

# Absolute Dates for the Hominid-Bearing Deposits in Java: An Overview

---

*Received 1 November 1982*

KARL L. HUTTERER

## INTRODUCTION

THE ARCHAEOLOGY OF the Pleistocene Period in Southeast Asia is faced with a number of problems. Among the more important are: the definition of geological and cultural sequences on local and regional levels, the classification and phylogenetic ordering of hominid remains, the reconstruction of palaeoenvironments, the assessment of lithic technologies and their development, and the correlation between cultural remains, geological sequences, and palaeontological assemblages. Many of these issues revolve around questions of relative and absolute dating of geological and cultural phenomena or are at least strongly affected by them. When techniques of radiometric dating were introduced to archaeology, there was widespread optimism that it would eventually be possible to resolve questions of dating and thereby contribute to the resolution of other problems as well.

A number of radiometric dates have been produced over the past few decades. With the exception of a few radiocarbon dates for Niah Cave in Sarawak and Tabon Cave in Palawan, most of these dates are either directly associated with hominid-bearing beds in Java or can be related to these deposits in some way. Among the reasons for this focus on the Javanese fossiliferous formations are: (a) Java has so far yielded the longest, most continuous, and richest series of hominid fossils in Southeast Asia; (b) partly for that reason, Java has the most intensively studied and best-documented sequences of vertebrate fossils and Pleistocene geological horizons in the region; and (c) none of the putatively "Middle" and "Lower Palaeolithic" artifacts have so far been found in primary and directly datable deposits, so that the formations yielding hominids constitute the only datable horizons of archaeological significance.

The dates, and discussions of their validity and problems, are scattered over a wide range of publications, many of them unfamiliar to archaeologists. Since some of the dates have become widely accepted while the existence of others is hardly known, and because

of the importance of the chronological issue in general, it seemed useful to collect the presently available published information and present it in synoptic form. It must be stressed, however, that this collation takes into account only *published* dates. There is also much unpublished information that cannot be considered in the present context.<sup>1</sup>

This paper constitutes not so much a critical review of the problem of relative and absolute dating of the Javanese (and Southeast Asian) palaeolithic but rather a simple compilation of basic information with minimal commentary. Even a brief glance at the material presented will tell, however, that the earlier optimism is still unfulfilled. Although some strong tendencies are emerging, there are problems with most of the dates proposed so far, so that the general issue of dating must be considered far from resolved. This does not mean that reliable absolute dating may not eventually become available; it is simply a warning against naïve acceptance of any chronological interpretation proposed at this time.

Six estimates of absolute age are available for the Putjangan beds, six for the Kabuh beds, and two for strata from which Solo-type hominids have been recovered. The estimates consist of age calculations based on measurements of potassium-argon content in basalts, volcanic tuffs, or tektites; on fission-track studies on tektites; on palaeomagnetic measurements; on micropalaeontological investigations; and on time-regression studies on the brain sizes of hominid fossils.

## AGE ESTIMATES FOR THE PUTJANGAN BEDS

### A

Potassium-argon date on a tuff sample from Modjokerto; collected by T. Jacob and G. H. Curtis and dated by Curtis at the University of California, Berkeley.

DATE: 1,900,000  $\pm$  400,000.

NOTE: A number of samples were taken at several hominid sites (Sangiran, Trinil, Watualang, Ngandong, Kedungbrubus, Modjokerto), but all except this one proved to be contaminated. The sample for the present date was taken "from the Djetis beds (Putjangan formation) a few meters below the site where the Modjokerto skull was found at Perring, Modjokerto, East Java" (Jacob 1972:148). Curtis (1981:16) states that the sample was extracted about 50 m below the fossil site. The date represents the average of two runs on hornblende extracted from the pumice. The very high atmospheric argon content of the sample (99%) greatly reduces the reliability of this date.

SOURCES: Curtis (1981); Jacob (1972); Jacob and Curtis (1971).

### B

Potassium-argon date on andesite from the Putjangan formation at Kebonduren near Kedungbrubus; submitted by T. Jacob (?); dated by G. H. Curtis at the University of California, Berkeley.

<sup>1</sup>The "Indonesia-Japan Research Cooperation Program" (1979) has been involved in efforts of radiometric and palaeomagnetic dating of hominid-bearing formations in Java, but their preliminary reports are at present not available to me; cf. Nishimura et al. (1980); Yokoyama et al. (1980); Indonesia-Japan Research Cooperation Program (1979)—cited in Bartstra (1982); Sartono et al. (1981).

DATE: 1,910,000.

NOTE: No standard deviation given. The sample was collected "below and some distance from the site of the juvenile mandible of *P. erectus* found in 1889."

