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Evolution

# Evidence on the age of the Asian Hominidae

(human evolution/*Homo erectus*)

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**ABSTRACT** **A number of separate lines of evidence indicate that all of the known Asian hominids are less than 1 million years old. A review of paleontologic, radiometric, and paleomagnetic data strongly supports this conclusion. This more recent age estimate provides important implications about the taxonomy and paleocultural adaptations of the early Asian hominids. All of the early Asian hominids can be accommodated in the taxon *Homo erectus*. This hominid species is associated in Asia with non-Acheulian cultural contexts, which may indicate substantial dependence on a sophisticated nonlithic technology.**

An appreciation of the antiquity of the early Asian hominids (demonstrably habitual bipedal hominoids) is of paramount importance to our understanding of the course of human evolution as a whole. For decades, accurate estimates of the antiquity of the Asian hominids have been impeded by overly simplistic biostratigraphic schemes, the lack of adequate provenience for hominid specimens, and a paucity of radiometric dates. In spite of these difficulties, many workers have accepted the supposed occurrence of Asian hominids in basal Pleistocene [*ca.* 1.8 million years ago (MYA)] sediments. However, on the basis of a recent analysis of both past and newly collected data, it is now apparent that the earliest known Asian hominids are less than 1 million years old (Fig. 1). This conclusion is supported by a large body of paleontologic, stratigraphic, paleomagnetic, and radiometric evidence. In addition to being of intrinsic importance, this more recent dating also alters many previous taxonomic and paleoecological interpretations of the fossil record of the Asian Hominidae. It now seems fairly certain that all of the known early Asian hominids represent the single taxon *Homo erectus*. Furthermore, the Far Eastern (Southeast and East Asia) members of this taxon are associated with non-Acheulian cultural contexts, which are suggestive of extensive dependence on a nonlithic technology.

Indonesia and China have afforded the earliest evidence of the Asian hominids. The Indonesian hominids have been assigned to a number of taxa (1–4), some of which have been accorded an earliest Pleistocene age. Chinese hominids, with the exception of a few isolated teeth, have usually been allied with "*Sinanthropus pekinensis*" (5). Until recently, the earliest Indonesian hominids (from eastern and central Java) have usually been considered to be substantially older than the earliest known Chinese hominids.

## Indonesia

Estimates of the age of the early Javanese hominids were originally based in ill-defined lithostratigraphic (6–8) and overly simplistic biostratigraphic (9–11) subdivisions that failed to recognize the complex nature of Javanese stratigraphy. Von Koenigswald's subdivisions encompassed a number of local faunas whose elements frequently lacked provenience. Despite this fact, many workers continue to recognize distinctions between a Plio-Pleistocene, Siva-Malayan "Djetis fauna" (Pucangan Formation); a middle Pleistocene, Sino-Malayan "Trinil fauna" (Trinil and Kabuh Formation); and a late Pleistocene "Ngandong fauna" (Notopuro Formation). Furthermore, until recently very few workers (but see Hooijer, refs. 12 and 13) have objected to von Koenigswald's contention (14) that key early and middle Villafranchian faunal elements have been recovered from Java. Recent biostratigraphic studies in Java have not only failed to support von Koenigswald's contention, but they have also indicated that the Trinil Fauna is actually the same age [unpublished report of The Indonesia–Japan Cooperation Survey Team (1978); ref. 15] or older (16, 17) than the Djetis fauna. De Vos *et al.* (17) have argued that the Trinil assemblage represents a highly endemic and impoverished assemblage that lacks a number of mainland Asiatic species.

These elements could only have reached Java by means of the infrequently exposed Sunda Shelf. The effectiveness of even the exposed Sunda Shelf as a faunal filter is indicated by the complete absence of open dwelling forms such as camelids, equids, and giraffids. It now appears that the Sunda Shelf has been exposed only briefly during the last 3 million years. After reviewing a diverse body of micropaleontological and sedimentological data from deep sea cores, Berggren and Van Couvering (18) have concluded that maximal periods of cold (and thus maximal exposure of continental shelves such as the Sunda) occurred approximately 3 MYA, 1.25 MYA, and 0.65–0.45 MYA. It is important to identify periods of *maximal* exposure because the Sunda Shelf was largely a swamp and forest enviroment during the Pleistocene, which was probably similar to present-day eastern Sumatra (19). No evidence suggests an open woodland savanna as some workers (20, 21) have argued. Exposures that occurred 1.25 MYA and 0.65–0.45 MYA are most likely to have provided the opportunities for the migration of both hominids and other Pleistocene mammals recovered from the hominid-bearing sediments in Java. The bulk of the radiometric data considered below suggests that hominid migration may have occurred during this latter period.

