the Kedung Brubus faunal stage—at a time when world sea levels were generally low and the island was land-bridged for a long period to the Asian mainland. At present it is not clear if this scheme will completely replace the traditional one; reservations about it have been expressed by Bartstra (1983) and Hooijer (1983). The disagreements have arisen in part because of uncertainties over the exact findplaces of animal bone assemblages—especially those of the Trinil fauna.
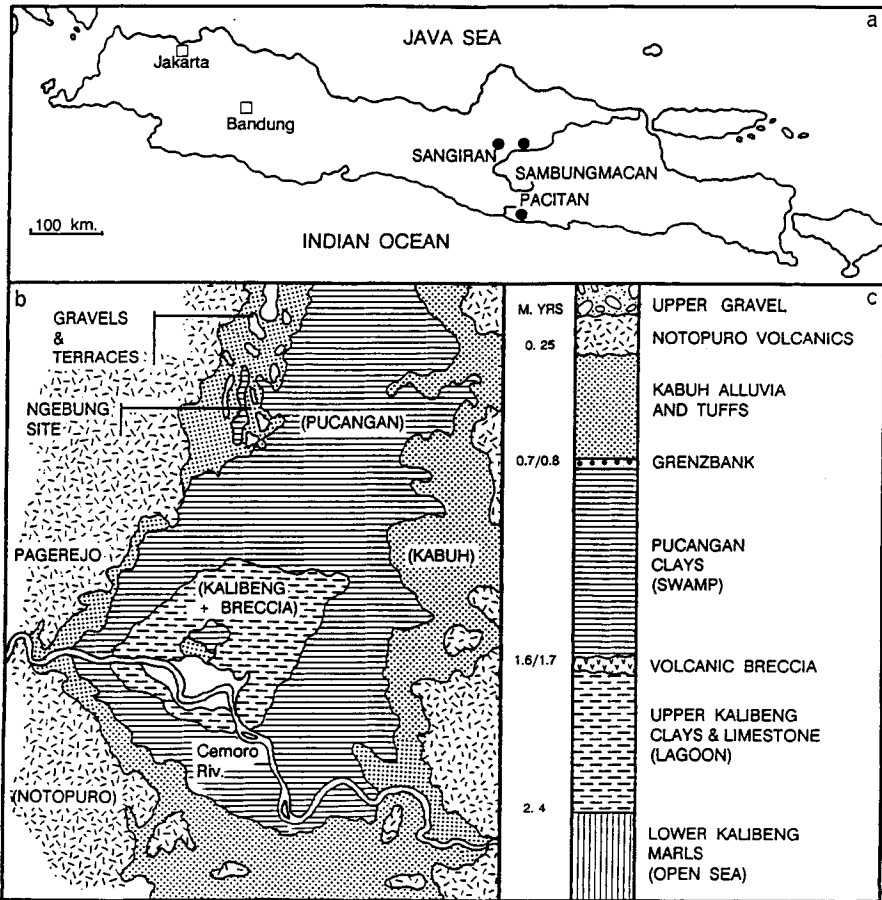

Fig. 1.10 A simplified geological map and section of the Sangiran "dome," showing the location of the Ngebung site. Courtesy: François Sémah.

The best record of human and faunal evolution in Java comes from a rather dramatic locality known as Sangiran (Plate 1 and Fig. 1.10), where a domed formation of Pliocene and Pleistocene deposits pushed up by volcanic activity has been cut open and exposed by the Cemoro River, a tributary of the much larger Solo. The craterlike exposure here measures approximately 8 by 4 kilometers, and in its rather dissected base are exposed Pliocene estuarine sediments upon which lie patches of terrestrial Pleistocene formations (Matsu'ura 1982; Watanabe and Kadar 1985). During late Pliocene times the region around Sangiran was still partly under the sea, and it appears that a long marine strait occupied much of the area of the present Solo Valley. Sangiran seems to have been quite near the coastline, as recent pollen analyses of the Pliocene estuarine sediments have indicated the presence of mangroves, nipa palms, and pandanus trees (A-M. Sémah 1982a).

