Journal of Archaeological Science 1993, **20**, 169–174

Thermoluminescence Date for the Mousterian Burial Site of Es-Skhul, Mt. Carmel

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(*Received 9 October 1991, revised manuscript accepted 13 March 1992*)

In the 1930s, the skeletal remains of at least 10 hominids were uncovered in the cave of es-Skhul (Mt. Carmel, Israel). Thermoluminescence (TL) dates have been obtained on six burnt flints from level B in which these so-called "proto-Cro-Magnons'" remains were found. The TL average date, 119 ± 18 ky BP, is consistent with the previous ESR estimates (81 ± 15–101 ± 12 ky BP) and confirms the great antiquity of early modern humans in the Levant.

Keywords: TL DATING, ES-SKHUL, MODERN HUMANS, NEAR EAST.

Introduction

In recent years it has been established that during the Middle Palaeolithic period the Levant was inhabited by two morphologically different kinds of humans producing similar lithic industries. The two are best represented by the so-called "proto-Cro-Magnons" discovered at Qafzeh and es-Skhul and the Neanderthals found at the Tabun, Kebara, Amud and Shanidar caves.

The phylogenetic relationship between these two populations has been a hotly-debated subject for years. Some anthropologists (Trinkaus, 1984) were of the opinion that the Neanderthals evolved into modern humans. Others (Vandermeersch, 1982, 1985), on the other hand, saw no such succession, believing that the two populations were phylogenetically independent. Cited in favour of succession was the metrical analysis of the Tabun cave lithic assemblages, which exhibits, according to Jelinek (1982), an evolutionary trend expressed in the degree of decreasing thickness of flakes over time. So the relative ages of these skeletal remains became of great importance in resolving this argument.

In 1988 the age of the lower Mousterian levels of Qafzeh where numerous skeletal remains were uncovered, was given as 92 ± 5 ky BP (Valladas *et al.*, 1988). This age, determined from the thermoluminescence (TL) date of the burnt flints, was confirmed

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0305–4403/93/020169+06 $08.00/0

Table 1. TL and ESR dates obtained for the sites cited in the text

	TL ages (ky)		ESR ages (ky)	(EU)	(LU)
Qafzeh	Mean age: Layers XVII–XXIII	92±5	Mean ages: Layers XV–XXI	96±13	115±15
Kebara	Mean ages:		Mean ages:	60·4±5·9	64·3±5·5
	Layer VI	48·3±3·5	Layer X		
	VII	51·9±3·5			
	VIII	57·3±4·0			
	IX	58·4±4·0			
	X	61·6±3·6			
	XI	60·0±3·5			
	XII	59·9±3·5			
Es-Skhul	Mean age: Layer B (This study)	119±18	Mean ages: Layer B	81±15	101±12
Tabun			Mean ages:		
			Layer B	86±11	103±16
			C	102±17	119±11
			D	122±20	166±20
			Ea	154±34	188±31
			Eb	151±21	168±15
			Ec	176±10	199±7
			Ed	182±61	213±46

All the results are given in ky BP.

soon after by a similarly great age (96 ± 13 ky to 115 ± 15 ky BP) derived from the electron spin resonance (ESR) date for associated dental remains (Schwarcz *et al.*, 1988). The dates (Table 1) agree with an early estimate based on a palaeoclimatic reconstruction and a microfaunal analysis which put these hominids somewhere during stage 5 of the marine oxygen isotope stratigraphy (Bar-Yosef & Vandermeersch, 1981; Tchernov, 1981).

Since es-Skhul is the only other Levantine site to have yielded "proto-Cro-Magnon" fossils associated with Mousterian industries, the importance of establishing a correct chronology for the relevant layers is evident. The ESR dates (81 ± 15 to 101 ± 12 ky BP) for two bovid teeth from the hominid-bearing level B at es-Skhul (Stringer *et al.*, 1989) suggested that the es-Skhul and Qafzeh hominids lived at about the same time period. The wide age gap between the two ESR estimates results from calculations assuming two regimes for the uptake of uranium by teeth.

To establish more firmly this relative contemporaneity and antiquity of the two representatives of the "proto-Cro-Magnon" occupation of the Levant an independent date was needed for the relevant es-Skhul levels. Six burnt flints from level B at es-Skhul from the collections of the Peabody Museum (Harvard University) were therefore dated by thermoluminescence. Because of conditions peculiar to this site, and the fact that only two teeth had been dated, TL offered certain advantages over ESR which will be dealt with below.

