Dating Of Remains Of Neanderthals And Homo Sapiens From Anatolian Region By ESR-US Combined Methods: Preliminary Results

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Abstract: We tried in the present study to apply the electron spin resonance method (ESR) combined with uranium-series method (US), for dating fossilized human teeth and found valuable archaeological sites such as Karain Cave in Anatolia. Karain Cave is a crucial site in a region that has yielded remains of Neanderthals and Homo sapiens, our direct ancestors. The dating of these remains allowed us to trace the history, since the presence of man on earth. Indeed, Anatolia in Turkey is an important region of the world because it represents a passage between Africa, the Middle East and Europe. Our study was conducted on faunal teeth found near human remains. The combination of ESR and US data on the teeth provides an understanding of their complex geochemical evolution and get better estimated results. Our samples were taken from the central cutting where geological layers are divided into archaeological horizons each 10 cm. The AH4 horizon of I.3 layer, which represents the boundary between the Middle Paleolithic and Upper Paleolithic, is dated to 29 ± 4 ka by the ESR-US model. Below, two horizons AH6 and AH8 in the same layer I.4 are dated respectively 40 ± 6 and 45 ± 7 ka using the ESR-US model. In layer II, where a stalagmite floor was taken, we made two U-Th dating, at the base and on the top, ages oscillated around 120 ka. Since human remains were collected from AH3 horizon for Homo sapiens and AH5 and AH7 horizons for the Neanderthal man, so the dates obtained in AH4, AH6 and AH8 represent maximum ages. Thus they provide the disappearance of Neanderthal man between 45 and 40 ka and the appearance of Homo sapiens in 29 ka in Anatolia region. Undoubtedly, there is a chronological gap between the Middle and Upper Paleolithic, represented by the disappearance of Neanderthals and the appearance of sapiens, and none of our results confirm the contemporaneity of these two species in this region.

Index Terms: Anatolia, datation, ESR, Homo sapiens, Karain, Neanderthal, teeth, US

1 INTRODUCTION

Abone or a tooth receives permanently in the ground alpha, beta and gamma radiation from internal and surrounding radioactive elements as well as cosmic radiation. By ionization of atoms, these radiations release into the sample single electrons which will be trapped in the defects of imperfect crystal lattice according to the theory of the bands in solid-state physics. Indeed, the electrons take two values of energy inside the solid, named valence and conduction bands. The valence band contains electrons that contribute to local cohesion of the solid and are well located. Conversely, the conduction band contains delocalized electrons (Fig. 1A) which can jump into the interstice named gap separating the valence band of the conduction band. It is at this level where takes place the trapping of electrons at different energy levels (Fig. 1B). The accumulation of electrons in the crystal lattice is function of the irradiation dose to which the sample is subjected during his burial in the soil [1]. Knowing the annual dose Da and the total dose DE received by the sample or paleodose, it allows us to determine its age. It means that if the annual dose Da corresponds to a year, then the total dose DE received by the sample corresponds to how many years? Age is then: DE / Da. To determine the annual dose, it is sufficient to measure the internal and external dose to the sample. To determine the total dose DE, it should count electrons accumulated in the traps through time.

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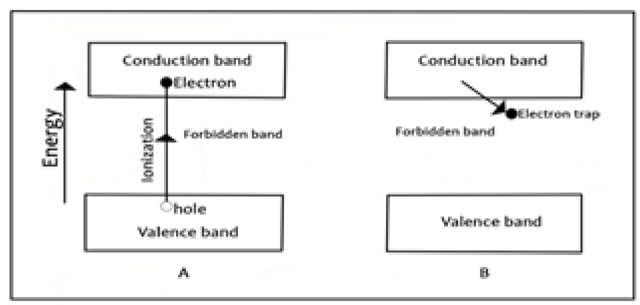

Fig. 1

2 METHODOLOGY

The electron spin resonance ESR method also known as EPR electron paramagnetic resonance principle is based on unpaired electrons called paramagnetic which accumulate in the sample due to the radiations received in the ground. The ESR method has the advantage of counting electrons directly into their trap; no need to empty them and thus several measures can be carried out. Indeed, the paired electrons in an atom form opposed spins with zero magnetic moment. Therefore, putting a sample in a magnetic field, only the unpaired electrons of the last electronic layer will be excited. These free electrons are able to react to a magnetic field in contrast to diamagnetic paired electrons with the magnetic moment is zero. Thus, applying the sample to a magnetic field H divides these electrons into two populations, called Zeeman levels, parallel and anti-parallel to the field (Fig. 2).

