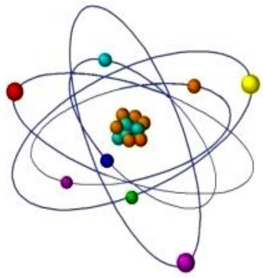
ELECTRON PARAMAGNETIC RESONANCE METHOD FOR DATING OF ARCHEOLOGICAL SITES IN GEORGIA



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ABSTRACT**:** *In Georgia there are many sites which have archeological value and interest on the side of cultural heritage but none of these sites is used as the experimental basis for modern scientific technologies. For this aim it was created a research group, including specialists in archeology, physics and radiology for development of new physical methods for dating of archeological materials found in Georgian. The first interesting results have already been by Electron Paramagnetic Resonance (EPR) method which we shortly present in this article.*

Key words: gamma-irradiation, EPR, archeological dating

For archaeological dating of human tissues and bones in range of millions of years very many physical methods were used.

One of such used method is the radiocarbon dating method of biological remains and materials of biological origin by the way of the radioactive isotope ^{14}C content establishment in the archaeological material as compared with the stable carbon isotope content. It is known that ^{14}C isotope is constantly formed in the atmosphere under the radiation effect. The ratio of the radioactive and stable carbon isotope contents in atmosphere and biosphere in the same time and place is identical because living organisms constantly participate in the carbon exchange and receive carbon from surrounding medium because isotopes due to their chemical identity participate in biochemical processes practically in the similar way. With the organism death carbon exchange ceases and after this as the radioactive isotope ^{14}C experiences the beta-decay its content in remains gradually diminishes while the stable isotope is preserved. But the method of radiocarbon analysis gives a wide data scattering and, in addition, it always exists the danger of sample contamination by alien organics.

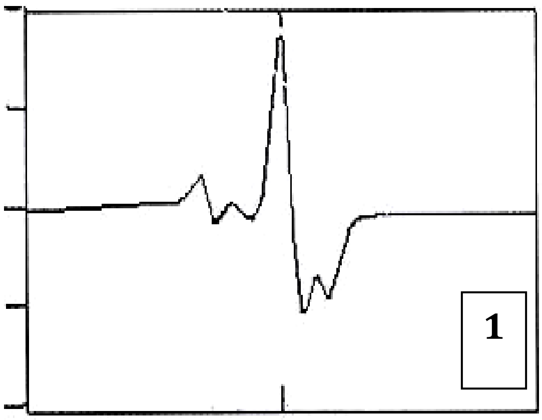
There are also other dosimetric methods of dating such as electron paramagnetic resonance (EPR) and thermoluminescence (TL) [1-3]. For EPR and TL datings it is used unpaired electrons emerging in result of radioactive damage what causes their similarity. The EPR has some advantages as compared with TL caused by the fact that this is a non-destructive technique when signal doesn’t change during experiment and a sample could be investigated in different experimental conditions.

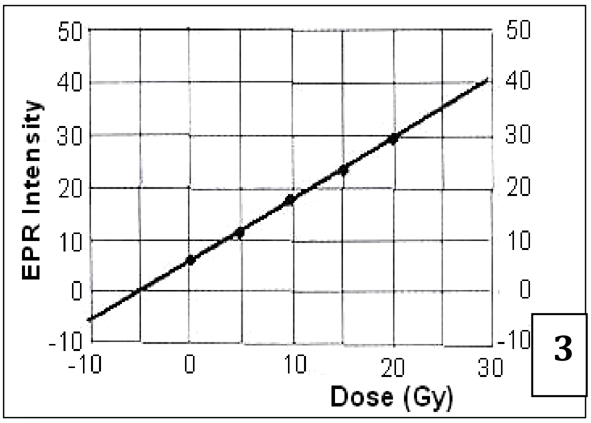
But EPR is less sensitive than TL in some cases, as example, in the case of ceramic item dating.

The EPR dating technique is based on the measurement of density of electrons captured by traps which were accumulated in bones and organics at irradiation after the burial of materials. It is defined the natural radioactivity of material and also the sources of radioactivity such as uranium and thorium. Then the remains are subjected to the standard dose of irradiation. The intensities of natural and laboratory EPR signals are compared and using the established dependence of EPR signals on the irradiation dose and the assessments of annual natural irradiation dose of a sample one could easily evaluate its age [4].

In the last two years for the first time in Georgia it was created a complex research group including specialists in archeology, physics and radiology from Ivane Javakhishvili Tbilisi State University and Institute of Radiology for development of new physical methods for dating of archeological materials found in Georgia. In the first turn it was started investigations using the electron paramagnetic resonance (EPR) method. The first interesting results have already been obtained by EPR method which we shortly present in this article.

