ELECTRON SPIN RESONANCE DATING FOR THE AGE OF PEKING– MAN, LOC.1, ZHOUKOUDIAN, BEIJING

Huang Peihua (黄培华), Jin Sizhao (金嗣昭), Liang Youren (梁又任),
Lu Zhongjia (陆仲家) Zheng Lizhen (郑丽珍)
(University of Science and Technology of China, Hefei 230026, China)
Yuan Zhenxin (袁振新), Cai Bingxi (蔡炳溪)
(Institute of Vertebrate Palaeontology and Palaeoanthropology, Academia Sinica, Beijing 100044, China.)
and Fang Zhaomeng (方超萌)
(Institute of Atomic Energy of China, Beijing 102413, China)

(Received January 1990)

ABSTRACT

In this paper, we used ESR dating method to measure the accumulative dose of the fossil teeth samples, which are contemporaneous with the Peking– Man. The internal annual dose rate of samples are got by neutron activation analysis and the environ– mental annual dose rate by highly sensitive TL dosimeters to be embedded in cave deposits in the site. The results of ESR dating are corresponded with the dating results obtained by U– series, FT, TL and paleomagnetic stratigraphical methods on the 3rd, 4th, 7th and 10th layers. Calculation of using different models, the close– equilibrium model, the linear uranium accumulation model and radon loss– linear uranium accumulation model, for travertine, deer teeth and rhinoceros tooth, we obtained the age of the First Peking– Man in the 11th layer is 578 ka and gave ages of other layers, from the 1st to the 13th layer in Peking– Man site.

Key words: ESR dating Peking– Man's age

I . INTRODUCTION

Sixty years ago, Prof. Pei Wenzhong (W.C.Pei) discovered the first skull of Peking– Man at Zhoukoudian, in December 1929[1]. However, the exact age of the skull is still a mystery up to now.

In dating research of the Peking– Man site, the methods of U– series, thermoluminescence (TL), fission track (FT) and paleomagnetic stratigraphy were adopted. The 3– 4th layer age, the ages of the 7th and the 10th layers were determined[2] But the age of the 11th layer with the first skull of Peking– Man has been not still obtained as yet.

In this paper, the fossil teeth, which are contemporaneous with the Peking– Man, were used for dating. We collected the fossil teeth of deer and rhinoceros from the 3– 4th layer, the 8– 9th layer, the 11th layer and the 12th layer at the site. The calculational formula of ESR age for the fossil teeth is as follows:

$$\text{ESR age } T\,(\text{ka}) = AD\,(\text{Gy})\,/D\,(\text{mGy/a}) \quad (1)$$

where AD is the accumulative dose, D is the annual dose.

Ⅱ. DETERMINATION OF ACCUMULATIVE DOSE

Accumulative dose (AD) of the natural radiation is usually determined by the "additive dose method", the teeth enamel samples are given different additional ^{60}Co–γ doses, the ESR signal intensity is increasing with the growth of the additional dose, the ESR signal intensity is used as the Y coordinate, while the γ doses as the X coordinate, were treated by means of the least square method and back extrapolation to zero ESR intensity to obtain AD value [3-4-5].