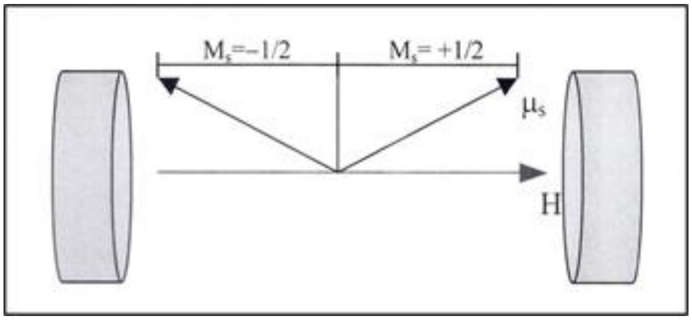

Fig. 2

Resonance is the absorption of energy by the system due to a variation of a wave perpendicular to a magnetic field H whose value of the frequency of this wave coincides with that of electron. Indeed, the energy supplied to the system tends to the maximum, provides a signal proportional to the number of trapped electrons as a function of time. This technique can cover a very long period reaching up to 2 million years in the past. In the present work, its application to teeth of mammals requires a combination with uranium–series method US for the understanding of their complex geochemical evolution in the soil. Uranium–series method US is described in detail in [2],[3]. Indeed, the combination of the two methods forms a new model of calculating the age ESR-US. This model was proposed by Grün and al. since 1988 [4] and it applies to today successfully despite sophisticated measurement techniques. This model calculates a uranium incorporation parameter p in the sample. Several models have been proposed in the literature since 1981:

- Early uptake Model EU [5] where the uranium is quickly incorporated into the sample after its burial in the soil and this incorporation is done in a very short period of time relative to the sample age.
- Linear uptake Model LU [6] involves a continuous and linear incorporation of uranium, i.e the same amount enters in function of time.
- Exponential uptake Model [7] assumes that the incorporation of uranium slows down through time.
- Model ESR-US [4] which combines data from both ESR-US methods used to calculate a uranium incorporation parameter p according to the equation:

$$U_t = U_0\left(\frac{t}{T}\right)^{p+1} \quad (1)$$

Ut is the amount of uranium at instant t.
Uo is the actual amount of uranium.
T is the age of the sample.
This equation includes the three previous cases. In fact:
p = -1 ⇒ closed system ⇒ early uptake model EU
p ≠ -1 ⇒ open system, it can be:
p = 0 ⇒ linear uptake model LU
-1 < p < 0 ⇒ exponential uptake model
p > 0 ⇒ late uptake (Fig. 3)

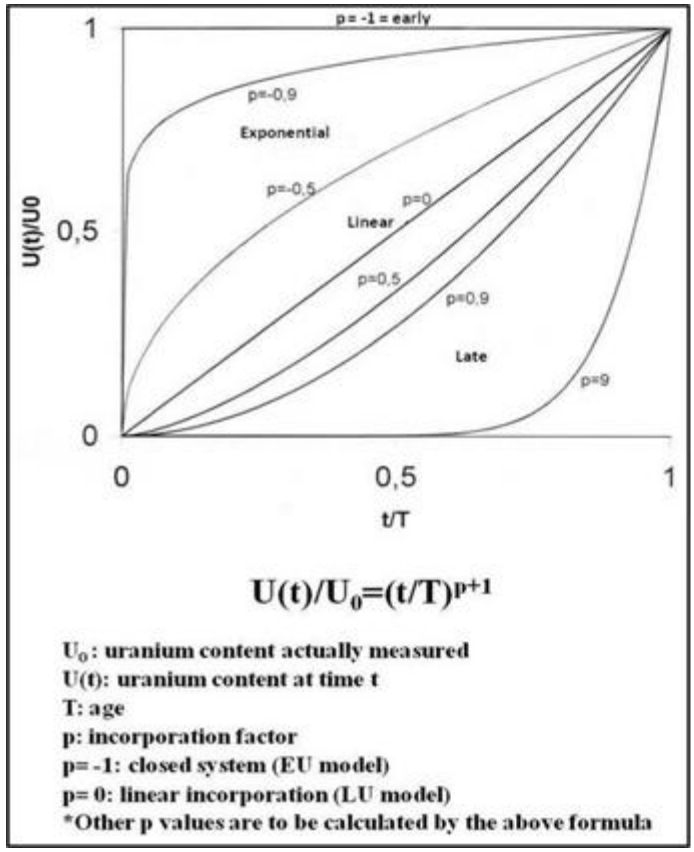

Fig. 3

For example, if the US age obtained, which is the ratio 230Th/234U is less than the ESR age thus the amount of uranium is over-estimated in the sample that acts as an open system post mortem. Equation (1) used to calculate the uranium incorporation parameter p and to know what type of uranium incorporation is it. However, if the US age is greater than ESR age, so we have a uranium leaching. Hence this equation cannot find a solution because we cannot know the amount lost so age is not calculable. The figure shows the different mathematical models proposed for uranium incorporation.