SOURCE: Jacob (1973:1).

## C

Potassium-argon date on hornblende extracted from volcanic materials collected from the Putjangan formation exposed between Trinil and Gadjah; submitted by G.-J. Bartstra to E. H. Hebeda, ZWO Laboratory of Isotope Geology, Amsterdam.

DATE:  $500,000 \pm 300,000$ .

NOTE: The last date diverges very strongly from the previous two and may highlight either problems with the potassium-argon dating technique itself or, more likely, problems of stratigraphic correlation. When the first of the three dates for the Djétis fauna became known in 1972, it created considerable interest since it seemed to date the earliest of the Javanese hominids and to put them on a footing of comparable age with some of the African finds. Koenigswald (1975:306) enthusiastically accepted the date and stated that it was "good for the upper Djétis only," while some other anthropologists and palaeontologists felt that the Djétis fauna could not possibly be quite that old (for example, Butzer and Isaac 1975:891). The problem was accentuated by the fact that Bartstra's sample came from deposits laid down during the early period of activity of the Wilis volcano, while the Djétis beds of Sangiran are found in black clays which were formed in a freshwater lake with materials derived from those Wilis deposits (Bartstra 1978:58). This would mean that the date indicated above would represent a lower limit for the Djétis fauna and its associated hominid fossils.

## D

Study of marine diatoms present in the Upper Kalibeng beds and the basal part of the overlying Putjangan beds, by D. Ninkovich and L. H. Burckle, Lamont-Doherty Geological Observatory, Palisades, New York.

DATES: 2.1–1.9 million years (?).

NOTE: The date was arrived at by correlating the diatom content of the samples with that of deep sea cores from the Indo-Pacific Ocean, which have been studied for palaeomagnetic changes and oxygen isotope fluctuations. Fluctuations in the relative abundance of the isotopes  $^{16}\text{O}$  and  $^{18}\text{O}$  in the sea water are caused by repeated formation of the northern ice sheets which retained a relatively large amount of water with the lighter oxygen isotope from the global water budget. These fluctuations are reflected in changes of the microfauna such as diatoms.

SOURCE: Ninkovich and Burckle (1978).

At first glance, the Ninkovich-Burckle date would seem to support the early potassium-argon dates for the Putjangan formation. A closer look indicates otherwise. Ninkovich and Burckle themselves remain extremely tentative about their age estimate, pointing out that much more work is needed to substantiate it. Also, the potassium-argon

dates from eastern Java, according to Koenigswald, refer to the upper portions of the Putjangan beds, while the diatom study deals with the basal deposits. The formation consists of several hundred meters of deposit which may represent a considerable period of time. In this context, it is of significance that very recent palaeomagnetic studies by Sémah et al. (1981), cited below, suggest that diatomite layers found in different sections may be of different ages and that the date indicated here cannot necessarily be extrapolated to diatom-bearing horizons at other sites without detailed comparison. The date noted here must be considered a basal date for the Putjangan formation. It is also important to remember that the boundary between the Kalibeng and Putjangan formations is not very well defined.

### E

Study of foraminifera contained in claystone associated with hominid mandible C, found near Mandigan in the "Sangiran Dome," by W. G. Siesser and D. W. Orchiston, University of Melbourne.

DATE: Younger than 4,200,000, older than 1,600,000.

NOTE: The lower age limit is defined by the presence of *Globorotalia crassaformis*, the upper limit by *Globigerinoides obliquus*. The investigators advance, therefore, a Pliocene date for the mandible, while Sartono (1970), on the basis of an earlier study of the foraminifera, had proposed a lower Pleistocene date. On the basis of relative stratigraphic position, there seems to be little question that mandible C represents the oldest hominid fossil from Java reported to date. However, the fact that this fossil was found in marine clays indicates that we are dealing with reworked materials, so that any absolute age estimate on the basis of nanofossil content of the matrix becomes highly questionable.

SOURCE: Siesser and Orchiston (1978).

### F

Palaeomagnetic measurements on an unknown number of samples taken by an Indonesian and French group of scientists from two sites at the "Sangiran Dome" in Central Java. Measurements were conducted at the Laboratoire de Géomagnétisme de St. Maur in France. Samples relating to the Upper Kalibeng and the Putjangan formations could not be interpreted chronologically. However, samples taken from a section at the north-western part of the dome showed a reversed/normal change in polarity "approximately situated near the boundary between the Pucangan and Kabuh formations" (Sémah et al. 1981:109). Primarily on the basis of palaeontological considerations, the investigators suggest two possible ages: the Jaramillo Event (c. 950,000 years B.P. and lasting for about 100,000 years) or the Matuyama/Brunhes boundary (c. 730,000 years ago). The investigators prefer the latter interpretation.

