COMPARATIVE THERMOLUMINISCENCE RESULTS USING TWO DIFFERENT INSTRUMENTATIONS

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ABSTRACT

In the archaeological fields has been essential to compare and interchange information and results of the material under study. That has been the case for radio carbon dating and consecuently for many years the same samples were measured around the world in different laboratories, resulting in the standarization and better understanding of the - obtained data. The same philosophy is now applied in the field of thermoluminiscence (TL) for dating of ceramic material.

This paper describes TL results using two different instrumentations for the same archaeologycal ceramic sample:

1) Model 2000, Harshaw TL Analyser.
2) TL-reader located at the Research Laboratory at the British - Museum.

Although, results agreement in the total archaeologycal dose determination for the ceramic material under study is 6.8%, there are proposed in this paper some changes in the commercial instrumentation to improve TL sensibility and general working condition.

1. INTRODUCTION

TL dating technique makes use of the fact that crystalline materials have the property to store energy from radiations emitted by radiactive substance and cosmic radiation. "Part of this stored energy in the form of light can be emitted when the material is heated to a - temperature below that at which black body radiation would occur"[(1)].

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The TL phenomenon can be described in terms of electron (or hole) - traps and luminiscent centers located at defects in the crystal lattice. Radiation exposure of the crystalline materials produce free electrons - and holes that are eventually captured by traps and centers instead of - recombining.

Traps as their name suggest have the ability to retain electrons - and releases them when the proper energy is provided.

On escape the electron may reach a luminiscent center and give rise to emission of a photon with a characteristic wave lenght of the center[2].

The glow curve is known as the plot of light emission vs. tempera-- ture and the area below the glow curve at a given heating rate is proportional to the absorbed dose of ionization radiation.

The fact that the stored energy in the crystal is drained when heated at the proper temperature, means that such and event will erase previous energy absorbed and only energy stored since last date of such heating can be recorded[1,2].

The time passed since last baked of the material is determined in - principle using the relation:

$$\text{Age (years)} = \frac{E\ D}{k\ D_{\alpha} + D_{\beta} + D_{\gamma} + D_{c}} \qquad (1)$$

where

$$ED = \frac{\text{total emitted TL}}{\text{TL per rad of beta radiation}} \qquad (2)$$

and

$$k = \frac{\text{TL per rad of alpha radiation}}{\text{TL per rad of beta radiation}} \qquad (3)$$

D_{α} and D_{β} are the annual dose received by the sample, made up of contributions derived from natural radioactive isotopes, principally -- U-238, Th-232 and K-40 present almost always in natural materials[3], see figure 1.

D_{γ} is the external annual dose contribution from radiactive environment surrounding the sample and D_{c} is the annual dose contribution due to the cosmic radiation.

To compare different instrumentations and results of the very same ceramic sample, it is sufficient to get values of ED, that is dose which given to the sample using a known strenght beta or gamma radiation source for a measured time, produce a TL light output similar to the one acquired for the sample over the archaeologycal time.

Therefore, in this paper, the values of ED for the sample under study are determined.

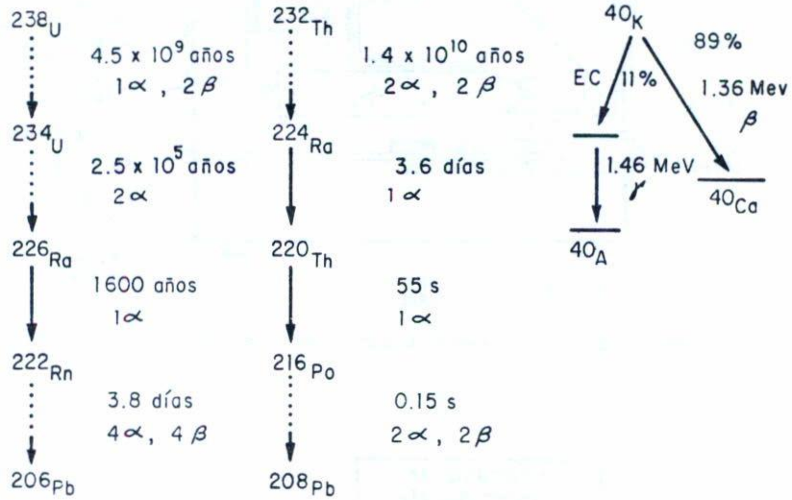

Fig. 1. Decay schemes for ^{238}U, ^{232}Th and ^{40}K (Aitken & Fleming, 1972)

2. TL - READERS

1) Commercial Harshaw serie 2000 equipment, that basically consist of two blocks:

a) the heating and b) the detection systems. For full description see references(4,5).