Determination of ESR age:

$$ESR\ age\ of\ a\ tooth = \frac{DE}{Da} \quad (2)$$

Annual Dose DA:

$$annual\ dose\ Da = enamel\ dose + sediment\ dose + cosmic\ dose$$

The annual dose is the sum of the alpha, beta, and gamma doses for each tissue: enamel and dentin; as well as external doses to a tooth, which are those of sediment (alpha, beta and gamma) and cosmic (electrons, nucleons, muons). The doses of enamel and dentin are calculated by alpha and gamma spectrometry (TABLE 2, TABLE 4). However, it is more accurate to use that calculated by alpha spectrometry because uranium is mainly alpha emitter. Alpha and beta doses for the enamel constitute an internal source to the mineral while gamma dose, covering a distance of 30 cm, is zero. For dentin surrounded by enamel; contribution of the alpha dose is canceled upon removal of the enamel as a thickness of 30 to 50 µm is taken away so any contribution alpha radiation is eliminated and some of the beta radiation, since these two radiations cover respectively a distance of 20 µm and 2 mm in a density of 2.5 g/cm3 [8]. For calculating the dose of beta of dentin, the initial thickness and the thickness of enamel removed should be measured (TABLE 3) [9]. The gamma dose of dentin is zero since the gamma radiations in the enamel are canceled during the calculation. The doses alpha, beta and gamma of the sediment surrounding the enamel from the outside, are measured by putting a very sensitive thermoluminescent dosimeter TL for a year at the location of the sample. This period is required to consider the annual fluctuation of the water in the sediment that may affect the value of the dose received. The distance between the dosimeter and the sample should not exceed 1 meter [10]. It should be noted here that the dosimeter receives only the gamma radiations of the sediment as it is in a copper capsule covered with a plastic capsule; the whole has a thickness greater than 2 mm. In addition, the dosimeter does not take into account the alpha and beta doses which cover respectively a distance of 20 µm and 2 mm. On the other hand, the contribution of the alpha dose of the sediment is canceled by removing a thickness of 20-50 µm of the enamel in the preparation. To calculate the dose beta of sediment, it needed to measure the activity of the sediment in the laboratory. Due to the separation of enamel from internal dentin and external sediment, the alpha dose of the dentin and the sediment is removed as well. For that, the dose of the enamel is multiplied by a correction value k equal to 0.13 in its calculation [11]. Cosmic dose depends on the latitude, altitude and depth of the sample in the soil. The first two contributions are calculated from graphs of Prescott and Stephan [12] while the depth is calculated from the formula of Yokoyama et al. [5], [13]: Where x (cm) is the depth of the sample in the considered site. It will be multiplied by the density of the sediment (g/cm3). The contribution of muons is the most important because of their slow decrease.

$$D_{cos} = D_{electrons} + D_{nucleons} + D_{muons} = 5.2\,e^{-\frac{x}{30}} + 12.1\,e^{-\frac{x}{160}} + 12.5\,e^{-\frac{x}{2500}}$$

Equivalent Dose DE:

The equivalent dose DE is also called archaeological dose DA by specialists of thermoluminescence. The abbreviation DA can also correspond to the designation of the accumulated dose. To avoid confusion with the annual dose Da, we use the term of equivalent dose DE. To determine DE, each enamel sample is divided into ten equal portions, which nine are irradiated at increasing doses and one represents the natural sample. Indeed, the aim of the irradiation is to grow old the sample under artificial doses. We obtained an ESR signal representing the amount of electrons that should have been trapped in the sample if it had received a dose of such actual radiation during its burial in the soil. Thereby starting from the natural sample, a curve of signal intensity depending on the dose will be obtained (Fig. 4).

