CHAPTER -V

EXPERIMENTAL RESULTS

The basic form of expression of the TL of a material is its "glow curve". A glow curve is the instantaneous rate of detection of emitted light plotted against time as the temperature of the sample is continuously and uniformly raised. It is usually obtained automatically on a chart recorder with the chart moving at constant speed with a two-pen chart-recorder. The second pen record usually indicates temperature, so that the rate of light detection is obtained also as a function of temperature. In the present thesis TL glow curves are presented as plots of TL intensity versus temperature. Intensity of TL-output is presented in amperes. Glow curves may contain one or more peaks and their relative and absolute heights may be influenced by many factors. In view of this, the variously pretreated material under investigation namely, TLD grade Ca^{++} doped sodium chloride in powder form, was examined after exposure to UV radiation (253.7 nm) at room temperature.

A series of TL glow curves in the temperature range 30 - 400°C were recorded for each and every specimen and typical glow curves are presented in this section for discussion. The main glow peak exhibited by the material are at 100, 137, 167, 180, 230 and 340°C. The appearance and disappearance of new peaks or

shoulders in the neighbourhood of isolated principal glow peak after various pre-treatments of the specimens results in slight variation in the peak temperature from those mentioned above. In this context, the assignment of the particular temperature to a TL glow peak may appear somewhat arbitrary. However, the peak temperatures mentioned in the thesis are typical and these have been used for identification of the glow peaks. In the present investigation extensive experimental measurements have been carried out on UV-irradiated untreated and pretreated (thermally and / or mechanically) pure and Ca^{++} doped NaCl for their TL behaviours. The results obtained are presented in Figs. 1 to 15. In these experiments, the phosphor was subjected to cyclical succession of irradiation at room temperature, heating to around 400°C with uniform heating rate (180°C/min) and then cooling to room temperature. In all these figures, continuous (____), dotted (....) and dashed line (----) curves indicate the first, second and third heating runs respectively.

Figures : 1 - 3

Thermal glow curves of pure Sodium Chloride specimens in three different physical conditions :

as-obtained from aqueous solutions, obtained after annealing at 550 and 750 °C temperature for two hours (in air) and subsequently cooled rapidly to room temperature, were recorded in the present experiments. They are presented in Figs. 1, 2 and 3 respectively. It is clearly seen from Fig. 1 that NaCl specimen as-obtained from aqueous solution displays a single isolated well defined peak at 100°C. The intensity of this peak grows with successive thermal cycling.

It is worth noting that the rapid air quenching of NaCl from 550°C enhances the intensity of 100°C glow peak alongwith the generation of new peaks at 137, 230 and 340°C (Curve : 1, Fig. 2). Beside this, it is also observed that all the four peaks namely; 100, 137, 230 and 340°C appear in the first heating run. Amongst them, high temperature peak at 340°C is found to be dominant one. In the second heating run the peak at 340°C is completely erased and the glow curve pattern finally appears to stabilise with well defined peaks at 100 and 230°C with ofcourse, considerable reduction in their intensities.

The NaCl specimen annealed at 750°C and air quenched NaCl (T) exhibits dominant peak at 167°C

alongwith shoulders on either sides with position at 137, 230 and 340°C in the first heating run (Curve : 1, Fig. 3). It is interesting to note that in the second thermal cycle the prominent peak at 167°C disappears and peak at 137°C and 230°C appear with higher intensities. The relative intensity of 137°C peak is higher than that of 230°C peak. Further, successive thermal cycles progressively increase the intensities of these peaks.

Figures : 4 - 6

Figures 4 through 6 respectively show the TL glow curves for Ca^{++} doped Sodium Chloride with Ca^{++} concentration 10^{-4} molar fraction (m.f.) in as-obtained condition and after quenching them from 550 and 750°C in open air. As-obtained NaCl:Ca specimens exhibit strong peak at 340°C alongwith two small peaks at 100 and 137°C, in the first heating run (Curve : 1, Fig. 4). In the second thermal cycle peak at 137 and 340°C are nearly suppressed and well defined peak at 100°C comes up with significant intensity. With further thermal cycling only the peak at 100°C appear as isolated prominent glow peak. The NaCl:Ca (10^{-4} m.f.) specimens annealed and quenched from 550°C show two equally intense well defined peaks at 137 and 340°C alongwith a shoulder at 185°C in the first heating run. The peak at 340°C

disappears and the 137°C peak appear with lower intensity in the second and subsequent thermal cycles. The TL behaviour of the specimens quenched from 750°C is more or less similar to that quenched from 550°C. There is however, one marked difference namely, the substantial enhancement in the overall intensity of the glow curve after first heating run. The peaks at 137 and 185°C are easily discernible in the corresponding glow curves for these specimens (Fig. 6). In the case of both the peaks, 137 and 185°C, it is observed that the intensity continues to increase with successive heating runs.

Figures : 7 - 9

Another batch of the NaCl:Ca specimens (10^{-3} m.f.) obtained by recrystallization from aqueous solution was annealed at two different elevated temperatures namely; 550 and 750°C for two hours in air and subsequently quenched rapidly to room temperature. The TL behaviours have been recorded for the thermally treated and untreated NaCl:Ca (10^{-3} m.f.) specimens which are presented in Figs. 7 to 9 . It is observed from Fig. 7 that untreated specimen displays strong peak at 340°C alongwith two weaker peaks at 100 and

167°C in the first heating run. It is also seen that lower temperature peaks at 100, 167 and 230°C are distinctly observed in the second thermal cycle. Further, it is observed that in the subsequent heating run the 100°C glow peak grows whereas the 167 and 230°C peaks subside.

It is of interest to note that 550°C quenched NaCl:Ca (10^{-3} m.f.) specimens (Fig. 8) exhibit all glow peaks occurring in untreated Ca^{++} doped Sodium Chloride. The effect of successive heating runs on the glow curve is more or less similar to that described above. The TL behaviour of NaCl:Ca (10^{-3} m.f.) specimens quenched from 750°C designated as NaCl:Ca (T) is identical with the specimen quenched from 550°C. The only difference observed is that the relative strengths of 167 and 340°C peaks are nearly equal in the first heating run in the case of 750°C quenched specimen. The peak at 167°C is well defined and dominant in the glow curve for 750°C quenched NaCl:Ca (10^{-3} m.f.) specimens.

Figures : 10 - 12

The characteristic glow curves of NaCl:Ca

with Ca^{++} concentration 10^{-2} m.f. were recorded for three different physical conditions in the specimen preparation namely, as-obtained from solution and heat treated at 550 and 750°C. The corresponding glow curves are presented in the Figs. 10, 11 and 12 respectively. As-obtained specimens exhibit weaker peaks at 100 and 185°C alongwith a strong peak at 340°C. Further, it is seen that the overall emission under the glow curve is markedly reduced in heavily doped NaCl:Ca (10^{-2} m.f.) specimens. The phosphors, thermally treated at 550°C , exhibit well defined peaks of nearly equal strength at 100 and 185°C alongwith a dominant peak at 340°C in the first heating run . The peak at 340°C disappears and lower temperature peaks at 100 and 185°C diminish in intensity and the overall glow curve pattern remains unaffected in the second and subsequent thermal cycle (Fig. 11). It is of significance to note that the NaCl:Ca (10^{-2} m.f.) specimens air quenched from 750°C, particularly favours 185°C peak relative to 100°C peak. The effect of thermal cycling is more or less similar to that observed in 550°C quenched specimen.

Figures : 13 - 15

The effect of deformation on glow curves for untreated and heat-treated specimens were also investigated. Plastic deformations of untreated specimens did not result in measurable TL output and hence these results are not presented in the thesis. Thermal glow curves for NaCl and NaCl:Ca specimens annealed and air - quenched from 550 and 750°C do not exhibit any influence due to change in quenching temperature. Typical glow curves displayed by 750°C air - quenched NaCl and NaCl : Ca (10^{-4} and 10^{-3} m.f.) are presented in Figs. 13, 14 and 15 respectively. In these experiments, specimen in powder form was compressed to tablet in a stainless steel press. Tablets were then exposed to standard dose ($2.4 \times 10^{4} Jm^{-2}$) and thermal glow curves were recorded in the temperature region 30 - 400°C.

It is observed that in the case of undoped NaCl deformation induces considerable suppression of lower temperature peaks and enhancement in the intensity of 340°C peak in the first thermal cycle (Curve : 1, Fig. 13). In the second heating run the lower temperature peak at 185°C gain in strength at the cost of 340°C. There is no further change in the

shape of the curve due to subsequent thermal cycling.

The 750°C annealed and quenched NaCl:Ca (10^{-4} m.f.) specimens are examined for their TL behaviours after plastic deformation followed by standard UV exposure (Fig. 14). It is seen that in this case strong well defined peak at 260°C appears alongwith small peaks at 185 and 340°C in the first thermal cycle. The peak at 260°C is considerably suppressed and peaks at 185 and 340°C become descernible without any change in their intensities in the second and later heating run.

The 750°C air-quenched NaCl:Ca (10^{-3} m.f.) specimen when deformed by stressing exhibit a pronounced doublet with peak positions at 185 and 260° C alongwith weaker peak at 340° C in the first thermal cycle (curve : 1 ; Fig. 15). In the second thermal cycle the emission under the glow curve is significantly reduced with the generation of peak at 167° C. The nature of the glow curve is not altered by subsequent heating runs.

Figures : 16 - 19

Yet another set of measurements

aimed at finding the exposure range of gamma radiation which led to results identical with those obtained for the range of UV exposure. Hence the TL glow curves exhibited by NaCl:Ca (T) material under the influence of exposure to different UV and gamma doses were recorded separately under similar experimental conditions. Typical observed glow curves are presented in Figs. 16 to 19. In each Figure Curve : A and Curve : B respectively belongs to the UV and gamma radiation induced TL in NaCl : Ca (T) specimens. It is clearly observed that the nature of the TL glow curves displayed by NaCl:Ca (T) after excitation with UV radiation in the range 10^3 Jm^{-2} to 10^5 Jm^{-2} are more or less identical with those exhibited by the phosphor after gamma irradiation in the dose range of 500 m rad to 14 rad. The only difference is the slight change in the peak position from 167°C for UV irradiation to 147°C for gamma irradiation. It is important to note that TL sensitivity in both types of radiation is same for lower dose and nearly same for higher dose.

Figures : 20 and 21

It is seen from Fig. 20 that the higher

UV dose (19.2×10^4 Jm^{-2}) gives rise to TL output for NaCl:Ca(T) which is very much low (Curve : A) compared to that obtained for higher gamma dose (2.1×10^4 rad). The TL emission for UV dose could not be recorded even at higher sensitivity of the detecting system. The same could however be done with ease in the case of gamma irradiated specimen since the TL output in this case is sufficiently high (curve : B). The data presented in Fig. 21 demonstrate the TL glow curves for NaCl (T) (Curve : A) and NaCl:Ca (T) (Curve : B) and the TL emission spectra for undoped (Curves : C_1, C_2, C_3) and doped phosphors (Curves : D_1, D_2, D_3) recorded at 80, 130 and 200°C after subjecting them to standard saturated gamma dose at 2.1×10^4 rad . The range of temperature 80 to 200°C was selected for the record of TL emission because the glow peak of interest namely, 147°C for gamma irradiation or 167°C for UV irradiation, is located in this region.

The NaCl (T) specimen exhibits the prominent TL peak around 235°C (Curve A, Fig. 21) while there is a dominant glow peak at 147°C (Curve : B, Fig. 21) for NaCl:Ca (T) . It is clearly seen that NaCl:Ca (T) exhibits an additional emission band at

375 nm (Curves : D_1 to D_3 , Fig. 21) besides the two emission bands at 425 and 475 nm observed in NaCl (T) phosphor (curves : C_1 to C_3 , Fig. 21). The intensity of 375 nm emission band is optimum in 130°C region. (Curve : D_2, Fig. 21). The intensities of 425 and 475 nm emission bands are significant around 200°C (Curve : C_3, Fig. 21). On the basis of the comparison of the TL glow curves and TL emission spectra, the 235°C glow peak in NaCl (T) can be correlated to 425 and 475 nm emission bands. These may be due to inherent impurities in the base material. The glow peak at 147°C observed in NaCl:Ca (T) appears to be closely related to the 375 nm emission band. This band can justifiably be presumed to have its origin due to the presence of Ca - impurity in the base material.

Figures : 22 and 23

The thermally stimulated luminescence characteristics of NaCl (T) and NaCl:Ca (T) without exposure to any radiation have also been examined. The results obtained are respectively presented in Fig.22 and 23. It is of significance to note that without

irradiation both the samples exhibit a well defined peak around 340°C which disappears in the second and subsequent thermal cycles. The intensity of the peak is more in NaCl:Ca (T) compared to that in NaCl (T).

Figures : 24 - 27

In order to gain more information regarding the behaviour of 340°C peak, a series of experiments have been carried out. The TL glow curves for NaCl and NaCl:Ca specimens with three different Ca^{++} concentrations (10^{-4}, 10^{-3} and 10^{-2} m.f.) were recorded in as-obtained condition and also after thermal quenching from 550 and 750°C when subjected to a standard UV dose of 2.4×10^{4} Jm^{-2}. The typical glow curves for first thermal cycle in each of these cases are presented in Fig. 24 to 27. It is seen that in all the cases the 340°C peak has maximum strength for the specimens annealed and quenched from 750°C . The intensity of this peak rises with Ca^{++} concentration upto optimum concentration of 10^{-3} m.f. and then falls with further increase in Ca^{++} concentration. As indicated by the results presented in Fig. 9 for NaCl:Ca (T) specimen it is obvious that the 340°C peak is completely erased after first thermal cycle.

Figure : 28

The data presented in Fig. 28 demonstrate the glow curves for NaCl:Ca (T) after exposure to different UV doses. It is seen that unlike 167°C glow peak, the intensity of 340°C peak reaches saturation in the early stage of irradiation and hence does not vary significantly with the dose.

Figure : 29

The results presented in this figure correspond to the glow curves for NaCl (T) and NaCl:Ca (T) (10^{-4} and 10^{-3} m.f.) phosphors compressed to tablet when exposed to UV excitation (2.4×10^{4} Jm^{-2}). It is clearly observed that the 340 °C peak is present in all the specimens. The intensity of this peak for the phosphor in the tabletted form (10^{-6} AMP) is observed to be more for the phosphor in the powder form (10^{-7} AMP). Further, it is also observed that doping of NaCl with Ca^{++} leads to the suppression of 340°C peak alongwith the generation of other peaks.

Figure : 30

In order to know whether the standard

commercially available dosimetry material, LiF TLD-100, is sensitive to UV radiation or not, glow curves displayed by it with UV and gamma excitations were recorded under experimental conditions identical with those for UV irradiations in the present experiments. The glow curves presented in Fig. 30 show that the LiF TLD - 100 material is not sensitive to UV radiation in the temperature region of interest in the present work.

Figure : 31

TL glow curves for NaCl specimens as - obtained and for specimens annealed and quenched from 550 and 750°C, under standard UV dose (2.4×10^4 Jm^{-2}), are shown in Fig. 31. It is seen that only the glow curve for NaCl specimen quenched from 750°C exhibits measurable TL output with peak position at 167° C.

Figure : 32

This figure represents the glow curves for as - obtained NaCl:Ca specimen (10^{-3} m.f.) and for as - obtained specimens annealed and quenched from 550 and 750° C after a standard UV dose. It is observed that 167° C peak appears predominantly only in the case of specimen quenched from 750°C (curve:1).

Figure : 33

This figure exhibits the glow curves for NaCl:Ca (T) and LiF TLD - 100 exposed to UV irradiation (dose 2.4 x 10^4 Jm^{-2}). It is seen that LiF TLD - 100 does not give measurable TL output in the region around 167° C. In contrast to this the material under investigation namely, NaCl:Ca (T), displays strong TL emission at 167° C. It may thus be inferred that the NaCl:Ca (T) phosphor is sensitive to UV radiation.

