The KBS tuff controversy may be ended

from R. L. Hay

THE recent papers by Gleadow (*Nature,* **284,** 225; 1980) and McDougall *et al.* (*Nature,* **284,** 230; 1980) may have ended a decade of controversy over the age of the KBS tuff in the East Turkana region of Kenya. The KBS tuff is critical to the dating of Early Man and his tools in this important anthropological site. Efforts to date this tuff provide a fascinating and instructive case history of geochronology which illustrates the process of trial and error by which science progresses. Some of the highlights of this case history are sketched below.

The KBS tuff lies near the middle of the Koobi Fora Formation, which yielded its first hominid fossils to Richard Leakey's expedition in 1968. By 1973, 110 hominid fossils had been collected. Primitive artefacts were discovered in 1969, and two occupation sites were excavated in the KBS tuff by Isaac *et al.* (*Science* **173,** 1129; 1971). Feldspar from the tuff was dated by Fitch and Miller (*Nature,* **226,** 226; 1970) both by the conventional (total degassing) K–Ar method and by the newly developed ^{40}Ar/^{39}Ar step-heating method. The conventional method produced a wide scatter of ages, clearly in part because of contamination by older feldspar. An age of 2.61 ± 0.26 Myr was assigned to the tuff on the basis of the ^{40}Ar/^{39}Ar age spectra. Dates younger than 2.6 Myr from the conventional method were believed to reflect argon loss caused by regional hydrothermal alteration.

Doubt about the date of 2.6 Myr was raised by some palaeontologists, who found an age of 2 Myr more in accord with dated faunas at Olduvai Gorge and the Shungura Formation in the Omo basin (Cooke & Maglio in *Calibration of Hominoid Evolution* (eds Bishop, W. E. & Miller, J. A.) 303, Scottish Academic Press; 1972). The palaeomagnetic stratigraphy of the Koobi Fora Formation was now studied by Brook and Isaac (*Nature* **234,** 344; 1974) with the object of dating the strata by matching their polarity with the newly established polarity time scale. They found two possible fits with the polarity scale, one of which was compatible with the KBS tuff date of 2.6 Myr. Curtis *et al.* (*Nature,* **258,** 395; 1975) added to the controversy by reporting K–Ar dates of 1.60 Myr for the KBS tuff at one locality and 1.82 Myr from the tuff at another locality. Their results were particularly significant because dates on feldspar and glass were concordant, thus providing strong evidence against loss of radiogenic argon. If their results were accurate, the KBS tuff must be in fact two tuffs, separated in time by 200,000 years.

Next, zircons from the KBS tuff were dated by the fission-track method. The zircons contained low fission-track densities, but an age of 2.44 ± 0.08 Myr was obtained by Hurford *et al.* (*Nature* **263,** 738; 1976). Fitch *et al.* (*Nature* **263,** 740; 1976) recalculated their step-heating results and now suggested 2.42 Myr as the best K–Ar age.

In 1977 Harris and White (*Science* **198,** 13; 1977) concluded from their studies of suid evolution that deposits below the KBS tuff were equivalent to fossiliferous beds in the Omo basin and Olduvai Gorge that had been dated at about 1.8 Myr. Hillhouse *et al.* (*Nature* **265,** 411; 1977), in another palaeomagnetic study of the Koobi Fora Formation, found that although two correlations were possible with the polarity time scale, placing the KBS tuff in the Olduvai normal event (~1.7–1.85 Myr) created fewer difficulties in the geological history than did an age of 2.4 Myr for the tuff.

Cerling *et al.* (*Nature,* **279,** 118; 1979) now correlated the KBS tuff with tuff H_2 (~1.8 Myr) of the Shungura Formation on the basis of chemical composition of glass and feldspar. This correlation received strong support from additional dating of the KBS tuff by Drake *et al.* (*Nature* **283,** 368; 1980). They gave an age of 1.8 ± 0.1 Myr for the tuff, and explained that the date of 1.60 Myr reported earlier for the tuff at one locality was incorrect because of an error in K analyses.

The latest and perhaps the final statements on the age of the KBS tuff are provided by McDougall *et al.* Their meticulous K–Ar dating of feldspar gave an age of 1.89 ± 0.01 Myr. Fission-track dating by Gleadow yielded an age of 1.87 ± 0.04 Myr, and made a notable contribution to the methodology of fission-track dating of zircons which contain low track densities. In closing, it should be emphasized that the KBS tuff has been a testing ground for various geochronologic methods, both new and old, and the science of geochronology has learned much from the "KBS tuff controversy."

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Trans. R. Soc. **B267,** 503; 1974). These studies have involved the great albatross-like soaring pteranodontids of the Cretaceous, such as a 7 m wing-span *Pteranodon,* but even this is dwarfed by *Quetzacoatlus* from Texas, the humerus of which is 70% longer than that of *Pteranodon,* and which may have had a wing span of 15 m!

Modern workers seem agreed that the smaller pterosaurs, at least, were actively-flapping fliers, and it now appears that there was, after all, a strong ventral keel projecting forwards from the sternum, which was itself also strongly braced from the scapula by powerful coracoid bones, very much as in birds.

The freeing of the hind-limb of pterosaurs from the flight membrane also helps in the interpretation of their method of launching themselves into the air. Wellnhofer (*Palaeontographica* **A149,** 1; 1975) believes that the hind-limbs could at least have raised the body into the air far enough that, facing into the wind, the outstretched wings could lift the body from the ground, and that the hind-limb could also have helped to thrust it skywards.

But further problems arise from the diet of pterosaurs. Both their common presence in marine deposits, and their preserved stomach contents, show that most of them fed on fish. Wild has most recently discussed the problems of the method they used to catch their prey (*Boll. Soc. pal. Italiana* **17,** 176; 1978). Though some living birds catch fish from near the water surface by flying close above it, Wild points out that pterosaurs must have been far less competent aerodynamically. This, together with their proportionately much longer wings, would make it inevitable that a wing-tip would sooner or later hit the water, bringing the whole creature down into the sea. Wild also argues that the braking effect of dipping the beak into the water to catch fish would cause such a drop in speed as to bring the pterosaur down. He instead believes that they fished by folding their wings and diving into the water. (This would inevitably have placed considerable strain on their skull and skeleton, and it would be instructive to investigate whether they show any convergences with the adaptations of living diving birds such as gannets.)

There is evidence that the hind feet of pterosaurs were webbed and they must have used these for swimming, whether their immersion was voluntary or accidental. Wild thinks it possible that they might have been able to rise from the water surface by spreading their wings, or that they might instead have swum to nearby land so as to rise from a solid surface. (Could it be that the hairy covering had a water-repellent function?)

The pterosaurs which Wild describes come from the Late Triassic and include members of two different families. The origin of the group as a whole must therefore lie in the earlier Triassic at least. Wild points out that the whole organization of the early pterosaurs suggests derivation from a small running and climbing insectivorous reptile. He believes that this strongly suggests that they evolved from the little eosuchians of the Late Permian and Early Triassic, rather

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