A number of recent radiometric dates have done much to clarify the absolute age of the hominid-bearing sediments in Java. On the basis of dates obtained from tektites recovered from the base of the Notopuro Formation, Ninkovich and Burckle (22) have suggested an age of approximately 0.7 MYA for the Kabuh–Notopuro boundary. However, it is now clear that tektites have frequently been redeposited in younger sediments (22, 23). The Ngandong fauna (including the Ngandong hominids) is also probably redeposited in younger sediments.

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Abbreviation: MYA, million years ago.

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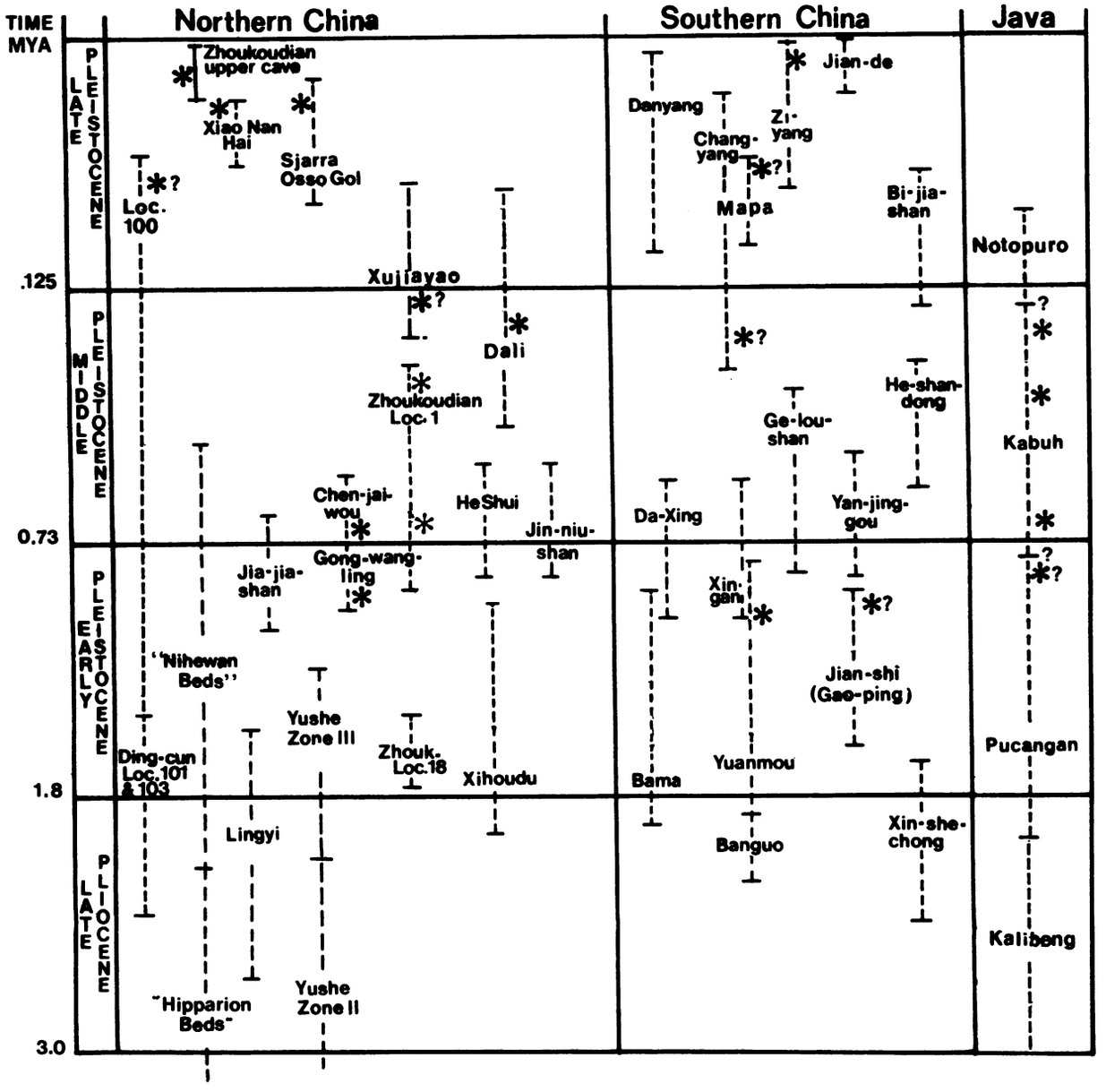


FIG. 1. Tentative correlation of Chinese faunal localities and Asian hominids. *, Hominid; position, probable age.

