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A Early Pleistocene Way of Life -- *Homo erectus* of Sangiran Dome, Central Java

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The remains of humans that lived over a million years ago have been discovered at Sangiran Dome, 12 km north of Surakarta (Solo). This article provides background information for a visit to the Dome, and specifically to the Sangiran Museum, where maps, displays, fossils, and other materials related to *Homo erectus* at Sangiran will be seen. At the museum, you can buy a booklet entitled "The Sangiran Prehistoric Site Museum as A Tourist Object in Solo," which contains both accurate and falacious information on the site. A technically sound popular account is available in Semah et al. (1990). A detailed description of the geology and paleontology is found in Watanabe & Kadar (1985) which can be purchased in Bandung from the Geological Research and Development Centre. A conference was held in Solo during September, 1998, and the Proceedings from the meeting, entitled "International Colloquium on 'Sangiran: Man, Culture and Environment in Pleistocene,' will contain contributions on both the scientific and public issues surrounding the Sanigran Dome anthropological site. In addition to the Sangirn Musuem, local museums with good displays of original fossil material are open at Miri, about 25 km north of Sangiran, and at Trinil, the first early man site in Java, near Ngawi in East Java.

As the introductory geologic information is presented here, broad questions about Javan *Homo erectus* are posed, such as "What was the way of life of these early people?" The questions and associated discussion help convey a sense of the broad anthropological significance of fossils such as those from Sangiran.

The "Sangiran Early Man Site" is one of 550 locales worldwide that UNESCO has recognized for its special cultural and natural value. Sangiran is among the most important paleoanthropological sites anywhere for addressing questions about the ecology of early humans. The fossils come from a 3 x 6 km uplift of Plio-Pleistocene mudstone and sandstone. The remains of dozens of *Homo erectus* have been discovered over the last 60 years, making Sangiran the most prolific source of early human fossils in Java. Eastern Java is the only part of Southeast Asia where such remains have been recovered. The fossils and stratigraphic column at Sangiran indicate a variety of paleoenvironments in the landscape inhabited by early humans.

The site therefore serves as an exemplar for complexity in *Homo erectus'* habitat. Sangiran is further significant scientifically because of the long time span that human occupation is documented.

Homo erectus lived in the Solo area for several hundred thousand years in the Pleistocene. What part of the Pleistocene is a controversial matter. The traditional view, the one followed by most Indonesian and foreign specialists on the Javan record, places early humans at Sangiran from 1.3 million years ago to 0.7 or even .125 ma (e.g., Watanabe & Kadar, 1985; Semah et al., 1990). This viewpoint is based primarily upon fission-track dates and paleomagnetic stratigraphy. On the other hand, the age of habitation recently has been placed at 1.7 to 1.0 ma on the basis of a new set of $^{40}Ar/^{39}Ar$ radioisotopic dates (Swisher, 1997). Sorting out the evidence will take some time. There are problems with the application of paleomagnetic studies in some parts of the section, some researchers suspect that key fission-track dates are unreliable, and while $^{40}Ar/^{39}Ar$ determinations are generally a dependable indication of age of the material dated, there are questions about how the human fossils relate to the stratigraphic sequence as dated. For example, there is a question about how deep in the section human fossils occur -- throughout the lagoonal and lacustrine section (Pucangan Formation) or only in its upper part.

Even if the earliest humans at Sangiran are mid- rather than basal-Early Pleistocene, *Homo erectus* lived in eastern Java as early as, or nearly as early as, anatomically similar humans inhabited East and South Africa, where the genus *Homo* is thought to have evolved. Plio-Pleistocene humans evidently inhabited both the Indonesian Archipelago and Africa contemporaneously for long periods of time and were well suited ecologically to both areas.

These records of ecological success are so long that they are hard to compare to more recent human history. It is therefore difficult to keep in mind the vast range of possible trajectories of early human history that such long time frames permit. Modern civilizations can be traced for only a few thousand years. Even the late prehistoric record, when humans living from Europe to Australia left clear signals of cultural sophistication, is only 25,000 to 50,000 years or so. How many profound events in early human history took place in the course of Early and Middle Pleistocene? What behaviors enabled *Homo erectus* to "succeed" in Java, parts of Africa, and possibly areas of Eurasia for so much of the Early Pleistocene?

Current models of early human evolution do not offer much help in answering this second question -- they portray Plio-Pleistocene humans as having little ecological (or cultural) versatility. Java alone is a place where versatility would seem to be a significant advantage. Moreover, Java and East Africa seem to differ a lot environmentally. And all the lands that lie between these distant points add to the spectrum of climates and terrains that Plio-Pleistocene humans apparently inhabited or traversed.

It is not clear whether *Homo erectus* of Java and anatomically similar humans in Africa and Eurasia are the same species or several. The Javan hominid fossils dating from the Plio-Pleistocene (approximately 2.5 to 0.7 milliion years ago) are classified by different paleoanthropologists into one genus but multiple species, one species but multiple subspecies, and a single taxon -- that is, the same genus and species with no

subspecies present. Some others include *erectus* in our own genus and species, *Homo sapiens*. For the purposes here, I follow those who take the one-species approach but separate the Sangiran fossils from modern humans. I term all the older fossil hominids of Java *Homo erectus* -- that is, our genus but not our species. Eugene Dubois, its discoverer, originally put *erectus* in it's own genus, *Pithecanthropus*, a name that is still sometimes used. Also, some oversized hominid teeth and heavier-boned jaw fragments from Sangiran are given the genus name *Meganthropus* by some paleoanthropologists.