2) Apparatus located at the Research Laboratory at the British Museum that consists of an oven in which the sample is heated and a light detector for measuring the emitted TL(6,7,8).

Figure 2 describes the block diagrams of the two TL apparatus.

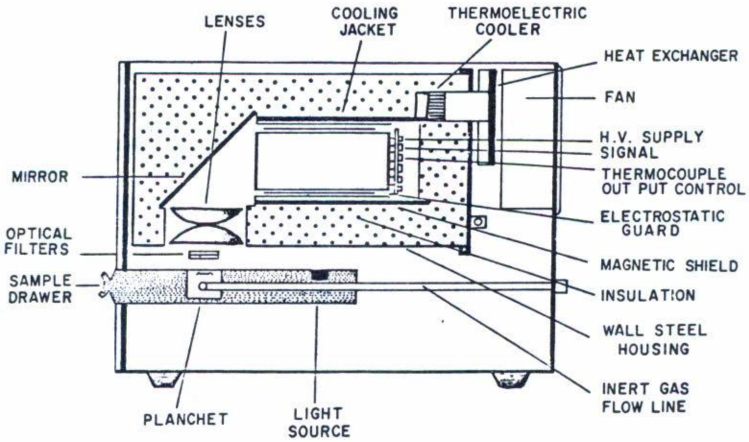

Fig. 2a. Commercial TL - reader located at the Physics Intitute, UNAM.

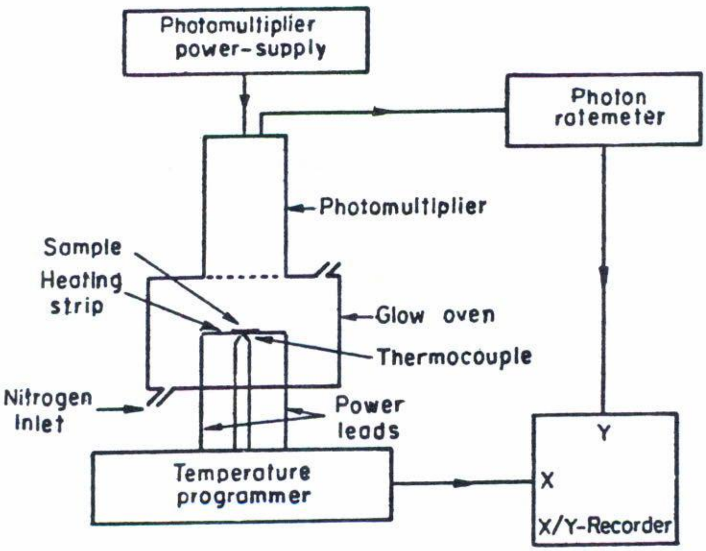

Fig. 2b. Schematic representation of TL apparatus located at the Research Laboratory at the British Museum.

3. RADIOACTIVE SOURCES

Irradiation of the ceramic materials was performed with the following radioactive sources:

Source A: ^{60}Co 120.92 rads/min., located at the Unidad de Oncología, Hospital General, Secretaría de Salubridad y Asistencia.

Source B: ^{90}Sr 12.5 rads/sec., located at the Instituto de Física, UNAM.

Source C: ^{90}Sr 72.5 rads/min., located at the Research Laboratory British Museum, London, England.

The schematic views of these devices are shown in figure 3, 4 and 5.

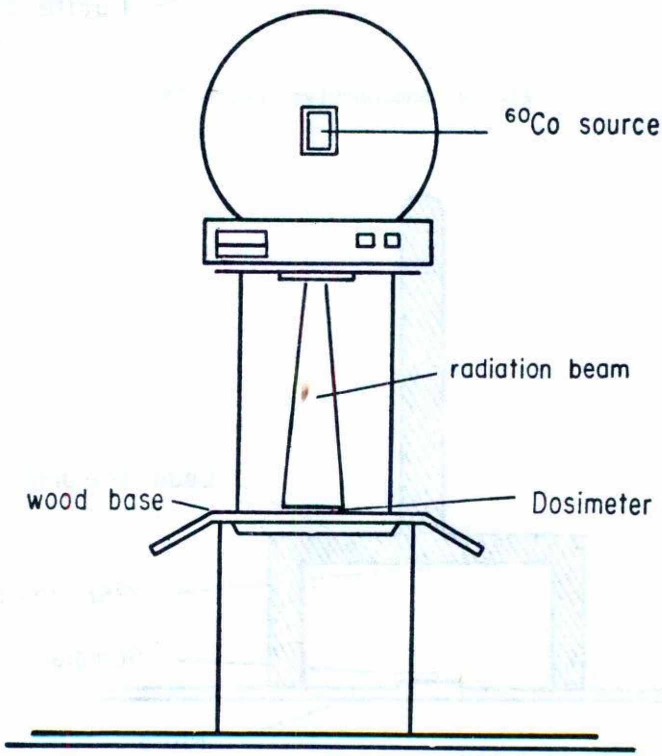

Fig. 3. Radioactive source "A"

