The global and persistent millennial-scale variability in the thermoluminescence profiles of shallow and deep Mediterranean sea cores

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Summary. — In this paper we present the thermoluminescence (TL) profile in the last 7500 y, measured in the upper part of the deep Tyrrhenian sea core CT85-5. This core was dated with tephroanalysis and radiocarbon techniques: a constant sedimentation rate (10 cm/ky) was found up to 200 cm. The sampling interval adopted for obtaining the TL profile is 2.5 mm, corresponding to 25 y. Using different spectral-analysis methods, we show the presence of a millennial-scale variability, corresponding to an average period of about 1315 y. This oscillation has been noted also in other climatic indices measured in North Atlantic sea sediment cores and in the Greenland GISP2 ice core. This result indicates that this millennial oscillation is the expression of climate changes of worldwide extent. We show that this millennial periodicity persisted during the last deglaciation. The transition to Holocene was determined in our core by the oxygen isotope ratio $\delta^{18}O$ measured in *Globigerina bulloides*. The fact that the observed TL changes do not have a local character is also suggested by the excellent agreement between this deep sea TL profile of the uppermost part of the core and the TL profile measured in the shallow Ionian sea GT89-3 core over the last 2500 y, with a time resolution of 3.096 y.

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1. – Introduction

The new method for the investigation of the past illumination-irradiation of the Earth, based on measurements of thermoluminescence (TL) variations in the fine polymineral material of marine sediment cores, was introduced in our Laboratory in the last decade [1-3]. The TL depth profiles, measured by us in the Tyrrhenian and Ionian sea cores, were transformed into accurate time series, using the sedimentation rates determined by radiometric, tephroanalysis and radiocarbon methods.

In this paper, we present the TL measurements of the CT85-5 Tyrrhenian sea core, obtained by different techniques and different sampling intervals, and we compare them with the TL measured in the GT89-3 Ionian sea core.

2. – Experimental procedures

The core CT85-5 is a deep water (2833 m) Tyrrhenian sea core, 6 m long, spanning a time interval of 60 ky BP. The high sedimentation rate of 10 cm/ky was estimated using the presence of historically dated tephra layers of the Pollena eruption (472 AD) and Pompei (79 AD). Older tephra layers at the depth of 290-334 cm and 400-426 cm have been correlated with the terrestrial deposits of the Campanian Ignimbrite and Citara, respectively [4, 5]. We also performed dating using the radiocarbon technique [6] at 30 depths: in general, the radiocarbon-based time scale and the time scale constructed using a constant sedimentation rate agree very well.

We performed the TL analysis of 295 samples at consecutive sampling depth of 2.5 mm from -5377 AD to 1973 AD with a time resolution of 25 y. In order to prepare the samples, we adopted the "disk technique" described in [7]. This preparation preserves the original composition of the minerals releasing the TL signal stored in carbonate, quartz and feldspar crystals of the sediment. Samples deposited on aluminium disks were measured using the TL analyser, described by Miono and Otha [8].

TL analysis was also performed using the fine-grains method [9] selecting the size (4 to 11) μm of the polymineralic carbonate-free grains of the sediment. With this technique we measured TL in 160 consecutive samples with a depth resolution of 1 cm, corresponding to 100 y, covering the time interval of the last 16 ky.

The core GT89-3 is a shallow-water Ionian sea core, taken from the *Gallipoli terrace* in the Gulf of Taranto. The sedimentation rate s, determined with an accuracy better than 1%, was found to be quite constant along the cores and uniform throughout the whole platform in the last two millennia, $s = (0.0645 \pm 0.0007)$ cm y^{-1} [10, 11]. In order to prepare the TL samples, we adopted the "disk technique" quoted above [7].