Behind the issue of taxonomical classification of the hominid fossils is at least one important question of human history. Did *Homo erectus* of Java contribute to the genetic pool and the Culture that comprise *Homo sapiens* today? Some anthropologists believe that the present day people in various regions of the Old World, such as China or Southeast Asia, evolved from indigenous populations of *Homo erectus*. As such the ecological and culltural history of the Plio-Pleistocene hominids in each region is directly related to the more modern human history. This concept is called the multiregional hypothesis of human origins. Other anthropologists conclude that modern humans derive from the human stock of Africa alone, and that *Homo sapiens* from Africa "replaced" populations of more "primative" humans in Eurasia, including those in Java, in the last 200,000 years. This proposition, the "replacement hypothesis," finds support in the genetic make up of modern human populations worldwide. Even if *Homo sapiens* from Africa did overwhelm Eurasian populations biologically, however, the cultural composition of the new populations may have been less completely African. Local cultural traditions, especially those tied closely to the regional environment, flora, and fauna, might have been transcended the biological "replacement."

In the early and middle parts of this century, much of what we knew of our distant ancestors was based upon the early human fossils from Java and China (Zhoukoudian near Peking). Over the past thirty years, many important and frequently publicized fossil finds have been made in East Africa. Based largely upon the African record, Western science has turned Plio-Pleistocene humans into savanna (grassland and open woodland) creatures, so that we tend to visualize the earliest people living on African plains. *Homo erectus* of Java, if it is brought into the picture at all, is assumed to be consistent with the savanna model. I believe, however, that the fossil finds at Sangiran and elsewhere in Central and East Java challenge this view. As the scientific community addresses the issue, we all will better understand *Homo erectus*' longevity in Java and the way people lived over one million years ago. Perhaps, the record of humans in Asia might again assume a central place in theory-making about human evolution and cultural development.

The Sangiran record prompts us to ask a number of interesting questions about our past; here are some that occur to me:

* What behaviors enabled humans to inhabit eastern Java in addition to the interior of Africa at such an early date in the history of the genus *Homo* and for such a long time in the Plio-Pleistocene? Does *Homo erectus* of Java fit the African savanna model? Were there anatomical differences between early humans in Africa and Asia that suggest varying biological adaptations? Was *Homo erectus* limited to those parts of Java having an East African-like environment? Or did early humans occupy forest, mountain and coastal habitats in Java in addition to whatever grassy interior lowlands

existed? Is Java an ecological microcosm that shows us better than anywhere else in the world the adaptive range that Plio-Pleistocene humans had in the tropics? Could Java be the basis for a more useful model of early human behavior than East Africa?

* Does the fossil record of Java indicate that *Homo erectus* inhabited all of Southeast Asia? Were early humans flexible enough ecologically (culturally) to have lived in the rain (ever-wet) forests of Sumatra, Borneo, and Malaysia? Is the lack of fossils in the rain forests attributable to poor fossil preservation, lack of outcrop, the use of perishable materials for tools, and low densities of frequently moving human populations, rather than a total absence of humans living there in the Plio-Pleistocene? And/or were early humans more attracted to Central and East Java because rain forests did not dominate the landscape and *Homo erectus* preferred drier climates, less-dense forests, or some other special environmental condition that existed there? Is the situation in Southeast Asia an indication that early hominids flourished in the jungles of Africa and along the African coasts?

* Did we evolve from hunters (or scavengers) in savannas, only to become a species with exceptionally diversified ways of life in the last several hundred thousand years? Or has our genus always been able to find the necessities of life in a variety of environments? And would this kind of versatility partially explain how *Homo erectus* was able to find adequate resources in Java and elsewhere throughout the Quaternary?

* Was the human genus a small-brained, slow-witted, nontalking primate until the modern human species (*Homo sapiens*) appeared in the last 200,000 years? Or did the earliest humans, such as *Homo erectus* of Java, have intellect and culture similar to Late Pleistocene anatomically modern humans despite having a brain much smaller than they had?

* What were the earliest humans like? If you were to meet a Pleistocene family at Sangiran, would you see in their eyes a people of our own kind, as we do when encountering the men, women and children from any culture of the present day world? Or would they seem remote to you, their visage being no more human than those of chimps, orangutans, and gorillas? If you could watch the erectines do daily routines, would you immediately understand the intent of their actions or would they be inscrutable?

How does Sangiran help with such far-reaching inquiries? From my perspecitve, Sangiran and the other hominid-bearing outcrops in Java document environmental diversity and thereby indicate sources of food and ways of life for *Homo erectus* that are not suggested in the savanna model. The Javan landscape contains rain-drenched volcanic mountains, calm and stormy sea coasts, and a variety of intermediate habitats. All this comprises a decidedly different setting from the vast, dry East African interior. Java would have provided early humans with mountain, sea coast, and lowland food resources that were a few days' walk from one another, a situation unlike East Africa.