Above the Pliocene estuarine deposits in Sangiran come two major terrestrial formations: the Pucangan and the succeeding Kabuh (termed the Sangiran and Bapang formations in Watanabe and Kadar 1985). The Pucangan (Sangiran) formation is exposed through a total thickness of about 160 meters and comprises mainly lacustrine black clays with periods of marine estuarine transgression. The base of the Pucangan has thick estuarine deposits that contain shark teeth and shells of oysters, pearl, and other bivalves. The pollen analyses support the stratigraphy in suggesting a gradual emergence of the land around Sangiran during Pucangan times, and the mangroves were slowly replaced by dryland vegetation with mainly open-country characteristics and patches of rain forest (A-M. Sémah 1982a,b; Watanabe and Kadar 1985). The Pucangan beds contain the earliest hominids.

Above the Pucangan beds at Sangiran lie the Kabuh (or Bapang) alluvial beds, with a calcareous conglomerate and bone-rich marker bed known as the Grenzbank between. The Kabuh beds contain the Trinil fauna; these beds are up to 60 meters thick and have also produced the bulk of the hominid finds. Pollen from the Kabuh layers at Sangiran is predominantly of nonarboreal type (Gramineae, Cyperaceae), but rain forest continued to exist in the general region. It may be that volcanic eruptions promoted some open vegetation at the expense of forest, and the possibility that the climate periodically had a longer dry season than now might also be considered. The middle Pleistocene animal faunas of Java also indicate conditions less forested than now (Medway 1972).

The ages of these deposits are difficult to determine and there is still much disagreement. Ninkovitch and Burckle (1978) dated the base of the Pucangan beds at Sangiran between 1.9 and 2.1 million years ago according to diatom correlations. The locations within the Sangiran sedimentary sequence of dated palaeomagnetic reversals of the earth's magnetic field (Jaramillo Transition and Brunhes-Matayama Boundary; see Fig. 1.8), together with fission track dates on

zircon grains in volcanic sediments, suggest that the boundary between the Pucangan and Kabuh formations lies somewhere between 0.7 and 0.9 million years ago (F. Sémah et al. 1981; F. Sémah 1982, 1986; Watanabe and Kadar 1985; Hyodo et al. 1993).

The hominid fossils from Sangiran, to be discussed in more detail in the next chapter, come from the upper part of the Pucangan formation, the Grenzbank, and the lower part of the Kabuh formation. Pope (1984) and Bartstra (1983) favor a commencement date for hominids in Java at a little over a million years ago, a date supported by the fission track and fluorine dates from Sangiran listed in Watanabe and Kadar (1985) and by Matsu'ura (1982). In Fig. 1.8, I give a most likely date range for Sangiran *Homo erectus* of about 1.2 million to 750,000 years ago. This is the date range accepted by most scholars today (e.g., Bergh et al. 1995a).

There are, however, continuing claims by other scholars for much earlier dates. For instance, Siesser and Orchiston (1978) have suggested that foraminifera found in sediment attached to one of the most ancient hominid mandibles from Java (the *Pithecanthropus* mandible C from the Pucangan formation at Sangiran) are at least 1.6 million years old. The Kabuh formation at Sangiran has produced a surprisingly old potassium-argon date of 1.2 million years (Curtis 1981:16), although the status of this sample has been questioned by Pope (1984). In 1994, the paleontological community received rather a surprise with the publication of an argon-argon date of 1.8 million years for pumice from the Pucangan deposit at Perning, near Mojokerto in eastern Java, that produced (in 1936) a *Homo erectus* child cranium. Another date of 1.66 million years was given for a pumice layer contemporary with hominid fossils in the Pucangan formation at Sangiran (Swisher et al. 1994). These dates have been challenged by other workers in the field (e.g. Bergh et al. 1996b), and it is only possible to conclude at present that the dating of the Javan Pleistocene and its hominids remains controversial. If the Mojokerto child really is 1.8 million years old, then our whole understanding of the course of human evolution is going to need substantial revision, a possibility discussed in more detail in the next chapter (see also Huang et al. 1995 for claims of similarly early dates from southern China).