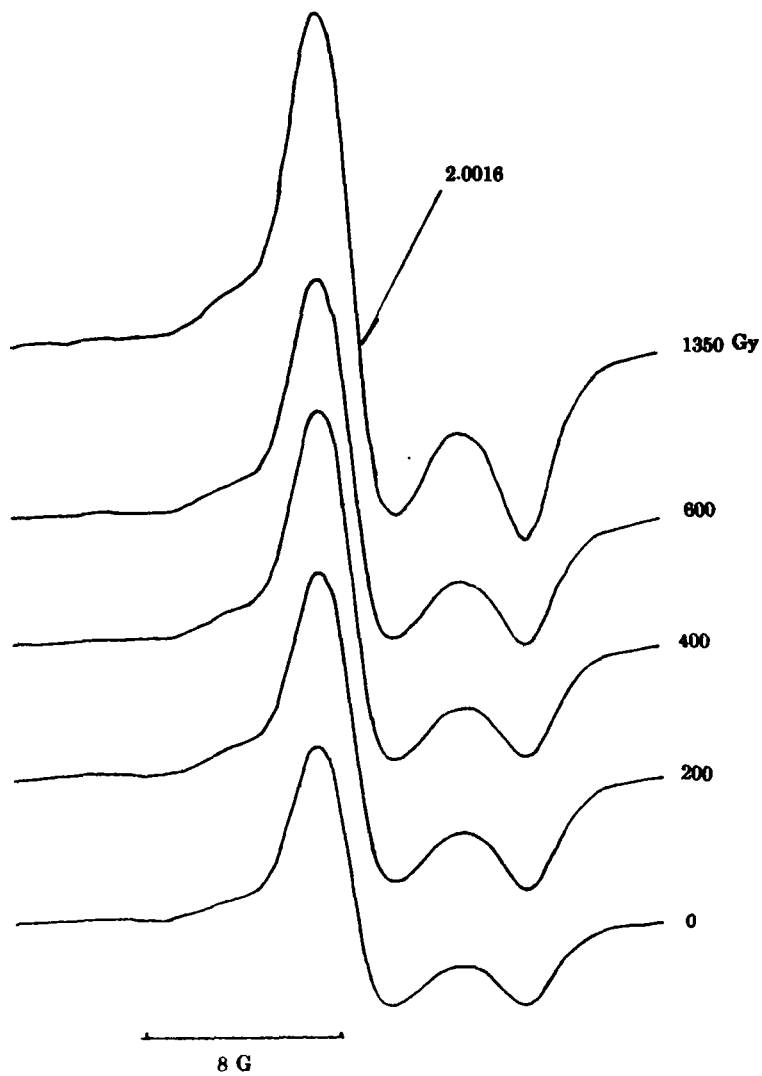

Fig. 1 ESR spectra of the deer tooth in the 11th lager

Fig. 1 is ESR spectra of the tooth enamel sample of deer in 11th layer, which are contemporaneous with the Peking– Man. The measurement conditions are 9.7319 GHz, 2 mw and 0.8 Gpp.

The relationship between the ESR signal intensity and the additional irradiation doses appears in good linearity (Fig.2). The correlative coefficient(r) of the straight line is 99.3% and the AD value is 1563.5 Gy for tooth enamel of deer in the 11 layer. Other AD values are shown in Table 1.

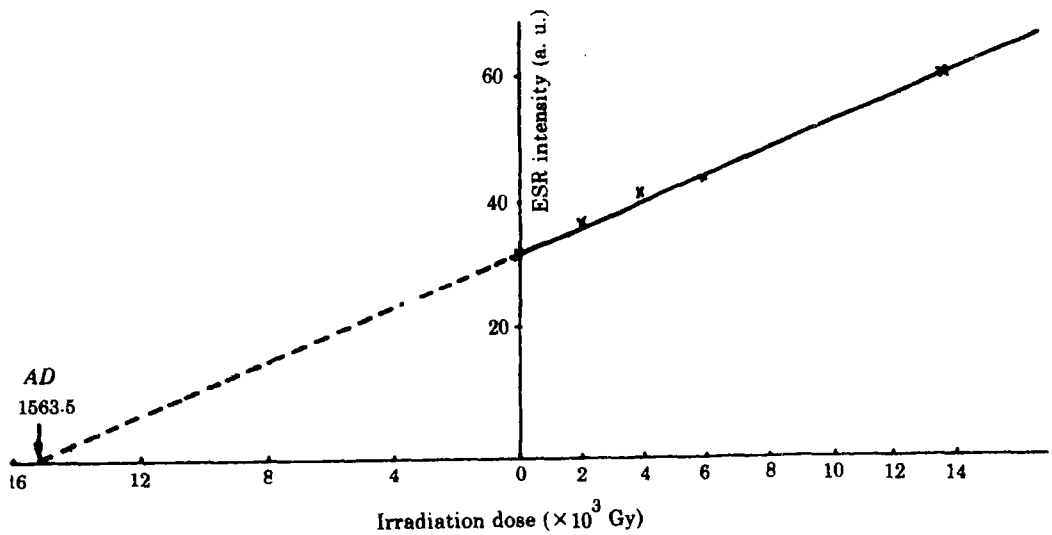

Fig.2 The relationship between the irradiation dose and the ESR intensity of the deer tooth in the 11th layer.

Table 1

ESR dating results of Peking– Man Site

Layer		1– 2	3– 4– 5	8– 9	11	12
Sample		Travertine	Deer teeth	Deer teeth	Deer teeth	Rhinoceros teeth
AD (Gy)		321.4	1182.6	1233.7	1563.5	3986.1
^{238}U (ppm)	enamel	0.33	14.90	9.70	6.24	
	dentine		38.70	20.70	23.60	34.10
^{232}Th (ppm)		0.71	0	0	0	0
^{40}K (ppm)		0.117	0	0	0	0
De (mGy/a)		1.4520	11.4839	7.9757	6.1064	13.6196
D_{34} (mGy/a)			0.5574	0.4096	0.2256	1.1123
D_{30} (mGy/a)			8.6588	5.7692	4.4372	13.8412
ESR age (ka)		221	282	418	578	669

Ⅲ. DETERMINATION OF ANNUAL DOSE

Annual dose (D) includes two parts: One is internal dose (Di) of tooth sample. Di is determined by neutron activation analysis for U, Th and K, another part is environmental dose (De), De is obtained by the embeded thermoluminescence

dosimeter in 1st layer to 12th layer at the site for three months. *De* consists of sample external annual dose (*Dex*) and the annual dose of the cosmic ray et al.

The first step, we calculated annual dose (D_E):

$$D_E = k_\alpha D_{i\alpha} + D_{i\beta} + De \quad (2)$$

where k_α is alpha efficiency, in this paper $k_\alpha = 0.1$, $D_{i\alpha}$ and $D_{i\beta}$ are internal annual dose rate of radioactive elements U, Th and K for α and β rays, respectively. Then we calculated D_{34} and D_{30} values, D_{34} and D_{30} are the dose rates of ^{238}U– series disintegrations from ^{234}U to ^{230}Th and from ^{230}Th to ^{206}Pb, respectively, because we need to use the linear uranium accumulation model to calculate ages of teeth samples.