Other radiometric dates indicate that the Kabuh Formation is substantially younger than 0.7 MYA. Zircons have yielded fission track ages of approximately 0.48 MYA for the uppermost Kabuh tuff and 0.58 MYA for the uppermost Pucangan tuff (24). Bartstra *et al.* (25) have reported K-Ar dates of approximately 0.5 MYA for samples from the Pucangan Formation. These dates also agree with those reported by Nishimura *et al.* (26). Fission track dates (mean ± SD) of 0.57 ± 0.03 MYA and 0.67 ± 0.04 MYA have been reported for Pucangan tuffs and dates of 0.47 ± 0.02 MYA and 0.50 ± 0.04 MYA have been reported for Kabuh tuffs. von Koenigswald also reported dates of approximately 0.5 MYA and 0.6 MYA for a tuff from the Mt. Muriah region, which overlies "typical Trinil" fauna (27).

In the past 10 years an earliest Pleistocene age for some Javanese hominids has been based largely on a single K-Ar date of 1.9 ± 0.4 MYA reported by Jacob and Curtis (28). Originally this tuff sample was reported as deriving from just below the level of the second "*Meganthropus*" specimen (Sangiran 8). Later the report was corrected and the sample was reported as deriving from just below the level of the "*Homo modjokertensis*" type specimen (Perning 1) (29). Both of these hominids supposedly derive from a level just below the boundary between the Pucangan and Kabuh Formation (the "Grenzbank") (30, 31). G. H. Curtis (personal communication) has stated that the tuff sample actually derives from approximately 400 meters below the Notopuro Formation, apparently with the sands and conglomerates of that formation. This date has little bearing on the age of either Sangiran 8 or Perning 1 and, at any rate, is of poor quality due to a very high content of atmospheric argon. Additionally, as with other type specimens from Java ["*Pithecanthropus dubius*" (Sangiran 5), "*Pithecanthropus robustus*" (Sangiran 4), and "*Meganthropus palaeojavanicus*" (Sangiran 6)], *Homo modjokertensis* cannot be shown to have been recovered *in situ*. Where excavations have been conducted, hominids have been recovered only from middle Pleistocene (0.73–0.125 MYA) sediments.

Thus, on the basis of the vast majority of radiometric dates, an age of 0.5–0.8 MYA seems the most reasonable estimate for the age of the earliest known Indonesian hominids. There is no evidence for attributing an age of greater than 1 MYA to any

of the known Javanese hominids. Additionally, the radiometric data agree with Semah's *et al.* (32) preliminary report of a paleomagnetic event at the top of the Pucangan Formation. Though recognizing that this event may represent the Jaramillo Normal interval, these workers feel that it is probably correlated with the Matuyama–Brunhes boundary.

## China

Five localities (Yuanmou, Xihoudu, Jian Shi, Lantian, and Zhoukoudian) have yielded the principal evidence for the earliest Chinese hominids. All of these localities, except Jian Shi, preserve evidence of fire. No hominids have been recovered from Xihoudu, but an early cultural association is documented there.

On the basis of biostratigraphy and paleomagnetic stratigraphy (33), two hominid incisors belonging to the same individual (34, 35) have been assigned an age of approximately 1.7 MYA at Yuanmou. However, it is clear that a correlation of the hominid-bearing sediments with the reversed interval post dating the Jaramillo Normal interval (Fig. 2, right side) is much more in accord with the world wide geomagnetic polarity scale than the correlation of Li *et al.* (33) (Fig. 2, left side). The only discrepancy arises in the recognition of four normal events preceding the Olduvai Normal interval. However, the recognition

