Thermoluminescence analysis

Figure 1. The analysed object (h: 52 cm)

Sampling date: September 23, 2025

Operator who carried out the sampling: Dr. Fulvio Fantino

Sample code: MPM/01

Sampling point: inner part of the right arm (casting core)

Geographical area of provenance: Korea

Amount of sample: 558 mg

Equivalent dose: 8.2 ± 0.7 Gy

Estimated annual dose: 0.7 ± 0.1 Gy/century

The average age range estimated in the laboratory for the sample suggests its last firing to be placed between 600 AD and 1000 AD.

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06.10.2025
10:57:51
GMT+02:00

Torino, 10/06/2025
Dr. Fulvio Fantino

NOTE:

- Supralinearity and anomalous fading were not measured.
- The annual dose was estimated by measuring the alpha nuclear activity of the sample (related to the decay of alpha particles) and by considering certain parameters derived from scientific literature.
- The average age range estimated since the last heating of the sample was calculated by comparing the measured effective dose with the estimated annual dose.

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Equivalent Dose

To measure the equivalent dose, the **additive dose method** has been adopted. In the following graph, a few examples of TL glow curves obtained for the analysed sample are reported, in particular: the curve related to the natural TL and those related to the aliquots of the same material, but artificially irradiated with different known doses (4 and 8 Gy).

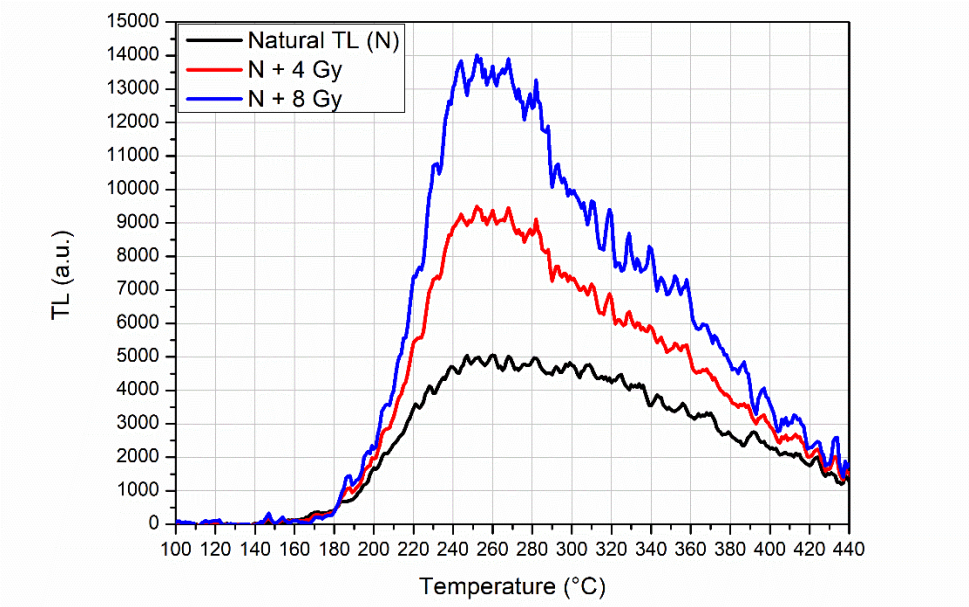
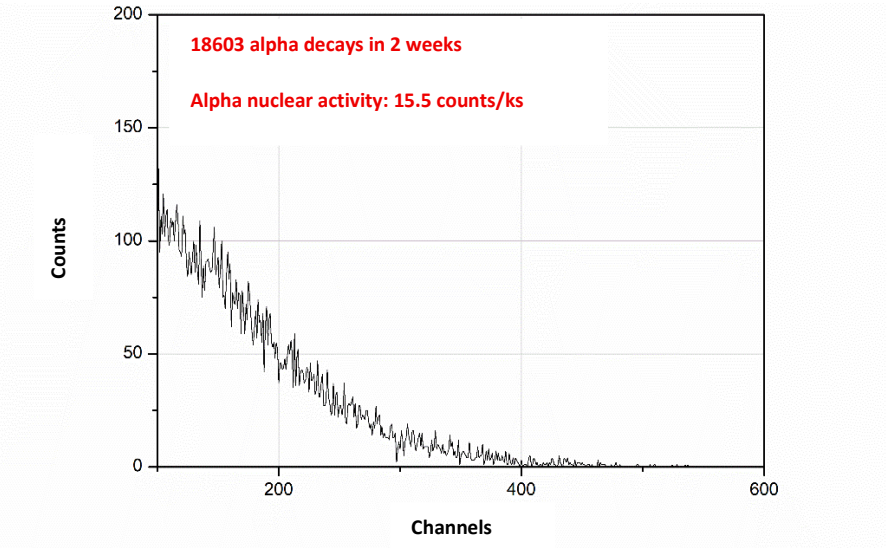


Figure 2. TL glow curves

Alpha nuclear activity

To determine one of the key parameters for estimating the annual dose, alpha nuclear activity was monitored over a 14-day period. The graph below displays the recorded counts of alpha particle decays for the sample.



The result obtained is: 15.5 counts/ks (counts per thousand seconds). Using the measured data for alpha activity and other parameters derived from the literature for samples belonging to Korea, the average annual dose value was estimated.

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Annex

Theoretical basis of the method

The thermoluminescence (TL) technique exploits the properties of certain materials to produce light emission when heated at high temperature (above 450 °C): the amount of light emitted is proportional to the age of the last firing of the sample. Consequently, higher is the TL signal, older is the object from which the sample has been taken. Indeed, when a material is produced, the firing process resets the TL signal. Starting from this event, physical phenomena due to radioactivity (both from the natural radioisotope content of the sample and its surrounding environmental) produces a TL signal that increases during the time. Therefore, this technique allows the dating of archaeological finds such as bricks, ceramics, pottery, etc.

In laboratory, after a proper chemical preparation, an aliquot of the sample extracted from the object is heated and its light emission recorded. In this way, the so called "natural thermoluminescence" is obtained. Other aliquots of the sample are then irradiated with a radioactive source of known intensity, in order to compare their TL signals (obtained after the artificial irradiation) with the natural one. This procedure is known as **additive dose method**, since a certain dose of radioactivity is added artificially to the natural doseacquired by the material over time.

The comparison of the signals (*glow curves*) by means of mathematical methods allows to determinate the **equivalent dose** (measured in Gray [Gy]), that added to other parameters (**anomalous fading**[a] and **supralinearity**[b]), permit to quantify the radioactivity dose acquired by the sample starting from the last firing. In order to perform an accurate dating, other kind of measurements are necessary, nevertheless the value of the equivalent dose is usually sufficient to indicate the historical period for a specific geographical area. For this reason, in the case of authentication, this parameter is normally enough.

Instead, to obtain an accurate dating of an artefact, the **annual dose**[c] has to be calculated by means of the following measurements: the environmental radioactivity of the place where the artefact was found (e.g., the excavation soil), radioactivity of the material constituting the object and others parameters[d].

For the authentication procedure, the annual dose is only estimated from the scientific literature, due tothe large amount of sample needed for the evaluation of this parameter and the difficulty to recover the excavation soil. Therefore, in a certificate of authenticity, a precise date is not reported (unlike it occurs in a dating report) but only a compatibility or not between the equivalent dose and the historical period indicated by the owner of the artefact.

NOTE:

[a] Non-linear behavior of thermoluminescence at low dose
[b] Loss of thermoluminescence signal at room temperature
[c] Radioactivity dose absorbed by the sample in one year
[d] Alfa nuclear activity and k-value

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