Although my tendency is to support the "conventional" chronology for the Javan Pleistocene offered in Fig 1.8, it would perhaps be unwise to be too precise about the overall ages of the Pucangan and Kabuh formations at this stage of research; the boundary between the two may not in fact be synchronous over the whole of central and eastern Java. Given current disagreements, it seems best to regard the Jetis and Trinil faunas as a continuous and intergrading sequence spanning the period from perhaps 2 million to about 500,000 years ago, with periodic new arrivals coming in from the Asian continent, including *Homo erectus* by at least a million years ago.

Descendants of the Trinil fauna presumably continued across a nonfossiliferous hiatus in the middle Pleistocene, represented at Sangiran by the volcanic Notopuro deposits, into the late middle and late Pleistocene Ngandong fauna. After the Notopuro tuffs and lahars were deposited in central Java, the area was subject to uplift, causing river rejuvenation and terrace formation. The Ngandong fauna has been found on one of these terraces in the Solo Valley and all its genera apart from *Stegodon* are still living; it may be regarded as the direct ancestor of the present fauna of Java.

C. Pleistocene Land-Sea Relationships in the Indo-Malaysian Archipelago

The question of sea level relative to land surface level during the Pleistocene in Sundaland now arises. The dispersal of animals and hominids might have been affected by the alternate flooding and exposure of this vast area in recurrent cycles of about 120,000 years (Chappell 1994). At present this possibility cannot be easily assessed, and the opinions published to date suggest several lines of disagreement. For instance, Batchelor (1979) has claimed that the Sunda shelf off western Peninsular Malaysia has submarine fan and braided stream deposits, evidence that it was emergent almost continuously until about 500,000 years ago, and even thereafter was not submerged to present levels until the last interglacial, only about 120,000 years ago. On the other hand, Tjia (1980) and Bergh et al. (1996b) are clearly unwilling to accept such a continuously low relative sea level in the early Pleistocene; the latter, following Prentice and Denton (1988), favor a major drop in sea level at about 800,000 years ago, the period of incursion into Java of their Kedung Brubus fauna. There are also some zoological arguments to suggest that Sundaland must have been separated into islands for quite long periods going back into the Pliocene; Chivers (1977) believes that such periodic geographical isolation is required to explain gibbon speciation, and Musser (1982) presents a similar viewpoint for rats.

This apparent difference of opinion about the possibility of a periodic drowning of Sundaland in the early and middle Pleistocene (see also Heaney 1985) cannot easily be resolved at present, mainly because the sea level history of Sundaland cannot simply be read from world absolute sea level curves. Even if isostatic compensation is allowed for, there is always the unknown possibility that localized tectonic movement has occurred. However, if such movement is arbitrarily discounted, then the general shallowness of the present seas over the Sunda shelf would indicate that a drop of only 50 meters with respect to the present land surface would be sufficient to join Peninsular Malaysia, Sumatra, Java, and Borneo to create a sizeable continent. Sundaland could therefore have been exposed as a continental area of varying size for the greater part of the Pleistocene, and its present island configuration may be unusual in terms of geological time.
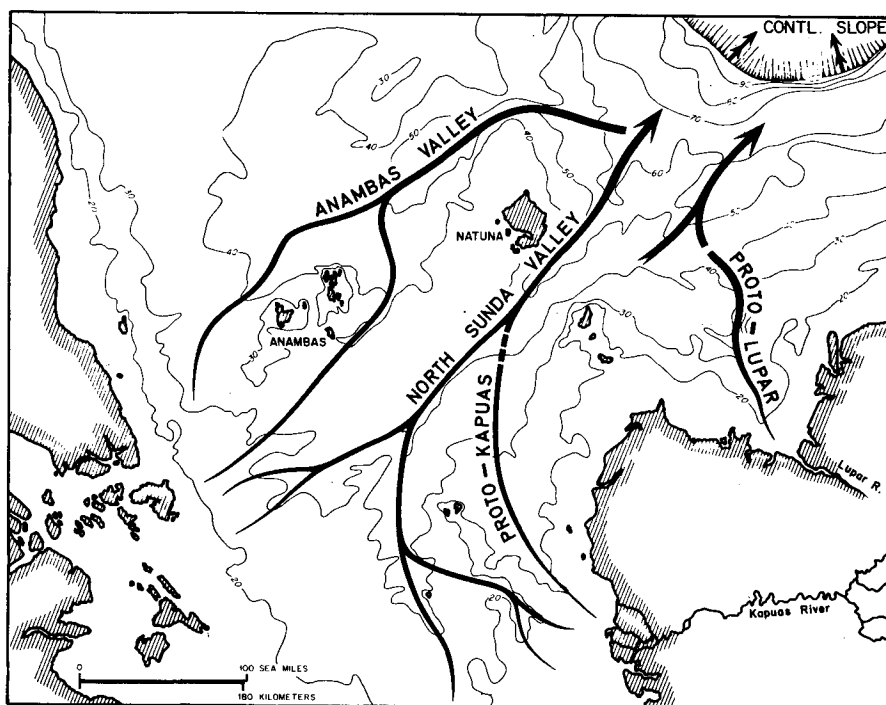
Fig. 1.11 The submarine topography of the northern Sunda Shelf. From Haile 1973. Courtesy: Tsukiji Shokan.

