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ESR dates for the hominid burial site of Qafzeh in Israel

Early modern hominids are found buried at the mouth of a cave at Qafzeh near Nazareth, Israel. They are associated with a Middle Paleolithic lithic industry. Previous dating of this site by TL analysis of burnt flint (Valladas *et al.*, 1988) gave an age of 92 ± 5 kyr. We have now used the ESR method to date enamel of teeth of large mammals from the hominid-bearing layers. Assuming a constant rate of uptake of U through time by the teeth, we obtain an age of 115 ± 15 kyr. This is consistent with the TL results demonstrating early arrival of fully modern humans in Southwestern Asia.

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The timing of the evolution of modern man has been a subject of controversy among paleoanthropologists concerned with human origins (Vandermeersch, 1981; Trinkaus, 1984). The site of Qafzeh has presented a particular problem because fully modern humans have been found there in association with a Middle Paleolithic lithic industry (Vandermeersch, 1981). This is in contrast with the situation in Europe where modern humans are invariably associated with Upper Paleolithic artifacts and occur at sites dated to younger than 35 kyr (Wolpoff, 1980). At the site of Kebara, about 35 km distant from Qafzeh, on the coastal plain, a Neanderthal skeleton has been found associated with a

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Middle Paleolithic industry. This site has recently been dated by thermoluminescence analysis of burnt flint (Valladas *et al.*, 1987) and the deposits have been found to range in age from 60 kyr to 48 kyr. The same method has now also been used to date the burial layers at Qafzeh yielding a mean age of 92 ± 5 kyr (Valladas *et al.*, 1988).

Previous estimates of the age of the hominids at Qafzeh were based on the presence of an associated micromammal assemblage which is common to at least 5 other caves, spaced less than 35 km from one another. The micromammal-bearing levels in these caves can in turn be correlated to a high sea-stand that dates to the last interglacial (≥85 ka) (Tchernov, 1981; Bar-Yosef & Vandermeersch, 1981). Jelinek (1981) argued for a younger date on archaeological grounds. Amino acid racemization dating was attempted on bone fragments from Qafzeh (Masters, 1982), yielding ages of 73 ± 5 to 51 ± 4 kyr for beds XXII to XVII in the sequence of sediments in which the burials are found. This sequence of deposits, found underlying the so-called "Terrasse" in front of the cave, contains only a Mousterian industry while, inside the cave, overlying an erosional gap, there are found Upper Paleolithic tools.

The hominid remains at the site are quite variable in skeletal morphology. While they all represent anatomically modern (a.m.) individuals, some display primitive features in cranial morphology (Vandermeersch, 1981; Stringer, 1978; Stringer & Trinkhaus, 1981). Nevertheless, their identification as early a.m. hominids, has led several workers to favour a young age (<50 ka) for the deposit (Trinkaus, 1984; Wolpoff, 1980).

In view of the importance of these deposits and the uncertainty surrounding their age we have attempted to date them by electron spin resonance (ESR) analysis of tooth enamel. The principles of this method have been recently described by Grün *et al.* (1987). The method has been applied to the dating of archaeological sites of Bilzingsleben (Schwarcz *et al.*, 1988) and La Micoque (Schwarcz & Grün, 1988). Briefly, the ESR method consists of using the peak-heights of certain characteristic ESR spectral features to estimate the amount of radiation dose that a sample of enamel has received while buried in sediment (the "accumulated dose" or AD). The age is given by the ratio of the AD to the dose rate as generated by the radioactive elements U, Th and K in the soil as well as cosmic rays. Teeth also experience an internal radiation dose due to uranium taken up by the enamel and dentin through time. We must therefore make some assumption about the history of U uptake. Grün *et al.* (1987) have derived expressions for the age assuming either that the present-day U content was all acquired soon after burial (early uptake: "EU"), or that the U was acquired at a constant rate through time (linear uptake; "LU"). The EU age is always the minimum possible age for a sample with a given AD, U content and external dose rate. We find in general that the LU ages agree with independent age estimates such as U-series dates on associated travertine deposits (e.g., Schwarcz *et al.*, 1988).

We selected samples of teeth from the macrofauna collected by the excavators from layers XV to XXI of the terrace deposits (Bouchud, 1974). The outer layer of enamel was removed from each tooth to eliminate the effect of external alpha particle dosage. AD values for the cleaned, powdered samples of enamel were determined by the additive dose method, using a ^{60}Co gamma source. Logarithmic fits were made of dose vs ESR intensity yielding correlation coefficients $r > 0{\cdot}99$ in all cases. Dose rates were estimated as follows: *Internal*: from U analyses of enamel; *External*: (a) from U content of dentine and cementum; (b) from U, Th and K analyses of soil found adhering to teeth (beta dose); and (c) combined gamma and cosmic ray doses from 13 TL dosimeters ($CaSO_4$/Dy) which had been buried for a year in the sediment of the site near where the tooth samples had been collected, as previously reported by Valladas *et al.* (1988). Ages have been calculated assuming both early (EU) and continuous, linear (LU) uptake of U by both enamel and dentin. The internal and dentin-derived doses are low and therefore the external dose rate is critical in estimating the age.

