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ESTIMATION OF NATURAL RADIATION DOSE AND OF THE AGE OF ANCIENT POTTERY BY MÖSSBAUER EFFECT

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Résumé.- On a étudié par spectrométrie Mössbauer les effets d'irradiation radioactive sur des potteries égyptiennes d'âge connu. On a établi une relation empirique donnant le rapport relatif des fractions magnétiques et non magnétiques. On suggère d'utiliser cette relation pour dater des potteries anciennes, ce qui constituerait une application nouvelle de la spectrométrie Mössbauer en archéologie.

Abstract.- The effect of natural radioactive radiation on the Mössbauer Effect (ME) spectra of ancient Egyptian pottery samples of known age has been studied. An empirical relation between the intensity ratio of the non-magnetic peaks and the dose has been established. It is suggested that this relation can be used for dating of ancient potteries as a new application of the ME spectroscopy in archaeology.

1. Introduction.- Recently few studies [1-3] observed aging effects in ancient pottery and explained it to be due to erosion caused by weathering effects which produces smaller particle size. They found that the ratio of the magnetic to the nonmagnetic components changed after annealing of the pottery at certain temperature for certain time. We observed the aging effect in a previous paper [4] : the pottery samples were irradiated by different gamma ray doses, then the ME spectra showed variations in the intensity ratio of the two central peaks. It was suggested that aging effects can be attributed to natural radiations effects more than to weathering effects specially for ancient pottery which had been buried in the soil under sufficient depth to be preserved from seasonal variations. In the present paper we extended the investigations and a quantitative empirical relation is suggested relating the peak intensities to the age of the pottery sample.

2. Measurements and results.- The measured samples were three groups of ancient Egyptian pottery sherds having known origin and age, as well as Greek pottery sherds of unknown age. The ME spectra of these samples were measured at room temperature before any treatment, then after annealing at 700°C for 2 hours and after gamma ray irradiation by different doses from 300 to 1800 rads. Figure 1 shows the ME spectra of group 3 where it can be seen that there is a noticeable decrease in the difference between the relative intensities of the two central non magnetic peaks after annealing the sample. However, the asymmetry began to appear again after the gamma

irradiation.

Fig. 1 : The ME spectra of an ancient Egyptian sample (4843 years old). a) The original sample; b) After refiring at 700°C; c) After refiring then irradiating with 1200 rads; d) with 1500 rads and e) with 1800 rads.

The effect of increasing the irradiation dose appeared as a systematic increase in the difference in the relative intensity between the two central peaks. Figure 2 shows the linear relation found between the relative intensity difference of the two central peaks, and the irradiating gamma ray dose. The samples from Egypt were found to have nearly the same slope which is different from that of the Greek sample.

Fig. 2 : The difference in relative intensity between the two central (non-magnetic) peaks of the refired samples and after these samples were irradiated with different doses (marked (')) while the (x) corresponds to the sample before annealing).

Using the ratio of the samples of known age, one can calculate the corresponding annual dose absorbed by the sample during its age. The results are shown in table I.

Applying this procedure to the Greek sample, its age was estimated to be 2960 ± 90 years, assuming the same annual dose.

3. Discussion and conclusion.— The obtained values for the natural radiation dose are in agreement with those (0.3 to 0.4 rads/year) given by Aitken /5/. It seems to us that a substantial part of the effect observed in the previous studies /1-3/, can be attributed to natural radiation effects. These radiations cause the observed asymmetry in the complex central doublet. The annealing of the samples causes diffusion of the lattice defects /6/ and after reirradiation by gamma rays the initial defects reappear. We hope that the present work will be the basis of a new application of the ME technique for determination of the age of ancient pottery which is of great importance in archaeology.

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Table I : Results of the measured Egyptian and Greek pottery sherds.

Group No.	Origin & period of the samples	Known age of the pottery (years)	Total absorbed pre-dose (rads)	Predose rate (rads/years)
1	El-Fayoum region Roman period (30 B.C.-640 A.D.)	1673 ± 335	525 ± 19	0.31 ± 0.05
2	Hawara region Middle Kingdom XI and XII Dynasties (2160-1788 B.C.)	3972 ± 115	1065 ± 41	0.27 ± 0.01
3	Pyramid region at Giza Old Kingdom III and IV Dynasties (1980-2750 B.C.)	4843 ± 115	1500 ± 60	0.31 ± 0.01
4	Unknown Greek Sample	determined value 2960 ± 90	determined value 630 ± 22	determined value 0.21 ± 0.07

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