This description fits Java today. What evidence is there that such conditions as these existed in Java a million years ago or so? The geology of the hominid beds helps confirm the similarity of ancient and present day environments, and thus ecological diversity in *Homo erectus'* homeland. *Homo erectus* fossils (80+ specimens) have been recovered from a 180 km long swath of medial eastern Java. The area extends from Sangiran Dome eastward to Mojokerto, near the Madura Strait (Figure 1). The fossils occur in and immediately south of the Kendeng Hills. The enclosing sediments largely are tilted or folded volcaniclastic beds. The deposits are made up of material derived

from the axial volcanoes of eastern Java. An isolated occurrence of mammalian fossils, including *Homo erectus* remains, is found on the southeast flank of Mt. Muriah volcano, which is north of the Kendeng Hills and east of Semarang (Figure 1).

In addition to the Plio-Pleistocene remains at Sangiran, Mojokerto, and Trinil (where the first *Homo erectus* was discovered in 1891), the *Homo erectus* has been found in flat-lying, Late Pleistocene terrace deposits at Ngandong. This site is situated about 20 m above the Solo River 65 km northeast of Sangiran. On the whole, then, the *Homo erectus* fossils of Java may represent as much as 1.7-1.8 million years of human history and certainly represent 1.2 my. However, this span of time appears to include an extended gap in the record of human fossils.

By virtue of the geologic context and nature of the Ngandong terrace deposits, Late Pleistocene *Homo erectus* must have inhabited a terrain that looked much like modern Java. The long gap in the human record is represented by volcanic deposits (the Notopuro Formation, mainly) that occur south of the Kendeng Hills and indicate the activity at Lawu and Wilis volcanoes. Beds of this kind crop out around the perimeter of Sangiran Dome and underlie the Solo basin more generally (Figure 1). Whether or not early humans lived in Java during the fossil gap cannot be determined, but the absence of fossils is not an indication that they did not.

Whatever the situation for the mid-Pleistocene might have been, the formations that contain the older *Homo erectus* fossils provide important evidence concerning earlier human ecology. In particular, the physiographic setting for earlier *Homo erectus*, including the early humans of Sangiran, can be read with confidence from the stratigraphic record of the hominid-bearing units (which are generally mapped as the Pucangan and Kabuh Formations). The analysis benefits from modeling the Plio-Pleistocene after interrelationships that exist today between tectonic regime, depositional environments, and landforms in the Indonesian Archipelago. Indeed, geologic studies demonstrate that the major features of the modern landscape in eastern Java were also present when *Homo erectus* first walked the land over a million years ago.

Figure 2, which is the product of geological research of this kind,[1] presents a portrait of the Plio-Pleistocene land in which *Homo erectus* lived. The landscape included: (1) The flanks and peaks of volcanoes at Wilis, Lawu, Ungaran, Muriah and elsewhere. (2) Calcareous uplands in the ancestral Kendeng Hills, Rembang Hills/Madura Island, and Southern Mountains; each presumably was less highly elevated than the upper portions of the volcanoes, by analogy with modern Java. (3) Broad valleys and sandy river courses lying between the volcanic and nonvolcanic uplands, and presumably extensive low relif slopes at lower elevations on the volcanoes and in the areas of nonvolcanic bedrock. (4) Lowlands such as (a) a coarse-clastic delta plain near Mojokerto, and (b) the muddy fringes of a lagoon and lake that was >35 km long in the Solo basin, where (c) a fluvially dominated environment developed later. (5) Muddy

[1] O. F. Huffman, 1997, Physiographic Diversity in the Homeland of *Homo erectus*, Java, p. A319 *in* Abstracts with Program, v. 29, n. 6, Geological Society of America, 1997 Annual Meeting, Salt Lake City, UT; O. F. Huffman, in press, Plio-Pleistocene Environmental Variety in Eastern Java and Early *Homo erectus* Paleoecology -- A Geological Perspective," Proceedings of the International Colloquium on "Sangiran: Man, Culture and Environment in Pleistocene" held in Solo on September 21-24, 1998 .

and calcareous marine shorelines along (a) the Randulatung embayment and (b) the northern Madura Strait. (6) A volcanic coastline along the southern Madura Strait. (7) The southern coast of Java, where rocky and sandy shorelines experiencing the fury of the Indian Ocean were probably present. Volcanoes, nonvolcanic uplands, valleys, deltaic lowlands, the volcanic shorelines, and the open-ocean coast are still part of the landscape of eastern Java.

This list of features is based upon generalized (i.e., time averaged) and patchy data. Undoubtedly, the actual physiographic diversity was more complex. Such a variety of physical conditions dictates, in turn, far greater diversity of biotic environments. The various ecological elements occurred in an area no more than 150 x 250 km -- volcanic peaks were not more than a few days' journey from the sea (<75 km) for *Homo erectus*.

Paleoecological study of *Homo erectus* has tended to be satisfied with environmental generalizations such as "open woodland," "rain forest," and "forest-edge." Clearly, the land that *Homo erectus* occupied was far more diversified topographically and ecologically than these characterizations imply. Any population of early humans that was large enough to be viable presumably would have frequented a variety of small-scale environments in Java to prosper. This activity would have provided *Homo erectus* with the opportunity to exploit a broad range of foods and other resources. In addition, because the tropics experienced climatic changes during Pleistocene glacial and interglacial episodes, the human population of Java may have survived significant environmental variations. Paleobotanical studies and the modern ecology of Indonesia support this portrait of environmental diversity and variability in Plio-Pleistocene Java. Indeed, eastern Java appears to have been a microcosm of ecological diversity and early human habitats in the tropics. What impact did this complex environment have on early human behavior?