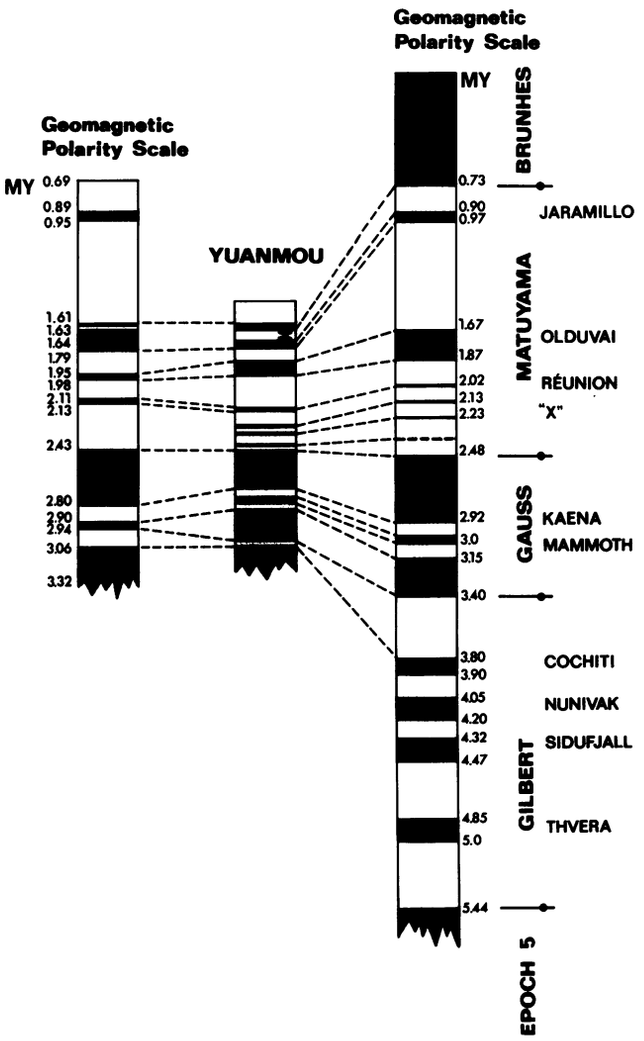


FIG. 2. Paleomagnetic stratigraphy of Yuanmou. Geomagnetic polarity scale from ref. 33. MY, million years. *, Hominid.

of these events at Yuanmou are in perfect agreement with the paleomagnetic stratigraphy of the Omo Basin in Ethiopia (36). The reversed interval at the top of the Yuanmou column has been suggested on the basis of inadequate data (33) and cannot be substantiated.

The biostratigraphy of Yuanmou does not compel a dating of 1.7 MYA (37) and is fully in accord with an age of less than 0.9 MYA for the hominid. The morphology of the hominid incisors themselves indicates an affinity with Zhoukoudian homologues (34, 35), which are middle Pleistocene in age.

At Jian Shi (Gao Ping), Hubei, three hominid molars have been recovered from a karst cave in association with *Gigantopithecus* and other mammals (38). Despite the fact that the hominid specimens were originally considered to be of early Pleistocene age this unique association of *Gigantopithecus* and hominids may be as late as the early middle Pleistocene. Gao (38) originally assigned the hominid specimens to *Australopithecus* cf. *africanus*, but these specimens are more appropriately assigned to *Homo* sp. (39). As with the Yuanmou fauna, the associated Gao Ping fauna does not compel the assignment of a lower Pleistocene age.

Xihoudu and Shanxi have yielded artifacts and traces of fire in association with a presumably early Villafranchian equivalent mammalian assemblage (including *Equus*, *Hipparion*, *Leptobos*, *Elephas planifrons*, and *Elephas namadicus*) (40). Although similar associations have been reported in other parts of Eurasia (41, 42) and Africa (43), such an association has never been confirmed in China (44). Xihoudu probably represents a time trangressive "mixed" assemblage. The artifacts from Xihoudu are heavily rolled and abraded and it is likely that they have been redeposited along with some of the faunal elements (e.g., *Elephas namadicus*) in older sediments.

Lantian (Gongwangling and Chenjiawou) and Zhoukoudian (Locality 1) both record the presence of hominids in sites that span the Brunhes–Matuyama boundary (45, 46). The Gongwangling cranium (47) occurs stratigraphically lower than the Chenjiawou mandible (48) in sediments of reversed polarity. The mandible occurs in normal sediments (45). The Brunhes–Matuyama boundary is also recorded at Zhoukoudian, but all of the hominid finds have been made well above this level. Thus, none of the hominids from these localities are earlier than middle Pleistocene or latest early Pleistocene.