The cosmic ray dose has been independently calculated, following Prescott (1982) and given the burial depth of 3 m of sediment; it is estimated to be about 12 mrad/yr, or about 50% of the total external dose rate. It is possible that, at the time of burial there was a rock roof projecting over this site, in which case, for some part of the history of the deposit the cosmic dose rate would have been less, perhaps half of the present-day value. In that case, the calculated ages (both ESR and TL) would become a few percent greater and should be taken, therefore as minimum estimates. The microfauna in the terrace layers is typical of that found inside a cave (E. Tchernov, pers. comm.), suggesting that a cover may have extended over the site in the past.

Table 1. **ESR Dates for enamel from Qafzeh**

		ESR ages (kyr)	
Sample	Layer	EU	LU
370A	XV	92·1	112·0
370B		94·2	114·0
373	XV	94·7	116·0
372	XVII	95·2	103·0
368A	XIX	87·7	106·0
368B		99·7	112·0
368C		102·0	117·0
368D		111·0	124·0
371A	XIX	107·0	128·0
371B		119·0	145·0
371C		82·0	101·0
369A	XXI	95·9	118·0
369B		118·0	143·0
369C		73·7	94·0
369D		74·2	89·1
369E		95·3	116·0
Averages:		96 ± 13	115 ± 15

The ages obtained (Table 1) show no systematic increase with depth. A similar narrow range of ages was observed by Valladas *et al.* (1988). EU ages are, as usual, lower than those calculated assuming continuous U uptake. U-series analyses of dentine from one of the samples gave an apparent age of 20 ka, indicating that continuous U uptake has occurred until recent times (Grün *et al.*, 1988); LU age estimates are therefore more appropriate. Burial to the present depth probably occurred soon after deposition since there is little variation in dose with depth, and therefore variation with depth in the cosmic ray component on the dose has remained constant through time.

Using these estimates of the dose rate and U-uptake, we obtain average ages of 96 ± 13 (EU) and 115 ± 15 kyr (LU). The EU estimate overlaps that obtained by TL analysis of burnt flints from this site (Valladas *et al.*, 1988) while the LU estimate is only marginally larger at the 1σ level. As noted, our most probable estimate of the true age is given by the

LU date, but a U-uptake history intermediate between the EU and LU profiles (Grün *et al.*, 1988) would also give ages that overlap the error limits on the TL age. As noted above, if the cosmic ray dose in the past was lower due to partial cover of the site, then both the ESR and TL ages could have been a few percent higher. Note that while the ESR dates make use of the same background radiation dose rate measurements as the TL dates, the short-range dose rates for the tooth samples were determined totally independently as were the accumulated doses. As noted above, the external beta dose to the enamel was estimated from the U, Th and K contents of soil found adhering to these teeth, or from the U content of the adjacent dentin. Whereas the external dose rate (from the sediment) was the dominant contributor to the accumulated ESR dose, the internal dose was dominant in the case of the AD obtained by TL on burnt flint (Valladas *et al.*, 1988). This further emphasizes the independence of the two dates for this site.

The TL and ESR results are also consistent with one another in showing that there was no measurable difference in age between the stratigraphically highest and lowest layers sampled in these two studies (layers XV to XXI). This implies that the entire deposit was formed over a time interval that was short relative to the age of the deposit. Vandermeersch's (1981) studies of the skeletal material as well as the lithic industrial assemblage also do not suggest a substantial range in time for these layers.

The ESR dates are consistent with the TL results in showing that fully modern humans were present in southwestern Asia near the end of oxygen isotope stage 5 (last interglacial *sensu lato*), and predated or even coexisted with Neanderthals in that region. These confirm the existence of anatomically modern hominids in southwest Asia long before their earliest known appearance in Europe or the rest of Asia. This result is consistent with the observation of anatomically modern hominids from the Klasies River Mouth cave, South Africa, found in beds which are inferred to date from the last interglacial (Singer & Wymer, 1982). We have presented here evidence that modern man arrived into western Asia from southern Africa by no later than 115 ka. His further advance into Europe appears to have been delayed for about 70 000 years, due possibly to the dominance of Neanderthal man in that region.

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