It is difficult to determine how Plio-Pleistocene human populations adapted to different environments. Neither fossil evidence nor analogies with present day primates suffice to answer the question adequately at this point of time. People during the historic past have adjusted to a variety of environments by adopting various cultural practices, many of which are expressed in their technologies. Stone tools are numerous in the African Plio-Pleistocene. Some, if not all, were used in food acquisition, and presumably were important in human ecology. However, Plio-Pleistocene stone implements, unlike the technology of more modern people, are similar in form over large areas and spans of time. Technology therefore appears to have played a different role in the behavioral repertoire of early humans than it did in more recent people.

The culture of modern people gives them a great deal more flexibility in the environment than is the case for other primates. Monkeys have clear-cut biological differences from place to place and environment to environment, and do not use tools. Wild chimpanzees have some socially transmitted technologies, suggesting that their ecological behavior depends partially on technologically based cultural practices analogous to those in humans.

But what about prehistoric fossil humans and hominid species intermediate between humans and great apes? To what extent did biological adaptations and cultural innovations contribute to their ability to live in various settings? Anthropologists are cautious in attributing cultural behaviors and social-biological adaptations such as

language to early prehistoric humans. The tendency has been to formulate theories about them that involve a limited range of environments and ways of life. Plio-Pleistocene people are seen as "primitive" culturally in keeping with the limited diversity of their stone tools. The Javan record argues for an alternate perspective.

Limiting Plio-Pleistocene humans to a narrow range of habitats and ways of life is difficult to do once the environmental complexity of Java is recognized. Rather than assuming that early humans relied on the resources from one part of Java's complex ecological microcosm, it is more reasonable to suppose that *Homo erectus* was capable of taking advantage of the diversity and did so by developing cultural practices appropriate to a variety of food acquistion activities. This would help explain why early humans were able to live in eastern Java for so long, despite environmental (i.e., climatic or tectonic) fluctuations, and why early humans could inhabit parts of Africa, Java, and Eurasia during the Plio-Pleistocene, despite differences in climate, terrain, and biota.

Actually, two possible modes of ecological behavior fit the situation in Java and only one of them requires multiple cultural adaptations; the alternatives are: (1) *Homo erectus* specialized in a limited number of plant or animal foods that were present in a variety of the island's microenvironments and survived the climatic cycles the region experienced; and/or (2) as early as the latest Pliocene or Early Pleistocene, *Homo erectus* was an ecological generalist, much like later humans, and flourished in Java because of an ability to exploit a range of resources and habitats, changing diet (thus, ecological and cultural behaviors) from time to time and place to place as environmental conditions required. I favor the second hypothesis because it connects the ecological behavior of *Homo erectus* with that of *Homo sapiens* in a straightforward way. Admittedly, this proposal does not help in understanding why so little technological change is evident in Plio-Pleistocene stone tools and why lithic artefacts are so rare in the hominid beds of Java.

Homo erectus still could have lived largely on the meat it hunted or scavenged, just as is postulated for the early humans in Africa. The animal resources eaten in Java did not necessarily inhabit savannalands, however. Some of the ungulates that have been found as fossils in the hominid-bearing formations of Java were long-lasting faunal elements, probably had broad ecological ranges, and therefore are consistent with both the scenarios listed above.

An example is the native cattle of Java, the bantengs. They are known in the fossil record from the latest Pliocene to the Holocene. They also survive in refuges on Java and Bali today. Bantengs had a broad ecological range in the historical past. Hints of this are found in the places they still occur. The same is true for many of Southeast Asia's larger mammals that might have constituted food for early humans, such as pigs and deer. Although they are generally grazing animals that therefore congregate in grasslands, cattle are noted (a) in the ever-wet parts of Java and in the more distinctly monsoonal ones, (b) in parts of the island where rain forest dominates and in areas where dry deciduous forests and savannas occur, and (c) along the coasts of southern Java and on mountain tops 2 to 3 km above sea level. Native cattle of several taxonomic designations actually occur in many parts of Southeast Asia that are dominated by forests. For instance, bantengs occur in the rain forests of Borneo, where they occur with deer, mouse deer, muntjaks, pigs, rhinoceroses, elephants, macques,

gibbons, orangutans, and other elements that are found as fossils with cattle in the hominid-bearing beds of Java.

Other potential game for *Homo erectus* also had long-lasting and ubiquitous distributions. Presumably, there were plant foods with broad distributions also. For example, forest fruits, nuts, tubers, and possibly bamboo or palm shoots and sugar cane, come to mind. Some combination of these could have buffered *Homo erectus* against environmental change, as long as lowland forest were available.

Still, it is unclear whether *Homo erectus* (1) was a dietary specialist or a generalist, (2) concentrated on plant foods or animals, (3) had a universal diet or included groups that lived on various combinations of food, (4) used the same resources throughout the Quaternary or changed them from time to time. Answers to these questions will impact theories of human evolution greatly, and influence our understanding of our distant biological and cultural heritage. Without such answers, placing early humans in a single biotope, such as a savanna, and endowing them with little culture presumes a "primitive" state that is not demonstrated.

It may be a surprise to learn that such a range of alternative interpretations of early human behavior would still be possible after as much scientific research as has been done on our distant ancestors. Early human fossils have been recognized and studied for over a century. And the record of Plio-Pleistocene humans started with the 1891 discovery by Eugene Dubois at Trinil, only 60 km east of Sangiran.