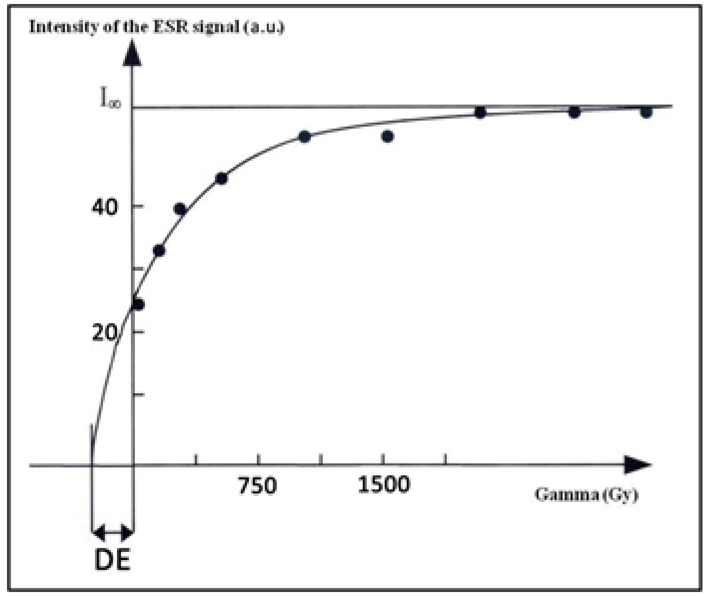

Fig. 4

Then by an exponential extrapolation to intensity zero, we can get a paleodose or an equivalent dose to the accumulated dose since the sample burial until its discovery at present. Extrapolation is exponential because at the beginning, the probability of filling traps is high so we get a linear rise. Then the shape is curved when the probability of filling traps decreases as the number of available traps becomes less important. Finally, the curve tends asymptotically to maximum intensity value I∞ which corresponds to the filling of all the traps.

3 STUDIED SITE: KARAIN CAVE

Karain Cave is located south of Turkey, about thirty kilometers from Antalya (Fig. 5). It was discovered for the first time in 1946 by Kiliç Kökten who undertook the excavations until 1973 [14], [15], [16]. During these years the excavations at Karain were stopped and taken up several times [17], [18]. After the death of Kökten in 1974, excavations were also stopped for a long time, leaving in the compartment E in the cave an important central block, a witness of the stratigraphy, known as central berm and another preserved behind the eastern wall named Eastern profile. In 1985, Ms. Yalçinkaya resumed excavations in compartment B of the cave [19], [20] in collaboration with the University of Tübingen in Germany and then continues alone until 1989 [19], [21], [22]. In 1989, research at Karain has been included in an international collaborative program between Isin Yalçinkaya of Ankara University in Turkey and Marcel Otte of the University of Liege in Belgium [18], [22], [23], [24], with collaborations of Janusz Kozlowski of the University of Krakow in Poland and Ofer Bar-Yosef of Harvard University in the USA [23], [24]. On the field, the excavations were carried out under the responsibility of Haroun Taskiran. This Turkish-Belgian team took over the excavations at Karain since 1996 [25]. Then from 1999 to the present, the collaboration continues with the laboratory of Prehistory in Paris, under the direction of Henry de

Lumley and Christophe Falguères, with whom we have carried out the collection of samples as well as their dating, with the help of Salah Abdessadok.

Fig. 5

3.1 Importance of the cave

The importance of Karain is that it is located in Anatolia, transition region between Africa, Europe and Asia. By discovering the lithic and faunal remains, the cave has supplied human remains of Neanderthal man and Homo sapiens. All these points made from Karain the subject of numerous publications and multidisciplinary studies [26], [19], [20], [21], [17], [18], [22], [25], [27], [28], [10], [29], [30], [31], [32], [33], [34], [35], [36], [24], [3], [37], [38], [39]. Karain Cave is the only cave in Turkey, which contains a stratigraphy ranging from the Lower Paleolithic to the Upper Paleolithic, like Tabun Cave for the Middle East. At the present, the information we have on the Acheulean and bifacial in Anatolia, prove that this region was frequented by man of the lower Paleolithic, Homo erectus. Indeed, bifacial considered as markers of Acheulean tradition, are at Karain with Clactonian trend at the bottom of stratigraphy. Thus at this stage, Anatolia appears at the intersection between African currents (Acheulean) and Asian currents (Clactonian). Upper levels at Karain contain both sets of Levalloisian and remains of Neanderthal [23]. So these Neanderthals seem to be gradually released from Europe to the Middle East, through Anatolia. However, Homo sapiens seems to follow another path, from the Middle East to Europe via Anatolia. This important position of Anatolia justifies the interest shown to research on the chronology of the Karain Cave. Sapiens and Neanderthal are both gone from Africa but not at the same time, i.e Homo sapiens attended the Middle East before Neanderthal is not yet out of Africa. The time when sapiens arrived in Europe, Neanderthal arrived in Gibraltar. Indeed, the meeting of these two species was confirmed in the Middle East according to two studies; a recent dating of the skull of Manot 1 in Palestine attributed to Homo sapiens shows an age of 54.7 ± 5.5 ka [40] and another showing that Neanderthals lived in nearby caves, such as Kebara south of Manot, dated between 60 ka and 48 ka [41]. The question that arises here if their meeting was also in Anatolia? The results in this paper provide new radiometric data and an answer to this question.