NOTE: While there was no reason to doubt the announced measurement results, the information provided on samples and sample provenience was insufficient for a critical evaluation of the chronological interpretation. The investigators also stress that the infor-

mation available so far does not permit a positive statement to the effect that the whole Kabuh formation was deposited during a normal polarity period.

### AGE ESTIMATES FOR THE KABUH BEDS

#### G

Potassium-argon date on leucitic basalt from the Muriah volcano; sample collected in 1981 (*sic*; 1961?) by R. M. D. Verbeek; submitted by G. H. R. von Koenigswald to H. J. Lippolt, Max-Planck-Institut, Heidelberg, Germany.

DATE: 496,000  $\pm$  100,000 / - 60,000.

NOTE: The date has been correlated with the Trinil layers of Central Java but the precise stratigraphic relationship is not clear.

SOURCE: Koenigswald (1964:325-326; 1968:199).

#### H

Potassium-argon date on leucite from the Muriah volcano; sample probably a duplicate of (g); submitted by G. H. R. von Koenigswald to J. F. Evernden and G. H. Curtis, University of California, Berkeley.

DATE: 500,000  $\pm$  20,000.

NOTE: As with (g), the date has been applied to the Trinil layers, but the precise stratigraphic relationship is unclear; what portion of the Trinil deposits (upper or lower) the date should be linked with is also not clear.

SOURCES: Evernden and Curtis (1965:361); Koenigswald (1964:326).

#### I

Potassium-argon date on samples of volcanic tuff derived from the upper Kabuh layers of two hominid sites (Sangiran 10 and Sangiran 12) where *Homo erectus* skull caps had been found in 1963 and 1965; submitted by T. Jacob to G. H. Curtis, University of California, Berkeley.

DATE: 830,000  $\pm$  40,000.

NOTE: This date represents an average of dates derived from four samples collected "from the layers below, at and above the levels of the sites where skull caps were found" (Jacob 1973:2). The determinations were made on hornblende extracted from the pumice. A high content of atmospheric argon again reduces the accuracy of the date. In a recent paper, Curtis (1981:16) notes that "a split of one of these samples was run at Berkeley under improved conditions" resulting in a date of 1,200,000  $\pm$  200,000 years. He notes further that the latter date "must be considered superior to the 0.83 Ma figure."

SOURCES: Bartstra (1976:32); Curtis (1981); Jacob (1973:2); Jacob and Curtis (1971).

*J*

Potassium-argon date on a series of tektites from Indochina, Indonesia, Philippines, Australia; investigations by W. Gentner and J. Zähringer, Max-Planck-Institut, Heidelberg, Germany.

DATE:  $610,000 \pm 15\%$  (c. 91,000).

NOTE: The date represents an average derived from 11 samples (five from Indochina, one from Indonesia, four from the Philippines, one from Australia); for further comments, see below.

SOURCES: Gentner and Zähringer (1960:95, 97); Koenigswald (1968:199–200).

*K*

Potassium-argon dates on a series of tektites from Indochina, Indonesia, Philippines, Australia; investigations by W. Gentner and J. Zähringer, Max-Planck-Institut, Heidelberg, Germany.

DATE:  $720,000 \pm 60,000$ .

NOTE: This date represents an average derived from a sample of 18 tektites (12 from Indochina and Indonesia and six from Australia); the difference in age as compared with (j) is apparently a reflection of the larger number of Australian tektites in the sample. A single tektite collected at Sangiran gave a date of  $730,000 \pm 50,000$ .

SOURCE: Koenigswald (1968:199–200); Zähringer and Gentner (1963:583); Zähringer (1963:292).

*L*

Fission-track date on tektites from Southeast Asia; investigations by R. L. Fleischer and P. B. Price, General Electric Research Laboratory, Schenectady, New York.

DATE:  $710,000 \pm 40,000$ .

NOTE: The date is supplied in Fleischer and Price (1964a:759) under the heading "Far Eastern Tektites." The same source notes that the standard deviation is derived from statistical counts, implying that this date is based on several samples. In another publication by the same authors (Fleischer and Price 1964b:336), five separate dates are quoted, derived from tektites collected in the Philippines (2), Indochina (2), and Thailand (1). The five dates give a mean of  $740,000 \pm 290,000$  years. The fission track dates of the tektites have been related to the Trinil layers by Koenigswald (1968:200).