The surface of Sundaland as an emerged continent contains some interesting features. The shallow shelves of the South China and Java Seas are incised by a number of fossil river channels; between Sumatra and western Borneo there are three major ones, termed by Haile (1973) the Anambas, North Sunda (with the Proto-Kapuas as a tributary), and Proto-Lupar valleys. These can be clearly followed to the edge of the Sunda shelf at a depth of about 100 meters (Fig. 1.11). Two large parallel rivers also ran along the bed of the Java Sea between Java and Borneo toward the Strait of Makassar (Umbgrove 1949; Verstappen 1975). Similarities in freshwater fish species between eastern Sumatra and western Borneo indicate that the rivers of these islands were once linked; the Musi of Sumatra and the Kapuas of Borneo in particular were once part of the North Sunda river system. On the other hand, some of these large rivers clearly served as faunal and floral divides of some magnitude; P. Ashton (1972) has pointed out that the Dipterocarp forest trees show some sharp breaks in distribution at the Lupar River in western Borneo, and the presence of the large rivers between Java and Borneo may have slowed down faunal dispersals between these two islands in the Pleistocene. Two large freshwater lakes also occupied the middle of the Gulf

of Thailand and the area immediately north of western Java, according to sea-bed contours presented by Butlin (1993:Maps 8a, 8b).

D. Environmental Conditions of the Last Glaciation in the Indo-Malaysian Archipelago

The environmental fluctuations of the past 120,000 years—since world climate and sea level were last at around their present configurations—are rapidly becoming quite well plotted. A graph of relative climatic severity over the past 130,000 years has been prepared by Kukla (1981; see Fig. 1.6, top), and this shows quite clearly how relative severity increased gradually and slowly, despite fluctuations, until the last glacial maximum about 18,000 years ago. The amelioration since then has been very rapid, especially after 14,000 years ago (Broecker et al. 1988; COHMAP 1988). This is important for the rate of the last major sea level rise. It has been estimated that parts of the Sahul shelf may have been drowned at rates of 25 to 45 meters horizontal migration per year (Andel et al. 1967), although this movement was interrupted by occasional standstills. Rates of vertical sea level rise probably rose to maxima between 1.0 and 1.5 meters per century (Chappell and Thom 1977:285). On the Sunda shelf, Haile (1973) has postulated a rapid drowning of the course of the Proto-Lupar River, although this could have involved local tectonic downwarping as well.

If we now focus on the last 40,000 years, for which there is increasingly good archaeological and environmental evidence, there is fairly widespread agreement that temperatures fluctuated at intermediate levels until about 25,000 years ago, when they began to downcurve rapidly to reach a nadir at about 20,000 to 18,000 years ago. Climates and sea levels then returned to approximately present conditions by around 8,000 years ago, following a reversion to glacial conditions between 12,500 and 11,000 years ago known as the Younger Dryas Interval (Hughen et al. 1996). In some parts of the world the mid-Holocene climate was perhaps a little warmer and wetter than at present (Kutzbach 1981; Lamb 1982). The conditions of the last glacial maximum in the tropics are of most interest here, and it is now becoming clear that some of these areas were considerably drier at this time, with evidence for relative aridity, decline of forest biomass, drying of lakes, and extensions of deserts in Australia, Africa, the Middle East, India, and South America (Rind and Peteet 1985; Hammen and Absy 1994; Yan and Petit-Maire 1994). The Bay of Bengal waters were more saline than now, which has been taken to reflect a decrease in summer monsoon rainfall and a consequent decrease in the quantity of fresh water entering the ocean from rivers (Duplessy 1982).

