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CURRENT PROBLEMS IN RESEARCH

Age of Zinjanthropus

The potassium-argon dates recently obtained from Olduvai Gorge, Tanganyika, raise several questions.

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The recent series of discoveries of *Zinjanthropus* and other hominid fossils at Olduvai Gorge, Tanganyika, by Dr. and Mrs. L. S. B. Leakey (*1–3*) constitute an outstanding contribution to paleoanthropology. Indeed, they may perhaps come to be ranked, as Napier (*4*) has said, "with Dubois' discovery of Java man and Dart's recognition of the adolescent australopithecine at Taung." Their full significance depends in part on their chronological relations to other hominid fossils—relations that involve many uncertainties. In this connection, the potassium-argon dates from the Gorge recently announced by Leakey, Evernden, and Curtis (*5*) for the strata containing these hominid fossils are of much interest. These dates raise many questions about rates of human evolution, both physical and cultural, about rates of evolution and migration of other vertebrates, rates of sedimentation, and rates of weathering and soil development. Other questions concern intercontinental correlations. We believe, however, that there are questions to be raised about the validity of the dates.

We share in full the very similar questions raised by von Koenigswald, Gentner, and Lippolt (*6*), and we quite agree with their general conclusion: "Having considered the many unanswered sedimentological and palaeontological questions which make Olduvai a difficult test case, we prefer . . . to be cautious until more dates for the lower Pleistocene are available."

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Precision and Accuracy

One must distinguish, as von Koenigswald *et al.* (*6*) do, between what has been called precision and what has been called accuracy. By precision is meant the ability to reproduce results, which involves the sampling, concentrating, and analytical steps. Isotopic age determinations, including those made by the potassium-argon method, may be analytically precise yet may not be accurate because of errors wholly unrelated to the sampling, concentrating, and analytical procedures.

An example of this is provided by the history of the discovery of argon itself, in 1904. Repeated and reproducible analyses of the atmosphere indicated that it was composed of oxygen (21 percent) and nitrogen (79 percent) in constant proportions; but the analyses contained a systematic error that was not recognized until the 1 percent of argon was isolated and identified (*7, 8*).

We do not question the analytical precision of the determinations of the potassium-argon ratios in the minerals from Olduvai Gorge. The error in precision seems to be less than 10 percent. Our questions concern the significance of the ratios. We suspect that difficulties arise, as von Koenigswald *et al.* (*6*) state, "from the sample itself" and that in consequence some or all of the indicated dates are in error.

Consistency in a series of isotopic dates is evidence only of precision and *not* of accuracy. Dates that are not consistent may still be precise, of course, but they cannot be accurate.

Arranged in stratigraphic sequence, the dates indicated for the beds at Olduvai Gorge, from top to base, are:

1) Bed II: tuff, 0.36 million years. [The hominid skull which Leakey (*3*) has termed "Chellean man" and hence, by implication, a hominine, was recovered from this bed.]

2) Upper part of bed I: biotite, 1.08 million years; oligoclase, 1.38 million years.

3) Lower part of bed I: anorthoclase, 1.75 million years. [The *Zinjanthropus* remains and stone tools of the Oldowan pre-Chelles-Acheul type came from this level (*1*); a mixture of other hominid bones, both adult and juvenile (*2, 3*), came from a slightly lower level.]

4) Basalt under bed I: 1.3 million years.

The dates for beds I and II were obtained by Leakey *et al.* (*5*), that for the underlying basalt by von Koenigswald *et al.* (*6*). These were obtained by analyzing the potassium-argon ratio in different minerals. Feldspar (anorthoclase) was used for the lower part of bed I, and biotite and another feldspar (oligoclase) were used for the upper layers of this bed. The indicated difference in age is about half a million years. The overlying bed II is dated as 0.36 million years; but the material from it that was analyzed is described only as tuff (*5*). Subsequently, a date of 1.3 million years was given for the basalt underlying bed I, a date which is almost half a million years later than that obtained for the lower part of bed I (*6*).

Except for the basalt, the ages reported are in proper relative stratigraphic order. Moreover, two samples of biotite and seven samples of anorthoclase from bed I were analyzed, and consistent results were obtained within each suite. Finally, tests independent of these indicate that the analytical methods are consistent between laboratories, as noted by von Koenigswald *et al.* (*6*). Such consistency is good evidence for precision, but perhaps in the same way that pre-1904 analyses of the atmosphere by different laboratories gave consistent results by the nitrogen removal method and equally consistent but slightly different results by the oxygen removal method (*7*).

Our questions about the significance of the potassium-argon ratios, and about the accuracy of the dates inferred from them, are based partly on the fact that different materials have been used for dating the different layers. The biotite and oligoclase from the upper part of bed I show an inconsistency (300,000 years). There is a greater discrepancy (450,000 years) between the anorthoclase from the lower part of bed I and the basalt which underlies it. We suspect that other discrepancies would also appear if additional kinds of materials were analyzed. We doubt that we as yet know which kind of material gives dependable results.