On the first stage of EPR application for dating aims the tooth enamel was chosen as the object because the radiation defects created in it under natural irradiation influence are conserved during long time (~ 10^7 years) due to a large durability and stability of teeth enamel to the influence of surrounding medium. One of the important problems is also the cleaning of samples from impurities. After the carrying out the cleaning procedure of a sample the EPR spectrum is recorded and then the sample is irradiated by different doses of radiation what is accompanied by the growth of EPR signal which is proportional to dose amount until a definite value after which linearity of dependence is broken. For this reason only linear part of dependence is used for extrapolation (see graph and Fig. 1).





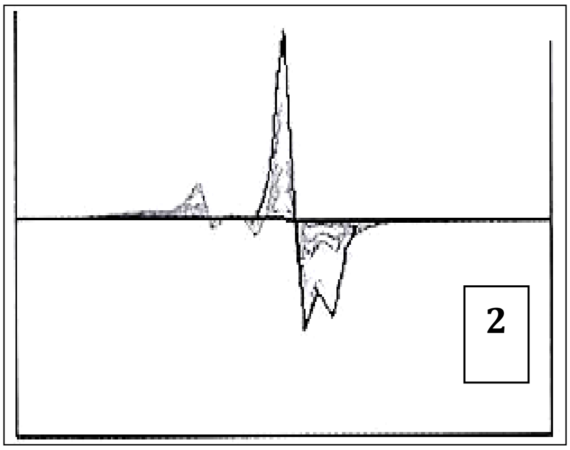


Fig.1

1. EPR spectrum shape

2. EPR spectrum shape and its intensity depending on the dose.

3. EPR signal intensity dependence on the dose.

The important advantage of this method is its non-destructive nature when it is not necessary to destruct a sample what guarantees the reproducibility of results.

For measurements it was used the tooth enamel samples taken from different archaeological sites with approximately known dating. The enamel was mechanically separated from teeth for further measurements.

The following samples were used

a) Unknown sample N 9

b) XIII-th century A.D. (found 16.12.2009), Atskuri Virgin Temple, sample N2.

c) IV-V centuries A.D. (found in April of 2010), Urbnisi, 8th burial site, sample N 5.

d) the end of IV-th century B.C., sample N 3.

e) XVII-XVI centuries B.C. (formed 18.09.09). Aspindza district, burial site N 1, sample N8.

So it is seen that all samples have definite dating.

These samples were mechanically and chemically treated to clear them off minerals. On the first stage the EPR spectra of samples were taken without their irradiation (see corresponding spectra in Fig. 2).

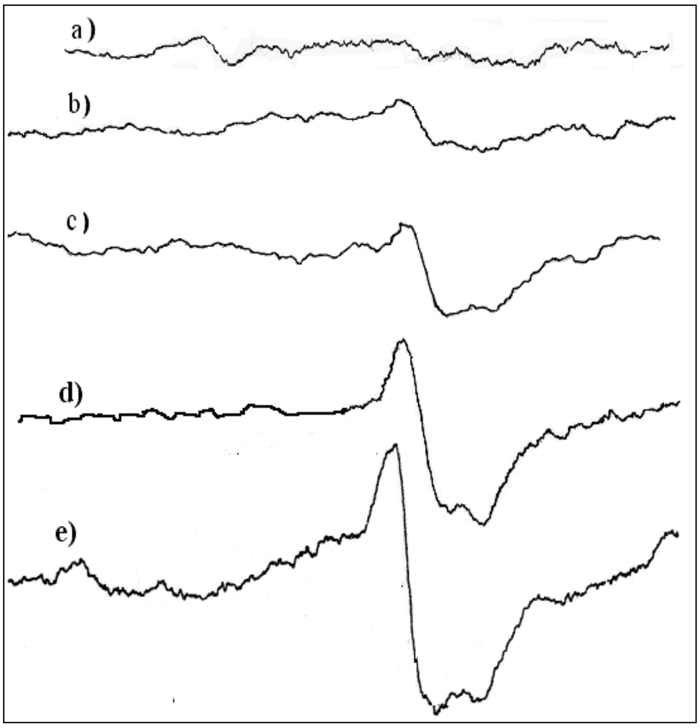


Fig. 2.

The obtained results were used to define the EPR signal integral intensity dependence on time of sample's dating. As it is seen from spectra the older the sample the more irradiation dose was accumulated by its tooth enamel and, correspondingly, its EPR signal intensity is larger.