3. – TL profiles and discussion of the results

Figure 1 shows the TL profile (295 data; sampling depth 2.5 mm, corresponding to 25 y) of the CT85-5 core (light line), spanning the last 7500 y. It is possible to note a strong millennial oscillation: in order to evidentiate it, we applied the Singular Spectrum Analysis (SSA) [12], using a window width $M = 70$. The Principal Components (PCs) 1 to 4 carry the frequencies associated to this oscillation: in fact in fig. 1 we note that the reconstructed (filtered) time series from PCs 1 to 4 (heavy line) reproduces very well the low frequencies of the original series. We applied the Maximum Entropy Method (MEM) to determine the dominant periodicity of the reconstructed series obtaining $T = 1315$ y. The average period and amplitude of the reconstructed series on the whole time interval covered by the series was also estimated using the method of superposition of epochs; we obtained the period $T = 1315$ y, with an amplitude $A = 22.5$ a.u. and a phase $\phi = 5$ rad (referred to 247 AD).

A similar climatic periodicity has been recently revealed in other indices measured in the Greenland GISP2 ice core [13] and in North Atlantic sea sediment cores. In particular, Bond *et al.* [14], by measuring the hematite-stained grains profile as a proxy

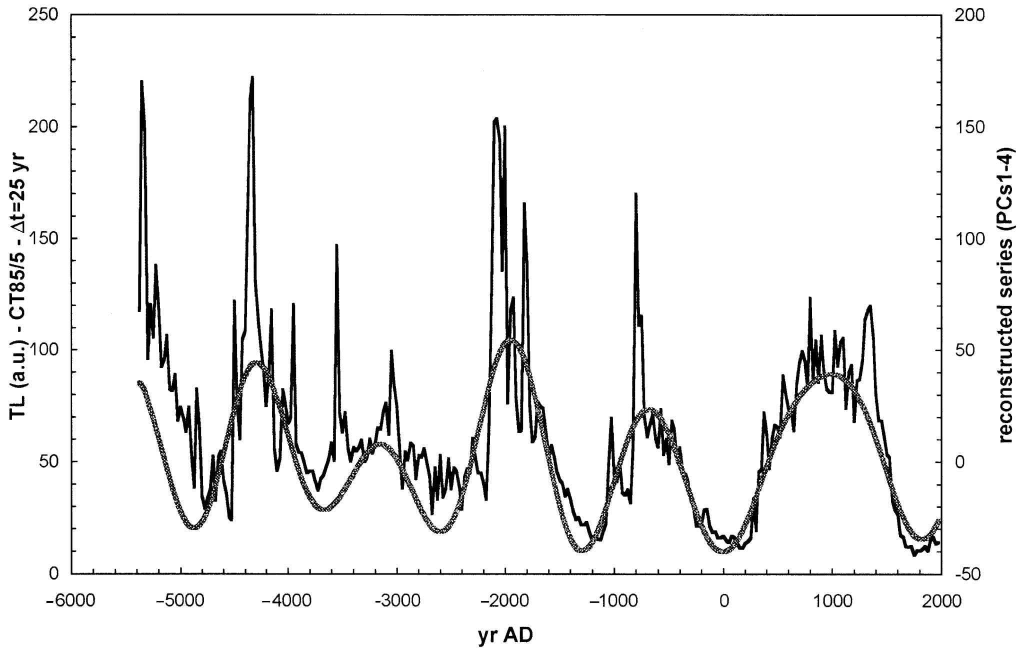

Fig. 1. – TL profile measured in the uppermost 80 cm of the CT85-5 core, sampled at 2.5 mm in a continuous way. Superposed we show the reconstructed series by SSA-PCs 1 to 4.