Chiefly, though, our doubts have been raised because the differences in indicated age within bed I and between it and bed II seem inconsistent with the physical geology and paleontology.

The argument is developed by assuming first that the dates for beds I and II are accurate.

Dates for Beds I and II

Assume that the dates for beds I and II are accurate. If the age estimates for beds I and II are accurate, bed I, which is 17 to 100 feet thick (*9*), accumulated over a period of roughly half a million years and is separated from bed II by an unconformity that had a duration of nearly 1 million years.

Discontinuities of such magnitude are commonplace in geologic sections, but they generally are marked by zones of weathering or, if the soils had been removed by erosion before the overlying beds were deposited, the contacts should be erosional unconformities. But no well-marked breaks are described within bed I. Moreover, the contact between beds I and II, although referred to as a "well-marked break" (*1*), evidently is obscure enough so that the two beds were not differentiated physically until recently but were separated on the basis of biostratigraphy (*1, 2*). This question was raised also by von Koenigswald *et al.* (*6*). Indeed, the latter are inclined, for various stated reasons —paleontological, physical-geological, and archeological—to look askance at both the indicated age differences between the upper and lower parts of bed I and the indicated great time interval between beds I and II. The questions perhaps could be answered by geologically mapping the beds sufficiently to determine their three-dimensional relationships and to establish the presence (or absence) of paleosols or erosional features at the unconformities.

Nor is a major break indicated by the vertebrate paleontology. Leakey *et al.* (*5*) regard bed I, the lower part of which contained the *Zinjanthropus* remains, as Villafranchian in age; but missing from the bed are *Elephas planifrons* and *Stegodon*, both of which are typical of the African Villafranchian (*6*). Moreover, according to Hopwood, "There is no faunistic evidence to suggest that the lower part of the Olduvai series is of Lower Pleistocene age" (cited in *6*). Leakey (*10, 11*) also regarded both beds (I and II) as of middle Pleistocene (Kamasian) age. After his discovery of *Zinjanthropus*, however, he reverted to an earlier view (*12*) that bed I was of lower Pleistocene age, hence considerably older than bed II. This attribution, if it could be maintained, would lend plausibility to the potassium-argon dates indicating a major unconformity between beds I and II. However, the contrary seems to us more likely, especially in view of the fact that von Koenigswald *et al.* (*6*) state that "Beds I and II have many species in common which do not occur higher up" and that their faunas "are roughly the same."

The evidence of physical anthropology per se can neither support nor contradict the indicated dates at Olduvai; "morphological dating" of hominid fossils has long since been abandoned by physical anthropologists in general. Lengthening the period of hominine evolution—as suggested by the dates and also, perhaps, by the hominid remains discovered in layers below the *Zinjanthropus* layer—would by no means prove unacceptable to most physical anthropologists. For one thing, it might reduce the seemingly high, anomalous rate of evolution of the hominine brain (see, for example, *13*) to a degree more compatible with other known rates of mammalian evolution. Yet any such recession in time of hominine emergence certainly is no *sine qua non*. Sequences and rates of human evolution can only be interpreted in the light of, and must rely on, the evidence provided by geology.

Finally, if the dates from beds I and II are accurate, the date for the underlying basalt must be wrong. This might be due to weathering of the basalt (*9*); but it seems strange that the basalt, which evidently is dense enough to be suitable for hand tools (*6*), should be more weathered than the overlying permeable volcanic ash, some layers of which are notably weathered (*5*).

Accordingly, the accuracy of one or another or all four of the suites of the potassium-argon dates for beds I and II is open to question. To consider some possible sources of error, we first assume that the dates provided by the anorthoclase are accurate, and that the dates indicated as younger are too young.

Dates for Anorthoclase

Assume that only the anorthoclase dates are accurate. If the anorthoclase dates are accurate, the date indicated for the underlying basalt must be too young, as indicated above. If the biotite dates and the date of the tuff in bed II are too young, this might very well be due to weathering of those materials. The quantity of argon in minerals in the 1.3- to 0.3-million-year range is exceedingly small (less than 0.1 microliter per gram; compare *5, 6*). Ever so slight weathering and escape of argon could make substantial difference in the ratio of argon to potassium and have correspondingly great effect on the age estimate.

In early tests of the potassium-argon method, it was discovered that argon escapes from potassium feldspars more readily than from biotite (*14*), probably because of difference in the internal structure of the minerals. However, these early tests were made on granites and other hard rocks in the age range of 100 million years or more. In minerals from volcanic ash in the 1-million-year range, however, the escape of argon may be controlled less by the internal structure of minerals and more by their size. Information available to us does not indicate the relative sizes of the minerals that were analyzed; but difference in size of the minerals might be a factor causing greater systematic loss of argon from small crystals than from large ones.

