THERMOLUMINESCENCE DATING OF CERAMICS FROM TEOTENANGO – MEXICO

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Abstract

This paper reports the results of studying four sherds from the archaeological site in Teotenango Mexico where the Matlatzinca culture blossomed before the Spanish arrival in America. The determination of the age, was carried out with the thermoluminescence (TL) method. The samples were obtained in order to test on TL some of the main ceramics from Teotenango, since there was no absolute dating on this matlatzinca ceramics, in previous reports. The TL dating technique used was that of fine grain using grains in the range of 4 to 11 µm. Paleodose and the supralinearity correction factor were determined by analyzing the glow curve in the temperature range of 250 to 400°C and giving additive laboratory doses. The ages of these four ceramic samples studied were 692 ±62, 763 ±38, 648 ±34 and 1197 ±40 years which agree well with the historical data for the site.

Resumen

Fechamiento por Termoluminiscencia de Cerámica de Teotenango-México. Este trabajo reporta los resultados del análisis de cuatro tiestos del sitio arqueológico Teotenango en México, donde la cultura Matlazinca floreció antes de la llegada de los españoles a América. La edad se determinó por medio del método de termoluminiscencia (TL). Las muestras fueron obtenidas para analizar la señal TL de algunas de las cerámicas principales de Teotenango, ya que no se contaba con datación absoluta de cerámicas matlazinca en ningún reporte anterior. La técnica de fechamiento por termoluminuiscencia que se utilizó fue la de grano fino, usando granos

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en el rango de 4 a 11 µm. La paleo dosis y el factor de corrección de supralinearidad se determinó por medio del análisis de la curva de emisión de luz en un intervalo de temperatura entre 250-400°C y dando dosis de laboratorio adicionales. Las edades de estas cuatro muestras de cerámicas estudiadas fueron: 692 ±68, 763 ±38, 648 ±34, 1197 ±40 años, las que concuerdan con los datos históricos del sitio.

Résumé

La datation par thermoluminescence de céramique provenant du site Teotenango au Mexique. Cet article présente les résultats d'analyse de quatre tessons de céramique provenant du site archéologique Teotenango au Mexique où la culture Matlatzinca avait connu son épanouissement avant l'arrivée des espagnols en Amérique. L'âge a été déterminé à l'aide de la méthode du thermoluminescence (TL). Les échantillons de Teotenango furent soumis à cette procédure puisqu'il n'existait aucune datation absolue des céramiques matlatzincas. La technique utilisa les grains fins mesurant entre 4 et 11 µm. Le paléo-dosage et le facteur de correction de la «supralinéarité» furent déterminés en analysant la courbe résultante en utilisant des températures entre 250°C et 400°C, tout en ajoutant des doses additionnelles de laboratoire. Les âges des quatre échantillons sont comme suit: 692 ±62, 763 ±38, 648 ±34 et 1197 ±40 années ce qui concorde bien avec les données historiques pour le site.

Resumo

Datação por Termoluminescência de cerâmicas de Teotenango-México. Este artigo apresenta os resultados da análise de quatro fragmentos do sítio arqueológico de Teotenango, México, onde a cultura de Matlatzinca floresceu antes da chegada do espanhol na América. A determinação da idade, foi executada com o método de termoluminescência (TL). As amostras foram obtidas a fim de testar com TL a cerâmica principal de Teotenango, pois não existia nenhuma datação absoluta da cerâmica matlatzinca em relatórios anteriores. A TL como técnica de datação usou grãos finos, na faixa de 4 a 11 µm. Os fatores de correção de "paleodose" e de "supralinearity" foram determinados pela análise da curva de brilho no alcance de temperatura de 250 a 400°C e dando doses aditivas no laboratório . As idades destas quatro amostras cerâmicas estudadas foram de 692 ±62, 763 ±38, 648 ±34 e 1197 ±40 anos que, concordam bem os dados históricos para o sítio.

Introduction

Thermoluminescence (TL) is the emission of light when a substance is heated below its incandescence temperature. It is a promising technique dating archaeological and geological samples (100-800,000a) and for testing the authenticity of an dating archaeological sample by using the TL signal induced by natural radiation through the years of burial.