3.2 Stratigraphy of the cave of the cave

Karain E contains a central section (center Berm) and East section (east profile) (Fig. 6).

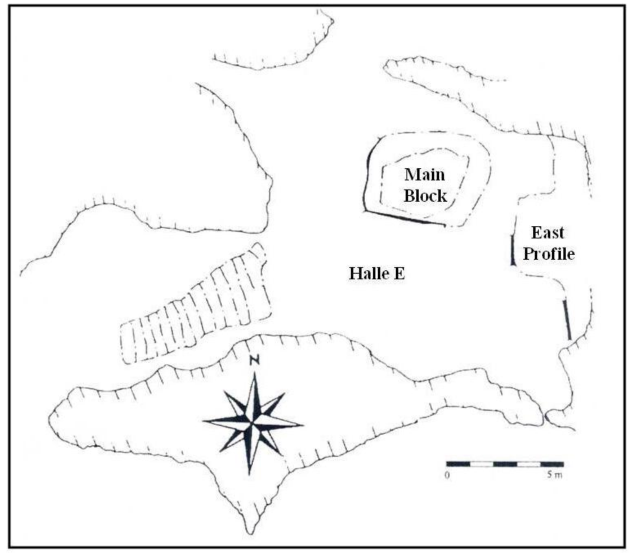

Fig. 6

In this work, three teeth and a stalagmite floor were analyzed. They are represented in the central stratigraphic section (Fig. 7). The deposit of sediment of the central berm of compartment E is divided into geological layers which are divided into archaeological horizons. From bottom to top (Fig. 7):

- Geologic layer V divided into horizons AH61 to AH57. It corresponds to the Lower Paleolithic with Clactonian type tools.
- Geologic layer IV.5 divided into AH56 to AH52. It corresponds to Denticulate Charentian.
- Geological layer IV.4 until 2, divided into AH51 to AH41. It corresponds to Acheuleo-Yabroudien with some bifaces and notches.
- Geological layer IV.1 divided into AH39-38. It is characterized by scrapers with Charentian trends.
- Stratigraphic complex which includes geological layers III.5, III.4 and III.3 divided into AH37 to AH33. The tools are dominated by scrapers and then by denticulate. It looks like IV.1 and may be the last phase of Charentian.
- Stratigraphic complex III.2, III.2.1 and III.1, divided into AH32 to AH27. The tools are marked by the first appearance of splinters and spikes with Levalloisian and Mousterian points. Besides these tools, there are also scrapers, denticulate and notches but whose Charentian appearance is much less pronounced. This complex corresponds to the classic Mousterian with Levalloisian technology.
- Complex of layers II.3, II.2 and II.1 corresponding to AH26 to AH19. It is enriched in scrapers but characterized by Levalloisian technique. It is assigned by a Mousterian of Karain type which is similar to Mousterian of Zagros [42], [43].
- Geological layer I.7 which represents the base of layer I. It corresponds to the horizons AH18 to AH15. The lithic industry is dominated by bipolar Levalloisian splinters and discoid splinters also the

rate of laminar splinters increases at this stage. This layer is a continuation of the classic or Karain Mousterian.

- Layers I.6-2 include horizons AH14 to AH5. This is the last phase of the Middle Paleolithic. Discoid splinters are more abundant than bipolar Levalloisian splinters. We note at this stage the dominance of scrapers and Mousterian points. The industry is more microlithic. This is the last phase of the Karain Mousterian where Levalloisian characters are less pronounced.
- Geological layer base of I.1 represented by horizon AH4 which forms a chronological gap between the Middle and Upper Paleolithic estimated at 40 ka by Otte et al. [33]. The horizon AH4 contains a mixture of industries of these two periods and thus represents the boundary between the Middle and Upper Paleolithic. The scrapers dominate and also discoid or Levalloisian splinters rather microlithic. We also note the presence of Upper Paleolithic tools such as scrapers and retouched blades.
- Geological layer I.1 represented by horizons AH3, AH2 and AH1. This is the Upper Palaeolithic but with remodel material i.e middle paleolithic tools, which do not come from local occupation are mixed with those of the Upper Paleolithic [31], probably originating from the compartment B of Karain or Ökuzini cave near Karain E. the tools are dominated by scrapers, followed by blades and back lamellas