What explains the slow pace of scientific advance in understanding early human ecology and behavior? A partial explanation lies in the limited, often fragmentary human fossils that one finds in Plio-Pleistocene age deposits. In Java, for instance, the vast majority of the human fossils are fragments of skulls, jaw bones, or teeth. Long bones, such as the shafts of femurs, are discovered in small numbers. The original *Homo erectus* fossils from Trinil, for example, are just a skullcap and partial thighbone. By no means do Plio-Pleistocene remains look like the skeletons that have been found in the human burials of the last 10,000 years or so.

One East African site (Nariokotome) did yield an Early Pleistocene skeleton of a *Homo erectus*-like individual in the mid-1980s. This is the most complete (40%) set of early hominid skeletal remains found anywhere. In order to recover the scattered fossils of this one individual, over 1,500 tons of earth had to be excavated and sifted by hand. The reconstructed Nariokotome skeleton nevertheless is dramatic substantiation of inferences made as long ago as the 1890s by Dubois that the main skeletal differences between humans of the Plio-Pleistocene and modern *Homo sapiens* are the shape of the cranium (largely, a lower, smaller brain case) and the thickness of the bones. The Nariokotome fossils are the remains of young boy, estimated to have been a 160 cm and 48 kg 10 to 12 year old when he died. His body, but not his skull, was quite modern in form and size.

Stone tools have been found with early human fossils in Africa, Europe, and China. The tools indicate a cultural side of Plio-Pleistocene humans that we otherwise might not suspect. Few implements have been discovered *in situ* in Java. Artifacts were found for many decades on the surface but none in the hominid formations. In the 1990s, however, chipped-stone cutting or chopping tools and stone hammerstones,

including spheroids and polyhedric shapes, were recovered from the Pleistocene Kabuh beds at Sangiran Dome (Ngebung site).

The rarity of stone implements in the hominid beds of Java led some archaeologists to believe some years ago that *Homo erectus* was somehow less intelligent in Southeast Asia than elsewhere. Conclusions of this kind are not warranted. Differences in the technology of modern human groups, for example, do not indicate differences in their intelligence. Sophistication with tools is therefore not necessarily a measure of intellect in ancient human species. Furthermore, stone tools survive in geological contexts where tools made of perishable materials, such as wood, do not. *Homo erectus* in Java, for example, might have used bamboo and rattan tools that quickly vanished from the geologic record, while early humans elsewhere made implements of lithic raw materials that survived burial and remain intact indefinitely. Even where lithic tools are abundant, the people who made them might have constructed many more objects out of perishable materials. In sum, finding no artifacts does not necessarily mean an absence of human presence or cultural sophistication.

Recently, late Early Pleistocene stone tools have been reported from Flores Island, 600 km east of Java. The reports encourage the view that *Homo erectus* was even more of an explorer than previously thought.

If the limited amount of Plio-Pleistocene human fossils and stone tools hinders paleoecological and behavioral understanding of early humans, what light can the other fossil material in the hominid beds, or the nature of the deposits themselves, shed on these issues? The *Homo erectus*-bearing formations, such as the mudstones (Pucangan Formation) and sandstones (Kabuh Formation) at Sangiran Dome, not only give us information about the paleophysiography and surface conditions of *Homo erectus'* homeland but also are rich in large mammal skeletal remains and plant fossils, such as pollen and leaf imprints, with which to infer biotic conditions.

The principal geologic evidence for each of the seven physiographic elements listed above is as follows (Figures 1 & 2): (1) **Axial volcanoes** are indicated by the volcaniclastic facies that comprises much of the hominid formations and their equivalents in eastern Java; the presence of a huge Plio-Pleistocene volcano at **Mt. Wilis** in the midst of the hominid area is indicated by the volcanic breccias (reportedly lahar deposits) that occur for a distance of 140 km along the south side of the Kendeng Hills (Trinil to Mojokerto, approximately), including several hundred meters of breccia that crops out near Mt. Wilis/Pandan on the apparent flank of the volcano. (2) **Nonvolcanic uplands** -- the sand and gravel that were derived from limestone and marl, the thinning of the Plio-Pleistocene sequence towards the central Kendeng Hills and the Rembang (Tuban) Hills, and the need to separate the volcaniclastic facies on the south side of the Kendeng Hills from a muddy marine facies on the north side. (3) **River courses** -- the fluvial deposits that contain vertebrate, nonmarine mollusk-, and plant-fossils and typify the Kabuh Formation and portions of the Pucangan Formation. (4) **Lowlands** -- the interfingering of fossiliferous volcaniclastic sediments and marine mudstone near Mojokerto (Mojokerto delta plain), and the fossil-rich Pucangan lagoonal and lacustrine mudstones exposed at Sangiran Dome and several other spots in the Solo basin (fringes of the lagoon and lake). (5) **Muddy marine shorelines** -- the mudstone equivalents of the hominid-bearing formations that occur north of the Kendeng Hills, on Madura Island, and under the modern Madura Strait. (6) **Volcanic**

coast -- the scattered evidence of Early Pleistocene volcanic rocks and marine sediments along the southern coast of the Madura Strait in easternmost Java. (7) **Open-ocean coast along the Indian ocean** -- the rapid deepening of the continental shelf and slope south of Java and the long time that the tectonic regime responsible for the bathymetry was active during the late Cenozoic. Palynological studies of the hominid beds support the presence of volcanic mountains and lowland features such as mangroves and swamps.