At this point, a general note about tektites and their role in the prehistory of Southeast Asia is indicated. Tektites are small lumps of dark colored glass ranging in size from a few millimeters to several centimeters. They are found in several regions of the world scattered over wide areas or "strewn fields." One of them is the region including Australia, New Guinea, Indonesia, the Philippines, and most of Mainland Southeast Asia. After much

debate, it is still not clear whether tektites are of strictly terrestrial origin (see, for example, Barnes 1971*b*; Faul 1966; Urey 1971), whether they come from elsewhere within the solar system (possibly the moon; see O'Keefe 1976; Chapman 1971), or whether they may even originate from outer space (see Adams and Huffaker 1964). However, since all the tektites within a single strewn field are relatively homogeneous in chemical composition, and—according to investigations during the past 20 years—apparently also in age, it is widely assumed that the tektites from any one field originated during a single event. Around the turn of the twentieth century, tektites were found in Southeast Asia in apparent association with geological layers containing Pleistocene animal fossils, and a find in 1935 seemed to associate them with the Trinil layers (Koenigswald 1935). The idea arose that tektites could serve as “guide fossils,” being reliable indicators for the contemporaneity of different hominid or archaeological sites. The issue of tektites aroused keen interest among palaeontologists and archaeologists working in that part of the world (for example, Beyer 1961; Harrison 1975; Koenigswald 1960; Loofs 1977). The development of two long-range dating techniques in the early 1960s eventually seemed to make it possible to assess the actual ages of tektites quite closely and, thereby, to use these glasses not only for relative chronological correlation of geological deposits but also to find out their absolute ages.

Unfortunately, the whole issue of the tektites has remained somewhat intractable, even with regard to the simultaneous origin of individual tektite “showers” falling over a particular region. Widely varying ages, ranging from four million years to 16,000 years, have been reported for Indochinese and Australian tektites, with the greatest disparities occurring among the Australian samples (Barnes 1971*a*; Fleischer, Price, and Woods 1969). The disagreements may, in part, stem from procedural problems with different dating techniques used; they may in part have to do with assumptions used in translating physical and chemical measurements into dates; or they may indicate that two or more separate events of tektite formation occurred in the Australian area. One pioneer of the potassium-argon dating technique stated that, with regard to tektites, measurements should simply be considered “as a basis for the age discussion” (Zähringer 1963:295). The possibility of several chronologically separated “showers” does not constitute a serious problem in the present context, since all of the tektite dates reported here seem to form reasonably tight clusters. However, a more serious problem is posed by the question of association between tektites and fossil or archaeological deposits. In most, if not all, cases tektites have been found either in surficial exposures or in gravel beds, and the possibility is strong that they have been reworked from older deposits (*cf.* Harrison 1975; Vondra et al. 1981).

## ESTIMATES FOR DEPOSITS YIELDING “SOLO” HOMINIDS

### *M*

Palaeomagnetic measurements on ten samples from the hominid site of Sambungmacan on the Solo River (laboratory not stated in published report). The samples were collected “from the beds between the Pliocene limestone and the disconformity overlying the fossiliferous beds” (Jacob et al. 1978:886). All samples were found to be of normal polarity. Jacob et al. (1978) tentatively assign the samples to the Jaramillo Event and estimate their age also on other grounds at about 900,000 years. However, it is important

to point out that "a number of processes can produce postdepositional normal magnetization, so that normal magnetization of samples need not indicate the polarity of the earth's field at the time of deposition" (ibid.). The next two closest periods of normal geomagnetic polarity are the relatively brief Olduvai Event within the Matuyama Epoch of reversed polarity, which occurred about 1.6 to 1.7 million years ago, and the Brunhes Epoch which started about 730,000 years ago.

SOURCE: Jacob et al. (1978).

## N

Estimates of absolute age based on linear regression of cranial capacity of hominid fossils from Java and Africa.

DATE: An original estimate by Lestrel and Read (1973:410) fixed the age of the crania from the Ngandong locality as lying between 169,000 and 408,000 years B.P. with a mean of 265,000 B.P., using a confidence interval of 99.9 percent. A later recalculation by Lestrel (1975:211), based on an enlarged sample size and slightly modified assumptions, more than doubled this estimated age, fixing the range between 463,000 and 790,000 years B.P.

NOTE: It is not possible to provide a detailed critique of this approach to dating. However, while few would question the observation of continuous increase in cranial capacity throughout the course of hominid evolution, problems of controls over a variety of biological, ecological, and chrono-stratigraphic variables as well as of sample size cast grave doubt on an interpretation of the data in terms of a linear chronological series, and particularly its use to date specific fossil specimens. The issue of brain size changes is intimately intertwined with the question of gradual versus punctuated models of evolutionary change, a question that has recently been discussed more explicitly with reference to *Homo erectus* by several authors (for example, Godfrey and Jacobs 1981; Rightmire 1981; Yaroeh 1982). Considering this problem, it is clear that regression lines on the available fossil material can possibly be used in testing the competing models—if the samples are considered adequate and the dates reasonably secure—but they can hardly be used for estimating the dates of individual fossils or fossil groups.