The TL emitted by the minerals present in a ceramic sample is produced by the prolonged exposure to ionizing radiation emitted by the radioisotopes ^{235}U, ^{238}Th, ^{232}Th (and their daughter products) and ^{40}K embedded in the sample as impurities and present in the surrounding soil. A small contribution to TL is due to cosmic rays.

The accumulated dose which gives rise to the TL is named the paleodose (P). Because all the radioisotopes responsible for TL have a very long half-life, their emission of radiation remains effectively constant and the amount of TL induced is proportional to the time that has elapsed since the pottery was fired. This firing removed all the TL acquired by the mineral during geological times and thus sets the clock to zero. The basic form of the age equation is:

$$A = {}^{P}\!/_{D}$$

where:

A = age (a)

P = paleodose (Gy)

D = annual dose (Gy/ka)

This paper presents the results of dating four ceramic samples from Teotenango, Mexico using the TL method. Teotenango is an archaeological site located at 19°06' North and 99°44' West, about 65 km from Mexico City (see Figure 1). The site shows three stages of human occupation; the Teotenanca, (900-1200 A.D.), the Matlatzinca (1200-1476 A.D.) and the Aztec (1476-1521 A.D.) the earliest stage and less known is related for this site with a transitional type of ceramic identified as Coyotlatelco; during the second one the Matlatzinca ceramic types are widely spread into the site. Sample results on both ceramics are reported here.

The chronology for this site was established in base of stylistic and comparative studies carried in the early 70's, these studies compared the diagnostic ceramic types found in Teotenango, with those from the Basin of Mexico and Teotihuacan; according to them, Matlatzinca ceramic was temporarily placed, nevertheless no direct dating was made for this site prior to this.