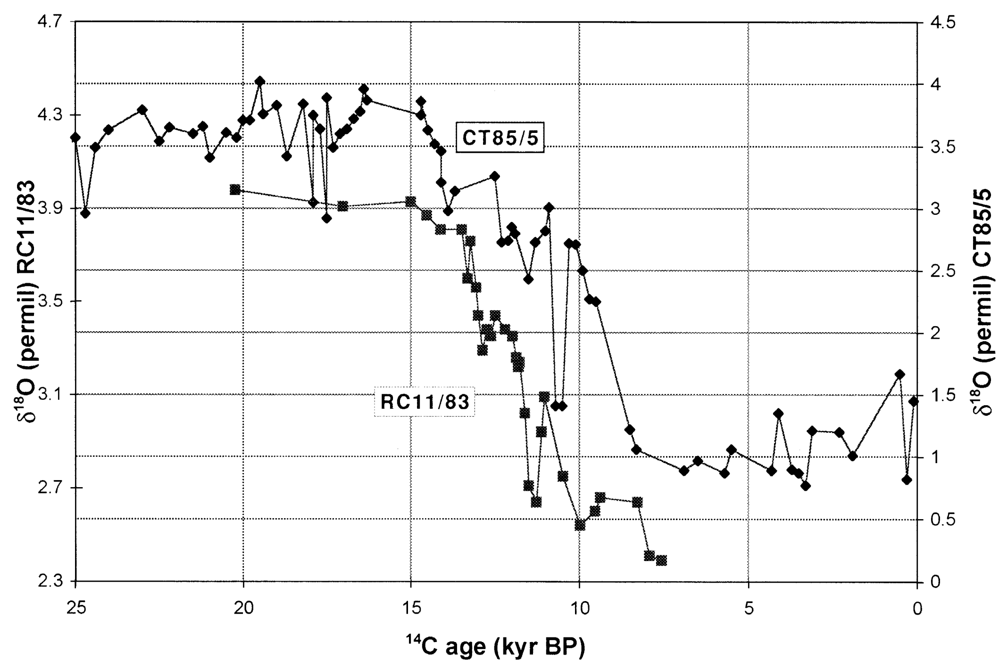

Fig. 2. – $\delta^{18}O$ in *Globigerina bulloides* in the CT85-5 core [15], together with $\delta^{18}O$ measured in the core RC11-83, taken from the Southern Atlantic Ocean [16].

to document the ice-rafting events in two cores taken from opposite sides of the North Atlantic (VM28-14 and VM29-191), found a cyclic signal of period (1536 ± 563) y for the glacial interval and of (1374 ± 502) y for the Holocene, showing that the millennial signal persists across the three major climate transitions: the Younger-Dryas-Holocene transition, the deglaciation and the boundary between marine-isotope stages 2 and 3 (at about 30 ky BP). Our result obtained in the Mediterranean sea demonstrates that this millennial periodicity is the expression of climate changes of worldwide extent.

The deglaciation in the CT85-5 core is marked by means of the classic oceanographic method of the oxigen isotope ratio δ^{18}O in *Globigerina bulloides* during the last 25 ky. In fig. 2 we show the CT85-5 δ^{18}O data [15], together with those measured in the core RC11-83, taken from the Southern Atlantic Ocean [16]. The common time scale is the radiocarbon scale. In both profiles we note clearly the abrupt variation starting at about 14 ky BP, corresponding to the glacial-interglacial transition, possibly related to the start of the North Atlantic Deep Water (NADW) circulation. Moreover, we can see similar stepwise behaviour during the transition, revealing global melting of polar ice.

In order to test if in the Mediterranean sea the millennial TL oscillation persists across the deglaciation event, we measured TL in 160 samples (sampling depth 1 cm, corresponding to 100 y) of the CT85-5 core using the fine-grains method [9] and we extrapolated the sinusoidal wave found by superposition of epochs for the time series of fig. 1 up to 16 ky BP.

The TL measurements (see fig. 3, heavy line) are compared with the extrapolated sinusoid (light line), obtained from the shorter record as discussed above. This