The evidence for Indo-Malaysian climatic conditions of 18,000 years ago is not as clear as it is for some of the larger tropical continental areas, partly

because this area is relatively complex in terms of land-sea and altitudinal patterning. For instance, in terms of temperature it is apparent that New Guinea highland averages fell to about 7 to 7.5° Celsius below present averages (see Section IIIB), and tree and snow lines fell by between 1,000 and 1600 m (but see Note 2). A similar drop in average temperature of 5 to 9° Celsius has been suggested by Tsukada (1966, 1967) for highland Taiwan, and by Newsome and Flenley (1988) for highland Sumatra (see also Stuijts et al. 1988). Such dramatic plunges in average temperature probably did not occur in the tropical lowlands, however, and last glacial estimates for Sundaland locations near sea level tend to fall between 2 and 5° Celsius below present (Verstappen 1975; Batchelor 1979; Kaars 1991). It is unfortunate that there are as yet no pollen sequences covering the last glacial in the lowland equatorial regions of Southeast Asia. While the evidence does seem to favor a lowland temperature drop of some extent, it was probably of less magnitude than at high altitudes and perhaps less in the oceanic environments of Wallacea than in the more continental regions of Sundaland.

Turning now to rainfall, we may recall that through much of the Pleistocene both Sundaland and Sahulland would have been above sea level as large continental areas. Periods of drowning like the present probably only occurred for short periods. The period of continentality at the maximum of the last glaciation would certainly have produced drier climates. Lower temperatures would reduce convectional rainfall and winds would tend to be drier because they would cross larger land areas and cooler seas. High-latitude glaciation would cause an increased pressure gradient between the Asian and Australian continents and the equator, and the Intertropical Front may have moved outside the limits of the Indo-Malaysian Archipelago for longer periods than it does now. Dry seasons would become longer and even the equatorial regions could have experienced briefer and smaller rainfall maxima (Verstappen 1975; Batchelor 1979; Morley and Flenley 1987). Verstappen (1975:10) has suggested that average rainfall in Sundaland could have been reduced by as much as 30 percent during the last glaciation.

All this suggests that the Indo-Malaysian Archipelago would probably have had much larger areas of monsoon forest during the last glaciation, even if the inner core regions of equatorial forest in Sundaland and New Guinea were relatively little affected. The rain forest itself has certainly maintained a stable composition in Borneo since the Miocene (Muller 1975), but there possibly were landscapes with longer dry seasons and more open vegetation during the successive Pleistocene glaciations, perhaps around the fringes of the Sunda shelf, along which open forest mammals and hominids could have passed more freely southward across the equator. This possibility was pointed out from a floral viewpoint some years ago by Steenis (1961, 1965; see also Scrivenor et al. 1942–
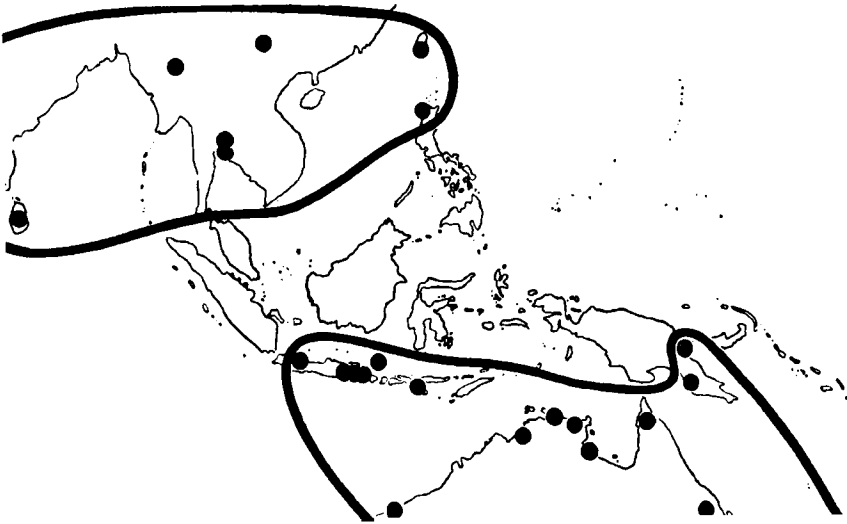
Fig. 1.12 The disjunct distribution of the plant species *Rhynchosia minima*, which grows under strong dry-season conditions. From Steenis 1961. Courtesy: Herbarium Bogoriense.