## The absolute age of the Asian hominids

Many lines of evidence show that the Asian hominids are all less than 1 million years old. The bulk of Javanese hominids seem to be less than 0.8 MYA. It is now apparent that the old biostratigraphic divisions and their supposed temporal framework should be abandoned as a means of assessing the age of the Indonesian hominids. Radiometric evidence and paleomagnetic data provide far more reliable criteria for assessing the true antiquity of the earliest known Asian hominids. These data all but rule out an earliest Pleistocene age. A more recent dating for the Asian hominids has important implications for taxonomic and even paleocultural interpretations of the hominid record in Asia. These are considered below.

## Taxonomic implications

Although strict morphologists and "phenetic purists" tend to oppose any consideration of temporal frameworks in taxonomic decisions, most paleoanthropologists would be extremely unwilling to recognize more than one species of synchronic and sympatric hominid in Asia if all of the Asian hominids are less than 1 million years in age. The possibility of this situation was

originally introduced not as the result of rigorous scientific arguments but rather as the result of informal classificatory approaches, diplomatic considerations, and logical polemics. Thus Weidenreich (4) described *Meganthropus* (from a cast representing a fragmentary and quite possibly pathological individual) as an informal orthogenetic stage of hominid evolution. *Homo modjokertensis* (3) was erected solely as an attempt to placate Dubois' seemingly unreasonable opposition to the inclusion of any subsequent finds in "*Pithecanthropus*" (49). The possibility of Asian australopithecines was promulgated by Robinson's original attempts (50, 51) to convince the scientific community that australopithecines must be considered hominid if *Meganthropus* was also hominid. The view that australopithecines are represented in Asia is not supported by the fragmentary materials that have been assigned to "*Hemanthropus*" (52, 53) and other specimens that have been assigned to *Meganthropus* (30, 54).

In spite of these considerations subsequent workers have continued to suggest that fundamentally different grades and clades of hominids are to be found among the Asian Hominidae (55). Recognition of a more recent age for these hominids may also go a long way toward clarifying the currently unresolved question of synonomy of *Homo modjokertensis* and *Homo habilis* (55).

Finally, in regard to taxonomy, recent discoveries at Hadar and Laetoli (56, 57) have done much to document the great range of size and sexual dimorphism that is to be expected in early groups of hominids. In view of these considerations there is no reason to include any of the early Asian hominids (including Ngandong) in any taxon other than *Homo erectus*. Although the inclusion of Ngandong hominids is somewhat arbitrary, it underscores the observation that the morphology of this group represents a variation of the same *Homo erectus* "bauplan" (58).

## Paleocultural implications

The revised dates for the Asian hominids also suggest a very parsimonious explanation of the nature of Asian paleolithic assemblages. The distinction between Acheulian assemblages (with "hand-axes" and "cleavers") and the "chopper-chopping tool" complex (in which these elements are rare) of East and Southeast Asia has many times been attributed to the position of the Far East as an "isolated cultural backwater" (59–63). Some workers have emphasized the possible existence in Asia of an extensive nonlithic (and therefore nonpreservable) technology (64, 65). An extensive nonlithic technology becomes more or less plausible depending on the antiquity that one attributes to Asian cultural assemblages.

Previously, I have suggested (37) a "bamboo-karst" model. Bamboo is widespread throughout the karst environments of East and Southeast Asia. Furthermore, I have emphasized the fact that bamboo is a highly versatile raw material from which any artifact except heavy and light chopping tools can be manufactured. The use of bamboo in conjunction with other nonlithic materials constitutes a highly portable technology that may have arisen as a specific adaptation to the heavily forested areas of Southeast Asia. Such a technology need not have been abandoned as hominids spread into the more open areas of China. The widespread evidence of fire at early Chinese sites [and at least one locality in Southeast Asia (66)] also supports this hypothesis as fire is an important part of a woodworking forest technology. The presence of karst features (which are much rarer in South Asia) would have provided a familiar "archipelago" of exploitable resources (e.g., caves, springs, game, and bamboo) for hominids whether they were encountered in Southeast Asia or China. The presence of more open adapted fossil mammals in South Asia as well as the present distribution of trees (67) and grasses (68, 69) indicates a marked contrast between the Pleistocene habitats of South and Southeast Asia. The differential distribution of Acheulian assemblages is also consistent with such a contrast in habitat distribution. Thus, instead of implying that the Far East was an isolated cultural backwater, the archeological and biogeographic data actually suggest the possibility that a well-established and sophisticated nonlithic technology was characteristic of this area of the world during the Pleistocene. A high degree of sophistication becomes even more probable if all the known Asian Paleolithic assemblages postdate 1 MYA.