The site

The site of es-Skhul is located on the western slope of Mt. Carmel, at the outlet of Nahal Ha'Mearot (Wadi el Mugharah), about 160 m north of Tabun cave. It was excavated by

T. D. McCown in 1931–2 as part of D. Garrod's project. McCown recognized three stratigraphically distinct units (McCown, in Garrod & Bate, 1937; McCown & Keith, 1939), as follows: Layer A was only 20–50 cm thick and contained a mixed assemblage of Natufian, Aurignacian and Mousterian implements. Layer B, in which the remains of ten individuals were uncovered, was about 2 m thick and was further subdivided into B1 and B2, although no apparent sedimentological changes were observed. Most of the hominid remains were identified by the excavator as intentional inhumations and only one contained what was considered to be grave goods: a complete jaw of a wild boar. The lithic industry of Layer B is Mousterian, produced by the Levallois technique and resembles that of Tabun C (Garrod & Bate, 1937) and Qafzeh (Meignen & Bar-Yosef, 1988). The faunal collection was dominated by numerous remains of bovids and was correlated by Bate with the faunal assemblages of Tabun D and C. The lower-most unit was layer C. It was a sandy deposit which filled some shallow cavities in the bedrock and yielded an abraded Mousterian lithic assemblage, comparable to Tabun C (Garrod & Bate, 1937).

Thermoluminescence Dating

We will briefly describe the principles of TL dating of burnt flint and show how it differs from the ESR dating of teeth. Thermoluminescence measures the number of electrons trapped at excited energy levels of certain crystalline components of flint. The energy responsible for exciting the electrons into these "traps" comes almost exclusively from radiation received by the flint. So from the number of trapped electrons one can estimate the total radiation dose accumulated by the burnt flint. Since heating flint above a certain temperature empties these traps, one can tell how long ago the fire into which the flint fell was last used if one can determine the "annual dose" of radiation received by the flint at its burial site. ESR also measures the number of electrons trapped in mineral components of teeth since the latter became buried.

Both flint and teeth receive radiation from two independent sources, one internal and one external, but in different proportions. The internal radiation dose in *flint* comes mostly from α- and β-rays emitted by the ever-present U, Th and ^{40}K and their radioactive decay products. Due to their relatively long half-lives the relevant radio-elements undergo so little loss during the time intervals of concern to us that the internal annual radiation dose can be treated as a constant. This dose can be calculated from concentrations of these radio-elements measured by neutron activation analysis with a precision of $\pm 6\%$.

Teeth, on the other hand, receive their internal radiation dose from uranium which replaces calcium during burial in uranium-containing soil. Since the past rate of replacement is unknown (it depends on the uranium and water content of the soil, temperature and pH) two extreme scenarios are usually proposed: in one, a rapid early uptake, soon after burial, is assumed; in the other, the uptake is assumed to be a linear function of time. Ages calculated on the basis of the two assumptions are usually followed by the letters EU and LU respectively. Consequently, the advantage of using flint with its constant and measurable internal annual dosage must be obvious.

Since the radionuclides mentioned above are present in most soils the external radiation dose comes mostly from the γ-rays originating within a radius of about 30 cm around the buried flint or tooth. This dose is measured directly by burying dosimeters at points near the object recovery site, or, if the relevant strata have been removed, from the radioactivity of any soil samples which might have been kept. To the external source mentioned above one adds the cosmic radiation dose. The external dose is the only datum shared by the TL and ESR methods.

The samples discussed in this article were subjected to the following treatment. After scraping off the outer layer penetrated by external α- and β-radiation, we crushed the flint core until the grain size was reduced to below 160 μm. This powder was divided into two

Table 2. Experimental data and calculated results of TL dating of burnt flints from level B at es-Skhul

Sample	U* (ppm)	Th* (ppm)	K* (ppm)	Sa†	Internal dose (mGy/y)	Annual dose‡ (mGy/y)	Palaeodose (Gy)	Age (ky BP)
ES1	1·564	0·294	900	2·58	1·067 ± 0·152	1·525 ± 0·190	170·83 ± 18·19	112·0 ± 16·1
ES2	1·384	0·334	1192	2·20	0·955 ± 0·063	1·413 ± 0·131	189·25 ± 25·40	133·9 ± 22·3
ES3	0·741	0·204	743	1·84	0·466 ± 0·036	0·929 ± 0·120	111·64 ± 7·89	120·2 ± 17·9
ES4	0·607	0·189	480	1·54	0·335 ± 0·022	0·799 ± 0·117	96·34 ± 5·41	120·6 ± 19·0
ES5	1·244	0·208	708	1·60	0·663 ± 0·046	1·119 ± 0·124	186·70 ± 20·98	166·8 ± 26·8
ES6	0·700	0·181	587	1·61	0·396 ± 0·031	0·859 ± 0·119	85·38 ± 6·66	99·4 ± 15·9