1943:148), who showed that several species of Leguminosae and grasses adapted to long dry seasons occur in the northern and southern monsoon areas, but with sharp gaps in distribution in equatorial Indonesia at the present time (Plate 1). To explain these disjunct distributions Steenis suggested that dry season zones or corridors had been more extensive in the past, particularly through Sulawesi and the Philippines. Morley and Flenley (1987:Fig. 5.5) also suggest that a relatively dry "savanna corridor" existed through western and southern Sundaland during glacial maxima.

Other geomorphic observations fill out this picture of late glacial dryness, especially in and around Sundaland. Verstappen (1975) has suggested that the coarse alluvial and colluvial deposits of the last glacial in Peninsular Malaysia indicate tree savanna conditions with considerable erosion and valley filling. Terrestrial deposits beneath the sea on the Sunda shelf include bauxite and laterite pans, kankar nodules, and possibly braided stream deposits, all suggesting past seasonal climates. Confirmatory evidence for a shrinking of rain forests during glacial periods in the tropics has also been claimed by Shackleton (1977) from curves of variation in carbon-13 content in equatorial Pacific foraminifera; he suggests that plant biomass and associated humus, especially in the tropics, increased by a factor of three during the overall warming between 14,000 and 8,000 years ago.

The Sahul shelf has produced similar evidence for glacial dryness. Andel et

al. (1967) have suggested that it received only between one-third and one-half of its present rainfall in the last glaciation. Nix and Kalma (1972) have reconstructed an open woodland vegetation for the shelf at this time, with a considerable restriction of the southward extent of the New Guinea rain forest. More recent palynological research from seabed cores by Kaars (1989) gives a similar picture, with grassland being widespread on the Sahul shelf between 38,000 and 17,000 years ago.

Some other nonclimatic differences between continental (glacial) and island (interglacial) phases of Sundaland have been outlined by Dunn and Dunn (1977). For instance, at a sea level 100 meters below the present, Sundaland had about twice as much exposed land as it does now, but only about 47 percent of the coastline. This is an important observation, for many ancient economies in this part of the world depended on the sea and periods of high sea level are clearly favorable for increasing coastal resources. On the other hand, interglacial conditions with high rainfall would not favor inland economies based on the hunting of herd animals in open parkland environments. Dunn and Dunn also note another important fact: The Sunda shelf is not flat and the exact extent of the Sunda continent would have varied with sea level. For instance, the island of Palawan, technically speaking a part of Sundaland, is separated from Borneo by a channel 140 meters deep. Because it also has an impoverished mammal fauna, it clearly was not linked to Borneo for long periods, although it certainly was linked at some point during the Pleistocene. Java also might have been an island at times when Sumatra and Borneo were joined to Peninsular Malaysia, as it also has some faunal peculiarities.

We are not really in a position yet to state clearly what impact these Pleistocene climatic and environmental fluctuations had on the floras and faunas (including humans) of the Indo-Malaysian region. The most recent cases of animal extinction at the end of the Pleistocene and in the early Holocene do give some interesting hints, but it is clear that these fluctuations in the Indo-Malaysian latitudes did not have such a massive ecological impact as those recorded for periodically glaciated temperate regions such as Europe and North America.