## Conclusion

A diverse body of evidence strongly suggests that past interpretations of the antiquity and taxonomy of the Asian Hominidae should be revised in favor of the view that all of the earliest Asian hominids can be accommodated in the taxon *Homo erectus*, which is unknown before 1 MYA in Asia. New radiometric and paleomagnetic data strongly support this conclusion. Furthermore, the Ngandong hominids should also be included in *Homo erectus*. Thus, the entire record of *Homo erectus* in Asia may only span a period of approximately 600 thousand years (i.e., from 0.9–0.3 MYA). Such an estimate may be in error by 100 thousand years or so; nonetheless, this estimate underscores my contention that it is extremely difficult to cite the Asian hominid record as evidence for long periods of morphological stasis.

A more recent dating also suggests a parsimonious interpretation of the Asian Paleolithic record as a specific adaptation to Far Eastern habitats that were different than those occupied by early hominids in other parts of Eurasia and Africa. Specifically, early Asian cultures quite possibly relied heavily on an extensive and sophisticated nonlithic technology that arose in response to tropical forest habitats.

It is important to realize that we should no longer rely on the antiquated taxonomic categories, simplistic archeological interpretations, and the unsupported temporal frameworks that have gained acceptance over the last 50 years. Instead, we must realize that the ultimate resolution of the nature and scope of hominid evolution in Asia will only be possible through the critical analysis of new data collected in a rigorous scientific framework.

**Note Added in Proof.** Recently, Matsu'ura (70) has provided further valuable evidence and discussion relevant to the age, relative and absolute, of Javanese Pleistocene hominids, with particular reference to the Sangiran anticline. A number of such specimens (including 3, 12, and 17) definitely derive from the middle-upper Kabuh Formation, in the final part of the Matuyama chron. Other specimens (including $1_b$, 2, 4, and 6) derive from the basal conglomerate (Grenzbank) of the Kabuh Formation and have an age most probably younger than, or as old as, the Jaramillo (Normal) event within the Matuyama chron. Conceivably, but uncertainly, the Sangiran 5 specimen (holotype of "*Pithecanthropus dubius*" von Koenigswald) *may* have derived from the same horizon or the uppermost part of the Pucangan Formation and thus be of similar or slightly older (1.1–1.3 MYA) age. The author's evaluation of the evidence for the age span of the Javanese hominids independently reaches conclusions essentially identical to my own as set forth here.

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1. Dubois, E. (1894) *Jaarb. Mijnwezen Nederlandsche Oost-Indie* **24**, 7–77.