This dependence was obtained by us for the first time and shown in Fig. 3. The result as it is seen from figure is sufficiently interesting. Concluding from this if one has on the first stage the calibrated EPR signal intensities then it is possible with a good accuracy to predict its dating (all EPR intensities are measured in similar calibrated conditions.

On the next stage the samples were gamma-irradiated by radiation source ^{60}Co. Firstly, for measurements it was taken the Atskuri sample dated by V-IV century B.C. (d) – sample (conditionally this sample was adopted as the standard sample). At conducting experiments we encountered difficulty related with the fact that for the precision measurements it was necessary to have thoroughly calibrated radiation source. On the first stage it was chosen the same dose for the irradiation of all samples. It turned out that the EPR signal intensities quickly reached the saturation (the non-linear interval of dependence was not used – namely spectra 5 and 6 from the sequence of EPR spectra, Fig. 4).

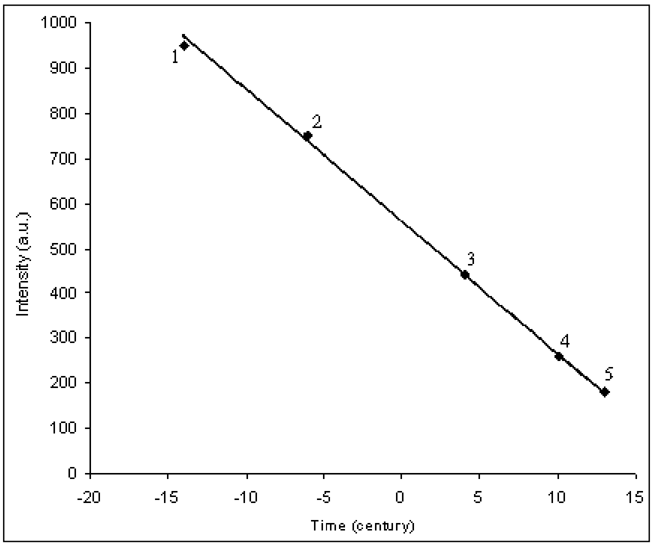


Fig.3.

Besides this, there were taken completely unknown samples with the aim of their dating which were irradiated simultaneously with the standard sample. The appearance of spectra and their shape in dependence on the dose value for the standard and other unknown samples is shown in Figs. 4-6.

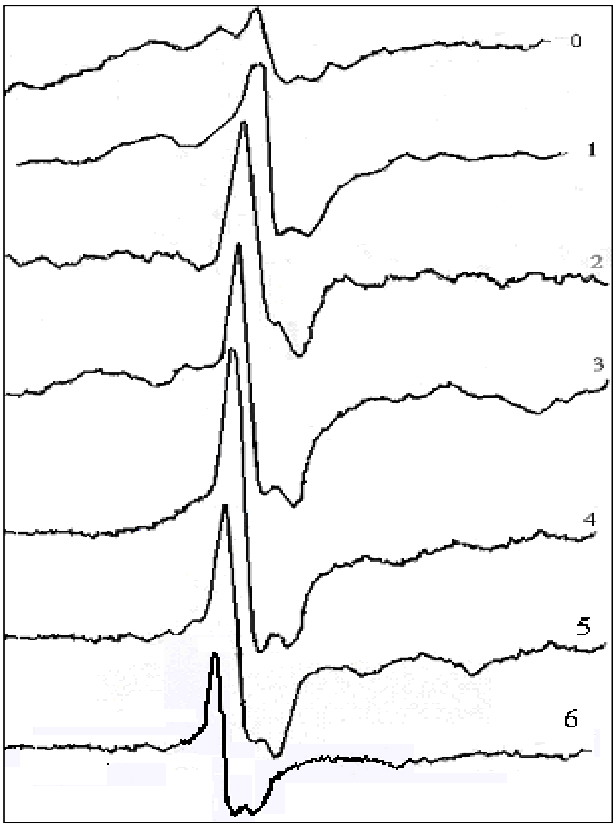


Fig.4.The end of IV-th century B.C. sequence of EPR spectra for the Atskuri tooth enamel sample-(d):
(0) – without irradiation; (1) – gamma–irradiated with dose 3.96 Gy;
(2) – 5.85 Gy; (3) – 7.8 Gy; (4) – 9.76 Gy; (5) 11.7 Gy; (6) – 15.6 Gy.