Figure : 34 - 38

The effect of different UV doses on the TL behaviours of NaCl:Ca (T) material has been examined separately for two UV dose ranges namely, 10^2 - 10^4 Jm^{-2} (low dose) and 10^3 - 10^5 Jm^{-2} (high dose). Data presented in Figs. 34 and 36 respectively represent the TL characteristics of NaCl:Ca(T) for lower and higher dose ranges. It is observed that UV irradiation generates peaks at 100 (peak - I) and 167° C (peak II). Further, it is important to note that peak position and glow curve pattern remain unaltered with increase in the UV dose. The only change observed is the increase in intensity of the emission under the glow

curve. Since the glow peak at 100° C is not the characteristic of Ca^{++} impurity and further, since it is of low intensity, its behaviour has not been examined from dosimetric aspect. The plots of UV dose versus TL output at peak II (167° C) in NaCl:Ca (T) for both the ranges are presented in Figs. 35 and 37. It is clearly seen that radiant exposure versus TL intensity (peak II) response is linear for both the dose ranges. The same feature for the complete UV dose range 10^2 - 10^5 Jm^{-2} is presented in Fig. 38. One can therefore conclude that the UV dose response is linear up to 3×10^3 Jm^{-2}.

Figure : 39

The glow curves of NaCl:Ca (T) phosphor have been studied separately for different gamma and UV doses. Typical glow curves for approximately equal peak strengths (TL - sensitivity) at dominant peak (peak II) after exposure to UV and gamma radiation, under identical experimental conditions, are presented in Fig. 39. It is found that except for the change in the position of dominant peak (peak II), (from 167° C for UV irradiation to 147° C for gamma irradiation) the other features of the glow curves remain more or less same. In

view of this it is inferred that gamma dose of 1 rad (10^{-2} Gy) is equivalent to 6×10^{3} Jm^{-2} radiant exposure to UV radiation.

Figure : 40

In yet another series of experiments, the NaCl:Ca (T)! specimens were exposed to a test dose (2.4×10^{4} Jm^{-2}) and stored at room temperature. TL glow curves exhibited by them after different durations of room temperature decay were recorded. It is observed that the glow curve pattern, peak temperature, and peak strength remain unchanged with change in post - irradiation interval. The plot of TL output versus room temperature decay time following excitation is presented in Fig. 40. The plot does not indicate substantial change in TL intensity of the peak (peak II).

Figures : 41 and 42.

Present measurements also included the low level gamma dosimetry study i.e. the examination of the growth of 147° C glow peak (peak II) in NaCl:Ca (T) phosphor with the increase in the gamma dose in the range 500 m. rad - 3 rad. Fig. 41 and 42 respectively show the TL characteristics of NaCl:Ca (T) with different gamma doses and TL output versus gamma doses response

at 147° C. The shape of glow curve and the nature of TL response to exposure at 147° C in the case of gamma irradiated specimen is observed to be identical with that of UV irradiated NaCl:Ca (T) subjected to different UV doses. The difference observed is of course, the change in the peak position. The experimental results obviously imply that the material under investigation is also useful for low level gamma dosimetry.

Figures : 43 - 45

In order to present the obtained experimental results in SI units, the traditional unit 'rad' is converted into "Gray" (Gy) the S.I. unit of dose. Fig. 43 shows the TL output versus gamma dose (Gy) response for NaCl:Ca (T) . Data in Fig. 44 represents the TL sensitivity (peak height) of the dominant peak (peak II) in NaCl:Ca (T) as a function of UV dose (Jm^{-2}) and ^{226}Ra gamma dose (Gy). The data shows that UV response is linear upto 4×10^3 Jm^{-2} and sublinear beyond that exposure. The gamma response is linear all through the dose range studied. The UV - response of NaCl:Ca (T) in equivalent gamma dose (Gy) as a function of UV exposure is presented in Fig. 45. The response is found linear all through the dose

range examined.

Figure : 46

Fig. 46 shows typical glow curves for tablet-tted NaCl (T) (curve : 2 ; Fig. 46 - A), NaCl:Ca (T) with Ca^{++} concentration 10^{-4} m.f. (curve : 2 ; Fig. 46 - B) and 10^{-3} m.f. (curve : 2 ; Fig. 46 - C), each for a standard UV dose 2.4×10^{4} Jm^{-2}. For comparison, thermal glow curves exhibited by the phosphors in the powder form are also presented in the figure (curve : 1 ; Fig. 46 - A, B and C). The examination of these curves clearly indicates that compression to pellets of NaCl (T) and NaCl:Ca (T) radically changes the nature of glow curve. In general, the TL emission for pellets shifts to higher temperature with considerable enhancement in the intensity. It is seen that NaCl (T) pellets display a broad glow peak at 340° C whereas the NaCl:Ca (T) pellets exhibit a well defined glow peak at 260° C for Ca^{++} concentration 10^{-4} mf and unresolved doublet with maxima at 185 and 260° C for Ca^{++} concentration 10^{-3} mf.

FIGURE - 1 : TL GLOW CURVES OF NaCl.

As - obtained from solution.

After 2.4×10^4 Jm^{-2} exposure dose.

Curves : 1 ——— 1^{st} Thermal cycle.

2 ..... 2^{nd} Thermal cycle.

3 ----- 3^{rd} Thermal cycle.

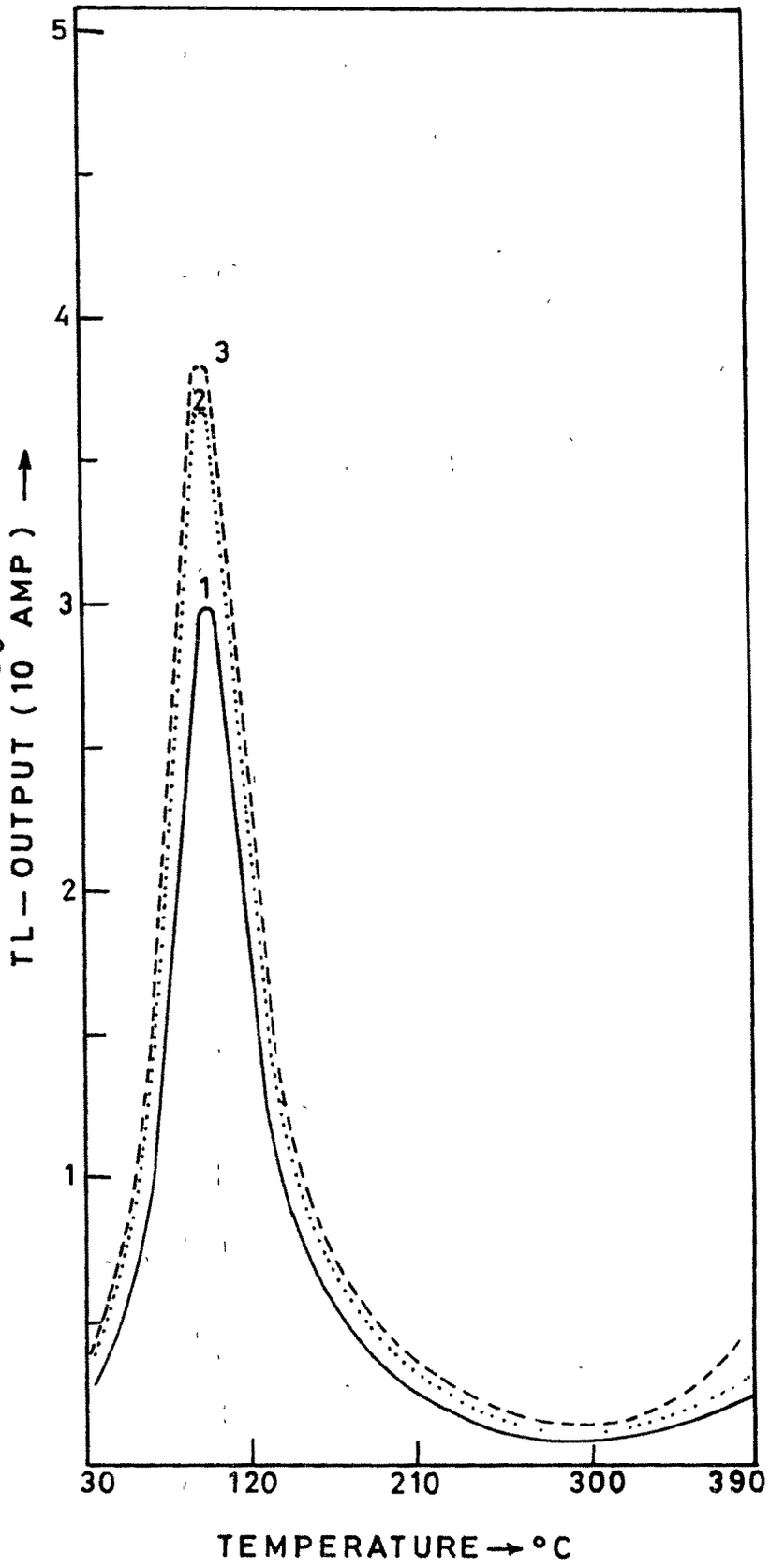


FIGURE : 1

FIGURE - 2 : TL GLOW CURVES OF NaCl.

Annealed and quenched from 550° C.

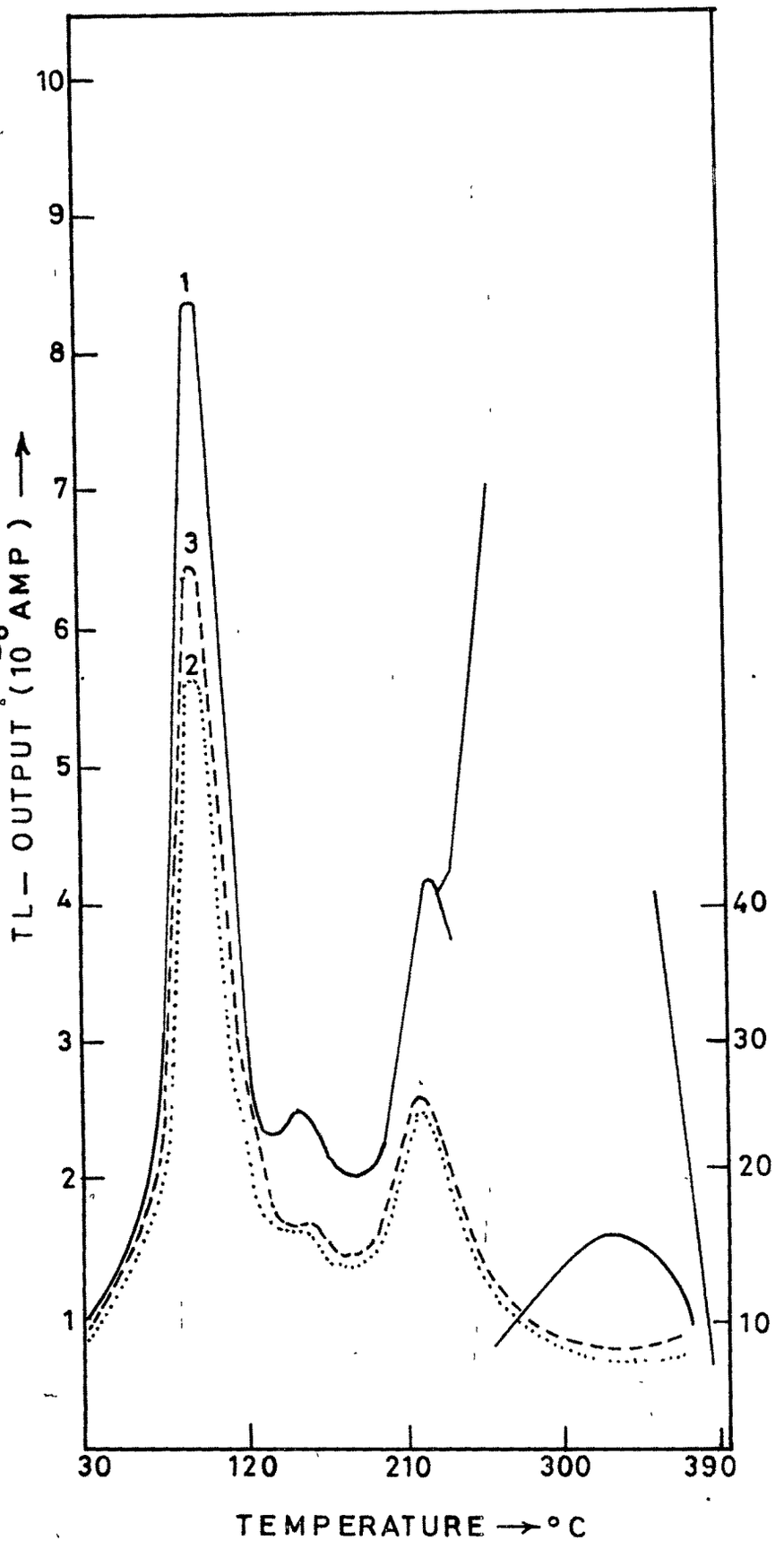
After 2.4×10^4 Jm^{-2} exposure dose.

The scale on the right relates to peak 340° C in curve 1.

Curves : 1 ——— 1^{st} Thermal cycle.

2 ∿∿∿∿. 2^{nd} Thermal cycle.

3 ----- 3^{rd} Thermal cycle.


TL – OUTPUT (10⁻⁸ AMP) →
TEMPERATURE → °C
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390

FIGURE : 2

FIGURE - 3 : TL GLOW CURVES OF NaCl.

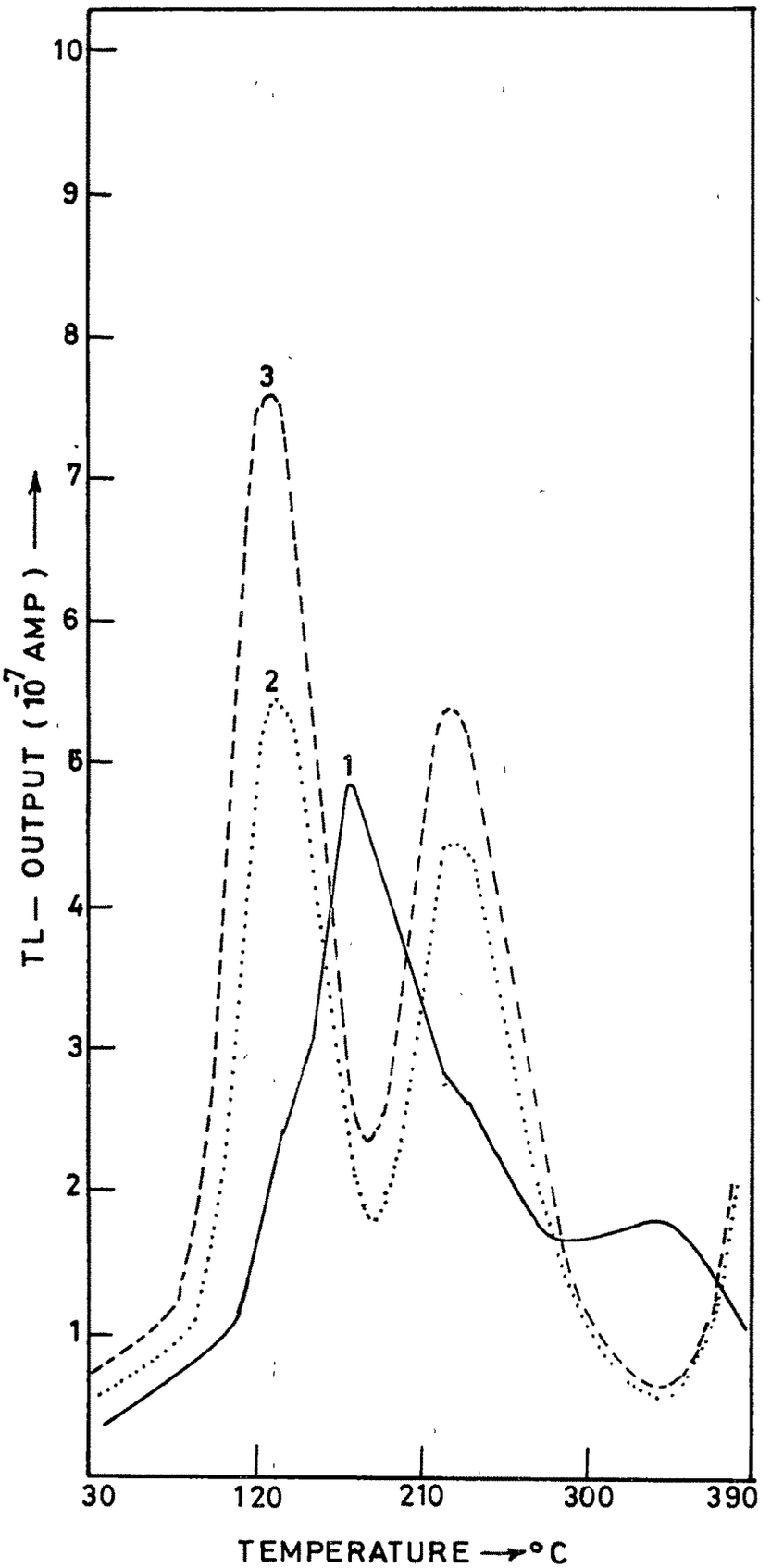
Annealed and quenched from 750° C.

