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Electron Spin Resonance Dating of Tooth Enamel

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ABSTRACT

In this work the ESR method has been applied to determine the age of tooth enamel found in Chukhur-Gabala archeological site (Azerbaijan, Gabala district). The investigated object was presumable the lower jaw of a bear with well-preserved tooth. The mean age of the sample was determined as 2550 ± 200 years.

Keywords: *ESR dating, pottery dating, tooth enamel*

INTRODUCTION

Electron spin resonance (ESR) analysis is one of the alternative methods on dating of ancient artifacts and enables to extend the time limit beyond the conventional radiocarbon dating. The upper limit of radiocarbon dating is about 50 to 60 thousand years. After 10 times of ^{14}C half-lives (which is 5730 years) the concentration radiocarbon becomes undistinguishable from the background, so-called "dead carbon" samples. Radiocarbon dating method is also limited by the samples with organic origin such as wood, charcoal, bone, beat etc. ESR method based on detecting, identifying and quantifying free radicals and paramagnetic centers produced in some materials by ionizing radiation. Due to long mean life of some paramagnetic centers (approximately $1x10^8$ years), it makes it possible to identify them in materials as old as $1x10^6$ years which can be applied to a variety of problems in geology, archaeology and paleo anthropology [1]. At the same time ESR method can be used as an alternative method on verification and/or crosschecking the results obtained by radiocarbon dating method. ESR dating is based on the fact that natural ionizing irradiation produces paramagnetic centers in some materials, particularly in tooth enamel with the long mean life. Those centers are stable at the temperatures below 100 ^oC and might be considered as a measure of the total irradiation dose to which a particular sample has been exposed. This effect has been used with tooth enamel for determining the age of archeological sites [2]. In this work the same method has been applied to determine the age of tooth enamel found in Chukhur-Gabala archeological site (Azerbaijan, Gabala district) using ESR method.

MATERIALS AND METHODS

The investigated object was presumable the lower jaw of a bear with well-preserved tooth. Sample preparation and ESR measurement procedures followed standard techniques [5].The enamel was initially removed from teeth using a dental drill and water cooling. The 2 mm mean thickness enamel was then placed in a 30% NaOH solution for one day to disinfect it and separate any remaining dentine.

A dental drill was used to strip around 50±5 μm from inside and outside of the enamel surface to ensure that alpha radiation had no effect. In total 1.2 gr. enamel was collected and it was air-dried at room temperature for three days. Enamel powder was divided into six equal parts and each aliquot was placed inside glass tubes (Suprasil) for irradiation. The samples were irradiated using 60Co source. Dose rate of the 60Co source has been determined by Magnettech Miniscope MS400 EPR Spectrometer using individually wrapped, bar code labeled BioMax Alanine Dosimeter Films (developed by Eastman Kodak Company). In nature the objects was irradiated at a very low dose rate conditions to compare with the laboratory irradiation. In order to identify the effect of dose rate we have conducted dose mapping around the 60Co

source. Dose mapping exercise have been conducted at three fixed location around 60Co source and does rates were 0.194Gy/s, 0.0194Gy/s and 0.0098Gy/s consequently.

ESR signal for the sample found at Chukhur-Gabala site of the Gabala district Azerbaijan was measured with a Bruker EMXplus (X-band) spectrometer. The spectrometer parameters used were: 3491 G central field, 100 G scan range, 3 G amplitude modulation, 100kHz modulation frequency, 163.840ms time constant and 2.232 microwave power. The samples were then irradiated with additional doses and ESR signals were measured at the same conditions.

In order to estimate the natural dose rate soil samples were collected from the site and U, Th, and K content analysis by gamma spectrometry Canberra GR4520 which has a low-level gamma spectrometry system with 15 cm lead shielding and high-resolution GeHP hyper pure germanium detector, having 43.5% resolution efficiency for 661.6 keV.

Results and Discussions

Figure1 shows the ESR spectra for the enamel sample from the tooth found at Chukhur-Gabala site of Gabala district of Azerbaijan.

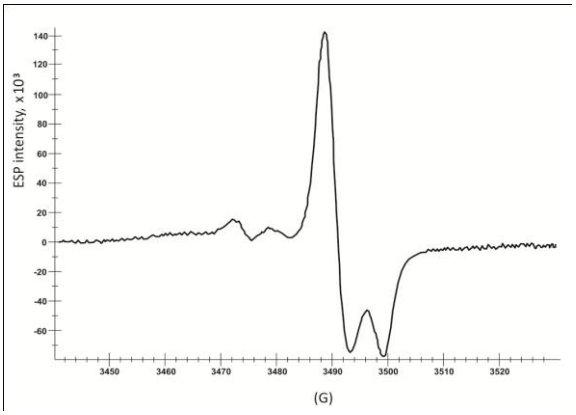

Figure1. *ESP spectra of tooth enamel for the sample found at Chukhur-Gabala site of the Gabala district Azerbaijan (g= 2.0018).*

Six equal aliquots of enamel sample have been irradiated at the 60Co source with the dose ranging from 5.7 to 45.6Gy. The intensity of the ESR signal with the spectroscopic splitting factor g= 2.0018 shows linear dependency (Fig.2) from the absorbed dose which is in line with the results reported by other authors [3]. We also established that the dose rate does not influence the intensity of the ESR signal. The archaeological dose (Da) obtained by the extrapolation back to zero ordinate was 2.17±0.15 Gy. (Fig.2)

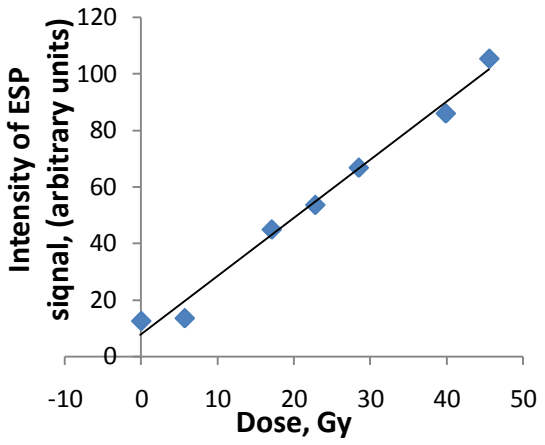

Figure2. *Variation of ESR signal intensity (in arbitrary units) in tooth enamel for the sample found at Chukhur-Gabala site of the Gabala district Azerbaijan with the adsorbed dose (dose rate =0.2Gy/sec.)*

ROSY software [4] was used for calculating the enamel sample's age A by comparing accumulated archaeological dose (Da) to the average dose rate (D) over such period:

$$A = \frac{Da}{D}$$

Calculation of D was based on estimated cosmic dose rate as well as U, Th and K content obtained from soil sample analysis. The cosmic dose rate determined to be 40x10-3Gy/year. The average moisture content of the sediment was taken as 25% on the bases of measurement at the site. Uranium concentration determined directly in the tooth enamel was less than detection limit, therefore the possible uranium uptake has not been taken into consideration.Total estimated annual dose ratewas equal to (850±35)x10-3Gy/year.

Conclusions

ESR signal intensity of paramagnetic center at g= 2.0018 identified in fossil tooth shows linear dependency with the adsorbed dose. The intensity of this peak increases with the amount of γ-irradiation absorbed by the tooth enamel. Additive dose method makes it possible to determine the accumulated archaeological dose and enables the estimation of the fossil tooth age.

The mean age of the sample found at Chukhur-Gabala site of the Gabala district Azerbaijan was determined as 2550 ± 200 years.

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