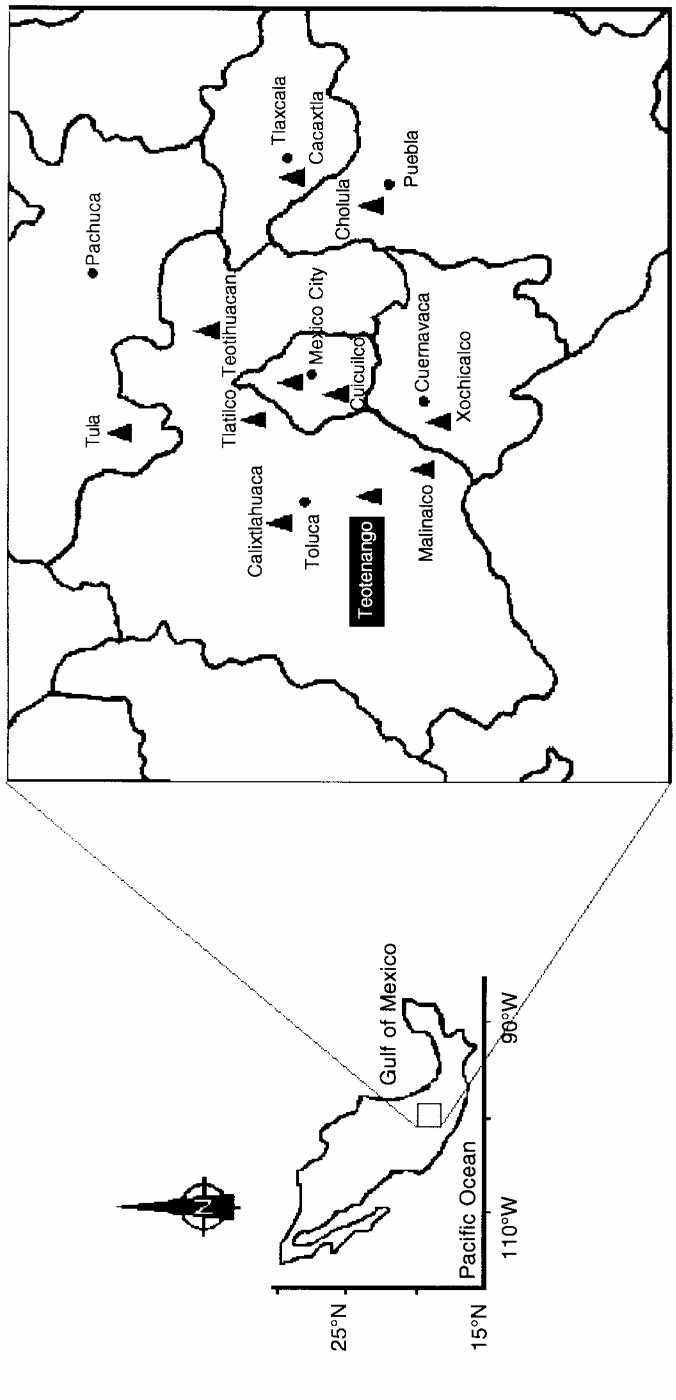

Figure 1. Location of the Teotenango archaeological site near Mexico City.

Experimental procedures

Various fragments of ceramics have been recovered for study. The samples were obtained from archaeological pits made in Teotenango, sample collection occurred during the morning, the sherds were not washed and immediately saved on black plastic containers, protected from heat and sun light, keeping them at the field lab in the Teotenango museum. The samples were delivered the next day to laboratory for TL analysis; only four samples, labeled T2, T4, T5 and T6 have been completely investigated.

The dating technique used was that of fine grain method (Zimmerman, D.W. 1971). A 2 mm layer was first removed from the surface. The remaining sample was crushed and powdered in an agate pestle and mortar. The grains sized from 4 to 11 μm (fine grains) were treated with H_2O_2 to remove the organic material and with HCl to neutralize carbonate.

More than 60 discs of each sample, each containing 2 mg of the sample, were prepared to check the reproducibility of the procedure. Discs were made of aluminum 0.5 mm thick and 9 mm in diameter. All the sample preparation and analysis was performed under red light illumination.

The TL reader used was a Daybreak 1100 Automated TL system, Instituto de Geofísica, UNAM. It is equipped with a sample-holder which can carry 20 discs and is coupled to a PC loaded with the software to control the whole reading process. This software permits the analysis of the plateau (region of interest) and uses least squares fitting of the growth curves to give an estimate of the dose equivalent (Q) and the supralinearity correction factor (I) (González, P. 1998), (Figures 2-4).

Artificial irradiation of the samples was performed with a ^{90}Sr beta source (Amersham International), with an activity of 3.7 MBq (100 mCi) at a dose rate of 190 $Gy{\cdot}h^{-1}$.

Sixteen readings of each of the unirradiated samples were taken to obtain the natural TL signal (NTL); the remaining samples were irradiated in vacuum at four different artificial doses, which were labeled as 1β, 2β, 3β, and 4β respectively in every cases (Figure 3a). The samples were stored one week in the dark prior to measurement.

The dose equivalent (Q) was determined by the additive dose method; while the determination of the supralinearity factor (I) was carried out by means of the regeneration method (Zimmerman, D.W. 1971; Aitken, M.J. 1985), using those samples from which NTL had been previously erased.

To calculate the annual dose rate due to alpha and beta radiation the concentrations of K, U, and Th in the ceramics and in the surrounding soil were determined. Determination of K concentration was performed by means of the microanalysis technique using a sweeping electron microscope Philips XL30. The determination of U and Th contents was carried out by the neutron activation analysis technique in a Triga Mark III reactor at ININ (González, P. 1998; González, P. 1999).

The gamma radiation dose rate was measured using locally made $CaSO_4$: Dy and LiF: Mg, Cu, P TL dosimeters (TLD) (Azorín, J. 1984; González, P.R. 2001) in cupper capsules.

Results

Table 1 shows the U, Th and K concentrations, the moisture contribution as well as the annual dose rates in Gy/ka. Taking an a efficiency factor of 0.10 and a Th/U ratio of 3:1 (Adamiec, G. 1998); annual dose rates in dry conditions were obtained.

The average gamma radiation dose rate measured by TLDs was 1.096 ±0.05 Gy/ka.