IV. LINEAR URANIUM ACCUMULATION MODEL FOR CALCULATING TEETH AGES

The teeth fossil samples was buried in cave deposits a long time, the uranium content in fossil tooth at present is not original uranium value and is a gradual and linear accumulative process since fossilization. Meanwhile, the uranium was unceasing disintegrating. Therefore, it is reasonable that the age of fossil tooth is calculated by the linear uranium accumulation model[6,7]. The formula is:

$$AD = (1/2)\, D_E T + D_{34}\,(r_0-1)/\lambda_{34}\{1-[1-\exp(-\lambda_{34}T)]/\lambda_{34}T\} - \quad (3)$$

$$D_{30}\{\frac{1}{\lambda_{30}}[1-\frac{1-e^{-\lambda_{30}T}}{\lambda_{30}T}]-\frac{r_0-1}{\lambda_{34}}[1-\frac{\lambda_{\frac{2}{30}}[1-e^{-\lambda_{34}T}]-\lambda_{\frac{2}{34}}[1-e^{-\lambda_{30}T}]}{\lambda_{30}\lambda_{34}(\lambda_{30}-\lambda_{34})T}]\}$$

where, r_0 is the initial ratio of $^{234}U/^{238}U$, in this paper $r_0 = 1.3$; T is the age of tooth sample; λ_{34} and λ_{30} are the decay constants of ^{234}U and ^{230}Th, 2.841×10^{-6}/a and 9.217×10^{-6}/a, respectively.

Using the iterate method, we obtained the buried age of the first skull of Peking Man to be 578 ka, other ages of fossil teeth samples are shown in Table 1, 2.

Table 2

Dating results of ESR and other methods for Peking– Man Site

Layer	ESR (ka)	U– series (ka)	FT (ka)	TL (ka)	Polarity epoch (ka)	Chronological scale (ka)
1– 2	221(1)	243(2)			BRUNHES	200
3– 4– 5	282(1)	256(3) 290(2)	306(6)	292(7) 312		250
6– 7		355(4)			370[8]	350
8– 9	418(1)				Biwa E	400
10			462(5)			450
11	578(1)				Normal epoch	500
12– 13	669(1)					600
					730	730

(1) Huang Peihua et al., 1989
(2) Chen Tiemei and Yuan Sixun, 1989
(3) Zhao Shusen et al., 1979[2]
(4) Xia Ming, 1982
(5) and (6) Guo Shilun et al., 1979[2] and 1989
(7) Pei Jingxian et al., 1979[2]
(8) Qian Fang et al., 1979[2]

V. THE INFLUENCE OF RADON LOSS RATE IN TEETH SAMPLES

According to the measuring the rate of radon loss for the horse molar in 10th layer, it is 21%[8]. In order to be compared with these teeth samples, we also used a dentine sample of rhinoceros tooth for dating 12th layer. However, the uranium content in the dentine sample is 34.1 ppm high, the influence on ESR dating result reached to 7% due to the rate of radon loss. So, we considered using the radon loss– linear uranium accumulation model for calculating the tooth age of 12th layer. We obtained the tooth age in this layer is 669 ka.

VI. AGE RESULTS OF ESR DATING

The age of upper travertine floor in 1st– 2nd layer is 221 ka which is calculated by the close– equilibrium model because the uranium content in the sample is very low. The teeth ages of 3rd– 4th – 5th layers, 8th– 9th layers and 11th layer are calculated by the linear uranium accumulation model to be 292 ka, 418 ka and 578 ka respectively. The age of 12th layer is calculated by the radon loss– linear uranium accumulation model because its uranium content is very high. All of these results of ESR dating are corresponded with other dating results as U– series, fission track, thermoluminescence and paleomagnetic stratigraphical methods very well. And then the systematic and whole chronological scale of Peking– Man site, from 1st to 13th layers, is given in Table 2.

ACKNOWLEDGEMENT

The authors thank Prof. Zhou Guien, Quan Yucai, Xu Yunhua, and Li Zhixiong for X– ray diffraction analysis, ^{60}Co source irradiation, ESR measurement and computer programming, respectively.

REFERENCES

[1] W.C.Pei, *Bull. Geol. Soc. (China)*, (1929), 8:203.

[2] Wu Rukang et al., Study of chronology of Peking– Man site, , Science Press, Beijing, 1985, p.239.

[3] Huang Peihua et al., ESR dating and dosimetry, IONICS, Tokyo, 1985, p.321.

[4] Jin Sizhao et al., *Journal of China University of Science and Technology*,17 (1987), 4:501.

[5] Liang Renyou et al., *Chinese Journal of Microwave and Radio– Freqency Spectroscopy*, 4 (1987), 3:265.

[6] Peng Zicheng et al., *Nuclear Techniques (China)*, 11 (1988), 11:11.

[7] M.Ikeya, Dating and age determination of biological material, Billing & Sons Limited, Worcester, 1986, p. 111.

[8] K. Komura et al., ESR dating and dosimetry, IONICS, Tokyo, 1985, p.9.