After 2.4×10^4 Jm^{-2} exposure dose.

Curves : 1 ——— 1^{st} Thermal cycle.

2 ..... 2^{nd} Thermal cycle.

3 ----- 3^{rd} Thermal cycle.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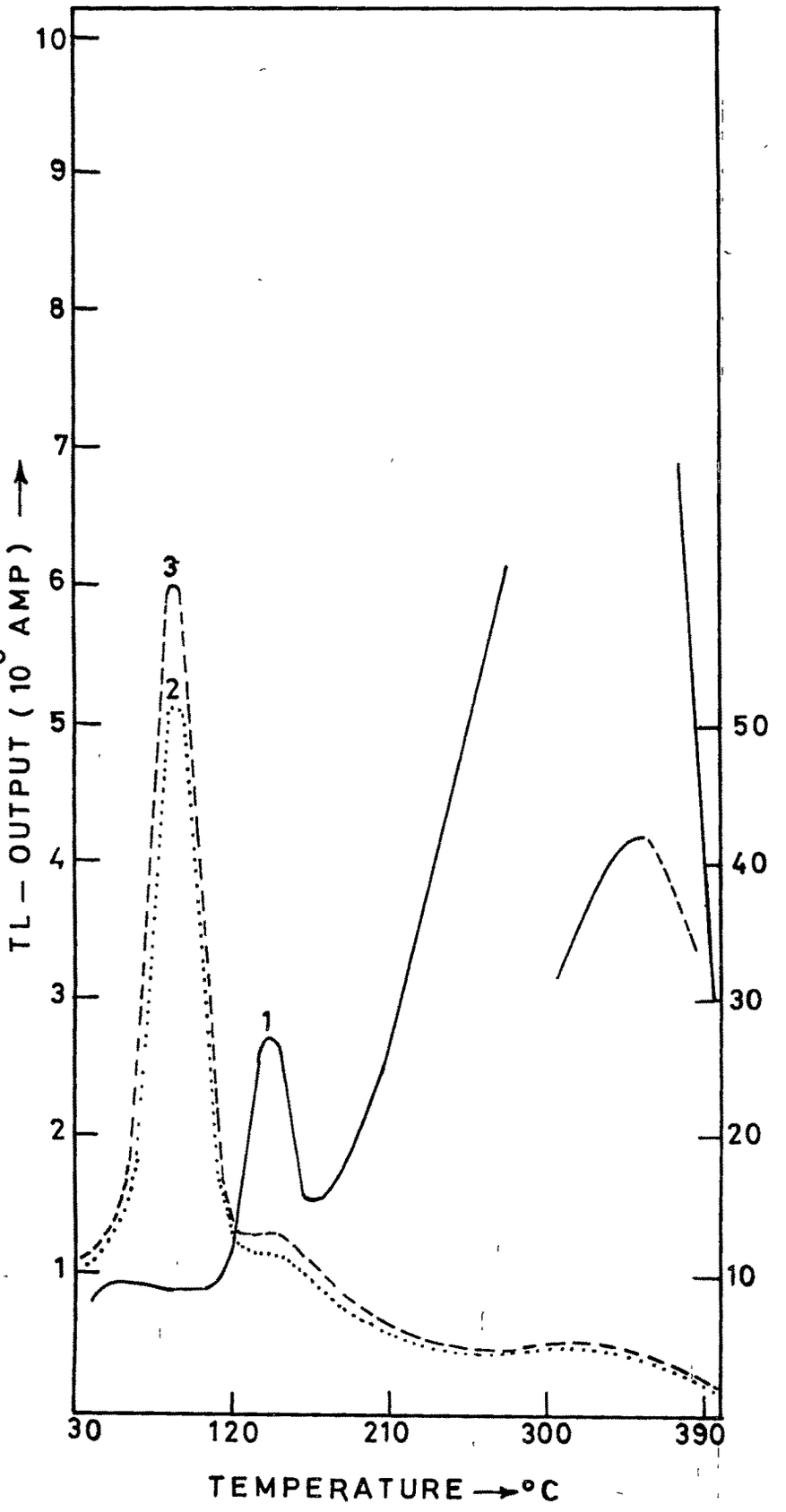
TEMPERATURE ⟶ °C

FIGURE : 3

FIGURE - 4 : TL GLOW CURVES OF NaCl:Ca (10^{-4} m.f.)
As - obtained from solution.
After 2.4×10^{4} Jm^{-2} exposure dose.
The scale on the right relates to peak 340° C in curve.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.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TL – OUTPUT (10^-8 AMP) →
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TEMPERATURE → °C

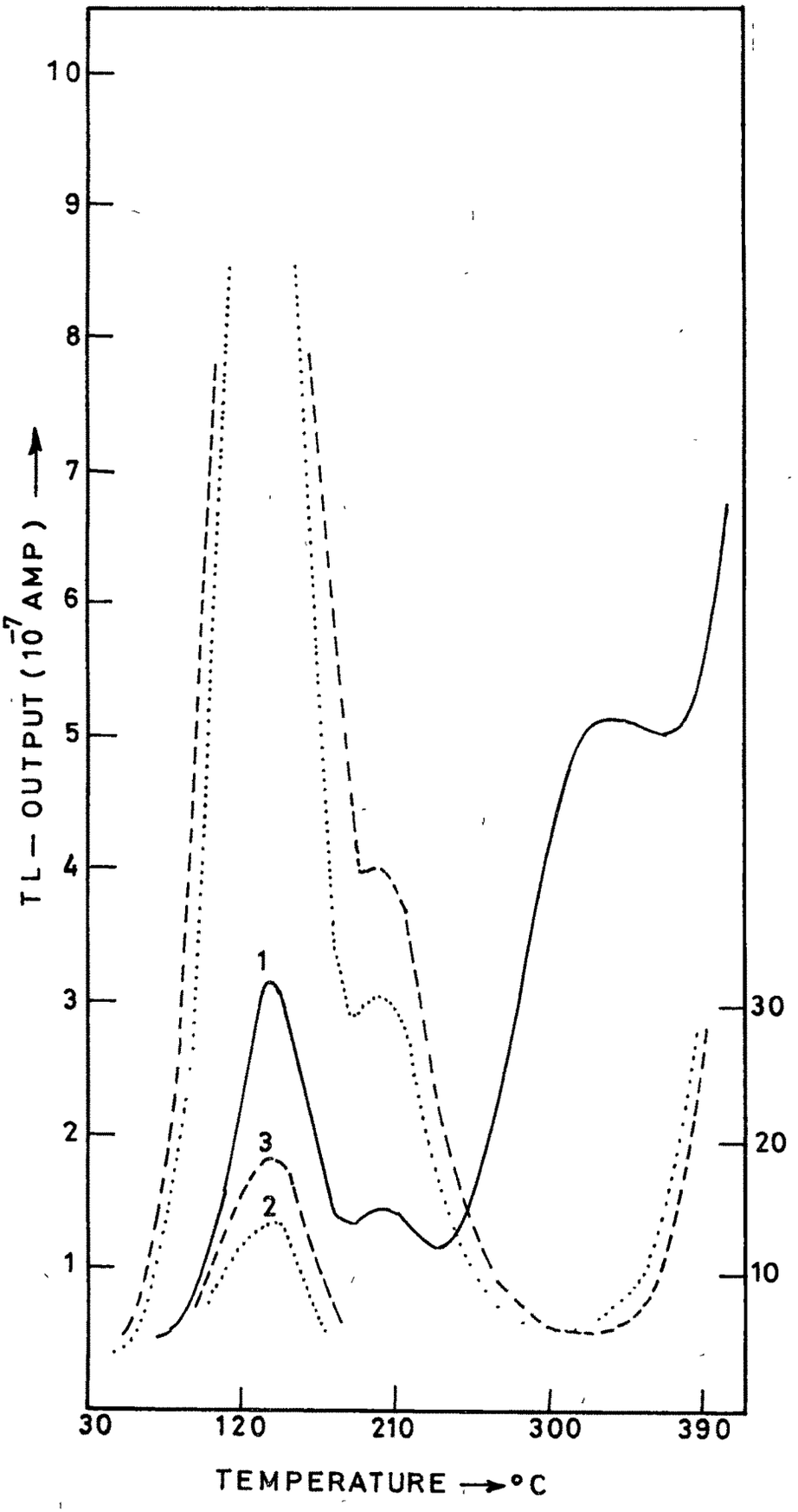
FIGURE : 4

FIGURE - 5 ; TL GLOW CURVES OF NaCl:Ca (10^{-4} m.f.)
Annealed and quenched from 550° C
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves ; 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.

FIGURE - 6 : TL GLOW CURVES OF NaCl:Ca (10^{-4} m.f.)
Annealed and quenched from 750°C
After 2.4×10^{4} Jm^{-2} exposure dose
The Scale on the right relates to peak 137°C in curves 2 and 3.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.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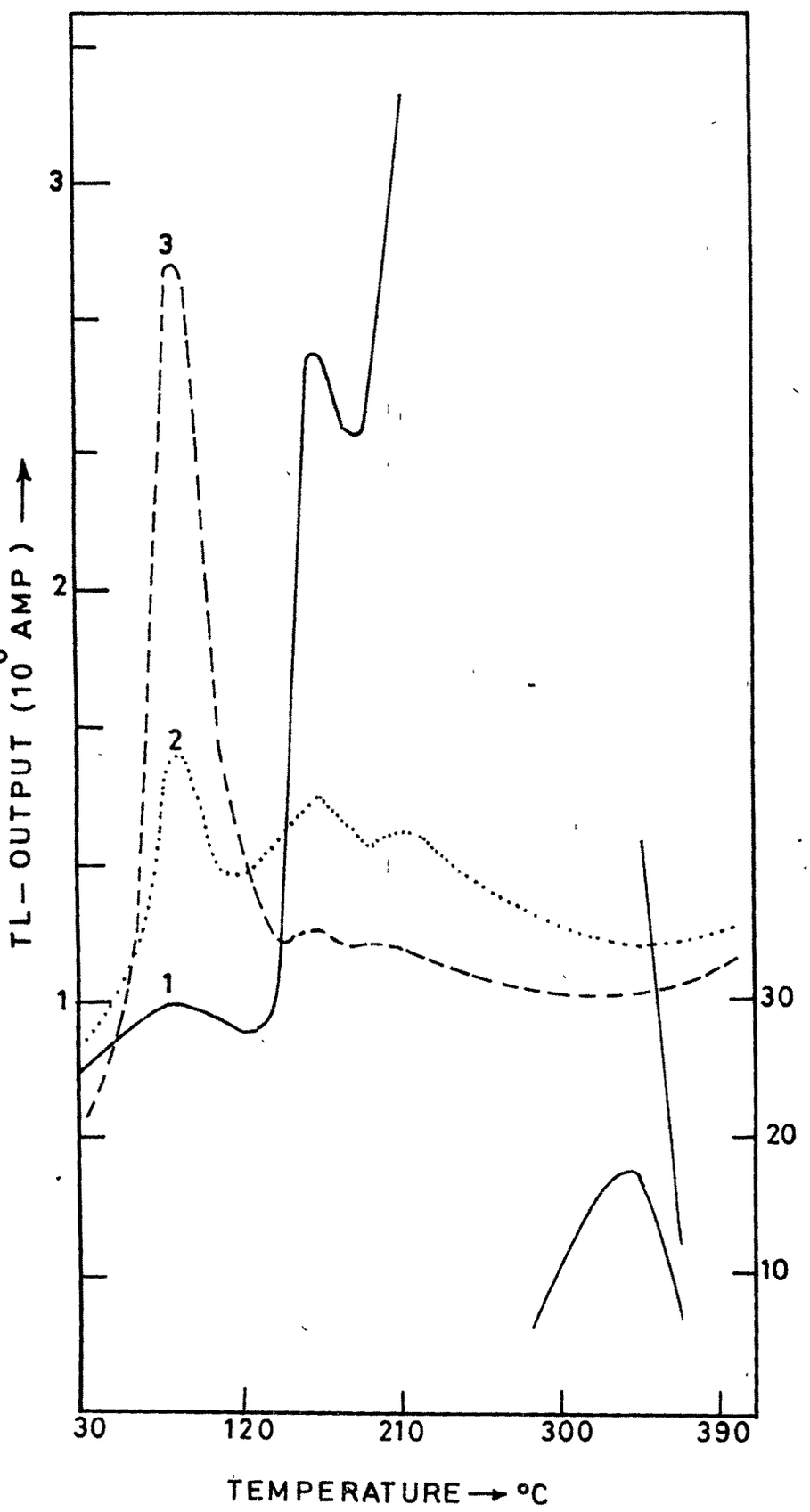
TEMPERATURE ⟶ °C

FIGURE : 6

FIGURE - 7 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.)
As - obtained from solution
After 2.4×10^{4} Jm^{-2} exposure dose.
The scale on the right relates to peak 340°C in curve 1.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.