E. Animal Extinctions and Habitat Shifts in Sundaland in the Late Pleistocene and Holocene

In 1972, Medway noted that out of two hundred extinctions worldwide during the late Pleistocene, only eleven occurred in Sundaland (this figure is now slightly larger). The 32,000-year-old fauna of Niah in Sarawak has a giant pangolin as its only truly extinct species (Harrisson et al. 1961). This is a very different story from the record of animal extinction in the late Pleistocene in Eurasia, North America, and Australia. Table 1.1 lists some approximately dated exam-

Table 1.1. Late Pleistocene and Holocene extinctions in Sundaland

Species	Site	Last recorded date of local or regional existence	Reference
Manis palaeojavanica (giant pangolin)	Niah Caves, Sarawak	c. 30,000 BC	Medway, 1977a
Tapirus indicus[2] (Malayan tapir)	"	c. 6000 BC	"
Hylomys suillus[1] (lesser gymnure, an insectivore)	"	Late Pleistocene?	"
Melogale orientalis[1] (ferret badger)	"	early Holocene?	"
Rhinoceros sondaicus[2] (Javanese rhinoceros)	Madai Caves, Sabah	6000 BC	Cranbrook, 1988a
Cuon sp.[2] (the dhole, a wild canid)	"	6000 BC	Cranbrook, 1988a (provisional identification only)
Panthera tigris (tiger)	"	between 7000 and 3000 BC	T. Harrison (pers comm)
small deer[1] (species unknown)	Guri Cave, Palawan	3000 BC	Fox, 1970
Elephas maximus[3] (Indian elephant)	Gua Lawa Cave, central Java	early Holocene?	Medway, 1972
Bubalus sp.[4] (water buffalo)	"	"	"
Neofelis nebulosa[3] (clouded leopard)	"	"	"
Cervus eldi[4] (a deer)	"	"	"

(1. locally extinct; 2. extinct on Borneo; 3. extinct on Java; 4. extinct in Indonesia)

ples of late Pleistocene and early to middle Holocene extinctions or habitat shifts in Sundaland. In a review of the whole topic of animal extinction, Medway (1977a) has argued against any major human role in this pattern and has suggested that the rapid environmental fluctuations of the late Pleistocene, especially the final glacial maximum and the subsequent rapid amelioration to warmer, wetter, and more forested conditions, may have been the main causes. However, this cannot account for all species extinctions; the giant pangolin appears to have vanished long before the end of the last glacial, and extinction

of the Palawan deer seems to have been recent enough for human predation to be considered as a cause.[3]

Of these animals, the giant pangolin is the only totally extinct species; the rest are merely locally extinct. *Cervus eldi* and wild water buffalo no longer exist in Indonesia today. The gymnure and ferret badger from Niah both survive today on the higher slopes of Mount Kinabalu in Sabah and their presence in the late Pleistocene at Niah supports the evidence for a cooler climate during that period. Medway (1977a) has also suggested that the giant pangolin would have required larger termitaria for its food supplies than exist in equatorial rain forests today, and this again suggests a more open environment in this part of Borneo in the late Pleistocene.

When looking at modern animal distributions (excluding human transportation of such species as deer, monkey, civet, and pig), we find some puzzling patterns (see Fig. 1.5). Elephants occur in Sumatra and Peninsular Malaysia, are extinct in Java, and are not definitely recorded for Borneo prior to recent introductions (Harrisson 1978); the Sumatran rhinoceros occurs in Sumatra, Peninsular Malaysia, and Borneo, but the Javan rhinoceros lives only in Java, Peninsular Malaysia, and Sumatra (the latter only until the 1930s); wild banteng cattle live in Java, Borneo, and northern Peninsular Malaysia, but are not certainly known in Sumatra or southern Peninsular Malaysia; the tiger occurs in Peninsular Malaysia, Sumatra, and Java, but not in Borneo. This list could continue, but I merely wish to point out the existence of these disjunct distributions. The reasons appear to be mainly ecological: ever-wet climates versus seasonal climates and vegetation; the presence of large rivers acting as faunal barriers; the compression of environmental zones against ocean or mountain barriers; and the possibility that some islands were cut off before others by rising postglacial sea levels. Indeed, recent archaeological research is indicating that some of these animals had larger ranges until well into the Holocene. The tiger, Javan rhinoceros and *Cuon*, for instance, are reported from the Madai excavations in Sabah (Table 1.1), and there is a possible record of elephant from Niah (Terry Harrison, pers. comm.).

Having looked at the histories of the environment, climate, and fauna of the Indo-Malaysian Archipelago from the Pliocene through to the Holocene, it is time to turn to the history of a major mammal species I have so far rather ignored: the human species.