Generally, dating of deposits referred to in the last two items is a particularly thorny issue. Fossil remains of a hominid form often popularly called "Solo Man" come from two localities. One is a short stretch of river bank along the Solo River near Ngandong where fragments of 15 individuals were found mostly in the early 1930s. The dating of these Ngandong finds has rested on the geomorphological evaluation of the terraces from which they were recovered and the developmental assessment of fossil morphology. On this basis, the deposits have most commonly been considered to be of either upper Middle Pleistocene or Upper Pleistocene age. However, at present there are no absolute dates for the Ngandong locality other than the regression dates based on hominid brain size proposed by Lestrel and Read (1973; Lestrel 1975). A single cranium was found in 1973 at Sambungmachan, about 80 km west of Ngandong, also on the Solo River. The Ngandong and Sambungmachan finds are thought to be roughly contemporaneous chiefly because of their close morphological similarity (Jacob 1975; Wolpoff 1980:219). Geologically, the Sambungmachan deposits have been seen as related to everything from the Lower Pleistocene Putjangan formation to the Upper Pleistocene Ngandong and Noto-puro formations (cf. Jacob 1978; Sartono 1979). Lestrel (1975:211) refers to a personal



communication by G. H. Curtis about a potassium-argon date "on the Solo deposits," with a value of  $310,000 \pm 100$  percent years B.P. The large standard deviation indicates the problematic nature of this date. However, since it has not been officially published, no details about it are available and it can not be properly evaluated. So far, the dating of the Ngandong/Sambungmachan complex has depended heavily on the developmental—hence chronological—interpretation of the morphology of the recovered fossils. Here again, opinions range from robust *Homo erectus* (*Pithecanthropus*) to early sapient ("neandertaloid") forms (cf. Jacob 1978; Koenigswald 1975; Santa Luca 1978; Sartono 1979; Wolpoff 1980). Sartono (1979) has questioned the correlation of the Sambungmachan deposits with either the Kabuh or the Putjangan formations on geological grounds.

### CONCLUSIONS

From the information presented above it will be evident that, at present, no absolute date for hominid-bearing Pleistocene deposits in Java can be accepted without some hesitation. The main questions revolve around the reliability of dating methods used, and the stratigraphic association between dated samples and hominid-bearing strata. Taken in the aggregate, dates related to the Trinil layers (Kabuh beds) appear to be the most solid as they form a surprisingly tight chronological cluster (Fig. 1). However, considered singly, each of these age estimates leaves considerable room for questions, primarily concerning issues of association. Dates related to the Djetis layers (the Putjangan beds) would seem to form a possible second cluster (Fig. 1) but considering the small number of dates, this clustering may be an artifact of sample selection and similar unintended biases. Also, the deposits commonly grouped together as "Putjangan beds" are rather massive and seem to cover a long period of time. Thus, the problem of association between samples and hominid-bearing strata is particularly critical here because of occasional difficulties in correlating geological layers from different sections and exposures.

The most unsatisfactory dates are those relating to deposits from which Solo-type hominids have come. In fact, the problems surrounding the Solo dates illustrate a syndrome affecting the larger dating issue. Two major lines of evidence have traditionally been used in chronological arguments: stratigraphic correlations between geological horizons and biostratigraphic analyses based on the composition of assemblages of fossil fauna as well as morphological variation among the hominid fossils. The use of either line of evidence has depended strongly on a series of assumptions that have, in most cases, been difficult or impossible to evaluate independently. Thus, as no single line of evidence has been entirely satisfactory, there has been a strong tendency by geologists to invoke biostratigraphic evidence for support, and for palaeontologists to lean heavily on geological arguments. In this way, virtually all the discussions of absolute as well as relative chronology of the Pleistocene deposits of Java are shot through with a heavy dose of circular reasoning. When physical and chemical techniques of absolute dating were brought into the picture, the hope was that their application would eventually solve this dilemma. Unfortunately, for reasons outlined above, this has not occurred. At this time, the evaluation of the available absolute dates still falls back on often controversial litho-stratigraphic and biostratigraphic arguments, and the new dates themselves have simply become one more element in the chronological merry-go-round. This statement does not belittle the efforts that have been made with regard to dating, which are considerable and certainly laudable, but simply cautions against undue credulity.