TL– OUTPUT (10^{-8} AMP) →
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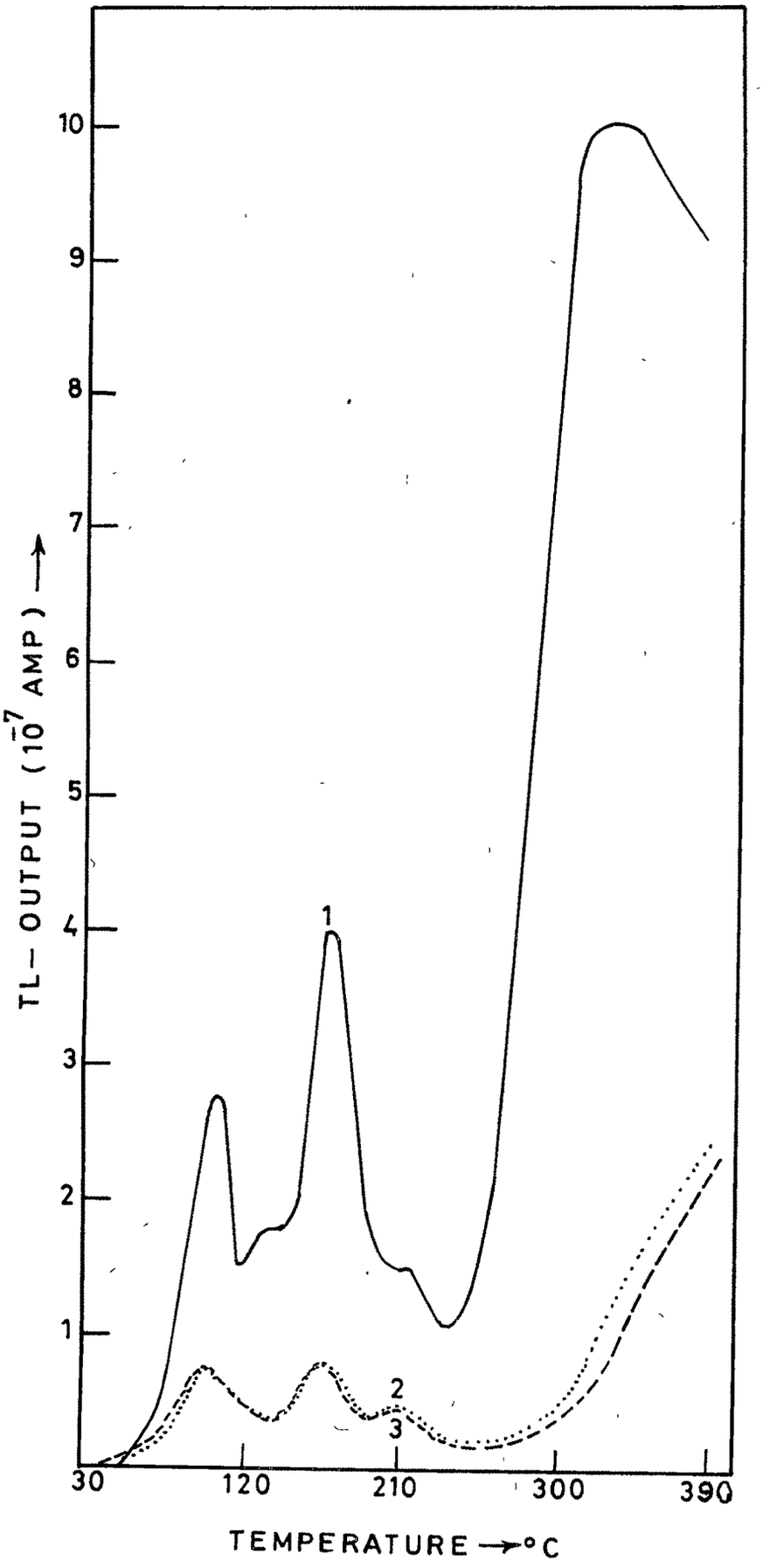
TEMPERATURE → °C

FIGURE: 7

FIGURE - 8 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.)
Annealed and quenched from 550°C
After 2.4 x 10^{4} Jm^{-2} exposure dose.

Curve : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.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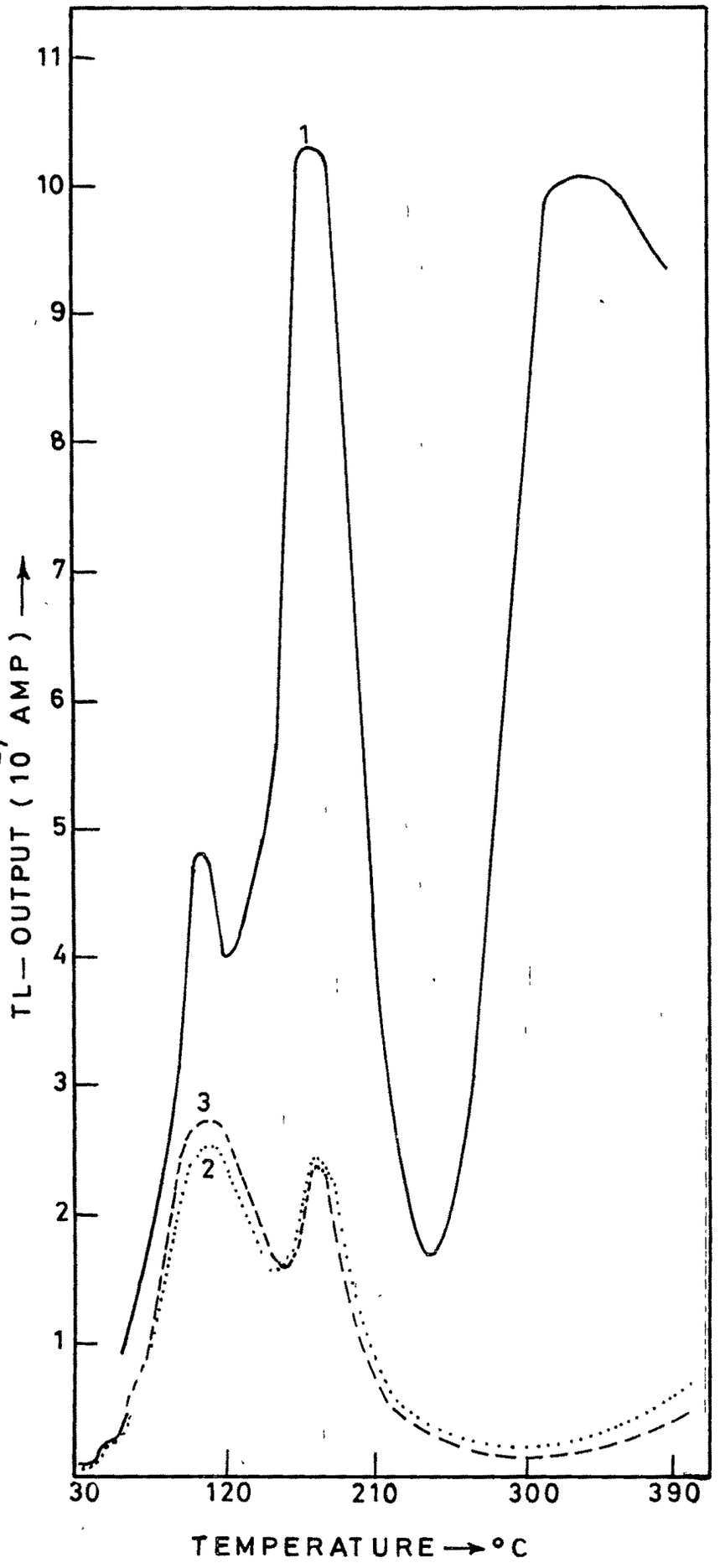
TEMPERATURE ⟶°C

FIGURE : 8

FIGURE - 9 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.)
Annealed and quenched from 750°C
After 2.4×10^{4} Jm^{-2} exposure dose.

Curve : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.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TL— OUTPUT (10^{-7} AMP) ⟶
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300
390
TEMPERATURE ⟶ °C

FIGURE : 9

FIGURE - 10 : TL GLOW CURVES OF NaCl:Ca (10^{-2} m.f.)

As- obtained from solution .

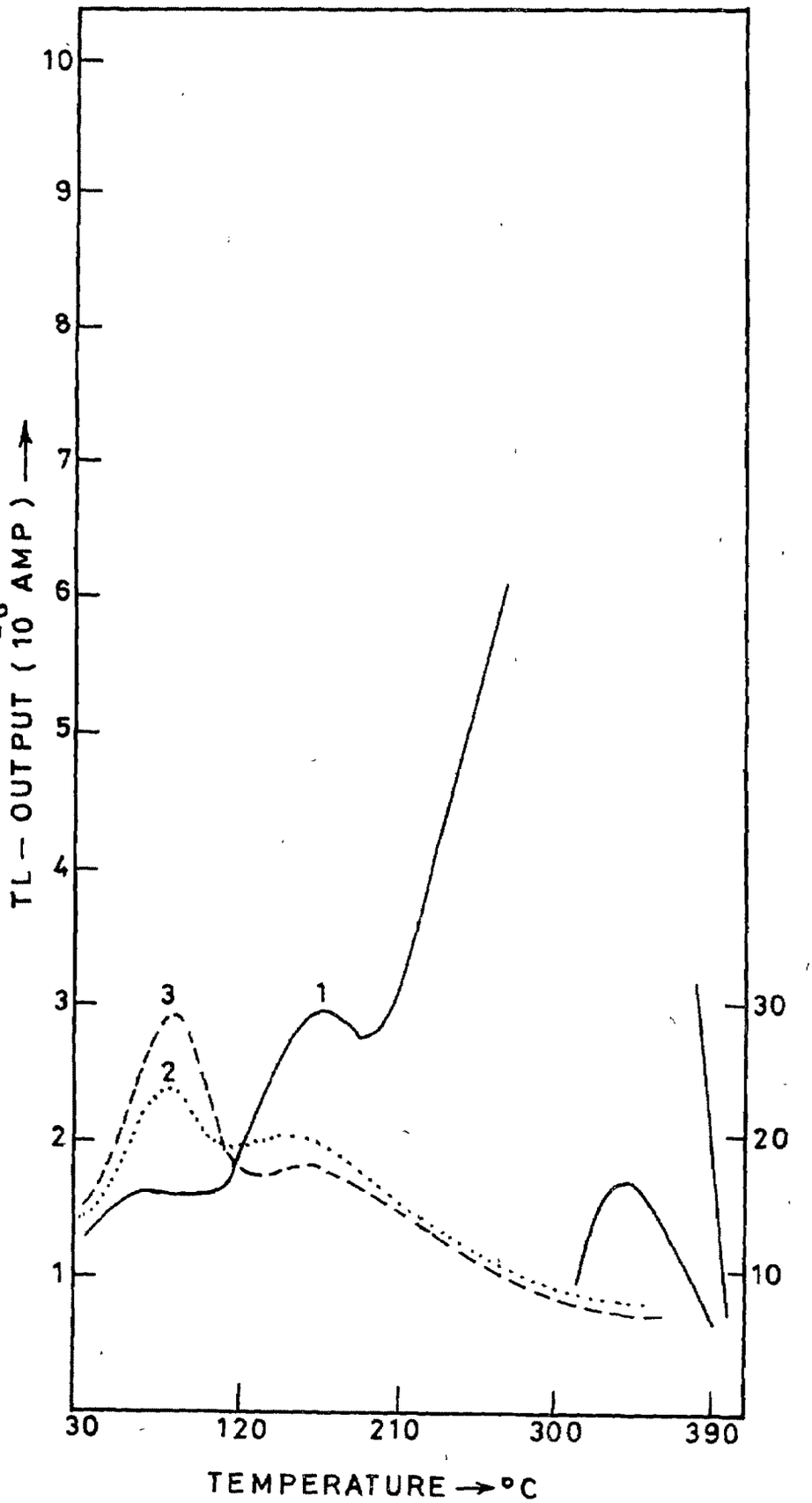
After 2.4 x 10^{4} Jm^{-2} exposure dose.

The scale on the right relates to peak 340 °C in curve 1.

Curves : 1 ——— 1^{st} Thermal cycle.

2 .....2^{nd} Thermal cycle.

3 -----3^{rd} Thermal cycle.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TL – OUTPUT (10^{-8} AMP) →
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1
30
20
10
30
120
210
300
390
TEMPERATURE → °C

FIGURE : 10

FIGURE - 11 : TL GLOW CURVES OF NaCl:Ca (10^{-2} m.f.)
Annealed and quenched from 550°C.
After 2.4×10^{4} Jm^{-2} exposure dose.
The scale on the right relates to peak 340°C in curve 1.

Curve : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.

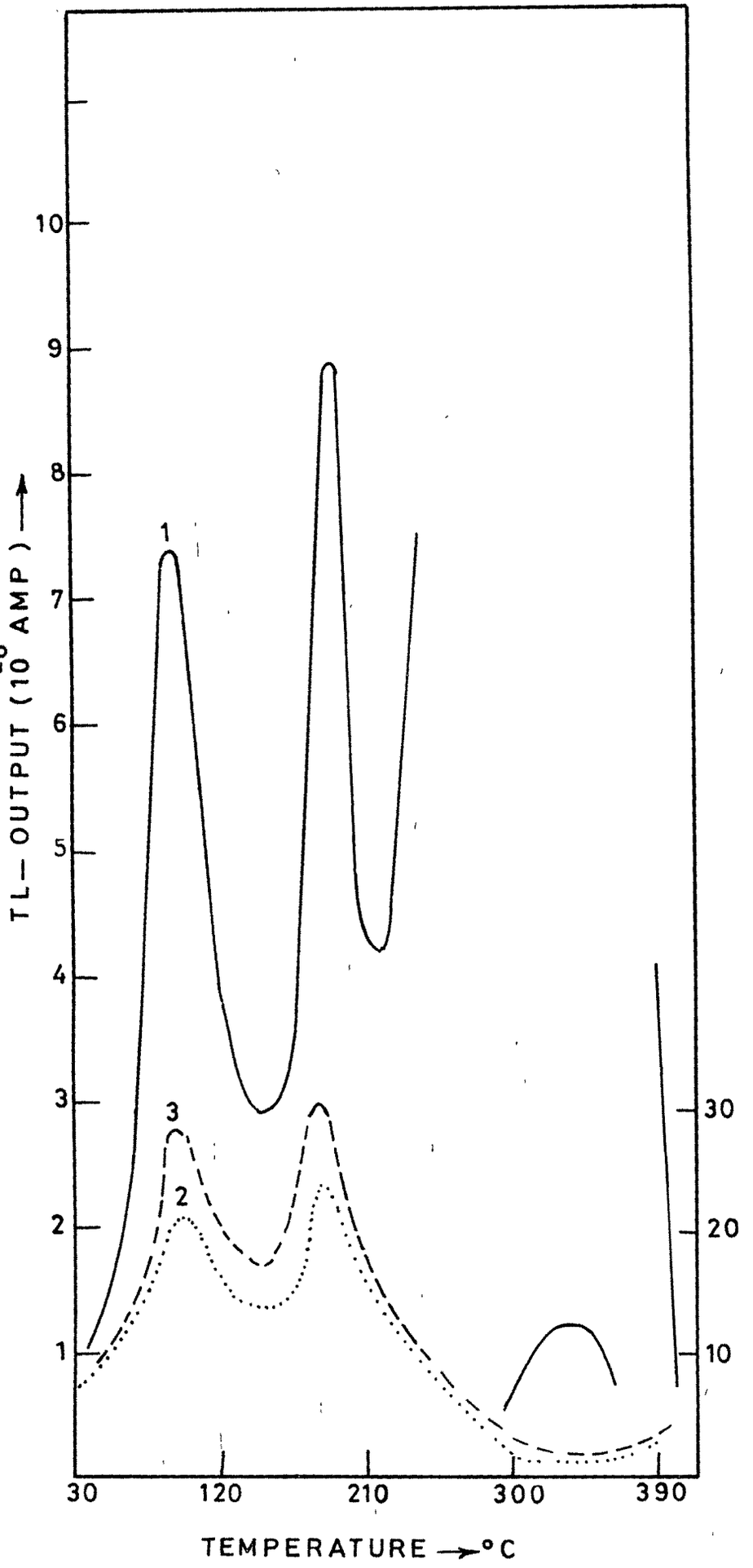
TL— OUTPUT (10^{-8} AMP) ⟶
10
9
8
7
6
5
4
3
2
1
30
20
10
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 11

FIGURE - 12 : TL GLOW CURVES OF NaCl:Ca (10^{-2} m.f.)
Annealed and quenched from 750°C
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.