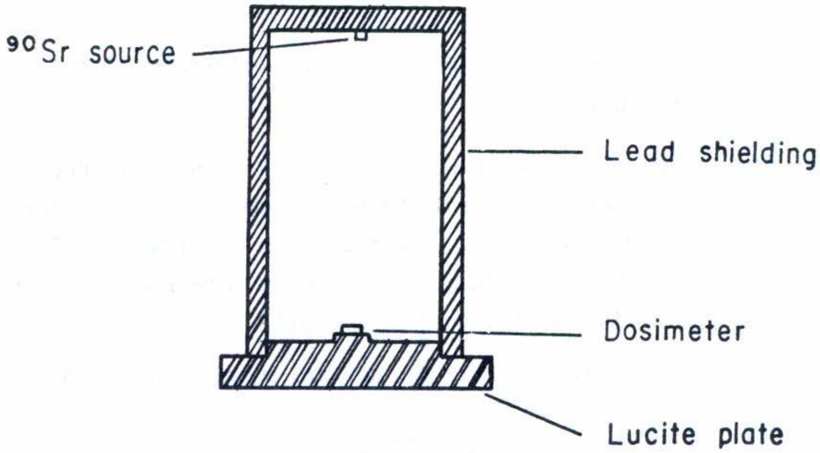

Fig. 4. Radioactive source "B"

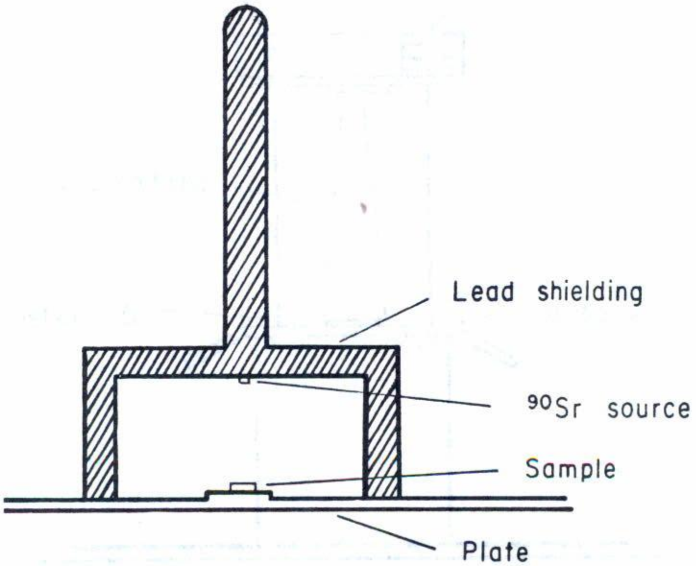

Fig. 5. Radioactive source "C"

4. CALIBRATION OF RADIOACTIVE SOURCE "B"

Calibration of the ^{90}Sr radiation source describes above as source B, was carry out using TLD-100 and TLD-700 dosimeters[9], irradiated with the calibrated radioactive sources A and B in electronic equilibrium condition and readed out in a commercial TL reader;[10] correspondant results are presented in figure 6.

Figure 7 shows that correction due to thermoluminiscent decay or - the elapsed time between irradiation and reading of the dosimeter it is not necessary, if the TL reading is made in the interval of 160°C and - 240°C, the reason for that being the half-lives[11] of the associated - luminiscence centers, see figure 8.