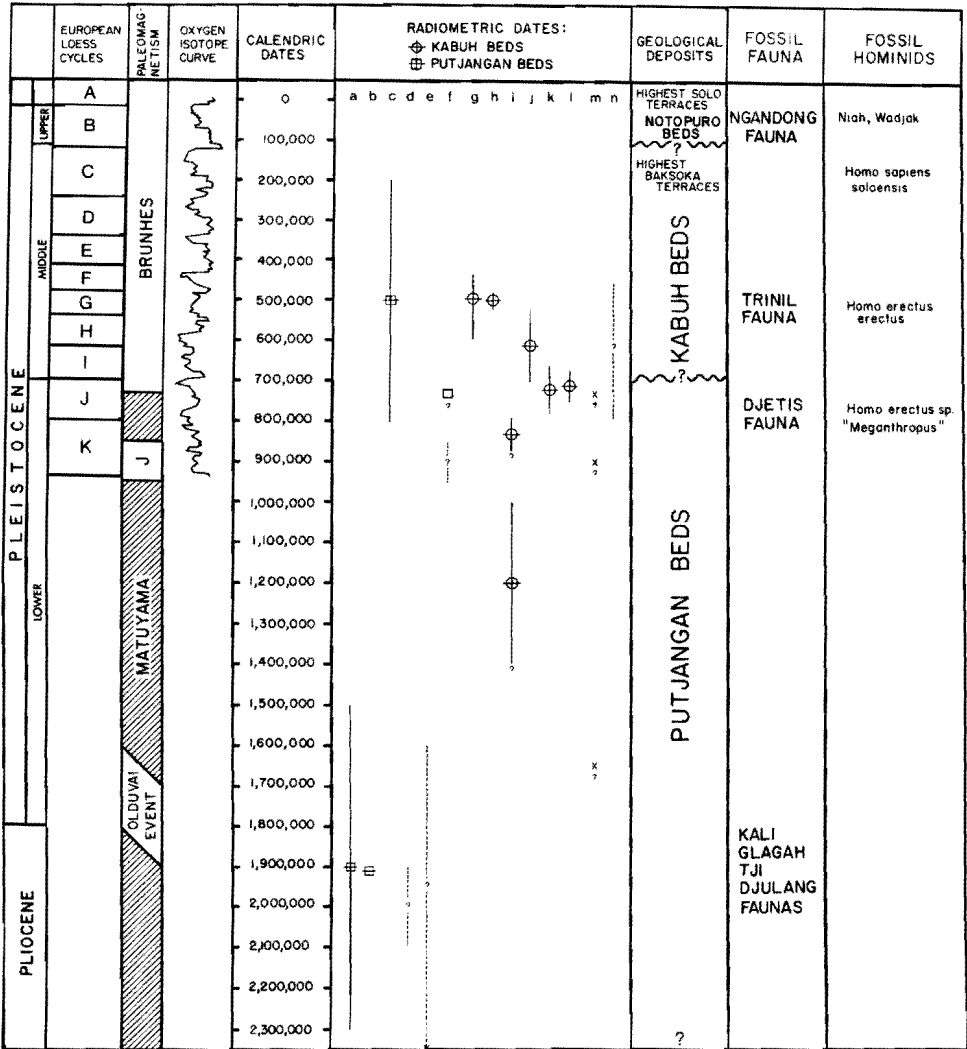


Fig. 1 Synoptic chart of dates for Pleistocene hominid-bearing deposits in Java. O dates on samples from Putjangan beds; □ dates on samples from Kabuh beds; × dates related to Solo-type hominids. For reference purposes, the dates are juxtaposed on the left with general Pleistocene sequences and on the right with lithostratigraphic and biostratigraphic sequences in Java. The sequence of glacial cycles is based on Kukla (1977), the paleotemperature curve on the study of deep sea cores by Shackleton and Opdyke (1973). The Javanese sequences shown here represent a best-fit interpretation of varying opinions expressed in the palaeontological and geological literature and should not be taken to constitute a definitive frame of reference.

## POSTSCRIPT

Since the manuscript for this paper was finished in 1982, several research projects have produced a number of new chronometric dates for the Javanese hominid deposits. It has not been possible to incorporate these newer age determinations, however, the basic conclusion of the paper—that the true age of these deposits remains uncertain—continues to be valid.

## ACKNOWLEDGMENTS

The present paper has benefitted from conversations with C. L. Brace, W. R. Farrand, W. G. Solheim II, A. G. Thorne, M. H. Wolpoff, and A. L. Yaroeh. I thank them for their suggestions. Any error of fact or interpretation contained herein is solely the responsibility of the author.