2. Oppenoorth, W. F. F. (1932) *Wetenschappelijke Mededeelingen, Dienst Mijnbouw Nederlandsch-Indie* **20,** 49–75.
3. von Koenigswald, G. H. R. (1936) *Der Ing. Nederlandsch-Indie* **8,** 149–157.
4. Weidenreich, F. (1945) *Anthropological Papers, American Museum of Natural History, New York,* Vol. 4, pp. 1–143.
5. Black, D., Teilhard de Chardin, P., Young, C. C. & Pei, W. C. (1933) *Memoirs of the Geological Survey of China, Peking,* Vol. 11.
6. Dubois, E. (1895) *Bull. Soc. Belge Geol. Paleontol. Hydrol.* **9,** 151–160.
7. Dubois, E. (1908) *Tijdschrift Koninklijk Nederlandsch Aardrijkskundig Genootschap, Leiden* **25,** 1235–1270.
8. Verbeek, R. D. M. & Fennema, R. (1896) *Geologische beschrijving van Java* (Madioen, Amsterdam).
9. von Koenigswald, G. H. R. (1933) *Wetenschappelijke Mededeelingen, Dienst Mijnbouw Nederlandsch-Indie* **23,** 1–28.
10. von Koenigswald, G. H. R. (1934) *Der Ing. Nederlandsch-Indie* **1,** 185–201.
11. von Koenigswald, G. H. R. (1935) *K. Akad. Wet. Amsterdam, Proc.* **38,** 188–198.
12. Hooijer, D. A. (1952) *K. Akad. Wet. Amsterdam, Proc.* **55,** 436–443.
13. Hooijer, D. A. (1957) *Zool. Mededeelingen, Leiden* **34,** 239–341.
14. von Koenigswald, G. H. R. (1950) *Int. Geol. Cong. 18th Sess. Great Britain, Proc.* **9,** 59–61.
15. Indonesia-Japan Research Co-operation Program (1979) *Bull. Geol. Res. Dev. Center,* Univ. Tokyo, **1,** 47–60.
16. Sartono, S., Semah, F., Astadieredia, K. A. S., Sukendarmono, M. & Djubiantono, T. (1981) *Mod. Quaternary Res. Southeast Asia* **6,** 91–102.
17. De Vos, J., Sartono, S., Hardja-Sasmita, S. & Sondaar, P. Y. (1982) *Geol. Mijnbouw* **61,** 207–211.
18. Berggren, W. A. & Van Couvering, J. A. (1979) in *Treatise on Invertebrate Paleontology,* eds. Robinson, R. A. & Teichert, C. (Geol. Soc. Am., Washington, DC), pp. 505–543.
19. Pfeffer, P. (1974) *Natural Resources of Humid Tropical Asia* (UNESCO, Paris), pp. 95–306.
20. Medway, L. (1975) *Mod. Quaternary Res. Southeast Asia* **13,** 63–98.
21. Verstappen, H. T. (1975) *Transactions 2nd Aberdeen–Hull Symposium on Malaysian Ecology,* University of Hull, Department of Geography, Miscellaneous Series, Vol. 13, pp. 3–36.
22. Ninkovich, D. & Burckle, L. H. (1978) *Nature (London)* **275,** 306–308.
23. Harrison, T. (1975) *Asian Perspectives* **18,** 60–63.
24. Nishimura, S., Sasajima, S., Hirooka, K., Thio, K. H. & Hehuwat, F. (1977) in *Proceedings of the First International Congress on Pacific Neogene Stratigraphy, Tokyo,* 1976, eds. Saito, T. & Ujiie, H. (Geol. Soc. Jpn., Tokyo), pp. 378–379.
25. Bartstra, G. J., Basoeki & Santosa, B. (1975) *Mod. Quaternary Res. Southeast Asia* **2,** 23–36.
26. Nishimura, S., Thio, K. H. & Hehuwat, F. (1980) in *Physical Geology of Indonesian Island Arcs,* ed. Nishimura, S. (Kyoto Univ., Kyoto, Japan), pp. 72–80.
27. von Koenigswald, G. H. R. (1962) in *Evolution und Hominisation,* ed. Kurth, G. (Fischer, Stuttgart, Federal Republic of Germany), pp. 112–119.
28. Jacob, T. & Curtis, G. (1971) *Univ. Calif. Archeol. Res. Facility Contrib.* **12,** 50.
29. Jacob, T. (1972) *Antiquity* **46,** 148.
30. Marks, P. (1953) *Indones. J. Nat. Sci.* **109,** 26–33.
31. von Koenigswald, G. H. R. (1938) *K. Akad. Wet. Amsterdam, Proc.* **41,** 185–192.
32. Semah, F., Sartono, S. & Djubiatono, T. (1980) *C. R. Hedb. Seances Acad. Sci. Ser. B* **290,** 477–480.
33. Li, P., Fang, C., Ma, H.-H., Pu, C.-Y., Hsing, L.-S. & Chu, S.-C. (1977) *Sci. Sin. (Chin. Ed.)* **20,** 645–663.
34. Hu, C. C. (1973) *Acta Geol. Sin.* **1,** 65–71.