*Uranium (U), Thorium (Th) and Potassium (K) contents measured by neutron activation; each value has an error of ±6%.
†β-dose equivalent to the flux of one α · cm^{-2}, as deduced from fine grains measurements (Huxtable & Jacobi, 1982). The error on Sα ranges from ±3 to ±15%.
‡The annual dose includes the internal dose deduced from the U, Th and K contents of the flint (Bell, 1979; Valladas & Valladas, 1982) and the external γ-dose estimated at 0·38 ± 0·12 mGy/y (Stringer *et al.*, 1989); the estimated cosmic radiation dose of 0·10 mGy/y takes into account the attenuation produced by the adjacent cliff.

parts: one to be used for the determination of radionuclide concentrations by neutron activation analysis, the other for TL measurements. The latter was sieved and the 100–160 μm fraction was collected and washed with hydrochloric acid to remove any carbonates present. The TL was measured at a rate of 10 °C s^{-1} by means of a photomultiplier in front of which a violet optical filter (MTO, maximum transmission: 380 nm) was placed. Each TL measurement used 2 mg of powder. The flint TL exhibits a well-defined peak centred near 380 °C which shows suitable properties for dating purpose. The palaeodose was obtained by using the standard additive method, without performing any preheating before TL measurements. For more details, the reader may consult two recent publications by Aitken (1985) and Valladas (1992).

The mean age was calculated from the weighted average of the six results. The predicted error limit (random plus systematic) in the mean age was computed by the method described by Aitken (1976). A systematic error of ±30% has been attached to the environmental dose to allow for the possible variations of the γ-dose rate due to the inhomogeneity of the radio-elements distribution in layer B and for the variations of the water content in the sediment. The systematic errors in radioactive source calibration are respectively ±3% for the Co-60 artificial source (palaeodose measurement) and ±7% for the Pu-238 source (α-contribution).

Experimental Results

Table 2 lists data concerning each flint, which came from McCown's excavations. Since the relevant strata at es-Skhul were removed in the 1930s it was impossible to measure the external radiation dose *in situ*. The authors of the ESR article (Stringer *et al.*, 1989) did the next best thing—they estimated the dose from the measured uranium (1·86 ± 0·62 ppm), thorium (2·18 ± 1·31 ppm) and potassium (0·451 ± 0·225%) contents of soil specimens which had fortunately been saved. Although we have no way of knowing if the surviving soil samples are truly representative of what had surrounded the flints, we are using the published values as the best possible estimate of the true γ-dose. It should also be kept in mind that the external dose is unlikely to have remained constant over the millennia that the samples remained buried because the water content of the surrounding soil has probably varied. In the case of es-Skhul we have assumed, on the basis of palaeoclimatic data, a 15% water content for the relevant soil.

Fortunately, the high internal radiation doses found in the es-Skhul burnt flints made TL dating of flints much less sensitive than ESR dating of teeth to variations in the γ-component of the external dose. With the data and water-content assumptions mentioned in the preceding paragraph, the external γ-dose received by the es-Skhul flints was estimated to account on average for only about 33% of total. To illustrate the relative impact of external dose uncertainties on the TL and ESR dates we estimated the effects of a hypothetical 30% error in the external dose: the average TL age of the burnt flints would differ from the one calculated by only 10% while for the average ESR date for the two teeth, the difference would be 18%, when including the contribution of the β-external dose.

The TL dates for level B average 119 ± 18 ky BP. Considering the uncertainties in the external dose the results are in relatively good agreement with the somewhat lower ESR dates cited above.

Conclusions

The TL date for *level B* at es-Skhul provides additional support for the published ESR date which first suggested considerable antiquity for the early modern humans who were buried in the site. The confirmation was useful because of the uncertainties regarding the properties of the soil which originally surrounded the remains, uncertainties which have much less impact on dates calculated from the TL of burnt flints than on those computed from the ESR of teeth. Thus, we now have confirmatory evidence that the Qafzeh hominids were not the only early modern humans to have been present in the Levant by about 100 ky BP.

The recently published ESR dates (Table 1) for *level C* at Tabun (Grün *et al.*, 1991) put the "Neanderthal woman" whose skeletal remains were attributed to that level in the same time range (102 ± 17 (EU) to 119 ± 11 (LU) ky BP) as the early modern humans at Qafzeh and es-Skhul. It should be stressed that D. Garrod was not certain about the stratigraphic position of this burial and indicated that it could have been of Tabun B age (Garrod & Bate, 1987: 64). Since the Kebara dates (Valladas *et al.*, 1987; Schwarcz *et al.*, 1989) show that some Neanderthals were still living in the area by 60 ky BP, the question of contacts and possible interbreeding between the two types of *Homo sapiens* will have to be addressed by archaeologists and anthropologists.

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