## REFERENCES

- ADAMS, E. W., AND R. M. HUFFAKER  
 1964 Aerodynamic analysis of the tektite problem. *Geochimica et Cosmochimica Acta* 28:881–892.
- BARNES, V. E.  
 1971a Age of Asian tektites. *Bulletin of the Geological Society of America* 82:1995–1996.  
 1971b Description and origin of a large tektite from Thailand. *Chemie der Erde* 30:13–19.
- BARTSTRA, G.-J.  
 1976 *Contributions to the Study of the Palaeolithic Patjitan Culture, Java, Indonesia*. Leiden: E. J. Brill.  
 1978 The age of the Djétis beds in East and Central Java. *A* 52(204):56–58.  
 1982 *Homo erectus erectus*: the search for his artifacts. *CA* 23:318–320.
- BEYER, H. O.  
 1961 *Philippine Tektites*. Manila: University of the Philippines.
- BUTZER, K. W., AND G. L. ISAAC  
 1975 Correlation charts compiled at the symposium. In *After the Australopithecines*, edited by K. W. Butzer and G. L. Isaac, pp. 889–899. The Hague: Mouton.
- CHAPMAN, D. R.  
 1971 Australasian tektite geographic pattern, crater and ray of origin, and theory of tektite events. *Journal of Geophysical Research* 76:6309–6338.
- CURTIS, G. H.  
 1981 Man's immediate forerunners. *Philosophical Transactions of the Royal Society of London, Series B* 292:7–20.
- EVERNDEN, J. F., AND G. H. CURTIS  
 1965 The potassium-argon dating of Late Cenozoic rocks in East Africa and Italy. *CA* 6:343–385.
- FAUL, H.  
 1966 Tektites are terrestrial. *S* 152:1341–1345.
- FLEISCHER, R. L., AND P. B. PRICE  
 1964a Fission track evidence for the simultaneous origin of tektites and other natural glasses. *Geochimica et Cosmochimica Acta* 28:755–760.  
 1964b Glass dating by fission fragment tracks. *Journal of Geophysical Research* 69:331–339.
- FLEISCHER, R. L., P. B. PRICE, AND R. T. WOODS  
 1969 A second tektite fall in Australia. *Earth and Planetary Science Letters* 7:51–52.
- GENTNER, W., AND J. ZÄHRINGER  
 1960 Das Kalium-Argon-Alter von Tektiten. *Zeitschrift für Naturforschung* 15a:93–99.
- GODFREY, L., AND K. H. JACOBS  
 1981 Gradual, autocatalytic and punctuational models of hominid evolution: a cautionary tale. *Journal of Human Evolution* 10:255–272.

HARRISSON, T.

- 1975 Tektites as "date markers" in Borneo and elsewhere. *AP* 18:61-63.

INDONESIA-JAPAN RESEARCH COOPERATION PROGRAM

- 1979 Progress of the Indonesia-Japan joint research project on geology of human fossil bearing formations in Java (1). *Bulletin of the Geological Research Development Centre* 1:58-59.

JACOB, T.

- 1972 The absolute date of the Djetis beds at Modjokerto. *A* 44(182):148.  
 1973 New finds of Lower and Middle Pleistocene hominines from Indonesia and their antiquity. Paper read at the IXth International Congress for Anthropological and Ethnological Sciences, Chicago.  
 1975 Morphology and paleoecology of Early Man in Java. In *Paleoanthropology. Morphology and Paleoecology*, edited by R. H. Tuttle, pp. 311-325. The Hague: Mouton.  
 1978 The puzzle of Solo Man. *Modern Quaternary Research in Southeast Asia* 4:31-40.

JACOB, T. AND G. H. CURTIS

- 1971 Preliminary potassium-argon dates of early man in Java. *Contributions of the University of California Archaeological Research Facility* 12:50.

JACOB, T., R. P. SOEJONO, L. G. FREEMAN, AND F. H. BROWN

- 1978 Stone tools from mid-Pleistocene sediments from Java. *S* 202:885-887.

KOENIGSWALD, G. H. R. VON

- 1935 Vorläufige Mitteilungen über das Vorkommen von Tektiten auf Java. *Verhandelingen, Koninklijke Nederlandse Academie van Wetenschappen*, Series B, 38:287-289.  
 1960 Tektite studies (I + II). The age of the Indo-Australian tektites. *Verhandelingen, Koninklijke Nederlandse Academie van Wetenschappen*, Series B, 53:135-153.  
 1964 Potassium-argon dates and Early Man: Trinil. *Report on the 6th International Congress on Quaternary, Warsaw, 1961*, 4:325-327.  
 1968 Das absolute Alter des *Pithecanthropus erectus* Dubois. In *Evolution und Hominization*, edited by G. Kurth, pp. 193-203. Stuttgart: G. Fischer Verlag. 2nd ed.  
 1975 Early Man in Java: catalogue and problems. In *Paleoanthropology. Morphology and Paleoecology*, edited by R. H. Tuttle, pp. 303-309. The Hague: Mouton.