3.3 Human remains of the cave

In the layer III.2, excavations in 1996 have identified human bones attributed to the Neanderthal man: four phalanges of one hand, two diaphyseal fragments of ulna and radius and a mandibular fragment which seems to correspond to a young individual. One of two diaphysis corresponds to traces of scraping following the longitudinal axis of the bone and the other corresponds to traces of scavenging by a powerful carnivore, probably a hyena. In the layer III.4, excavations in 1996 were also able to identify two human remains, a vertebra fragment and a diaphyseal fragment of femur, which could correspond to archaic Homo sapiens. In the higher deposits, layers I.6-2, excavations in 1949 delivered a baby tooth, without specifying in what horizon, attributed to Neanderthal man and was the first Neanderthal remains from Anatolia. In layers I.6-2, specifically in horizons AH7 and AH5, excavations in 1986 delivered two human teeth attributed to the Neanderthal man. In layer I.1, horizon AH3, excavations in 1987 delivered a tooth, a humeral head and a skull fragment covered with a thick layer of calcite, attributed to modern Homo sapiens.

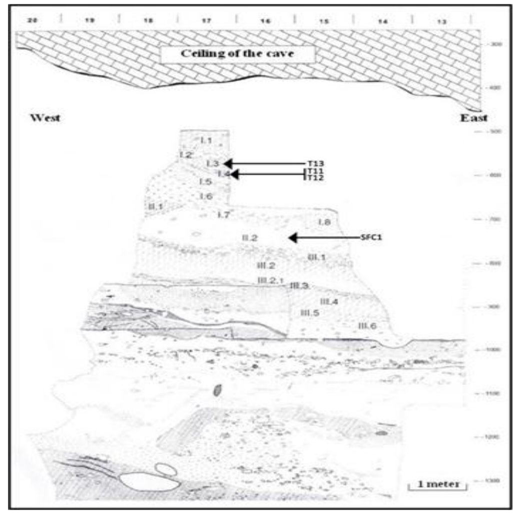

Fig. 7

4 RESULTS

The coordinates of the teeth in the central berm as well as their correspondence in the eastern section of cave, are presented in TABLE 1. However, since the layers have a dip towards the east, the sediments taken from the corresponding cut are lower. For the floor C1, we did not put his correspondence because we did not need sediment to calculate its age. The ages of the two tissues, enamel and dentin, and the age of the stalagmite floor, are determined by uranium series method US and presented in TABLE 2.

TABLE 1

Position Of Teeth And Stalagmite Floor, Their Altitude In The Central Berm And Their Correspondence To The East Profile

		Square	GH	AH	Alt.(cm) B.C	Alt.(cm) au P.E.
Tooth	T13	I17	I.3	4	-560/-550	-562/-571
	T12	I17	I.4	6	-580/-570	-593/-600
	T11	I17	I.4	8	-600/-590	-609/-619
S. Floor	C1	H17	II.2	20-18	-720/-700	-

The altitudes are different because the layers have a pendange eastward. GH: geological layer. AH: layer or archaeological horizon The sign (-) represents the altitude above zero reference plane.

However ESR age is determined only for the enamel because this tissue is mineralized at 97% and therefore more reliable than the dentin mineralized at 70%. The results are shown in TABLE 3. We use the gamma spectrometry to calculate the activity of the collected sediment (TABLE 5) and teeth (TABLE 4). In teeth, the calculation of contents of radium (Ra) and radon (Rn) that are mobile, inform us about their possible escape therefore on the opening of system. 232Th relative to 230Th contents can estimate contamination of the sample by clay.

TABLE 2

Measures Of Dental Tissues (Enamel (E) And Dentin (D)) And Stalagmitic Floor By Alpha Spectrometry

		U dpm	234U/238U	230Th/232Th	230Th/234U	Age US	Age cor(1)	Age cor(2)	Age cor(3)
T13	e	0.118	1.545 ± 0.15	64	0.556 ± 0.083	83 +21/-17			
	d	1.159	1.03 ± 0.042	>100	0.340 ± 0.029	45 ± 5			
T12	e	0.08	1.275 ± 0.111	85	0.710 ± 0.092	126 +38/-27			
	d	3.897	1.157 ± 0.037	>100	0.241 ± 0.014	30 ± 2			
T11	e	0.12	1.289 ± 0.094	>100	0.371 ± 0.042	49 +8/-7			
	d	1.923	1.151 ± 0.04	>100	0.661 ± 0.05	114 +20/-16			
SFC1t		0.052	1.241 ± 0.102	>100	0.701 ± 0.062	124 +25/-19			
SFC1b		0.074	1.147 ± 0.089	2	0.817 ± 0.062	172 +46/-30	120 +32/-21	78 +21/-14	non calculable

dpm = disintegration per minute per gram (1 ppm uranium is equivalent to 0734 dpm). SFC1b and SFC1t: base and top of stalagmitic floor C1. Analyzed teeth are teeth bovidae, they do not contain cement.