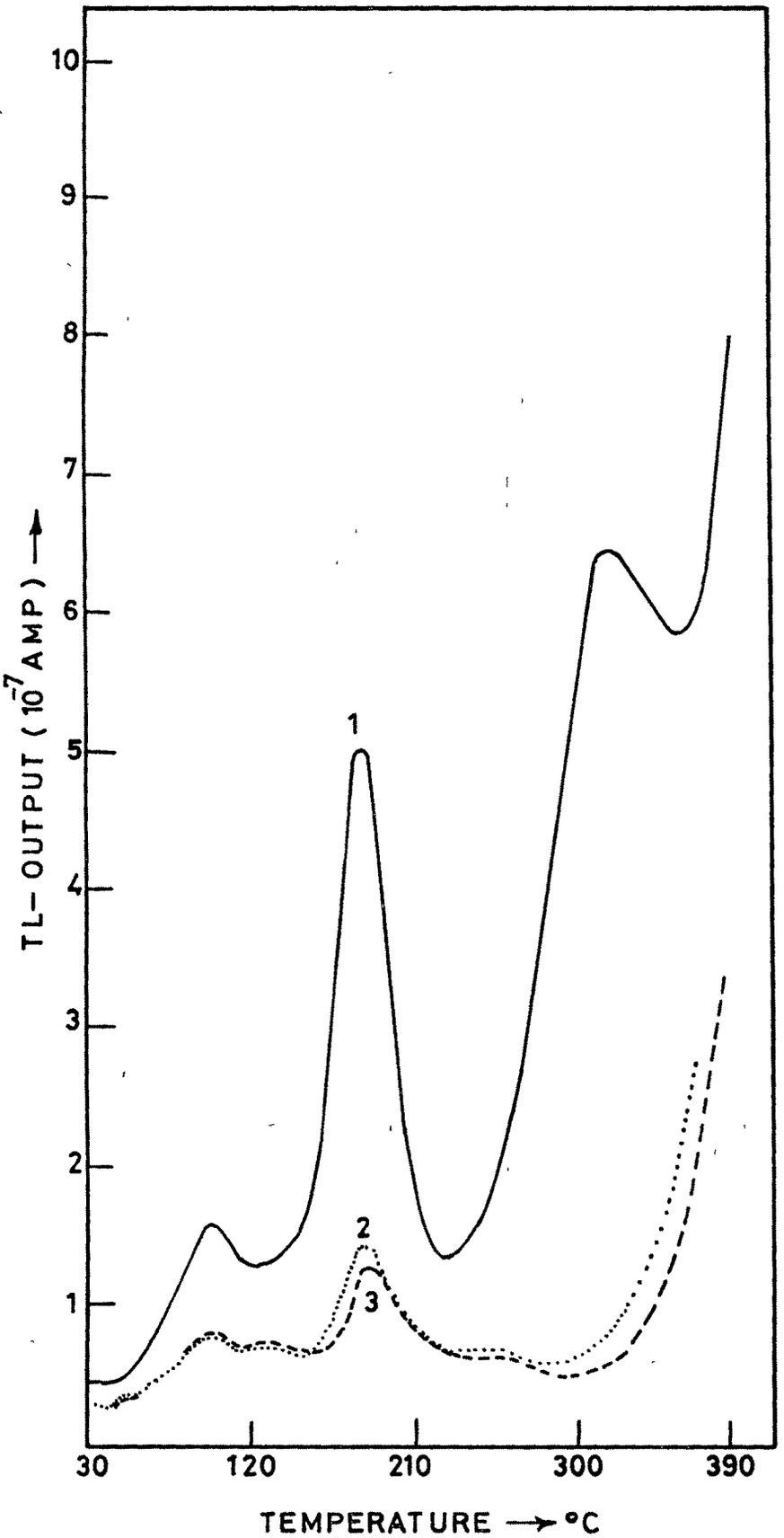

FIGURE : 12

YAMATAS

FIGURE - 13 : TL GLOW CURVES OF NaCl

Annealed and quenched from 750°C.

and subsequently deformed.

After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1 ——— 1^{st} Thermal cycle.

2 ..... 2^{nd} Thermal cycle.

3 ----- 3^{rd} Thermal cycle.

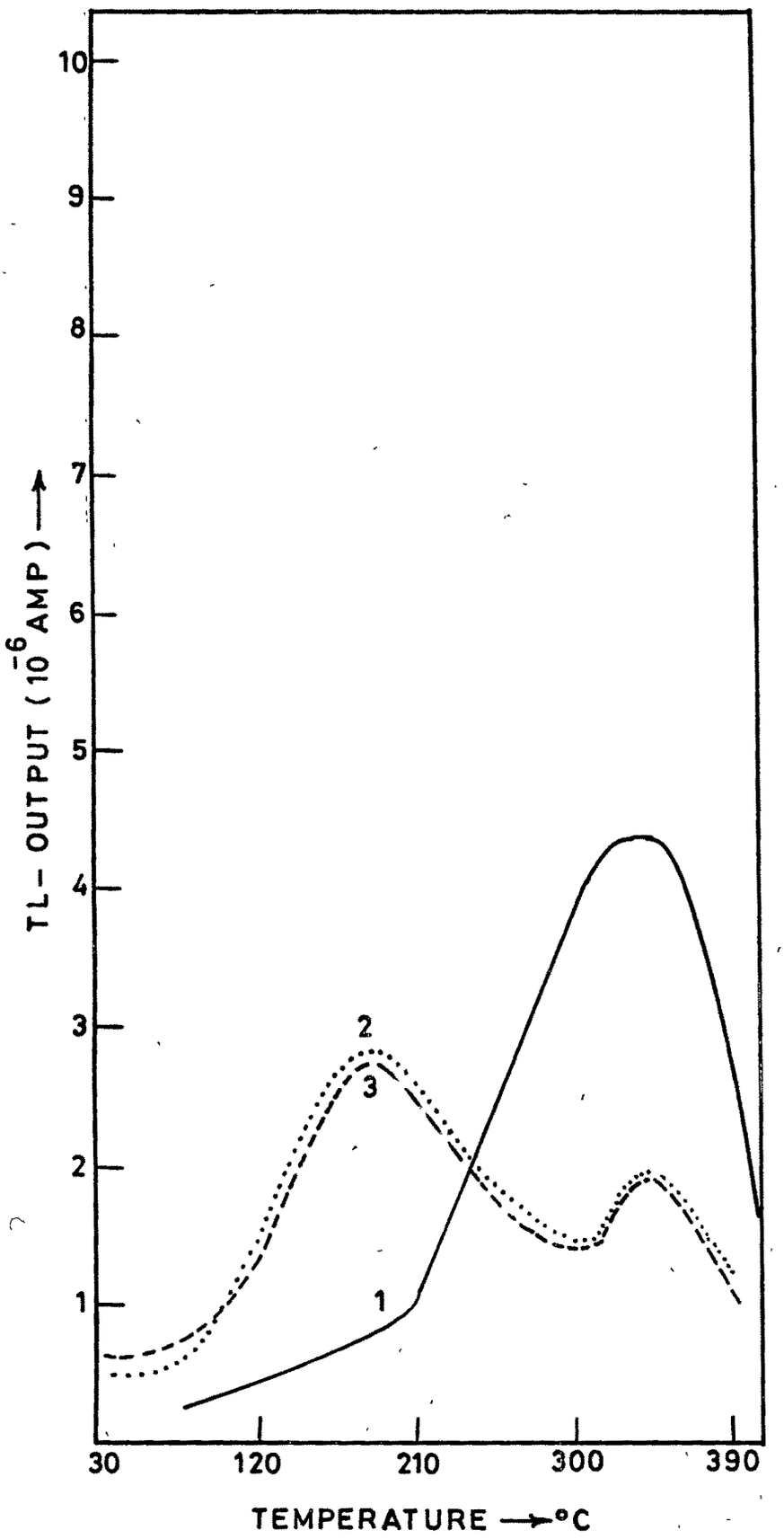
10
9
8
7
6
5
4
3
2
1
TL- OUTPUT (10^{-6} AMP) ⟶
2
3
1
30
120
210
300
390
TEMPERATURE ⟶°C

FIGURE : 13

FIGURE - 14 : TL GLOW CURVES OF NaCl:Ca (10^{-4} m.f.)
Annealed and quenched from 750°C and subsequently deformed.
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.

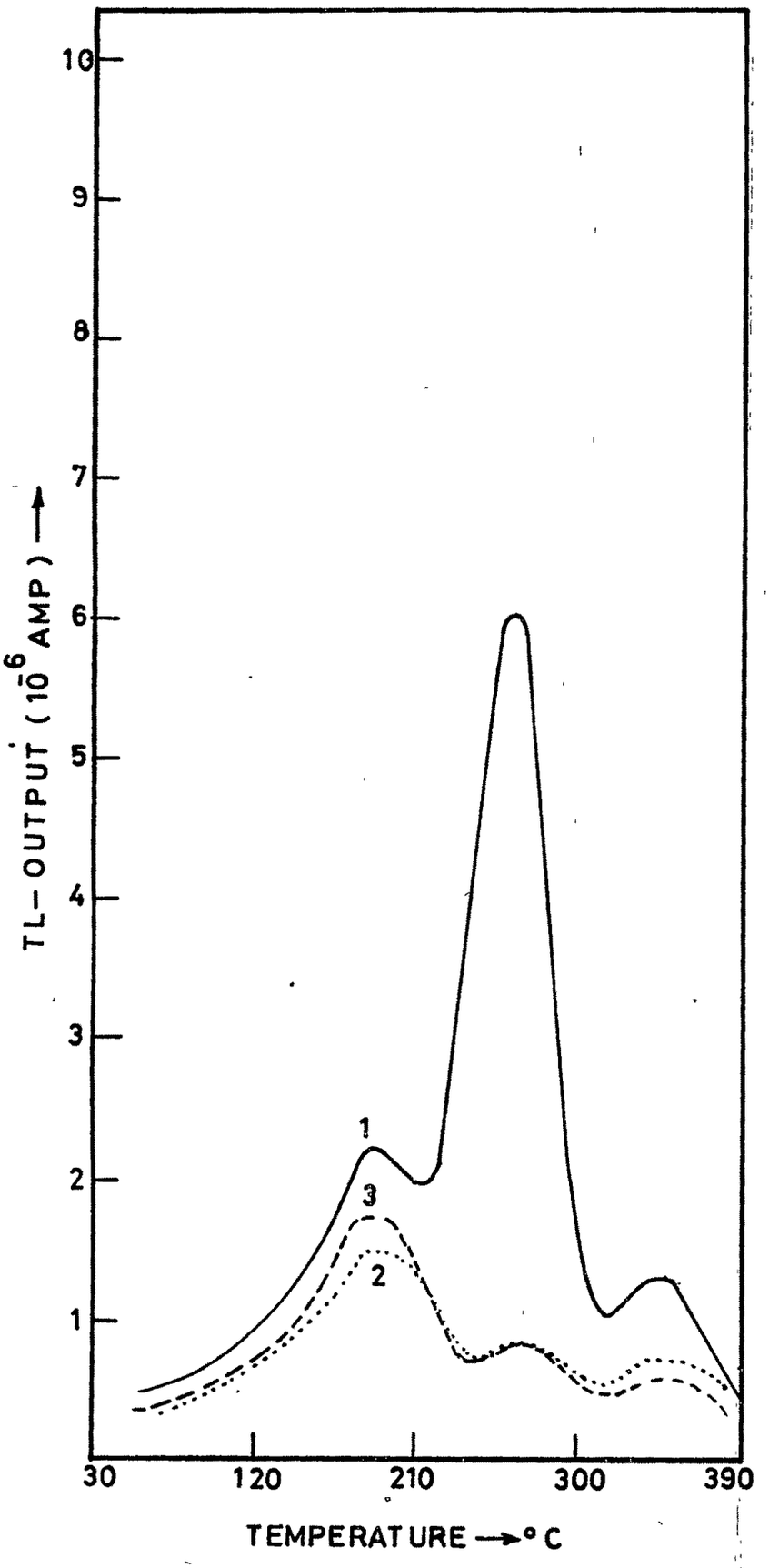
10
9
8
7
6
5
4
3
2
1
TL-OUTPUT (10^{-6} AMP) ⟶
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 14

FIGURE - 15 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.)
Annealed and quenched from 750°C and subsequently deformed.
After 2.4×10^{4} Jm^{-2} exposure doses.

Curves : 1 ——— 1^{st} Thermal cycle.
2 ..... 2^{nd} Thermal cycle.
3 ----- 3^{rd} Thermal cycle.

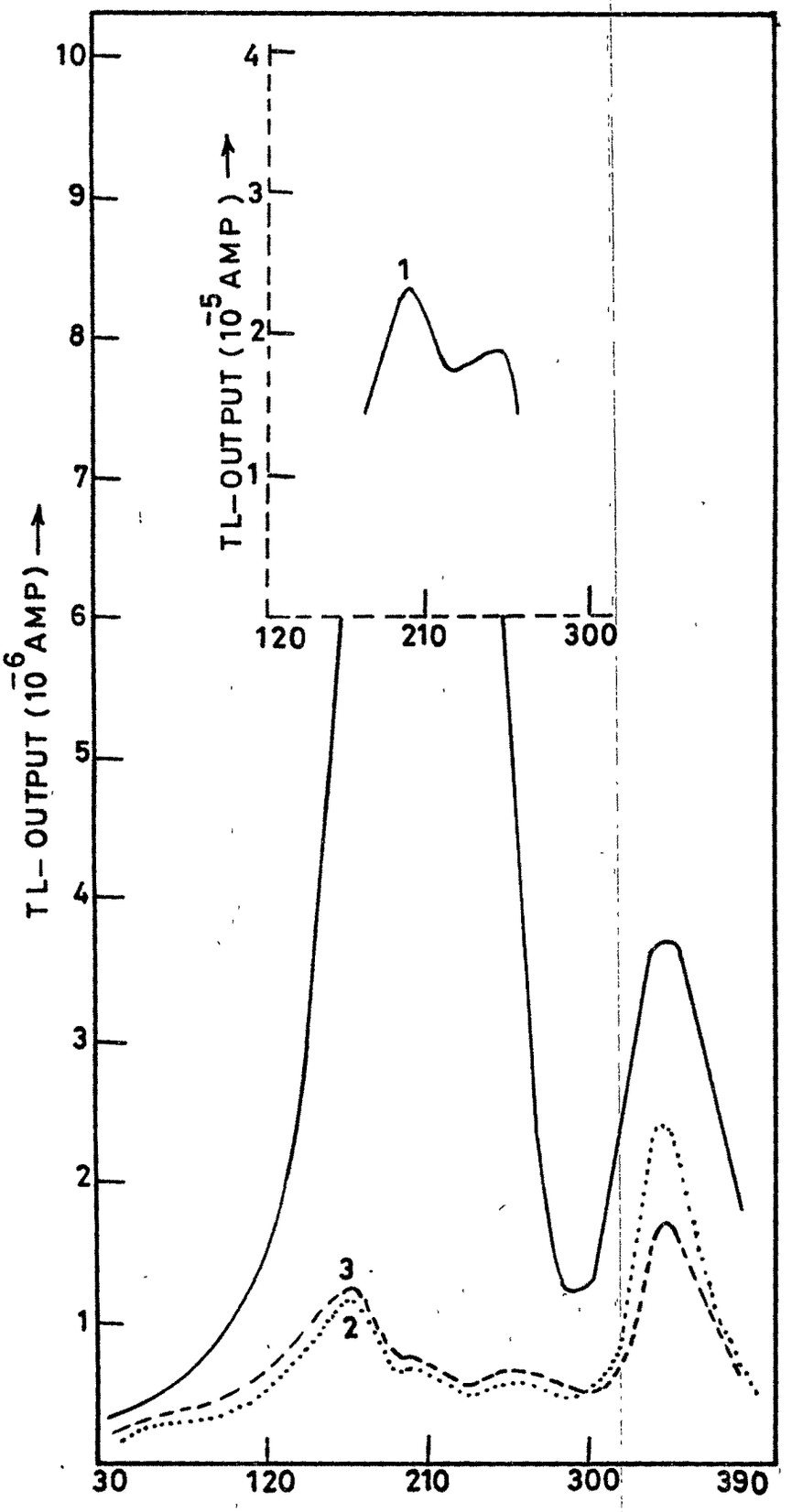
TL- OUTPUT (10^{-6} AMP) →
TL-OUTPUT (10^{-5} AMP) →
1
2
3
4
10
9
8
7
6
5
4
3
2
1
120
210
300
30
120
210
300
390
TEMPERATURE → °C

FIGURE : 15

FIGURE - 16 : TL GLOW CURVES OF NaCl:Ca (T)

Curves : (A) ——— 1 x 10^{3} Jm^{-2} UV dose.