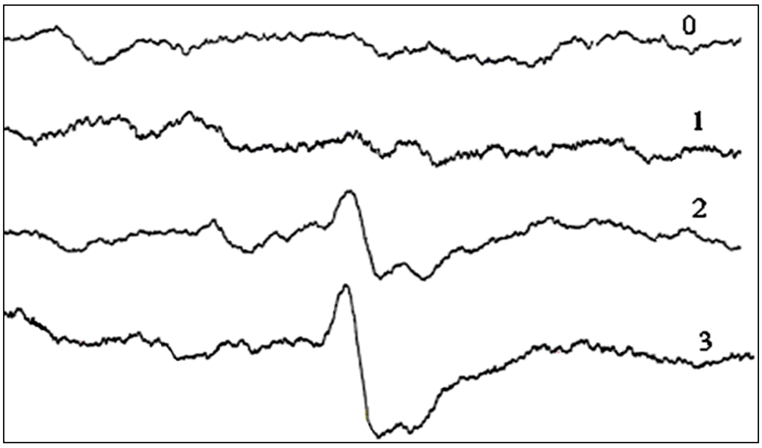


Fig.5. Sample (a): (0) – without irradiation;
(1) – irradiated by 1.95 Gy; (2) – 7.8 Gy; (3) – 11.7 Gy.

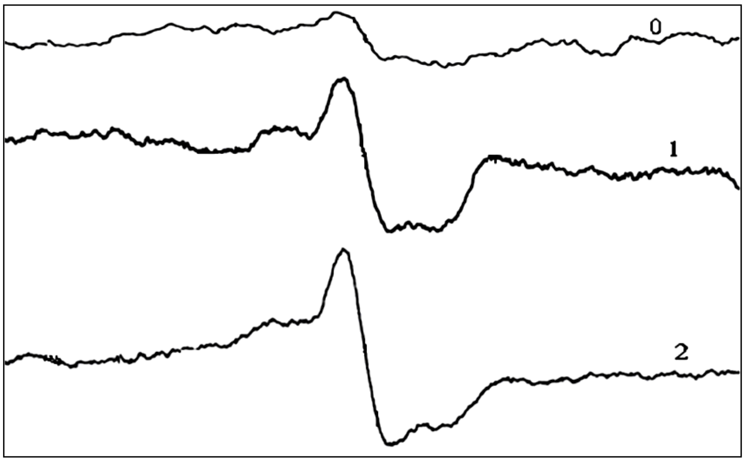
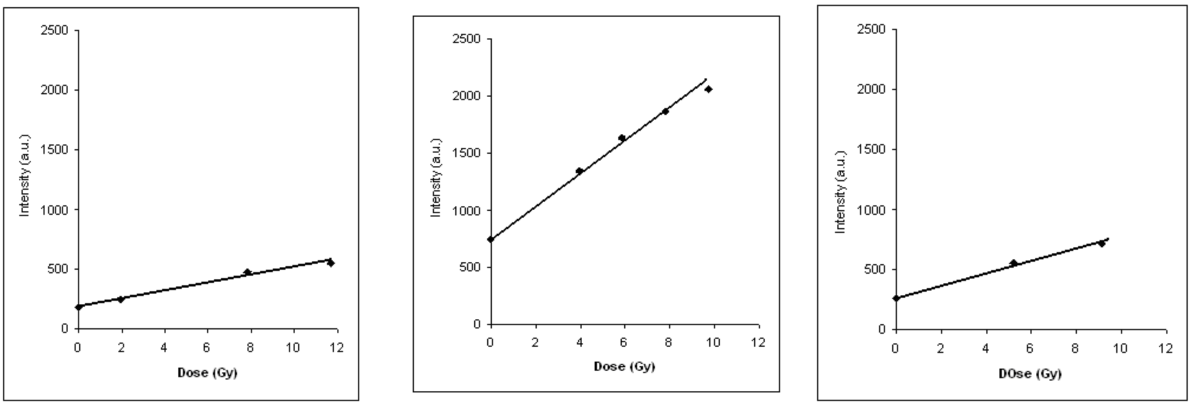


Fig.6. Sample (b): (0) – without irradiation;
(1) 5.2 Gy; (2) 9.1 Gy.

The irradiation and EPR measurements carried out on these three samples were completely identical. As it is seen from Fig. 7 for all samples EPR spectra intensities depend linearly on dose in complete agreement with work [4].



Sample (a) Sample (d) Sample (b)

Fig.7. EPR spectra intensity dependence on the gamma-irradiation dose

For obtaining dating results in accordance with works [4] it is necessary to measure annual irradiation on-site dose and know inclination angles of experimentally established straight lines (in Fig.7) of EPR spectra intensity dependence on the dose. It is also necessary to know starting intensity of EPR spectra of a sample. After establishing on-site annual irradiation dose the exact dating will be easily done what will be made on next stage of this work.

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