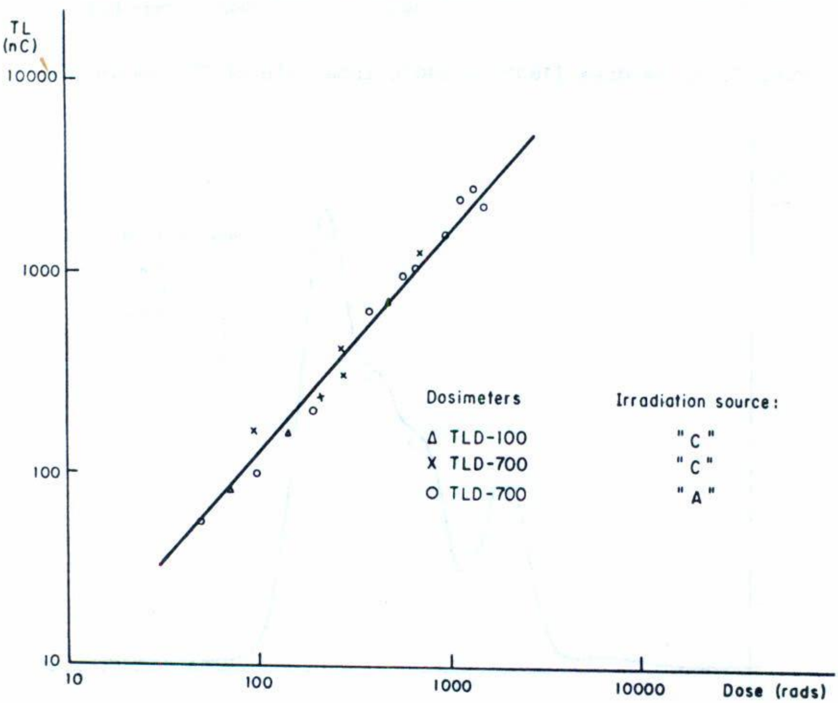

Fig. 6. Calibration of source "B"

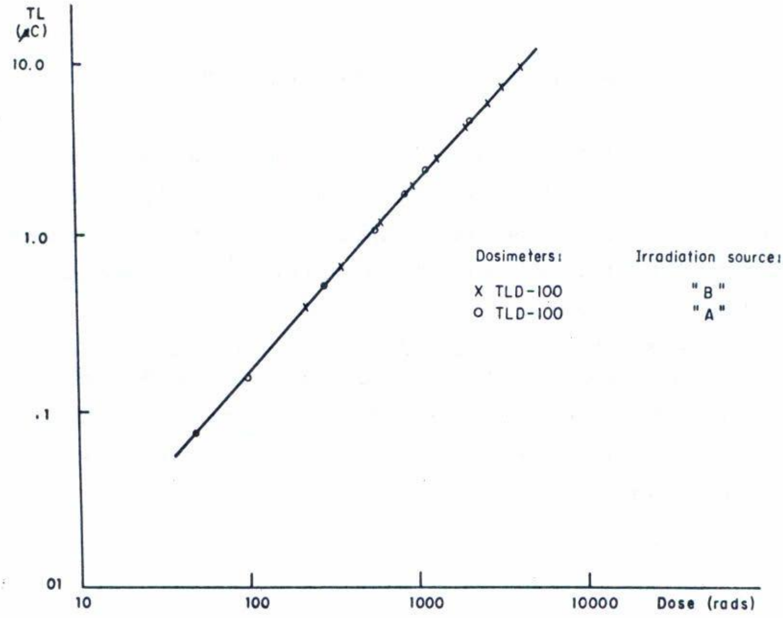

Fig. 7. TL vs dose (160°C - 240°C intervale of TL reading)

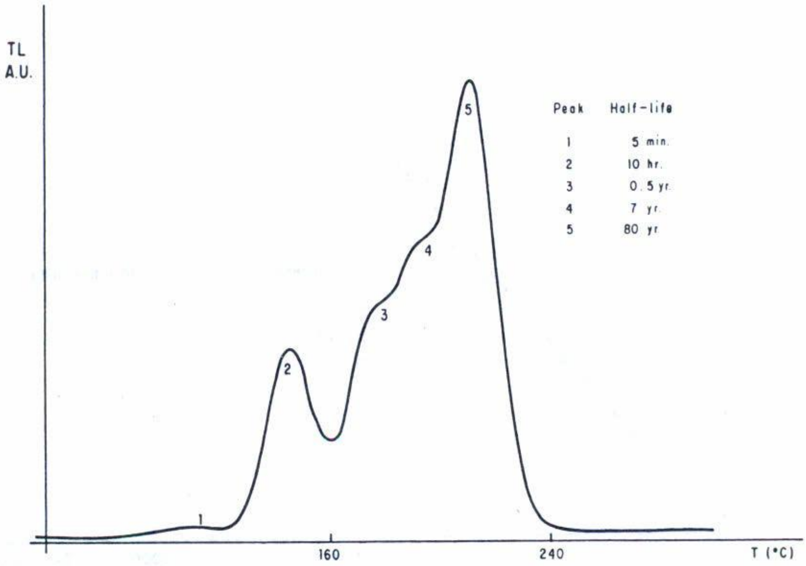

Fig. 8. Glow curve of TLD-100; source B: 93.75 rads.