5 DISCUSSION

The enamel being mineralized at 97% behaves like a closed system. Despite this, the alteration may affect a tooth and the water penetrates into and causes extensive damage with bacterial action. Dentin (70% mineralized) and cementum (50% mineralized) as the bones (50% mineralized) are more accessible at the inlet and outlet of the water than the enamel thus to a change in the amount of uranium initially entered in these tissues, which has the effect of distorting the ages obtained. For this, we tried to apply the combined model ESR-US on the teeth. Concerning the teeth, the external dose coming from sediment represents a large part of the annual dose and therefore the age depends strongly on the activity of the sediment. EU and LU ages are very close to each other and also close to the age obtained from the combined model ESR-US because they depend essentially on the external dose. Accordingly, leaching or uranium incorporation into a tissue, enamel and dentin, should not affect too much the obtained age. For the tooth 13, the annual dose was calculated by combining the data of TL dosimeter with those of the sediment. The US age is older than the ESR age. Since US age is the relation 230Th/234U, we can deduce two hypotheses:

1. Contamination by exogenous thorium. This hypothesis must be excluded as the ratio 230Th/232Th> 20 in both tissues; enamel and dentin (TABLE 2).
2. There is a uranium leaching having the effect of grow old the US age, which is equal to 83 ka for enamel and 45 ka for dentin. Since the uranium incorporation parameter p is not calculable in enamel and dentin, this shows uranium leaching in both tissues and this leaching is more important in the enamel, where the age is older, than the dentin. US-ESR age calculated for the entire tooth is equal to 29 ± 4 ka.

For the tooth 12, the annual dose was calculated from the sediment without dosimeter. The very old US age of enamel corresponds probably to a limit of the measurement technique due to the low uranium content in this sample. In contrast, dentin has a parameter p = -0.689 showing a uranium incorporation with a low exponential manner, which tends to rejuvenate age slightly that is most likely between 35 and 40 ka. Indeed, US-ESR age of 40 ± 6 ka calculated for the entire tooth confirms this. In contrast, dentin has a parameter p = -0.689 showing a uranium incorporation with a low exponential manner, which tends to rejuvenate age slightly that is most likely between 35 and 40 ka. Indeed, US-ESR age of 40 ± 6 ka calculated for the entire tooth confirms this. For the tooth 11, the annual dose was also calculated from the sediment without dosimeter. For enamel, the activity of uranium determined by alpha spectrometry (TABLE 2) is equal to the activity of radon determined by gamma spectrometry (TABLE 4). This means that the radon is in equilibrium with its father uranium; therefore enamel behaves as a closed system. In addition, the parameter p, calculated for the enamel, is -1; this confirms that uranium incorporates there according to the EU model. US age of dentin is very old equal to 114 ka, which is abnormal because the two teeth 12 and 11 are in the same layer. Therefore dentin presents significant uranium leaching, having the effect of grow old age. Thus the US age of enamel 49 +8/-7 ka is correct. This is confirmed by the ESR-US age for the entire tooth that gives 45 ± 7 consistent with that of the tooth 12 in the same layer that gives 40 ± 6 ka. It should be noted that the amount of uranium determined by gamma spectrometry is not taken into account in the calculation even if there is a balance between the elements; son and father due to the low percentage of gamma radiation emitted compared to alpha radiation.

TABLE 3
Calculation Of The Total Dose De (Or Paleodose) And Annual Dose Da

Tooth	Enamel						Dentin	Sediment	Cos.		AgeESR
	DEμGy	Ti	Td	Ts	Dα	Dβ	Dβ	D (β + γ)	Dm	$Da_{\mu Gy}$	
T13	24200000	0.64	0.04	0.03	108.4	2.8	25.7	78.3 + 600	20	835.2	29000
T12	28100000	0.63	0.06	0.05	19.7	0	43.2	174.3 + 457.7	20	714.9	39500
T11	28400000	0.57	0.04	0.04	26.5	0	26.8	161.2 + 389.3	20	623.8	45500