At Sangiran Dome, the mudstones (Pucangan) are lagoonal and lake deposits, and the sandstones (Kabuh) represent ancient river beds. Tuffs occur at many horizons, indicating active volcanism. Also a prominent laharic deposit is found at the base of the Pleistocene at Sangiran; the unit is exposed at the Sangiran Museum and contains vertebrate remains as well as shelly fossils. The sands and associated gravels of the younger Kabuh Formation are mostly volcanic debris, reflecting the presence of volcanic edifices such as Mt. Lawu. The sediments also include nonvolcanic clasts from the limestone and marl terrains to the north (Kendeng Hills) and south (Southern Mountains) of the Solo basin.

The lagoon and lake stretched for an east-west distance of 35 km or more during the earlier part of the time span that the region was inhabited by *Homo erectus*. Thick soils and vegetation apparently blanketed the surrounding hills because little coarse sand and gravel made its way into the basin. This was not the case everywhere in eastern Java at the time; voluminous amounts of sand and gravel were laid down around Mt. Wilis (Figure 2). Most of the early human fossils at Sangiran Dome have been found in fluvially dominated Kabuh Formation, which overlies the lacustrine Pucangan. Apparently, new tectonic activity fostered bedrock exposure and rapid erosion in the volcanic and nonvolcanic uplands surrounding the basin during the deposition of the fluvial beds.

The new conditions dramatically altered the landscape in Solo area on the whole. *Homo erectus* apparently did well in both sets of conditions. Other fossil occurrences support the impression that Plio-Pleistocene *Homo erectus* lived in a variety of settings, but none of the evidence is conclusive. The Trinil fossil was deposited in fluvial sediment also but the age of the deposit is poorly determined. The Mojokerto fossil apparently predates the human remains in the mudstones of Sangiran and lived at a time when marine conditions still prevailed at the Dome (Kalibeng Formation). Although it came to rest in a nearshore marine environment, the Mojokerto *Homo erectus* inhabited either the coarse clastic delta plain, the banks of the gravely river upstream of the delta, or the volcanically disturbed and rapidly eroding flanks of a large volcano.

The uncertainty in these interpretations largely arises because the human fossils, like most of the other Plio-Pleistocene vertebrate fossils in eastern Java, were transported before deposition. As a result, little direct evidence of human habitation has been found. One archaeological excavation that was carried out during the last decade in the Sangiran area (Ngebung) reportedly has exposed a human habitation surface with stone tools. *Homo erectus*, therefore, can be placed in the basin when it was dominated by sandy and gravely river courses. The presence of early humans in other parts of the terrain must be inferred. The presence of *Homo erectus* along the shores of the lagoon and lake that preceded the riverine phase is assured because of the numerous human fossils found in the (Pucangan) mudstones.

Evidence documenting habitation outside lowlands is not available now and may never be. The compactness of *Homo erectus'* homeland (Figure 2) nevertheless permits the assumption -- a preferred working hypothesis -- that early humans inhabited or frequented all ecologically attractive land areas in eastern Java.

What potential foods did the land provide? What animals might early humans have hunted or scavenged? The best general listing of the large-bodied animals that inhabited the early *Homo erectus* landscape comes from the "Jetis Fauna." This fossil assemblage appears to be older than (or as old as) any in the hominid-bearing formations. It dates to about 1.8 million years ago, based upon K-Ar and $^{40}Ar/^{39}Ar$ radiometric results. The fossils were collected at a number of localities near the Mojokerto hominid sites, at the east end of the hominid belt near Surabaya. Nearly all the same genera are found at Sangiran Dome.

The primates recorded are hominid (*Homo*), orangutan, gibbon, macaque, and leaf monkey. Carnivores are tiger*, leopard*, large-tooth cat, hyena, wild dog*, sun bear*, otter*, and civet*. Elephantids include both elephant* and Stegodon. Ungulates are hippopotamus, rhinoceros*, tapir*, pig*, Asian buffalo*, wild cattle (banteng)*, an endemic ox, antelope, several species of deer*, muntjak*, and mouse deer*. Anteater*, turtle*, crocodile*, and fish* also occur. Porcupine*, rabbit*, rat*, and several bird* genera are known from other localities in the hominid-bearing formations. The fauna of Java lacked horses, camels, and giraffes -- elements common in Eurasia. The Javan assemblage is typically Southeast Asian, comprising mostly genera, although not species, that continued to inhabit Java throughout the Quaternary and in some cases still live in the region (indicated by *s). These genera occur widely in lowland ever-wet forests, but some are equally at home or more abundant in drier biotopes.

One striking aspect of the terrestrial fauna of Java is its similarity from age to age over the last 1.8 million years or more. Cattle, deer, pigs, elephants, rhinoceros, tigers, monkeys, etc. inhabited Java with humans 1.7-1.8 million years ago and in the Holocene. Were these large mammals *Homo erectus* food? The meat and bone of some, such as the wild cattle (bantengs) discussed above, are certainly candidates for early human dietary staples. Cattle fossils are abundant in Mesolithic (late preagricultural) archaeological sites in eastern Java, providing evidence that *Homo sapiens* found cattle an important food in the Holocene forests of Java. Perhaps, *Homo erectus* did also.