5. CERAMIC SAMPLES

Sample was kindly supplied by the Instituto de Investigaciones Antropológicas de la UNAM, under the name of TUZTLAN, excavated at Aquiles Serdan and Altamira located at Chiapas State, Mexico.

6. EQUIVALENT DOSE DETERMINATION (ED)

The quartz inclusion method established by Fleming and others[12] was the procedure follow in this work: Consist in isolating the 90-106μm fraction from the crushed sample by sieving and etching with 40% of hydrofluoric acid for 45 minutes; washed; dried and divided in aliquot portions for the following TL measurements:

i) Determination of the natural TL induced by the radioactive elements contained in the ceramic material.

ii) Determination of equivalent dose, using the "additive" procedure, that consist on irradiation of the natural sample with additional - known doses, i.e., natural TL plus $TL(D_i)$; where D_i is the additional - known radiation dose.

iii) Determination of the supralinearily (I) of the sample due to transparency change or mineralogical alterations produced by heating of the sample or other effects[13]. This determination is made by annealing the sample at 500°C and subsequent supply of radiation dose.

7. RESULTS

I. *Commercial Reader*

<u>Sample TUZTLAN</u>

The glow curves for natural TL and natural TL + TL induced by laboratory radiation correspondent to points i) and ii) are shown in figure 9, and the plateau test of TL storage stability over archaeological times is presented in figure 10; in which it is plotted $\frac{N}{N + \beta - N}$ against temperature. N is TL **natural** and β is natural TL + TL induced.

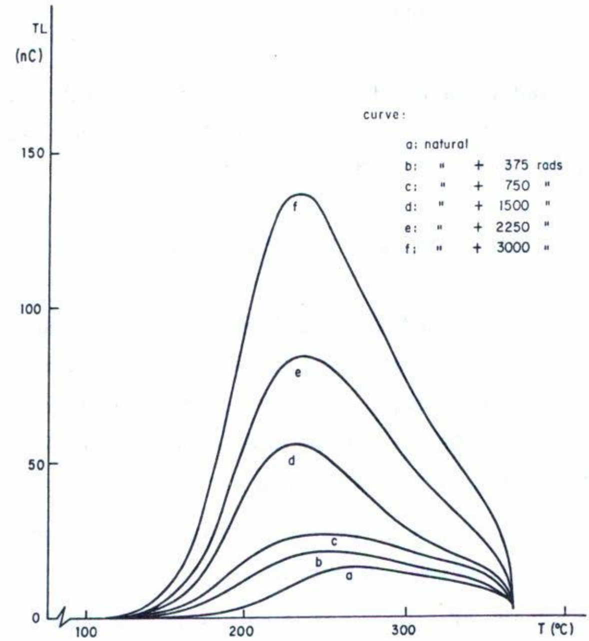

Fig. 9. Glow curves. Sample irradiated with source "B" and readed at the Physics Institute, UNAM.

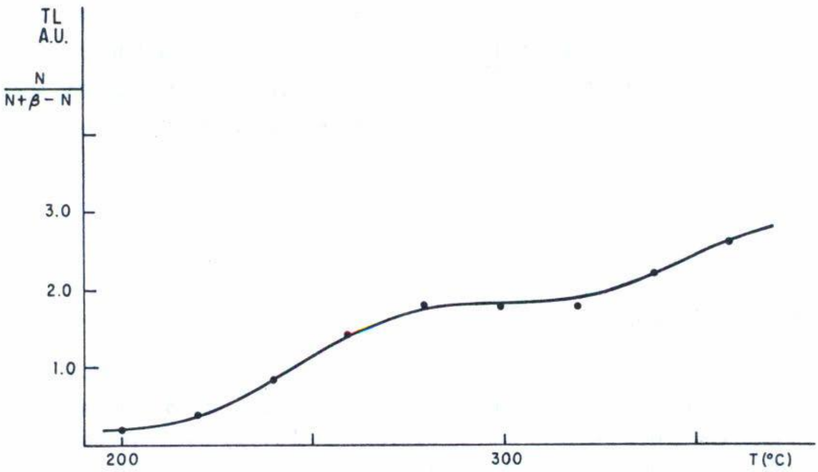

Fig. 10. Plateau test of TL storage stability

From figure 10 any value in the plateau region can be selected, - being 300°C the chosen value. TL output correspondent to this temperature in the glow curve set of figure 9, is plotted against radiation dose in figure 11, allows to determine value of EX = 396 rads by extrapollation.