(B) ----- 500 m rad Gamma dose

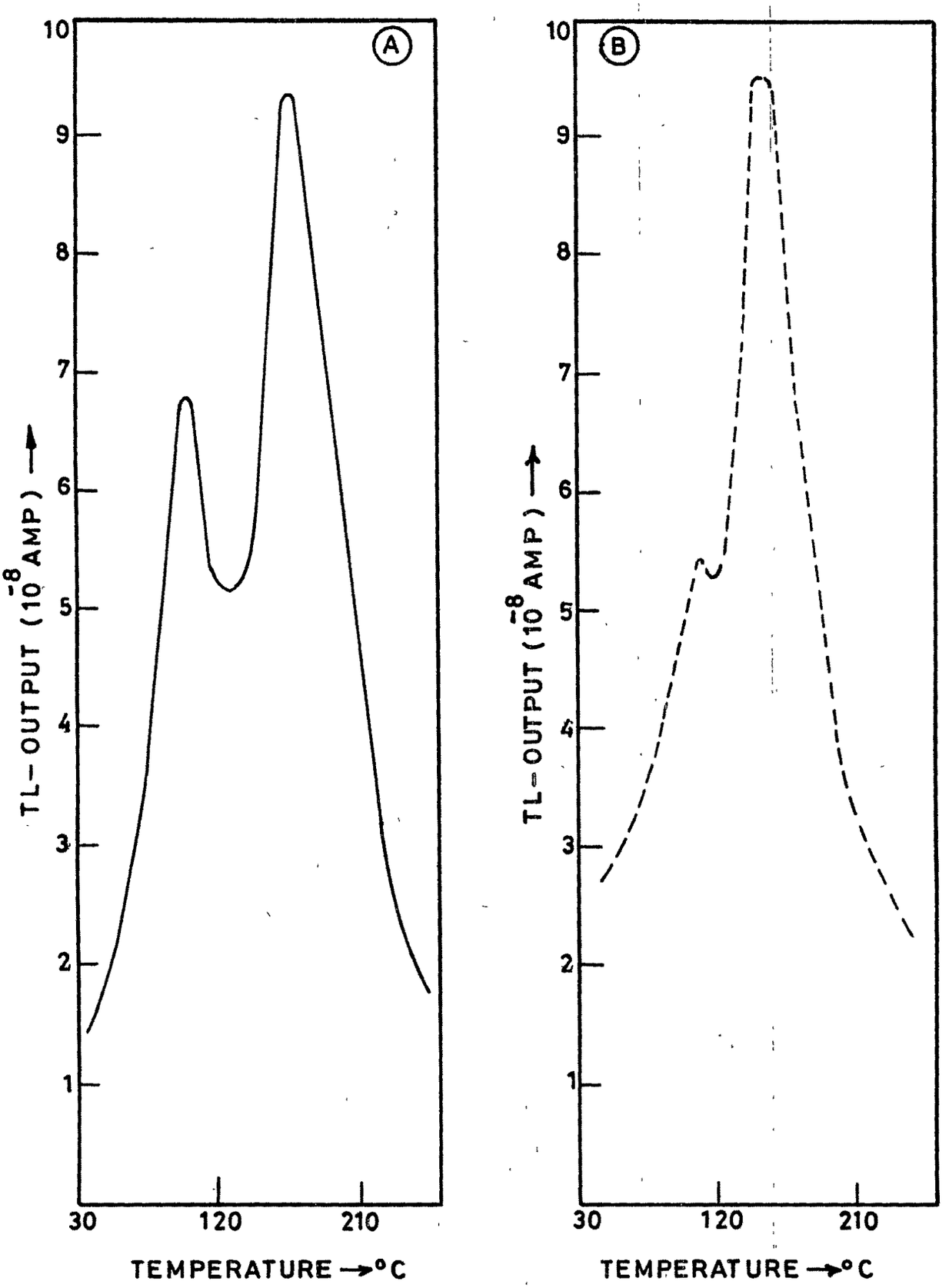

FIGURE : 16

FIGURE - 17 : TL GLOW CURVES OF NaCl:Ca (T)

Curves : (A) ——— 6×10^3 Jm^{-2} UV dose.

(B) ------ 1 rad Gamma dose.

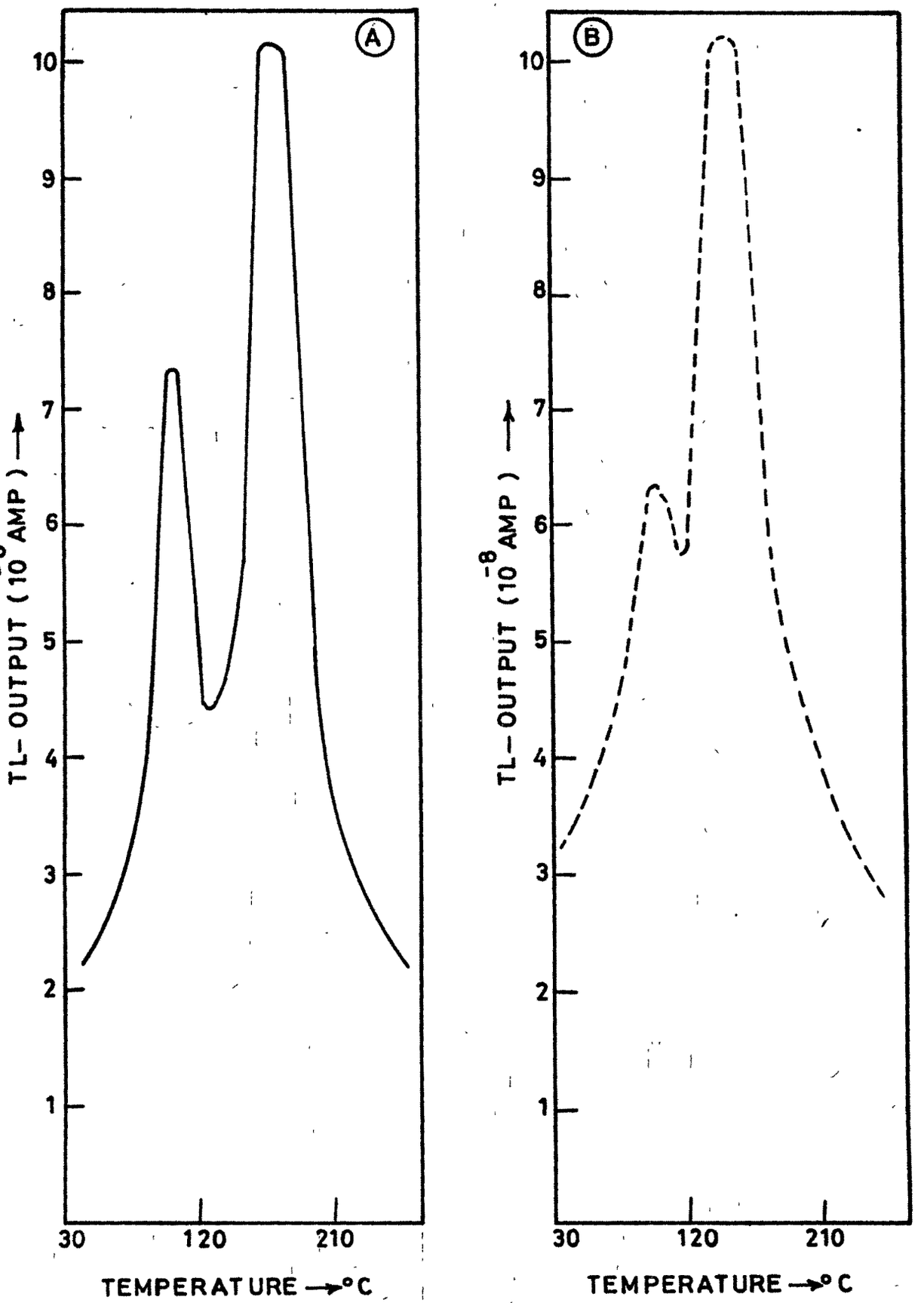

FIGURE : 17

FIGURE - 18 : TL GLOW CURVES OF NaCl:Ca (T)

Curves : (A) ——— 1.2×10^{4} Jm^{-2} UV dose.

(B) ----- 2 rad Gamma dose.

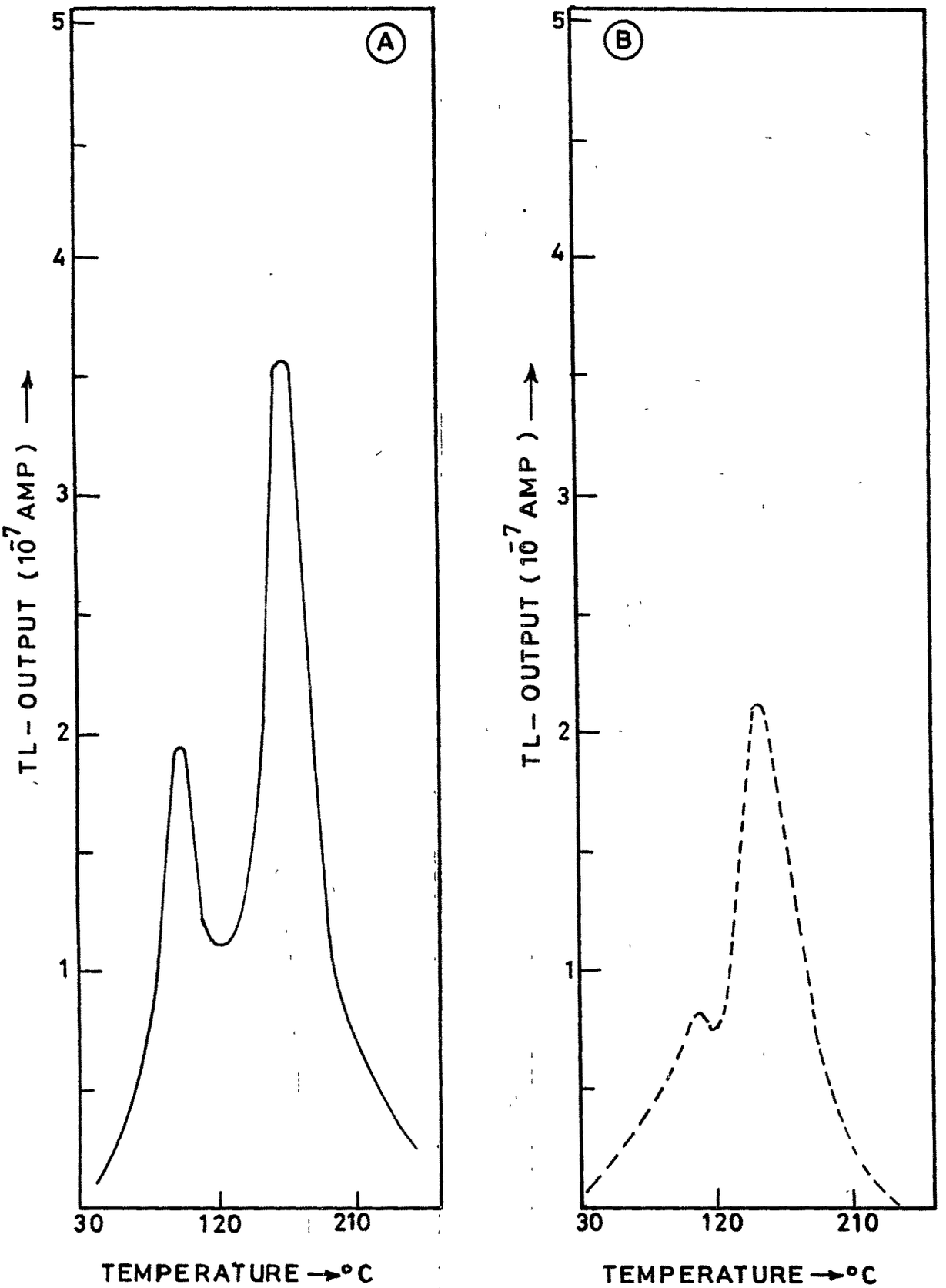

FIGURE : 18

FIGURE - 19 : TL GLOW CURVES OF NaCl:Ca (T)

Curves : (A) ——— 9.6×10^4 Jm^{-2} UV dose.

(B) ------ 14 rad Gamma dose.

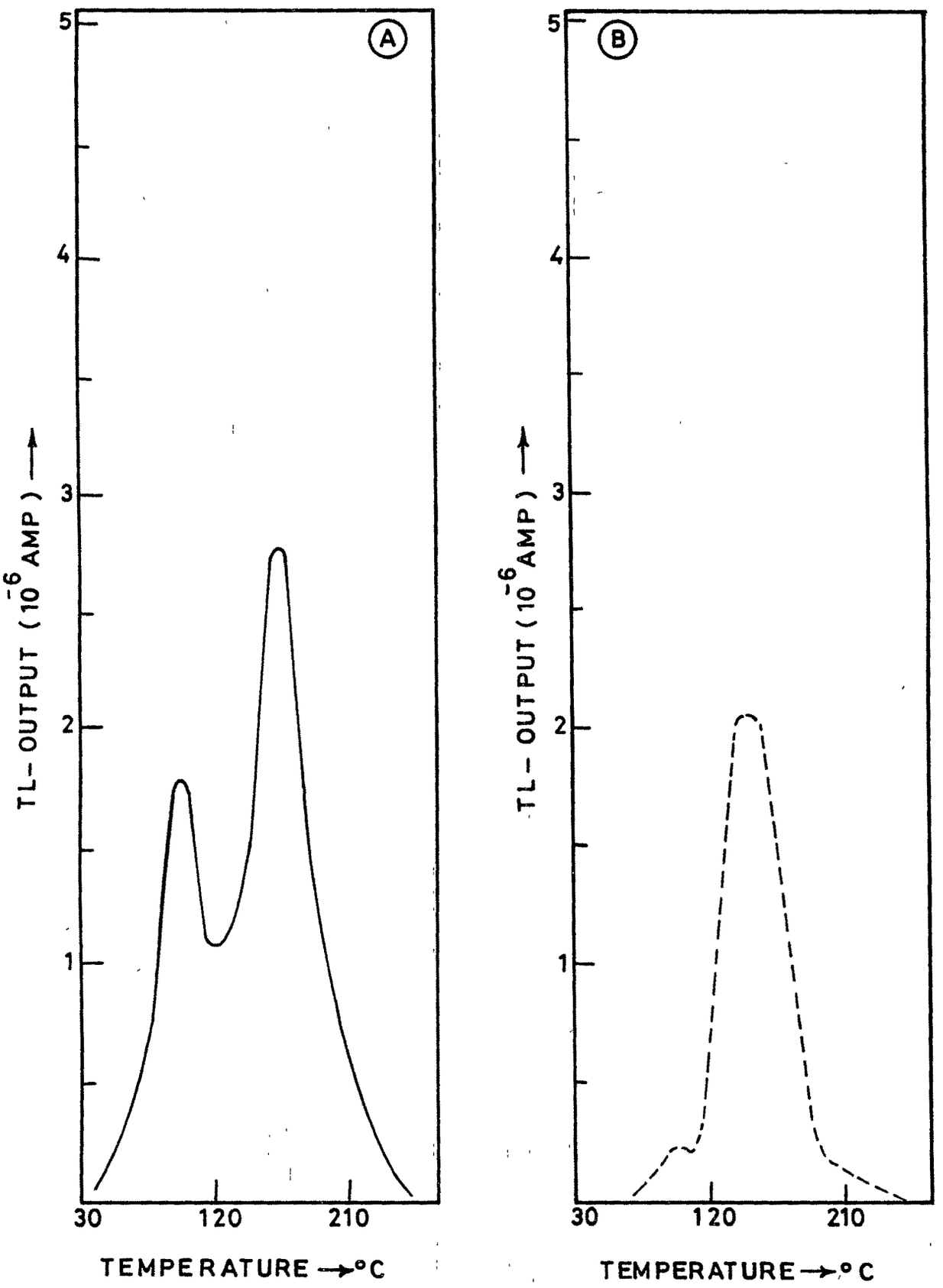

FIGURE : 19

FIGURE - 20 : TL GLOW CURVES OF NaCl:Ca(T)

Curves : (A) ——— 2.4 x 10^4 Jm^{-2} UV dose.