KUKLA, G. J.

- 1977 Pleistocene land-sea correlations. I. Europe. *Earth-Science Reviews* 13:307-374.

LESTREL, P. E.

- 1975 Hominid brain size versus time: revised regression estimates. *Journal of Human Evolution* 5:207-212.

LESTREL, P. E., AND D. W. READ

- 1973 Hominid cranial capacity versus time: a regression approach. *Journal of Human Evolution* 2:405-411.

LOOFS, H. H. E.

- 1977 Tektites in Thai prehistory. *AP* 20:113-129.

NINKOVICH, D., AND L. H. BURCKLE

- 1978 Absolute age of the base of the hominid-bearing beds in Eastern Java. *Nature* 275:306-308.

NISHIMURA, S., K. H. THIO, AND T. HEHUWAT

- 1980 Fission-track ages of the tuffs of the Pucangan and Kabuh formations and the tektites of Sangiran, Central Java. In *Physical Geology of the Indonesian Island Archipelago*, pp. 72-80. (Cited in Bartstra 1982.)

O'KEEFE, J. A.

- 1976 *Tektites and their Origin*. New York: Elsevier.

RIGHTMIRE, G. P.

- 1981 Patterns in the evolution of *Homo erectus*. *Paleobiology* 7:241-246.

SANTA LUCA, A. P.

- 1978 A re-examination of presumed Neandertal-like fossils. *Journal of Human Evolution* 7:619-636.

SARTONO, S.

- 1970 On the stratigraphic position of *Pithecanthropus* mandible C. *Proc. Institut Teknologi Bandung* 4:91-102.  
 1979 The stratigraphy of the Sambungmachan site, Central Java. *Modern Quaternary Research in Southeast Asia* 5:83-88.

SARTONO, S., F. SÉMAH, K. A. S. ASTADIREJA, M. SUKENDARMONO, AND T. DJUBANTONO

- 1981 The age of *Homo modjokertensis*. *Modern Quaternary Research in Southeast Asia* 6:91-102.

SHACKLETON, N. J., AND N. D. OPDYKE

- 1973 Oxygen isotope and paleomagnetic stratigraphy of equatorial Pacific cores V28-238: oxygen isotope temperatures and ice volumes on a  $10^5$  year– $10^6$  year scale. *Quaternary Research* 3:39–55.

SÉMAH, F., S. SARTONO, Y. ZAIM, AND T. DJUBIANTONO

- 1981 A palaeomagnetic study of Plio-Pleistocene sediments from Sangiran and Simo (Central Java): interpreting first results. *Modern Quaternary Research in Southeast Asia* 6:103–110.

SIESSER, W. G., AND D. W. ORCHISTON

- 1978 Micropalaeontological re-assessment of the age of *Pithecanthropus* mandible C from Sangiran, Indonesia. *Modern Quaternary Research in Southeast Asia* 4:25–30.

UREY, H. C.

- 1971 Tektites from the earth. *S* 171:312–314.

VONDRA, C. F., M. E. MATHISEN, D. R. BURGGRAF, JR., AND E. P. KVALE

- 1981 Plio-Pleistocene geology of Northern Luzon, Philippines. In *Hominid Sites: their Geologic Settings*, edited by G. Rapp, Jr. and C. F. Vondra, pp. 255–310. Boulder, Colorado: Westview Press.

WOLPOFF, M. H.

- 1980 *Paleoanthropology*. New York: Knopf.

YAROSH, L. A.

- 1982 Stasis versus evolutionary change in *Homo erectus*. Paper presented at the 51st Annual Meeting of the American Association of Physical Anthropologists, Eugene, Oregon.

YOKOYAMA, T., S. HADIWISASTRA, A. HAYASHIDA, AND W. HOWTORO

- 1980 Preliminary report on paleomagnetism of the Plio-Pleistocene series in Sangiran and Trinil areas, Central Java, Indonesia. In *Physical Geology of the Indonesian Island Archipelago*, pp. 88–96. (Cited in Bartstra 1982.)

ZÄHRINGER, J.

- 1963 K-Ar measurements of tektites. In *Radioactive Dating. Proceedings of the Symposium on Radioactive Dating*, pp. 289–305. Vienna: International Atomic Energy Agency.

ZÄHRINGER, J., AND W. GENTNER

- 1963 Radiogenic and atmospheric argon content of tektites. *Nature* 199:583.