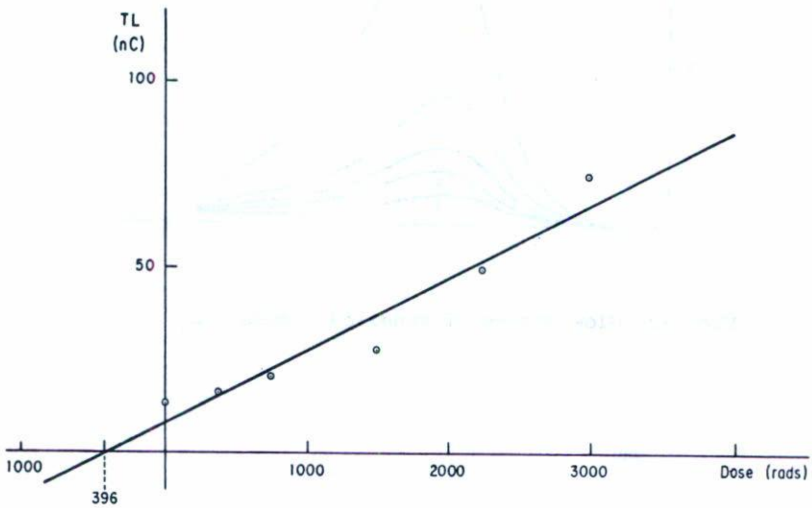

Fig. 11. Determination of ED = 396 rads.

The value of supralinearily (I) in the initial region of radiation response is obtained by replotting of the growth curve after drainage of the natural TL; the value of I = 150 rads is thus obtained; see figure 12 and 13.

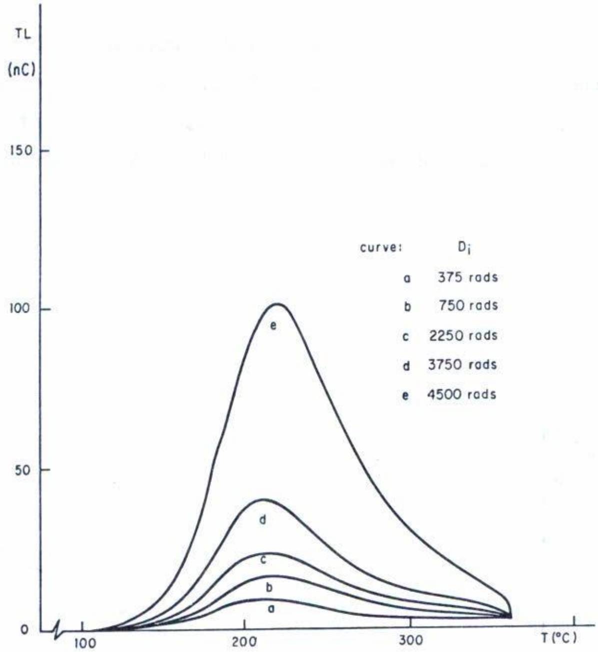

Fig. 12. Glow curves of annealed sample + D_i

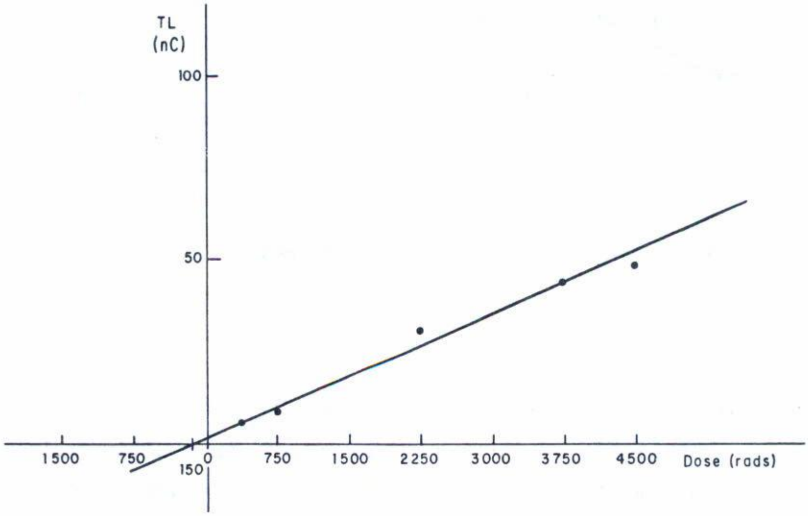

Fig. 13. Determination of supralinearity I = 150 rads.