35. Zhou, G. & Chen, C.-H. (1979) *Vertebr. PalAsiat.* **17,** 149–164.
36. Brown, F. H., Shuey, R. T. & Croes, M. K. (1978) *Geophys. J. R. Astronom. Soc.* **54,** 519–538.
37. Pope, G. G. (1982) Dissertation (Univ. of Calif., Berkeley).
38. Gao, J., Wang, L., Han, K. & Hsu, C. (1975) *Vertebr. PalAsiat.* **13,** 81–88.
39. Pope, G. G. (1977) *Kroeber Anthropol. Soc. Univ. Calif., Berkeley, Papers* **50,** 63–73.
40. Chia, L. P. & Wang, C. (1978) *A Culture Site of Early Pleistocene in Shansi Province* (Wenwu Press, Beijing).
41. Eisenmann, V. & Brunet, M. G. (1973) in *International Colloquium on the Problem "The Boundary between the Neogene and Quaternary"* (Nauka, Moscow), pp. 104–122.
42. Barry, J. C., Lindsay, E. H. & Jacobs, L. L. (1982) *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **37,** 95–130.
43. Eisenmann, V. (1976) in *Earliest Man and Environments in the Lake Rudolf Basin,* eds. Coppens, Y., Howell, F. C., Isaac, G. L. & Leakey, R. E. F. (Univ. of Chicago Press, Chicago), pp. 225–234.
44. Eisenmann, V. (1975) *Geobios* (Lyon) **8,** 125–135.
45. Ma, X., Qian, F., Li, P. & Ju, S. (1978) *Vertebr. PalAsiat.* **16,** 238–243.
46. Ren, M., Liu, Z., Jin, J., Deng, X., Wang, F., Peng, B., Wang, X. & Wang, Z. (1981) *Sci. Sin. (Chin. Ed.)* **24,** 843–850.
47. Woo, J. K. (1964) *Sci. Sin. (Engl. Ed.)* **13,** 801–811.
48. Woo, J. K. (1965) *Sci. Sin. (Engl. Ed.)* **14,** 1030–1036.
49. von Koenigswald, G. H. R. (1956) *Meeting Prehistoric Man* (Harper, New York).
50. Robinson, J. T. (1950) *Yearb. Phys. Anthropol.* **6,** 38–41.
51. Robinson, J. T. (1935) *Am. J. Phys. Anthropol.* **11,** 1–38.
52. von Koenigswald, G. H. R. (1950) *Eclogae Geol. Helv.* **43,** 268–274.
53. von Koenigswald, G. H. R. (1973) *J. Hum. Evol.* **3,** 487–491.
54. Sartono, S. (1981) in *Union International de Ciencias Prehistoricas y Protohistoricas, Congresso Comision 8—Los Hominidos mas Antiquas,* Mexico City, pp. 47–86.
55. Tobias, P. V. & von Koenigswald, G. H. R. (1964) *Nature (London)* **204,** 515–518.
56. Johanson, D. C. & White, T. D. (1979) *Science* **203,** 321–330.
57. White, T. D., Johanson, D. C. & Kimbel, W. H. (1981) *South Afr. J. Sci.* **77,** 445–470.
58. Santa Luca, A. P. (1980) *The Ngandong Fossil Hominids: A comparative study of a Far Eastern Homo erectus group* (Yale Univ., New Haven, CT), Publ. Anthropol., 78.
59. Movius, H. L. (1943) *Trans. Am. Philos. Soc.* **32,** 341–393.
60. Movius, H. L. (1944) *Trans. Am. Philos. Soc.* **38,** 329–420.
61. Movius, H. L. (1944) *Papers, Peabody Museum of American Archaeology and Ethnology, Harvard University* (Harvard Univ. Press, Cambridge), No. 19.
62. Van Heekeren, E. R. (1957) *The Stone Age of Indonesia* (Nijhoff, The Hague, Netherlands).
63. Movius, H. L. (1948) *Trans. Am. Philos. Soc.* **38,** 329–420.
64. Hayden, B. (1977) in *Sunda and Sahul,* eds. Allen, J., Golson, J. & Jones, R. (Academic, London), pp. 31–72.
65. Hutterer, K. I. (1977) in *Sunda and Sahul,* eds. Allen, J., Golson, J. & Jones, R. (Academic, London), pp. 31–72.
66. Pope, G. G., Frayer, D., Liangchareon, M., Kulasing, P. & Nakabanlang, S. (1981) *Asian Perspectives* **21,** 147–163.
67. Whyte, R. O. (1972) *Asian Perspectives* **15,** 127–151.
68. Whyte, R. O. (1974) *Natural Resources of Humid Tropical Asia* (UNESCO, Paris), pp. 239–264.
69. Whitmore, T. C. (1972) *Tropical Rainforests of the Far East* (Clarendon, Oxford).
70. Matsu'ura, S. (1982) *Bull. Natl. Sci. Mus. (Tokyo) Ser. D* **8,** 1–53.