----- 19.2 x 10^4 Jm^{-2} UV dose.

(B) ----- 7 x 10^2 rad Gamma dose.

..... 1.05 x 10^4 rad Gamma dose.

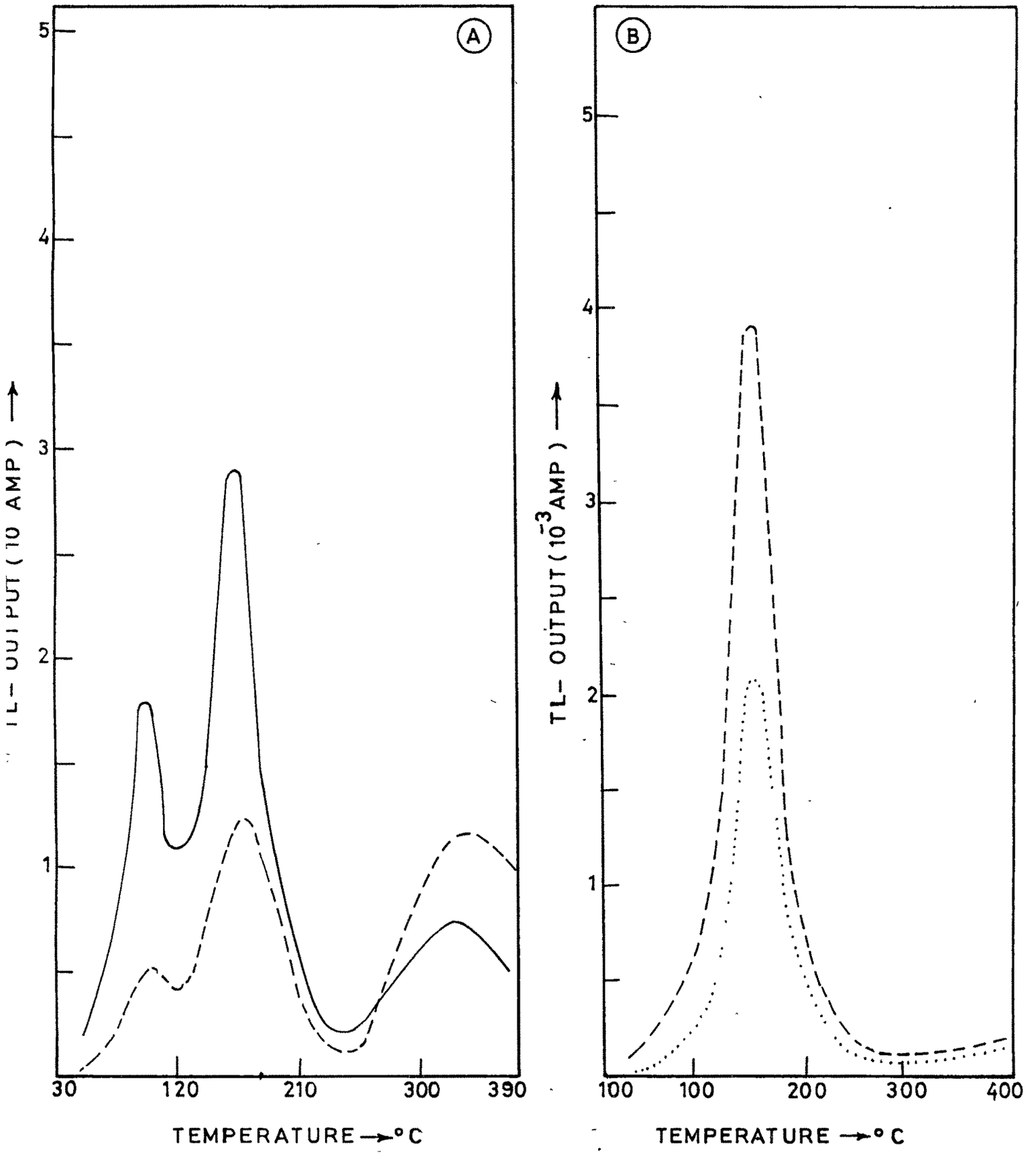
A
B
5
4
3
2
1
TL- OUTPUT (10 AMP) →
TL- OUTPUT (10⁻³ AMP) →
30
120
210
300
390
100
100
200
300
400
TEMPERATURE → °C
TEMPERATURE → °C

FIGURE : 20

FIGURE - 21 : TL GLOW CURVES OF (A) NaCl and
(B) NaCl:Ca (T)
After 2.1 x 10^4 rad exposure dose.

TL EMISSION SPECTRA OF NaCl
After 2.1 x 10^4 rad exposure dose.
Recorded at (C_1) 80°C (C_2)
130°C (C_3) 200°C.

TL EMISSION SPECTRA OF NaCl:Ca(T)
After 2.1 x 10^4 rad exposure dose.
Recorded at (D_1) 80°C (D_2) 130°C (D_3) 200°C

Curves : 1 ——— After annealed and
quenched from 750°C
2.----- Without thermal treatment.

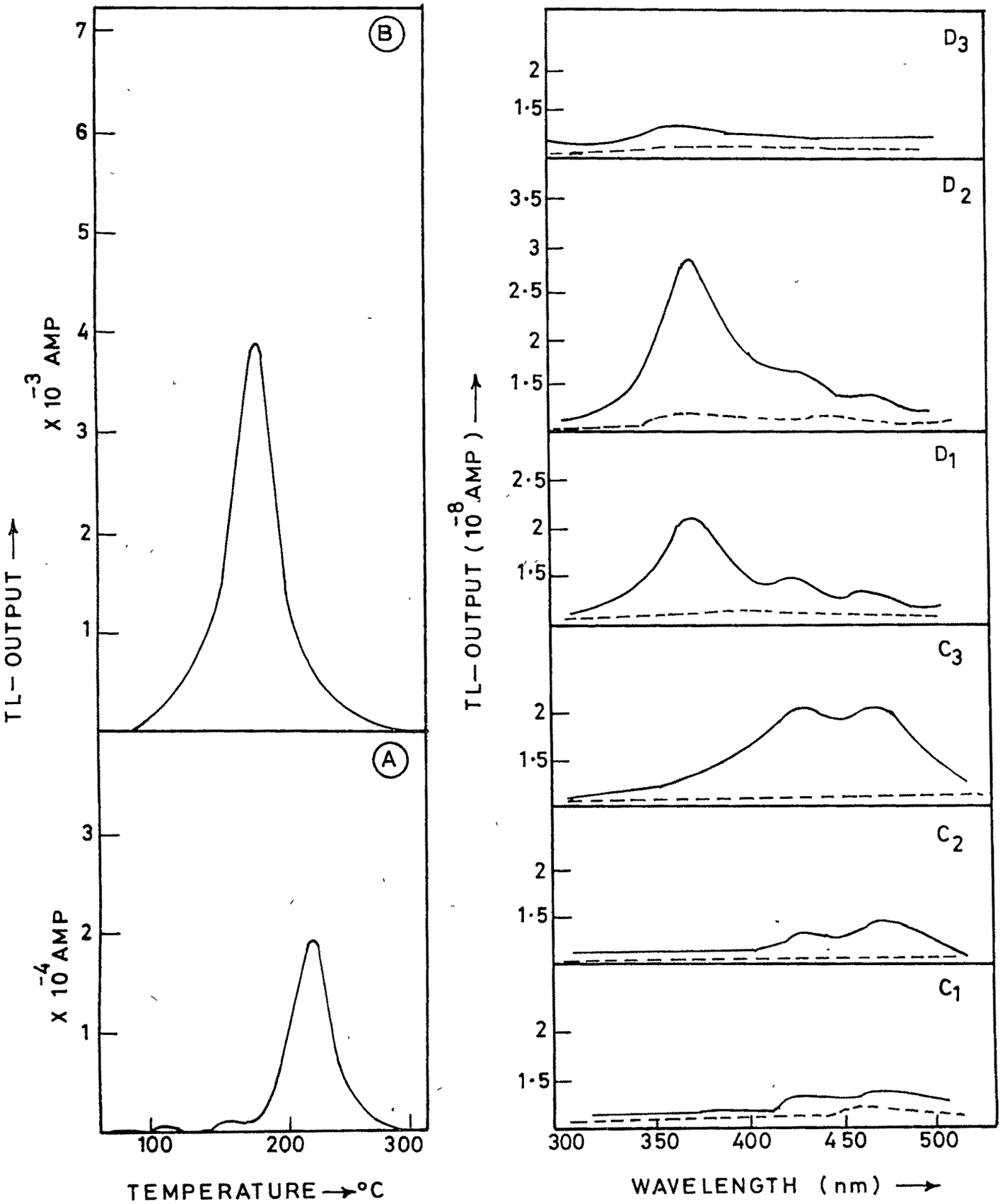
B
A
TL- OUTPUT →
X 10^-3 AMP
X 10^-4 AMP
TEMPERATURE → °C
100
200
300
D3
D2
D1
C3
C2
C1
TL- OUTPUT (10^-8 AMP) →
WAVELENGTH (nm) →
300
350
400
450
500

FIGURE : 21

FIGURE - 22 : TL GLOW CURVES OF NaCl

Annealed and quenched from 750°C

Without exposure.

Curves : 1 ——— 1^{st} Thermal cycle.

2 ----- 2^{nd} Thermal cycle.

3..... 3^{rd} Thermal cycle.

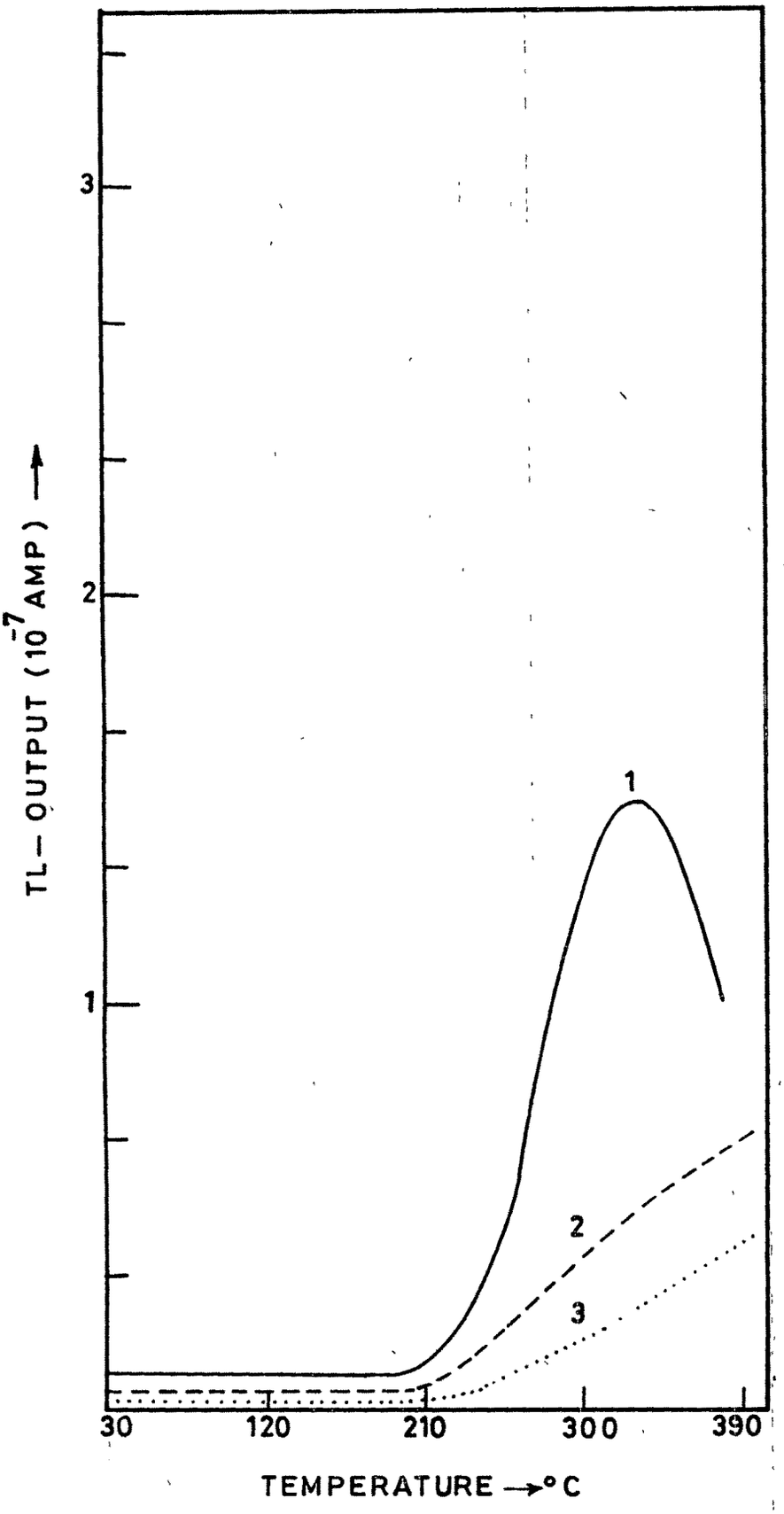

FIGURE : 22

FIGURE - 23 : TL GLOW CURVES OF NaCl:Ca (T)

Without exposure.

Curves : 1 ——— 1st Thermal cycle.

2 ----- 2nd Thermal cycle.

3 ..... 3rd Thermal cycle.