Ti in mm: initial thickness of the enamel. Td in mm: thickness removed the side of the dentin. Ts in mm: Thickness removed from the side of the sediment. Calculating the initial thickness removed and thus takes into consideration of the removed portion of the internal and external beta dose by debarrasant sediment when cleaning the enamel and dentin when extracting each tissue [5], [13], [9].
Dm = Dose of muons is the largest in the cosmic dose

TABLE 4
Data Obtained By Gamma Spectrometry Of Tissues

Tooth		U dpm	226Ra	222Rn	232Th
T13	e	0.486 ± 0.04	0.486 ± 0.04	0.141 ± 0.01	0.472 ± 0.046
	d	2.645 ± 0.661	1.751 ± 0.05	0.224 ± 0.02	0.111 ± 0.1
T12	e	0.304 ± 0.03	0.304 ± 0.03	0.110 ± 0.01	0.360 ± 0.03
	d	3.936 ± 0.441	1.211 ± 0.2	0.155 ± 0.01	0.511 ± 0.5
T11	e	0.751 ± 0.07	0.751 ± 0.07	0.119 ± 0.01	0.393 ± 0.03
	d	2.345 ± 0.363	1.016 ± 0.1	0.13 ± 0.01	0.427 ± 0.4

enamel (e) and dentin (d)

TABLE 5
Data Obtained By Gamma Spectrometry Of The Sediment Taken From The Eastern Cut Of Cave

	T	U dpm	226Ra	222Rn	232Th
-562/-571	13	1.055 ± 0.046	0.630 ± 0.103	0.679 ± 0.016	0.496 ± 0.02
600	12	1.515 ± 0.056	1.583 ± 0.115	0.856 ± 0.017	1.360 ± 0.028
619	11	1.467 ± 0.052	1.336 ± 0.112	0.805 ± 0.017	1.082 ± 0.026

For the stalagmitic floor C1, two datations were made, one at the base and the other at the top. The top shows a ratio 230Th/232Th>100; indicating that no contamination with exogenous thorium (coming from clay) has disrupted the dating. Indeed, if the 232Th is 100 times less than 230Th, this indicates that the contamination in case if it exists, is negligible. In other words, it is estimated that 230Th just originates from the decay of 234U initially present in the sample and not of 232Th. However, the base shows a very low ratio 230Th/232Th (<19) and required correction (Tab. 2). For this, the values 1, 1.5 and 2 for the ratio (230Th/232Th)exogenous are generally used [44], [45]. It should be noted here that the ratio 1.5 is used when it is impossible to calculate an age with a ratio equal to 2. For the SFC1b sample, the ratio = 1 is used [46] because on the one hand, the use of a ratio = 2 gives a non calculable age and on the other hand, the use of a ratio = 1.5 is overestimated and gives an age of the base much younger than the top of the floor, which is impossible (TABLE 2). Therefore, it was assumed that the same amounts of exogenous 230Th and 232Th were entered in the sample, i.e, a ratio (230Th/232Th)exogenous = 1. Thus, the dates obtained are 120 +32/-21 ka at the base and 124 +24/-19 ka at the top. Therefore, the age of the stalagmitic floor C1 oscillates around 120 ka. We suggest that it is deposited at the beginning of isotopic stage 5.

6 CONCLUSION

The US method applied alone to the teeth shows no success. In fact, for the teeth 13 and 12, the US age of enamel was older than that of the dentin. This result is surprising because histologically, the dentin mineralized at

70% should be more susceptible to the inlet and outlet of water than the enamel mineralized at 97%. Despite the difficulty of comparing the age of two different tissues having two different geochemical behaviors, the combination of ESR and US data and calculation of ESR-US age for the entire tooth allowed us to understand history of uranium incorporation in both tissues; enamel and dentin. For example, for the tooth 11 where the US age of dentin is older than the US age of enamel, uranium of dentin is then leached. In contrast, dentin of the tooth 12 of the same layer shows exponential uranium incorporation. So we can conclude that the ESR-US age calculated for the entire tooth is very close to the ESR age of enamel; so the internal dose of a tooth has not a great influence on the determination of the age which depends on the activity of the sediment. For the stalagmitic floor C1, we have two dates of which one is corrected and shows coherence with the second that does not require correction. This floor comes from layers AH18-20 in the central berm. U-Th age of 120 ka is also consistent with ESR age obtained for the teeth of layers AH14-18 of the central berm and dated by Çetin et al. [28] between 90 and 110 ka. It is also consistent with the ESR age of the teeth of layers AH16-27 of West profile and dated by Rink et al. [10] at 62 ± 7 ka for AH16, 108 ± 23 ka for AH17 and 121 ± 27 ka for AH27.

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