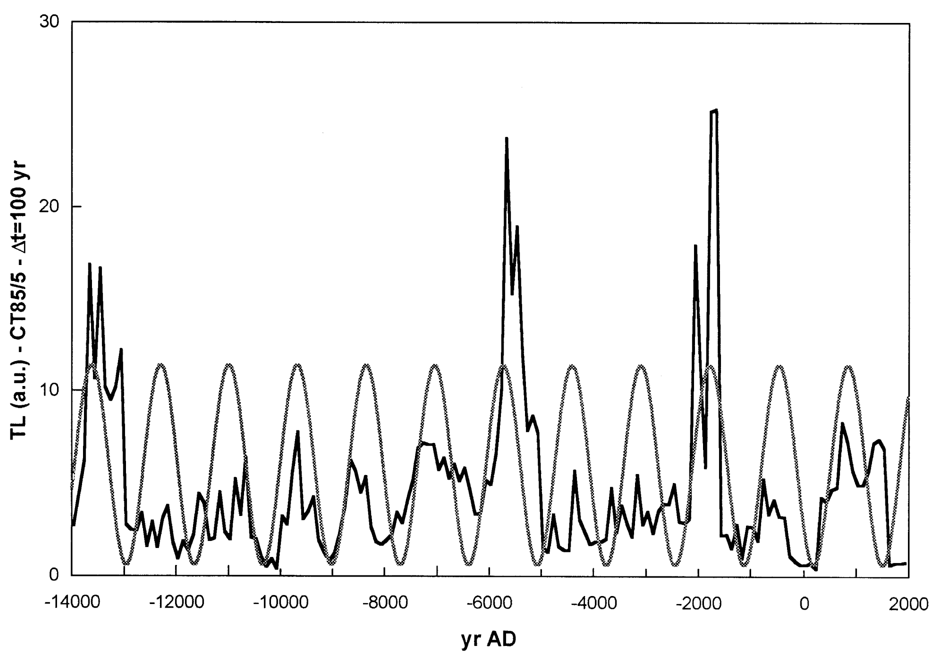

Fig. 3. – TL profile measured by fine-grains technique (heavy line); the sinusoid obtained from the time series of fig. 1 (light line) is superposed to the data showing that the millennial periodicity persists through deglaciation.

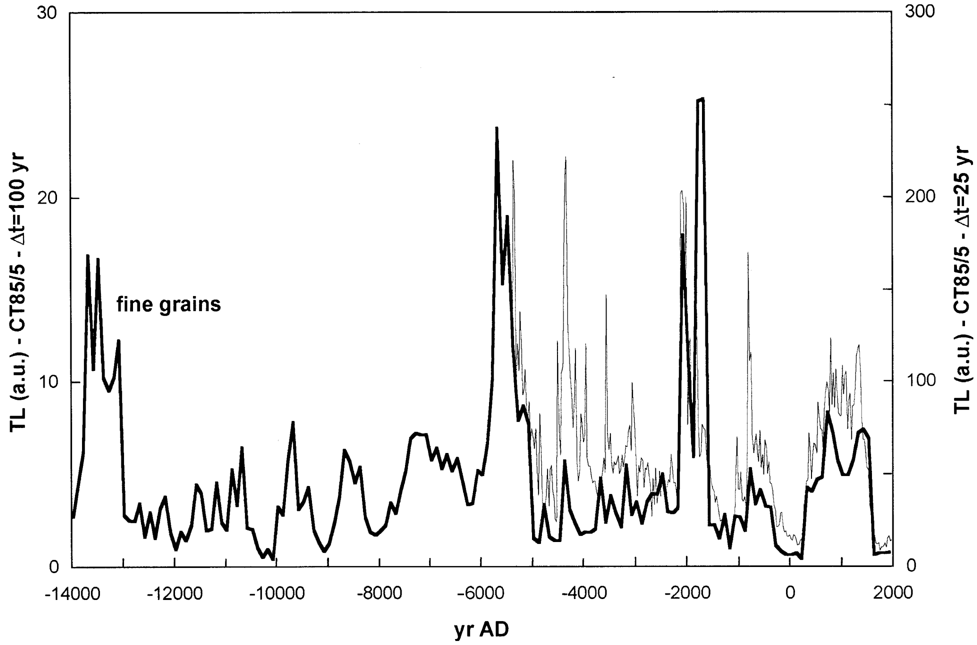

Fig. 4. – Comparison between the TL profiles mesured with two different methods and sampling intervals in the CT 85/5 core.