II. TL-Reader, research laboratory, British Museum (B.M.)

Sample TUZTLAN

The glow curves set of natural TL + D_i obtained in the B.M. figure 14; the plateau test figure 15; ED determination figure 16; glow curves of annealed sample plus induce dose figure 17; and supralinearity value I figure 18, are presented.

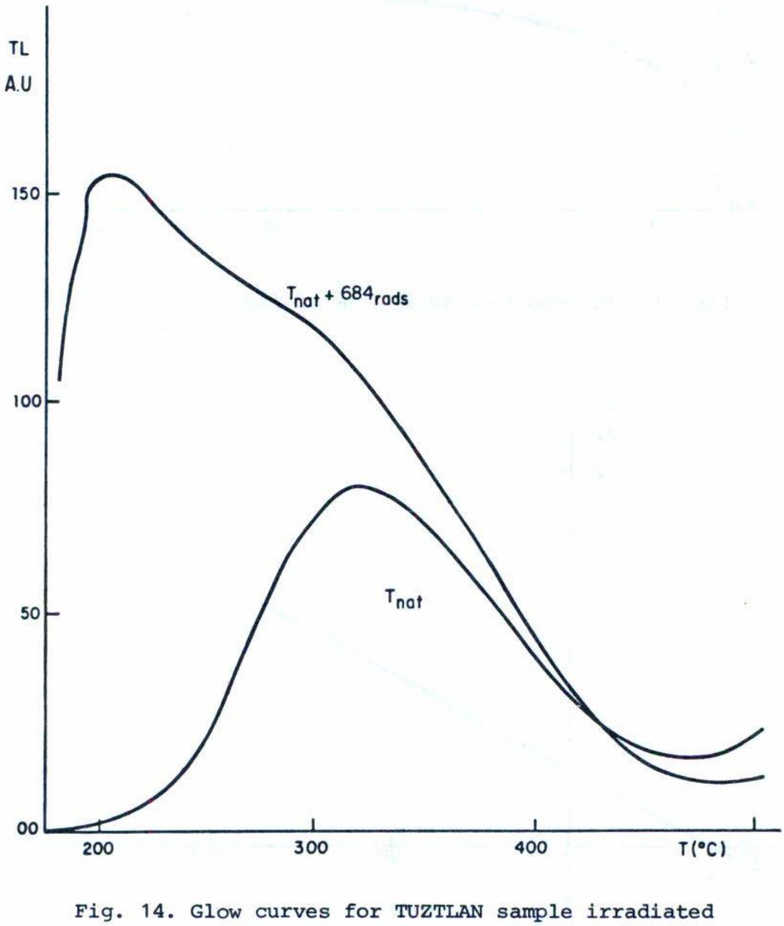

Fig. 14. Glow curves for TUZTLAN sample irradiated with source "C" and readed at the Research Laboratory at the British Museum.

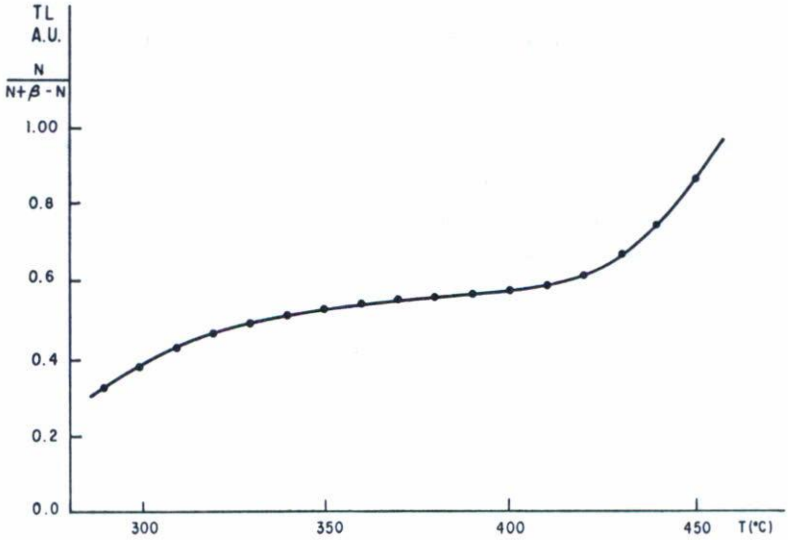

Fig. 15. Plateau test with data of figure 14.