Table 1
Concentration of U, Th, K and, moisture; as well as their dose (Gy/ka) to each samples studied

Sample	*U (ppm)*	*Th (ppm)*	*K (%)*	*Moisture (%)*	*Rate dose(Gy/ka)*
T2	4.28	5.33	1.96	17	4.25 ±0.13
T4	4.26	5	0.89	16	3.56 ±0.12
T5	2.38	5.31	0.29	14	2.58 ±0.10
T6	1.48	4	0.9	11	2.60 ±0.06

In Figure 2 we can observe the plateau which appeared in a wide temperature range in which it is possible to do the evaluation of the parameters within a high confidence level (Aitken, M.J. 1985).

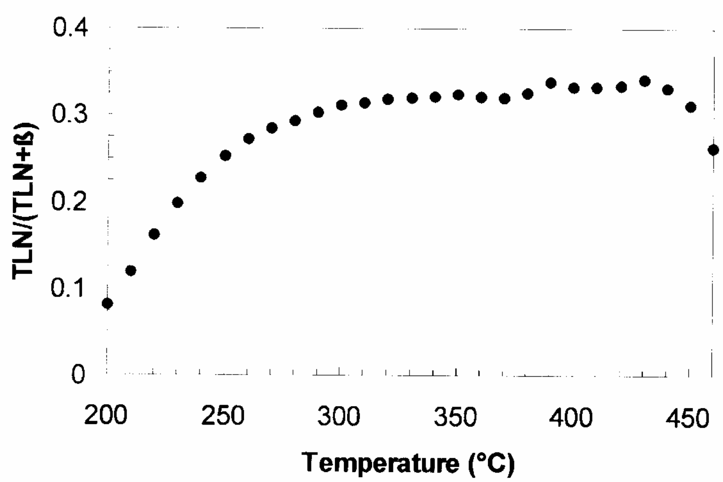

Figure 2. Plateau test of the T6 sample showing the stable region.

In Figure 3a we can observe the glow curves of unirradiated samples (NTL) as well as those irradiated with ^{90}Sr beta radiation at four different artificial doses (NTL+ATL). The dose response curves obtained by the additive dose method (González, P. 1999), for the T6 sample, are shown in Figure 3b. Interpolation of these curves to zero TL intensity (TL=0) gives the dose equivalent (Q); this was determined each 10°C temperature intervals in the range from 250 up to 400°C for T6 sample. The correction factor due to supralinearity was determined by means of the regeneration method at the same 10°C temperature intervals. These results are shown in Figure 4a and 4b respectively.

Table 2 shows the beta radiation for the equivalent dose (Q) and supralinearity factor (I) for each sample studied. Meanwhile in Table 3 the values of Q and I obtained as well as the paleodose (P) and age corresponding to the type of samples are presented.

Table 2
Beta radiation dose to obtain Q and I factors of each samples

To Equivalent (Q)	*Samples*			
Dose (Gy)	*T2*	*T4*	*T5*	*T6*
1ß	4.961	2.599	1.953	3.002
2ß	9.974	5.199	3.959	6.003
3ß	14.9	7.852	5.965	8.953
4ß	19.9	10.5	7.971	12.008
To Supralinearity Factor (I)				
1ß	4.961	1.963	1.953	2.999
2ß	9.975	3.979	3.959	5.999
3ß	14.9	5.995	5.965	8.999
4ß	20	7.958	7.972	12

Table 3
Values of dose equivalent (Q), supralinearity correction factor (I), paleodose (P) and Age (years) for the samples from Teotenango, Mexico

Sample	*Q (Gy)*	*I (Gy)*	*P (Gy)*	*Age (years)*
T2	2.118±0.060	0.824±0.272	2.942±0.279	692±62
T4	2.149±0.048	0.570±0.100	2.720±0.111	763±38
T5	1.526±0.030	0.146±0.050	1.672±0.059	648±34
T6	2.824±0.055	0.293±0.041	3.117±0.069	1197±40

The results presented on this paper allow to establish absolute dates in order to place chronologically four ceramic types from Teotenango, one of these, temporarily