What other sources of food might *Homo erectus* have found in medial eastern Java? Smaller terrestrial mammals are greatly underrepresented in the reported collections of Plio-Pleistocene vertebrate fossils when compared to living faunas. Small mammals nevertheless would have populated the homeland forests of *Homo erectus*, and therefore must also be considered an abundant potential dietary resource. The remains of aquatic and semiaquatic animals, such as mollusks, fish and turtles, also are present in the fauna. They suggest other readily available animal foods. Perhaps, *Homo erectus* sometimes lived off river mollusks and turtles.

Less is known of the plants that *Homo erectus* might have eaten. One study of surface wear on *Homo erectus* teeth suggests, however, that tough plant foods were important in the diet. Despite there being several studies of the Plio-Pleistocene flora of eastern Java, but not much about edible plants has been published. Temporal

continuity is evident in the botanical record of eastern Java as it is in the mammalian record. Many of the elements of modern mangrove, swamp, lowland-rain, lowland-deciduous, montane, and disturbed (i.e., by volcanism) forests are found in palynological samples at Sangiran Dome and elsewhere in the Plio-Pleistocene sequence. Perhaps the ancient and modern records can be used together to determine what edible plants are likely to have been within the grasp of *Homo erectus*. During times when lowland rain forests were widespread in Java, so too would have been fruit- and nut-bearing trees, as well as forest tubers or other edible vegetables. Yams and palm pith are important staples for some indigenous forest people. Some rain forest fruits are commonly eaten throughout the region; *Durio* (durians), *Nephelium* (rambutan), *Artocarpus* (jackfruit and breadfruit), *Mangifera* (mangos), and *Ficus* (figs) are examples. If present during the Plio-Pleistocene in Java, plants of the forest could have offered *Homo erectus* abundant food resources.

Long-term continuity is evident in landform (Figure 2), large mammals, and trees in the *Homo erectus* homeland. This suggests that a critical relationship existed between early human ecology and the particular environmental setting of eastern Java. Hypotheses based on reasoning of this kind might emphasize the advantages offered by diverse sources of food, mentioned above, and high biotic output from the landscape. The soils that supported the high productivity might have been enriched by periodical explosive eruptions of andesitic volcanoes and the hot, wet, seasonal climate of eastern Java. The latter elements of the modern ecology of Java are used to explain the high agricultural production and extraordinary population densities in the areas around the axial volcanoes of Central and East Java. One might suppose that *Homo erectus* was widely distributed in Southeast Asia but lived more densely around some of the volcanoes of Java than they did in places where no volcanoes existed or the climate was ever-wet.

Much of the debate that has taken place about the early human environment in Java has focused on whether *Homo erectus* favored a habitat that was forested or not (in which case it was a drier biotope, such as open woodland or grassland). Savanna environments have been associated with our distant ancestors in various scientific theories since the time of Darwin. On the other hand, rain forests are the typical vegetation in Southeast Asia. The question of past vegetation patterns in Java remains unresolved. Forests of many kinds certainly existed during the Plio-Pleistocene. Grassy vegetation (possibly including bamboo and swamp grasses) is represented in palynological samples by nonspecific pollen. However, it remains undetermined what types of grasses were present and how much of the landscape, if any, was dominated by grasslands. Whatever the principal vegetation, the complexity of the paleophysiographic picture (Figure 2) suggests that forest and savanna resources were only part of those that early humans could have exploited.

The sea coasts of Plio-Pleistocene Java, in particular, hint at the diversity of habitats and food resources that would have been available to *Homo erectus*. The coasts north of the axial volcanic belt (Figure 2) included low relief, muddy shorelines that doubtlessly were fringed with mangrove forests. The pollen of mangrove trees not only is a consistent part of the pollen record of the hominid-bearing formations of eastern Java but is a floral component in deposits representing many millions of years in Southeast Asia. Modern mangroves are rich in crabs, snails, and bivalves -- animals available for gathering. Snakes, monitors, lizards, frogs, monkeys, small otters, bats, and both nesting and migratory birds are potential hunting targets. A different

assemblage of shoreline resources was likely to have been available along Java's south coast, assuming a Plio-Pleistocene geologic situation similar to the modern one. Extensive sandy beaches are found today along some stretches of the south coast. Sea turtle eggs and hatchlings, if not the adult animals, afford a periodic and abundant opportunity for human food. Beach forests occur locally where bantengs, deer, monkeys, bats, monitors, and turtles live much as they do at inland locales. Elsewhere, cliffs occupy the southern coast. Colonies of seabirds, such as boobies, terns, and tropic birds, indicate the possibility of easily gathered food.

Evidence of this kind suggests that virtually every corner of the landscape envisioned for *Homo erectus* (Figure 2) held food resources that early humans might have used. Distant ancestors of modern humans therefore might have exploited all the montane, upland, riparian, and coastal biotopes available in Java, less intensely than modern Indonesians do but with geographical coverage as complete. If Plio-Pleistocene *Homo erectus* possessed the ability to adjust dietary behaviors to meet this broad spectrum of circumstances, then fewer behavioral differences exist between early and more modern humans than is usually supposed. Perhaps nowhere else in the world is it easier to see this aspect of humanity's distant past than in eastern Java and particularly at Sangiran Dome.