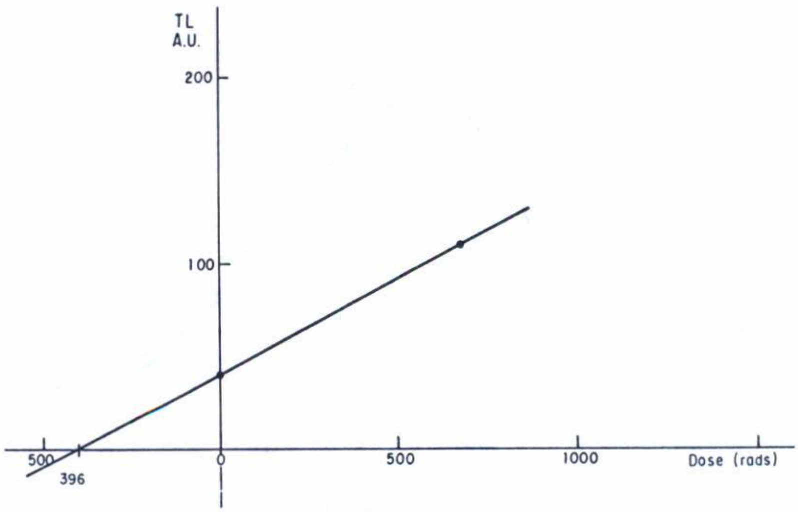

Fig. 16. Determination of ED = 396 rads.

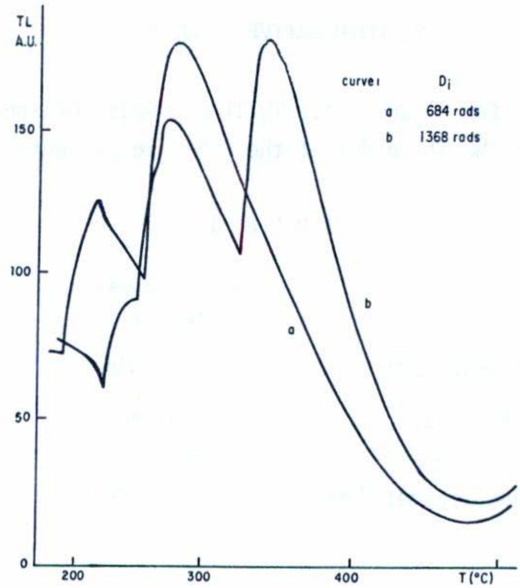

Fig. 17. Glow curves of annealed sample + D_i

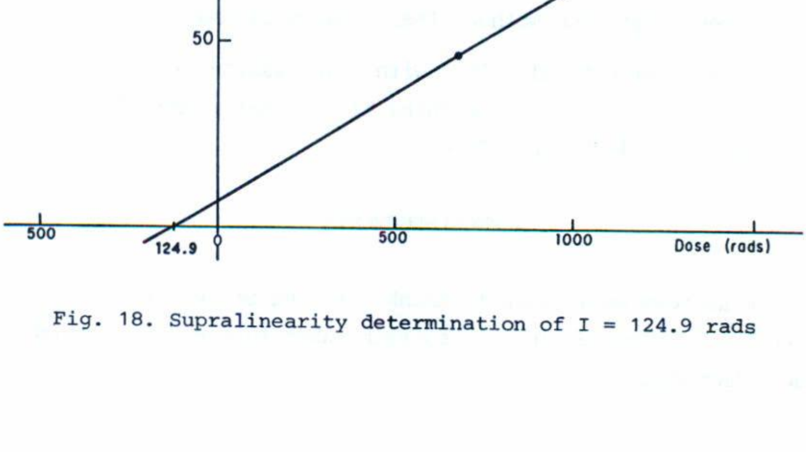

Fig. 18. Supralinearity determination of I = 124.9 rads

8. COMPARATIVE RESULTS

The values for ED and I for TUZTLAN sample obtained in the commercial reader and the TL-reader of the B.M. are presented in table I.

TABLE I

	TL-Commercial reader	TL-reader B.M.
Equivalent dose (ED)	396 rads	396 rads
Supralinearity (I)	150 rads	124 rads
Total archaeological dose	546 rads	510 rads

9. CONCLUSIONS

Although result agreement is 6.8%; to improve substantially the sensibility and the response of the commercial reader for TL-dating, it is necessary to make the following proposed changes:

a) PMT - C31000M^{j} RCA
   or
   PMT - 9635QB EMI

b) Linear-direct light transmission of the TL-signal instead of mirrow reflection method. (See figures 2a and 2b).

c) Change of optical filter with transmission of 320 to 680 nm and 700 to 1000 nm for a Corning blue filter number 7-51 with transmission of 290 to 420 nm.

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