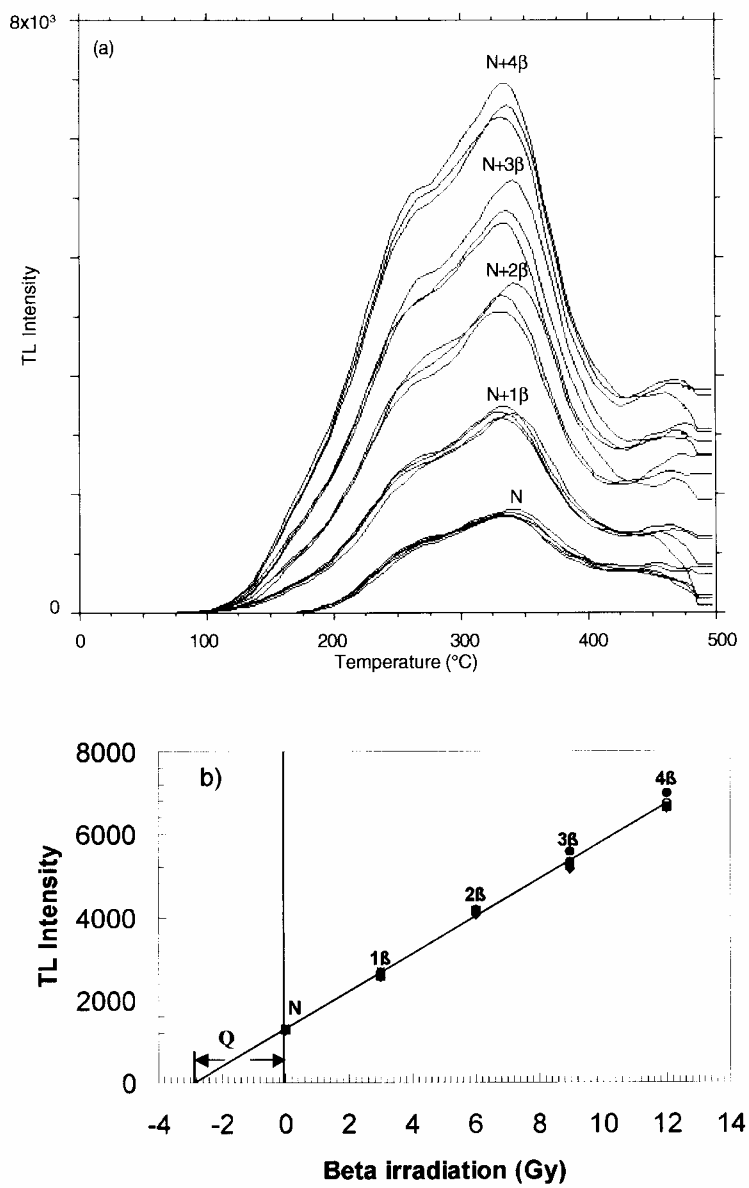

Figure 3. a) Glow curves of unirradiated samples (NTL) as well as those irradiated with ^{90}Sr beta radiation at four different doses (NTL+ATL). Sample T6 irradiated at; 1ß, 2ß, 3ß and 4ß. **b)** Dose response curves of the samples obtained by the additive method to sample T6.