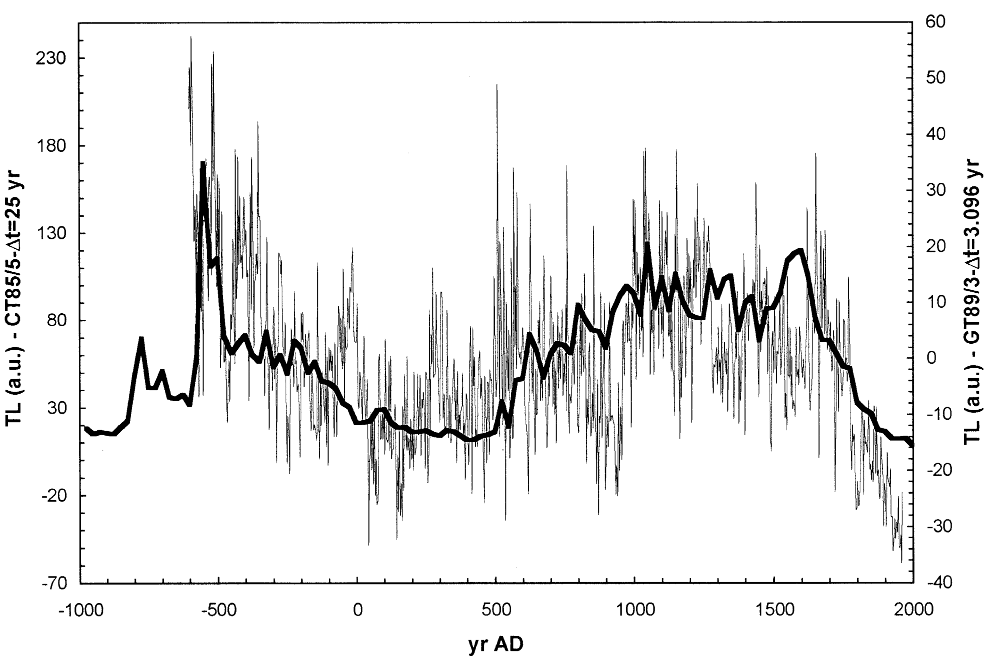

Fig. 5. – Comparison of the Tyrrhenian TL profile ($\Delta t = 25$ y) and the Ionian centered TL profile ($\Delta t = 3.096$ y) during the last 2600 y.

comparison suggests that the millennial periodicity, found in the Mediterranean sea in the last 7500 y, persists during deglaciation. Moreover, as shown in fig. 4, the two time series obtained in the same core by two different TL techniques (the classical fine grains and the natural total polymineralic TL technique) give similar results.

The fact that the observed TL variations do not have a local character, already supported by the preceding results, is confirmed by the good agreement between the TL profile, discussed above taken from the Tyrrhenian sea (CT85-5) and the other measured from the Ionian sea (GT89-3) with a different sedimentation rate (see fig. 5). The high-resolution profile of the GT89-3 core, covering the last 2600 y (light line), was obtained by sampling the core at consecutive intervals of 2 mm, corresponding to 3.096 y. The superposed heavy curve is the recent part of the TL CT85/5 profile shown in fig. 1. The excellent agreement between the two curves furtherly validates the dating of the deep sea core.

4. – Conclusion

In this paper, we have shown the similarity of the TL profiles of the CT85-5 core, obtained using different sampling intervals and different techniques. An oscillation of period $T = 1315$ y is found in the last 7500 y; TL measurements over the last 16 000 y show that this periodicity persisted across the deglaciation events, identified by $\delta^{18}O$ measurements of *Globigerina bulloides* in the same core. Furthermore, a good agreement between the TL profiles measured in the deep Tyrrhenian CT85-5 core and in the shallow-water Ionian GT89-3 core is evident.

These results, together with the fact that similar oscillations have been found in different climatic indices in North Atlantic sea sediment cores and in the Greenland GISP2 ice cores, supports the evidence that this millennial variation reflects global climatic changes.

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