What foods early *Homo erectus* actually ate, whether the erectines talked or only gestured, how they were organized socially, what intellectual life they had, and how they dealt with the environmental changes that took place over the decades and millennia in Java are questions that future discovery and study will begin to answer. Whatever the course of paleoanthropological research around the world, the record of Plio-Pleistocene paleoenvironmental diversity in Java, exemplified by the geological sequence and human fossils at Sangiran Dome, should contribute substantially to understanding our past.

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http://www.csus.edu/anth/physanth/ancestor.htm [Course on human evolution]

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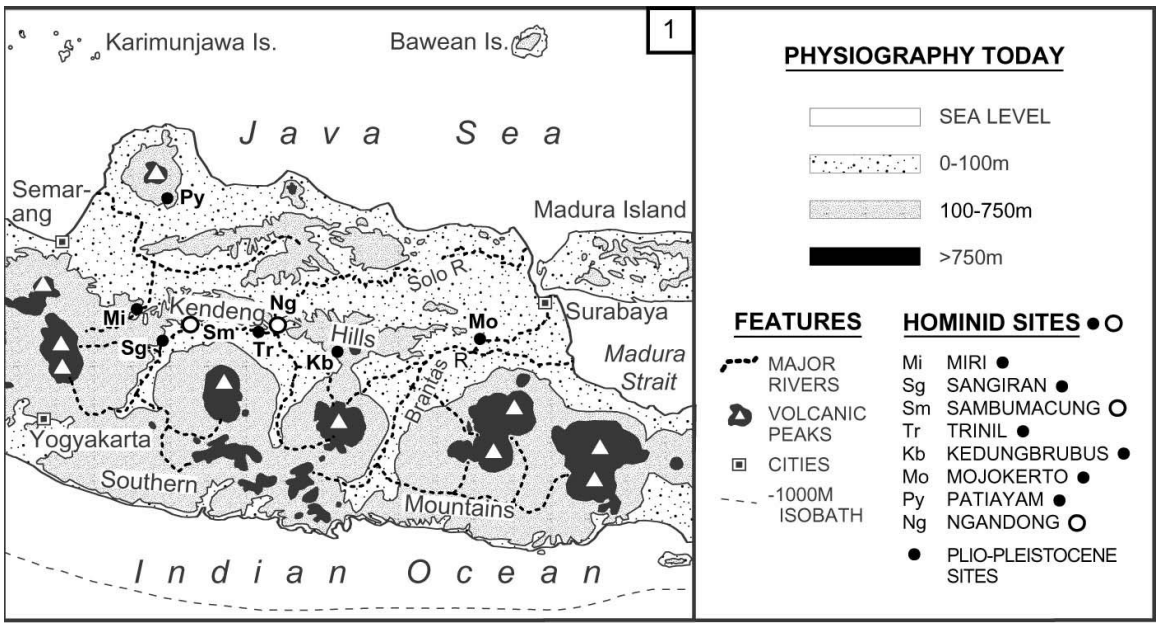

Figure 1: Geologic map of eastern Java, highlighting the formations that contain Plio-Pleistocene *Homo erectus* fossils, such as those at Sangiran Dome (Sg). Other labeled localities are Trinil (Tr) and Mojokerto (Mo). The Ngandong site lies northeast of Trinil, the Sambungmacan locality is between Trinil and Sangiran, and Kedung Brubus lies between Trinil and Mojokerto.

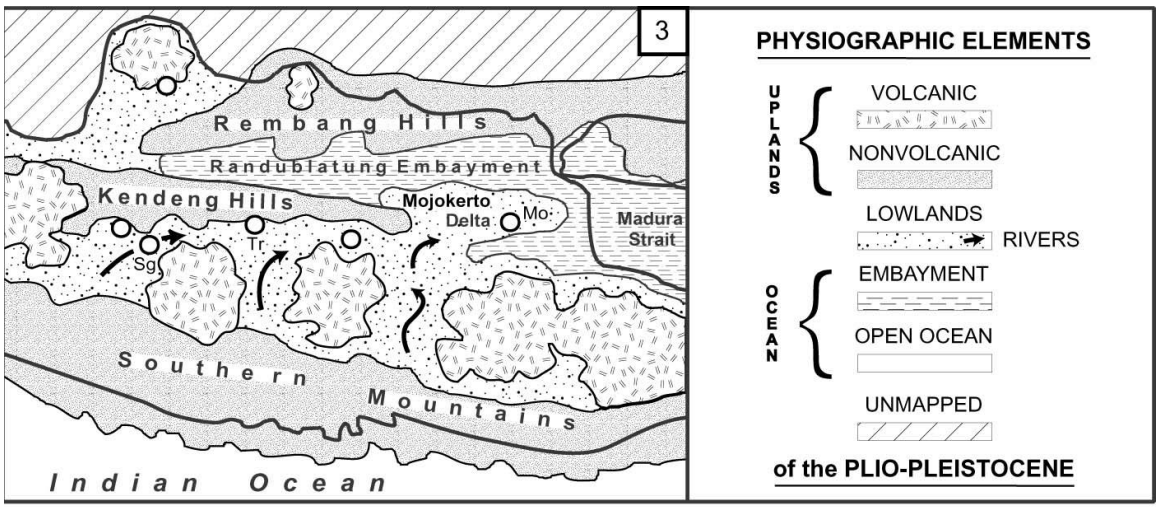

Figure 2: Plio-Pleistocene physiographic model of the homeland of *Homo erectus*. Hominid sites are same as in Figure 1, but the Late Pleistocene Ngandong locality is omitted.