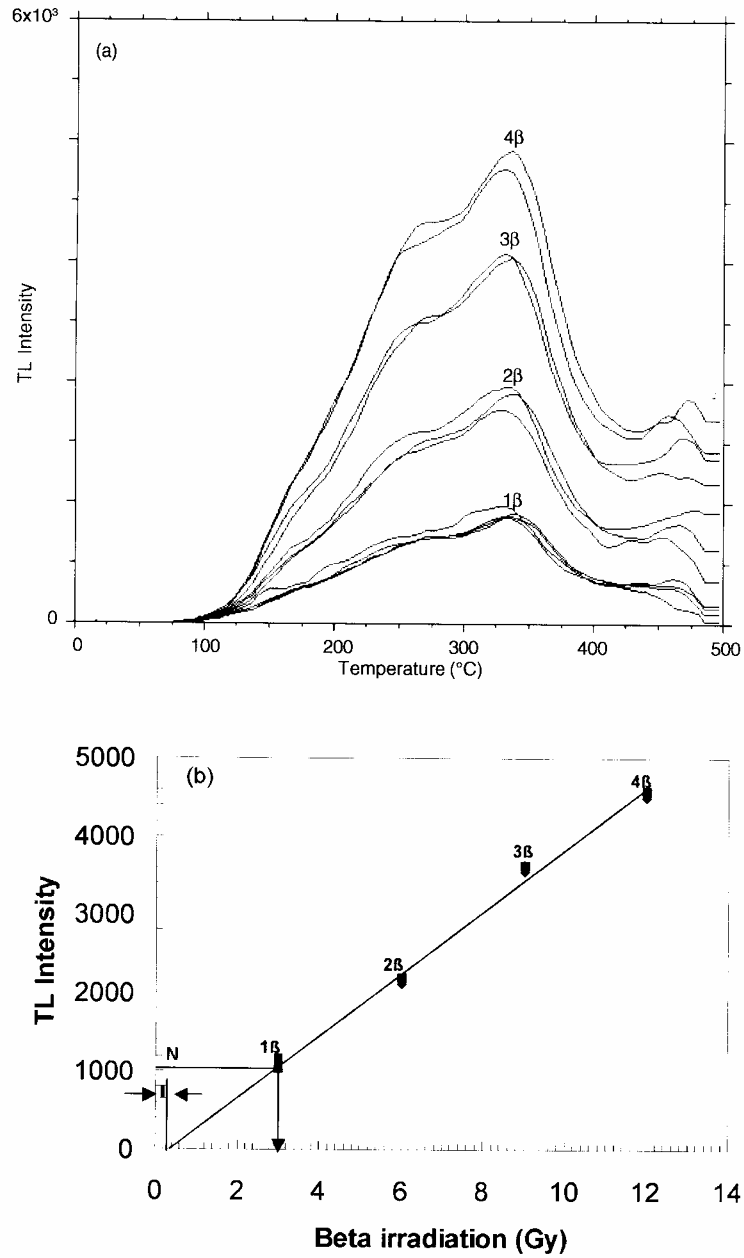

Figure 4. a) Glow curve of T6 sample beta irradiated at; 1ß, 2ß, 3ß and 4ß. **b)** Regenerated growth curve of T6 sample obtained from the glow curves.

associated to the Epiclasic period (750-900 A.D). The other ones, temporarily placed on the Early postclassic period are part of the Matlatzinca ceramic complex, which is present in a major geographical area; The Toluca Valley, therefore it gives a great possibility to extend our results to many other archaeological sites into the mentioned area.

Conclusions

The earliest sample studied is T6, dated for 1197 ±40 (803 A.D.) this type of ceramic is a Coyotlatelco domestic vessel. This ceramic type has been controversial in Teotenango, since based only on previous stylistic comparisons, its presence has been temporary placed on period 2 (700-1000 A.D.). Although this domestic ceramic is not a diagnostic type, it allow us to say that at least from 803 A.D. The Coyotlatelco type is already present on this site.

Domestic ceramic types are hardly chronologically placed on stylistic studies, since they are present along very wide spans of time, that is the case of T4 dated for 763 ±38 (1237 A.D.) it belongs to a Matlatzinca bowl (naranja rojizo [Vargas Pacheco, Ernesto 1975]) in this case we can conclude that it is present in Teotenango by the early postclassic period.

The sample T2 dated for 692 ±62 (1308 A.D.) belongs to another Matlatzinca domestic vessel (bayo monocromo type grupo café [*ibíd.*]) this ceramic was not either placed in previous studies on an specific chronology but due to our results we can conclude that the presence of this domestic Matlatzinca type is clear at the middle of the early postclassic period.

Sample T5 was dated for 648 ±34 it also belongs to a Matlatzinca bowl, in this case it was related to the type banda roja (*ibíd.*) this is a diagnostic type and was placed by stylistic studies on a span of time between 1162 and 1476 A.D. with our results it is possible to place it on 1352 A.D. which is according on previous estimations, nevertheless we can start to consider more accurate data for these diagnostic types on Matlatzinca ceramics.

From the results obtained we can conclude that archaeological dating by means of TL is highly confident (Piña Chan, Román 1975). That encourages us to continue this research due that our country is rich in archaeological sites which need to be dated.

Acknowledgments

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