Dates for Basalt and Biotite

Assume that the basalt and biotite dates are accurate. The biotite from the top of bed I gave dates that are not inconsistent with the date given for the basalt. For geological and paleontological reasons stated above, we feel that the date for the overlying tuff, bed II, would be too young. The anorthoclase dates would be erroneous and too old.

The apparent great age of the anorthoclase might be due to "inherited contaminants." One obvious possibility is that the ash beds, which include some that are crossbedded (*5*), include reworked foreign clastics derived by erosion from older ash beds in the surrounding terrain. This possibility has already been considered, and such foreign matter is regarded as minor (*5*). While we would accept the conclusion that the bed does not contain evident foreign matter, we would emphasize that reworked volcanic ash can be difficult or impossible to identify in a sequence of ash beds of similar compositions.

Another possible source of "inherited contaminants," one that has been pointed out elsewhere in connection with attempts to date other volcanic ash (*15*), involves the possibility that the ash bed was derived in large part from explosive brecciation of older glassy lavas in the throat of the volcano. There could be great difference in age between volcanic ash derived from explosive comminution of old lavas and tuffs as contrasted with explosive eruption of partly crystallized new melts. The paragenesis of the minerals could be critical, whether they are xenocrysts or phenocrysts. They may be very much older than the glass in which they are embedded. Still a third possible source of an "inherited contaminant" is suggested by the fact that mineral surfaces adsorb atmospheric argon, and so much so that precautions are taken against such contamination in the laboratory (*15*). Possibly the anorthoclase *in situ* not only adsorbed but may have absorbed radiogenic argon released by weathering of nearby deposits and transported to bed I by ground water, vadose water, or as gas in the soil atmosphere. Argon is inert, one of the noble gases, but it is soluble in water, more so, for example, than nitrogen, and some mineral springs and some mine gases contain considerable quantities (*16*). The anorthoclase crystals that were analyzed may have been bathed for hundreds of thousands of years in a soil atmosphere and soil moisture containing radiogenic argon. Moreover, the amount introduced might be increased to the degree that the anorthoclase is partly argillized, and argon possibly absorbed into the clayey fraction.

Date for Bed II

Assume that the date for bed II is accurate. If the date for bed II is accurate, we feel that the probabilities are that the anorthoclase, oligoclase, and biotite in bed I gave dates which are too old. For reasons already cited, bed I appears to be only a little older than bed II; the big unconformity in the section would seem to be between the basalt and bed I, and not within bed I or between it and bed II. The indicated age of the basalt therefore need not be regarded as inconsistent with the indicated age of bed II.

Conclusion

Because some of the Olduvai Gorge dates are inconsistent, some must be inaccurate; they may all be. Until further tests determine which materials give dependable dates, we do not know which dates are accurate. Until this is learned, the indicated ages must be taken *cum grano salis.*

Until the contradictory dates and the existence and duration of the unconformities are resolved, the dates are of doubtful value in formulating hypotheses about the rates of evolution of man and his culture, rates of other vertebrate evolution and migration, rates of soil development, rates of accumulation of volcanic ash, and of the persistence of ancient lakes. Whatever the hypothesis, it must be frankly admitted to be speculative. We heartily agree with the already quoted caution urged by von Koenigswald, Gentner, and Lippolt (*6*). The ages of *Zinjanthropus* and other hominid fossils from Olduvai Gorge thus are *sub judice.*

References

1. L. S. B. Leakey, *Nature* **184**, 491 (1959).
2. ———, *ibid.* **188**, 1050 (1960).
3. ———, *ibid.* **189**, 649 (1961).
4. J. Napier, *Lancet* **1961, II**, 767 (1961).
5. L. S. B. Leakey, J. F. Evernden, G. H. Curtis, *Nature* **191**, 478 (1961).
6. G. H. R. von Koenigswald, W. Gentner, H. J. Lippolt, *ibid.* **192**, 720 (1961).
7. L. Pauling, *College Chemistry* (Freeman, San Francisco, 1950).
8. Lord Rayleigh, "Argon," in *Encyclopaedia Britannica* **2**, 475 (ed. 11, 1910).
9. L. S. B. Leakey, *New Scientist* **12**, 501 (1961).
10. ———, *Olduvai Gorge* (Cambridge Univ. Press, Cambridge, 1951).
11. ———, *Sci. Am.* **190**, 66 (1954).
12. ———, *The Stone Age Races of Kenya* (Oxford Univ. Press, London, 1935).
13. B. Kurtén, *Cold Spring Harbor Symposia Quant. Biol.* **24**, 205 (1959).
14. A. Knopf, *Sci. Monthly* **85**, 225 (1957).
15. J. F. Evernden, G. H. Curtis, R. Kistler, *Quarternaria (Rome)* **4**, 13 (1958).
16. K. Rankama and T. G. Sahama, *Geochemistry* (Univ. of Chicago Press, Chicago, 1952).