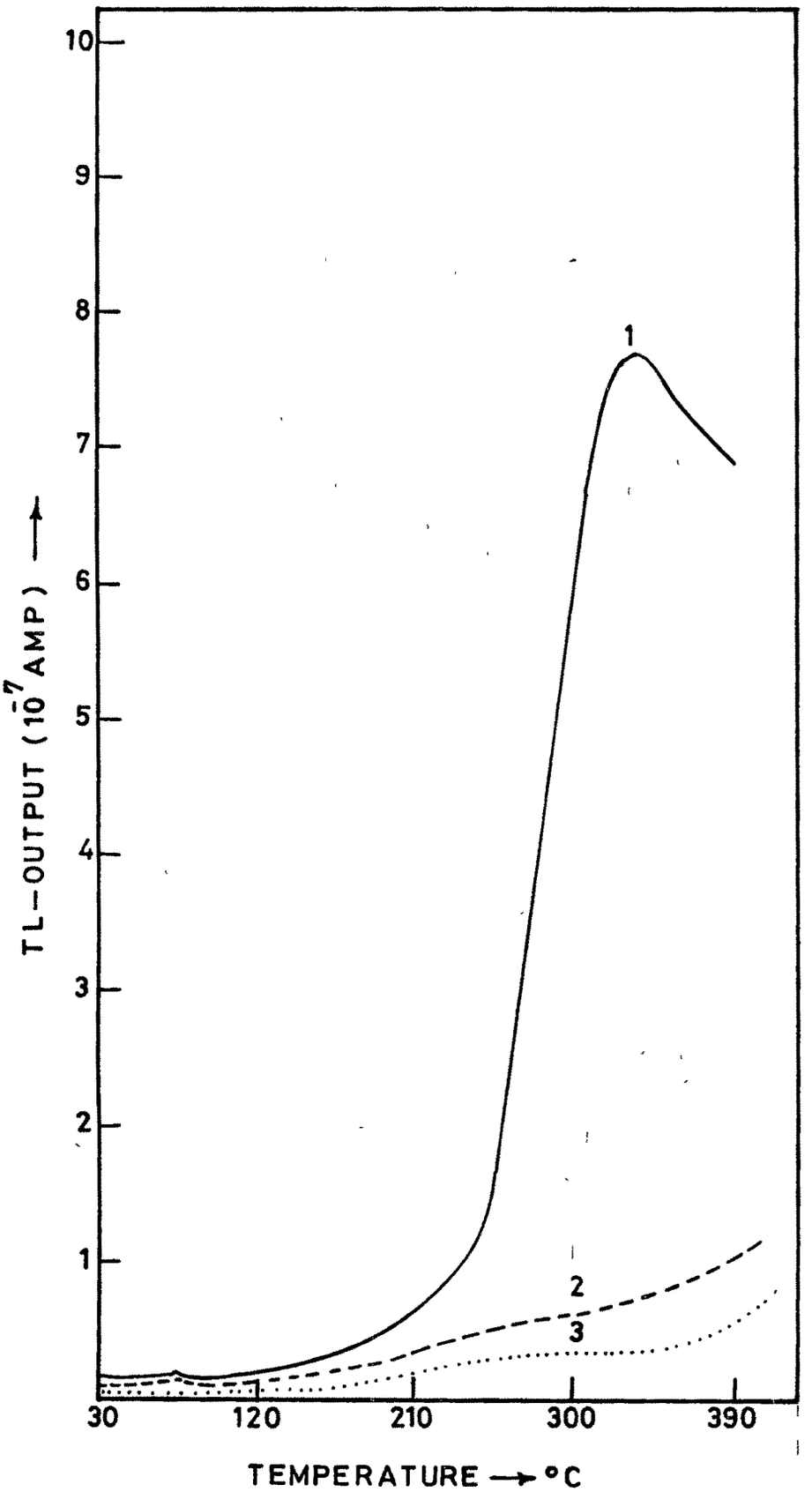
10
9
8
7
6
5
4
3
2
1
TL-OUTPUT (10^{-7} AMP) ⟶
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 23

FIGURE - 24 : TL GLOW CURVES OF NaCl.
After 2.4×10^4 Jm^{-2} exposure dose.

Curves : 1 ——— Annealed and quenched from 750° C.

2 ----- Annealed and quenched from 550° C.

3 ..... As - obtained from solution.

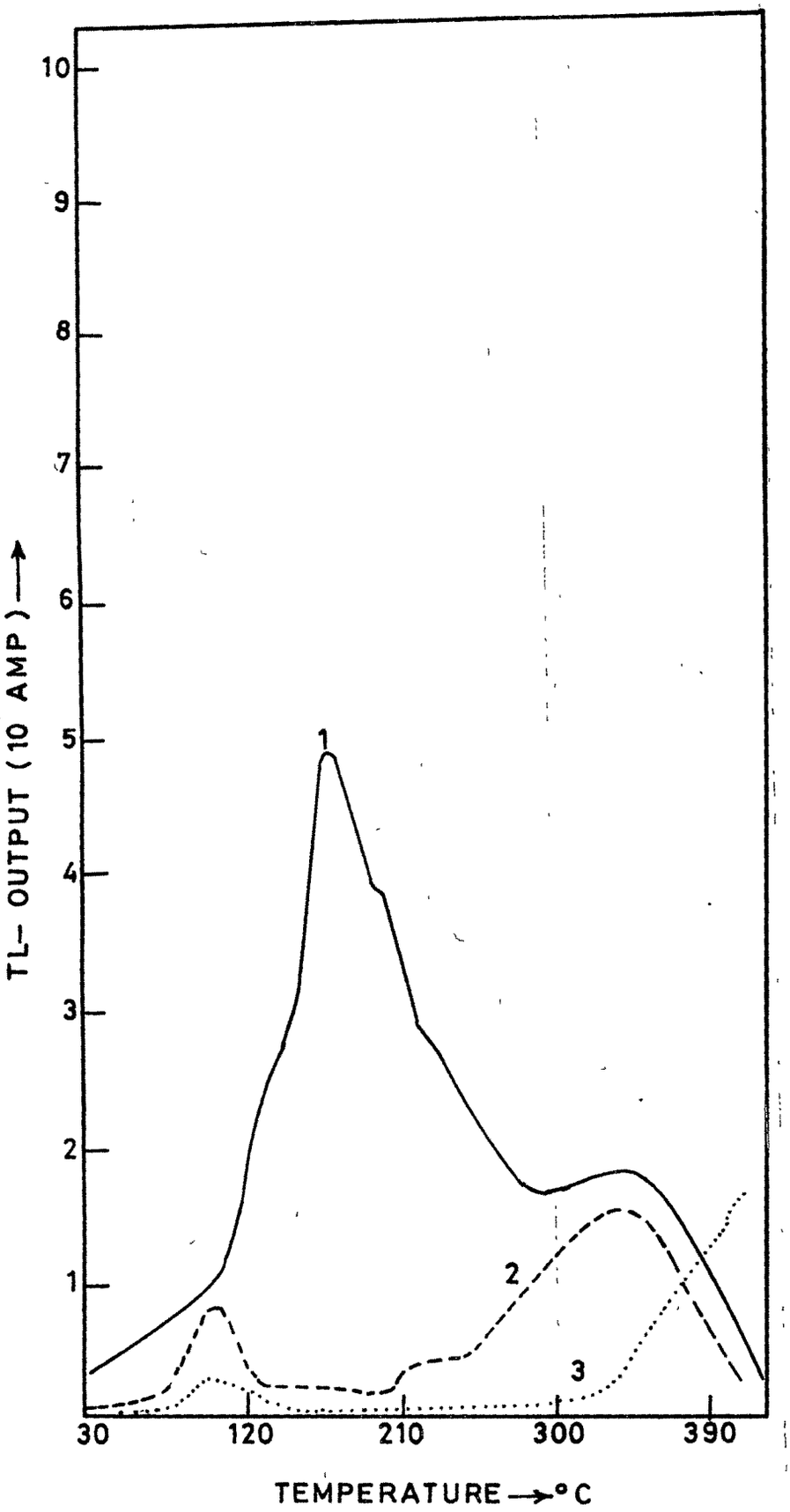
10
9
8
7
6
5
4
3
2
1
TL- OUTPUT (10 -7 AMP) ⟶
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 24

FIGURE - 25 ; TL GLOW CURVES OF NaCl:Ca (10^{-4} m.f.)
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1 ——— Annealed and quenched from 750° C.

2 ----- Annealed and quenched from 550° C.

3 ..... As - obtained from solution.

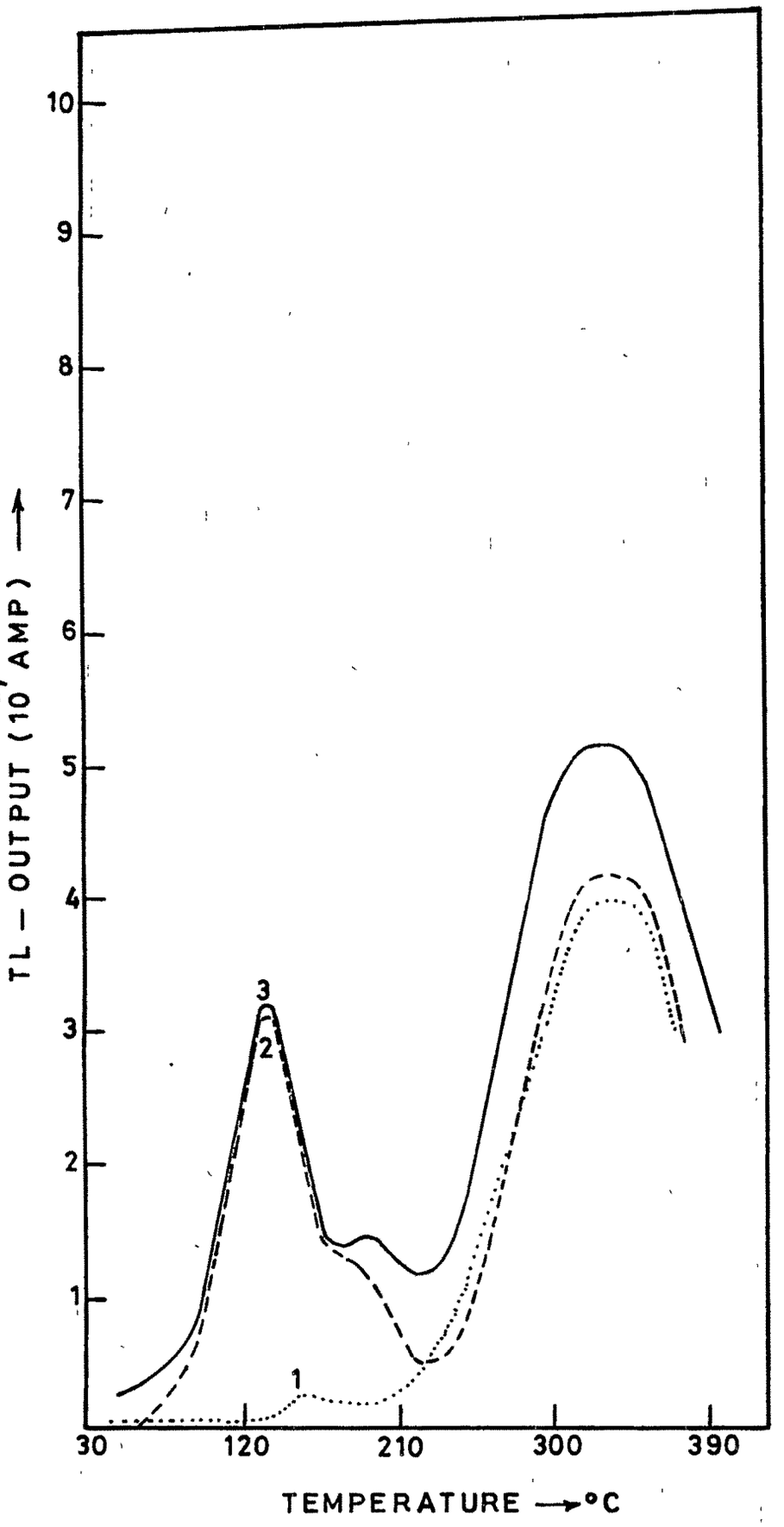
TL – OUTPUT (10^{-7} AMP) ⟶
10
9
8
7
6
5
4
3
2
1
3
2
1
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 25

FIGURE - 26 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.).
After 2.4×10^{4} Jm^{-2} exposure dose.

Curve : 1 ——— Annealed and quenched from 750° C.

2 ----- Annealed and quenched from 550° C.

3 ..... As-obtained from solution.

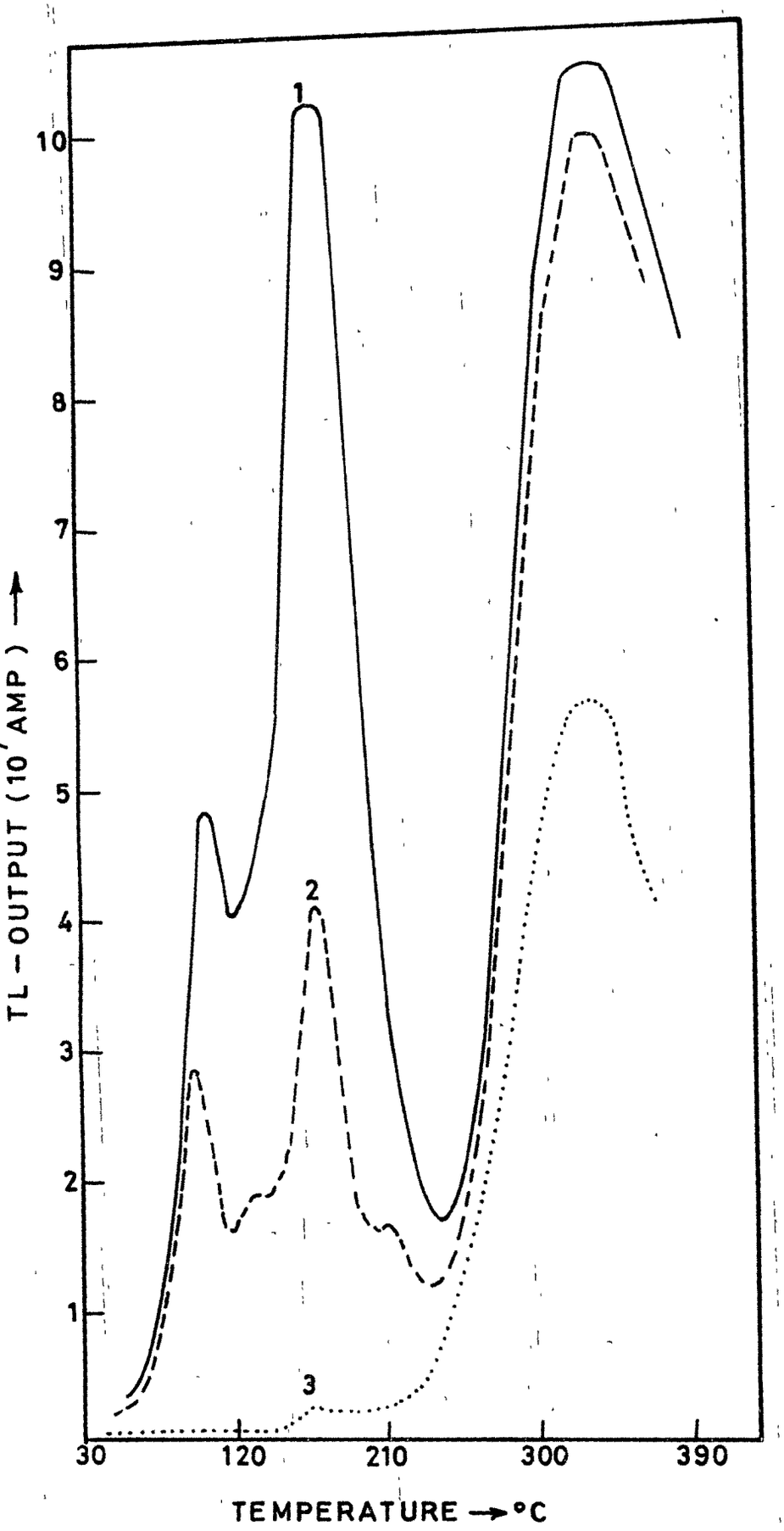
1
2
3
10
9
8
7
6
5
4
3
2
1
TL – OUTPUT (10^{-7} AMP) →
30
120
210
300
390
TEMPERATURE → °C

FIGURE : 26

FIGURE - 27 : TL GLOW CURVES OF NaCl:Ca (10^{-2} m.f.).
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1 ——— Annealed and quenched from 750° C.

2 ----- Annealed and quenched from 550° C.

3 ..... As - obtained from solution.

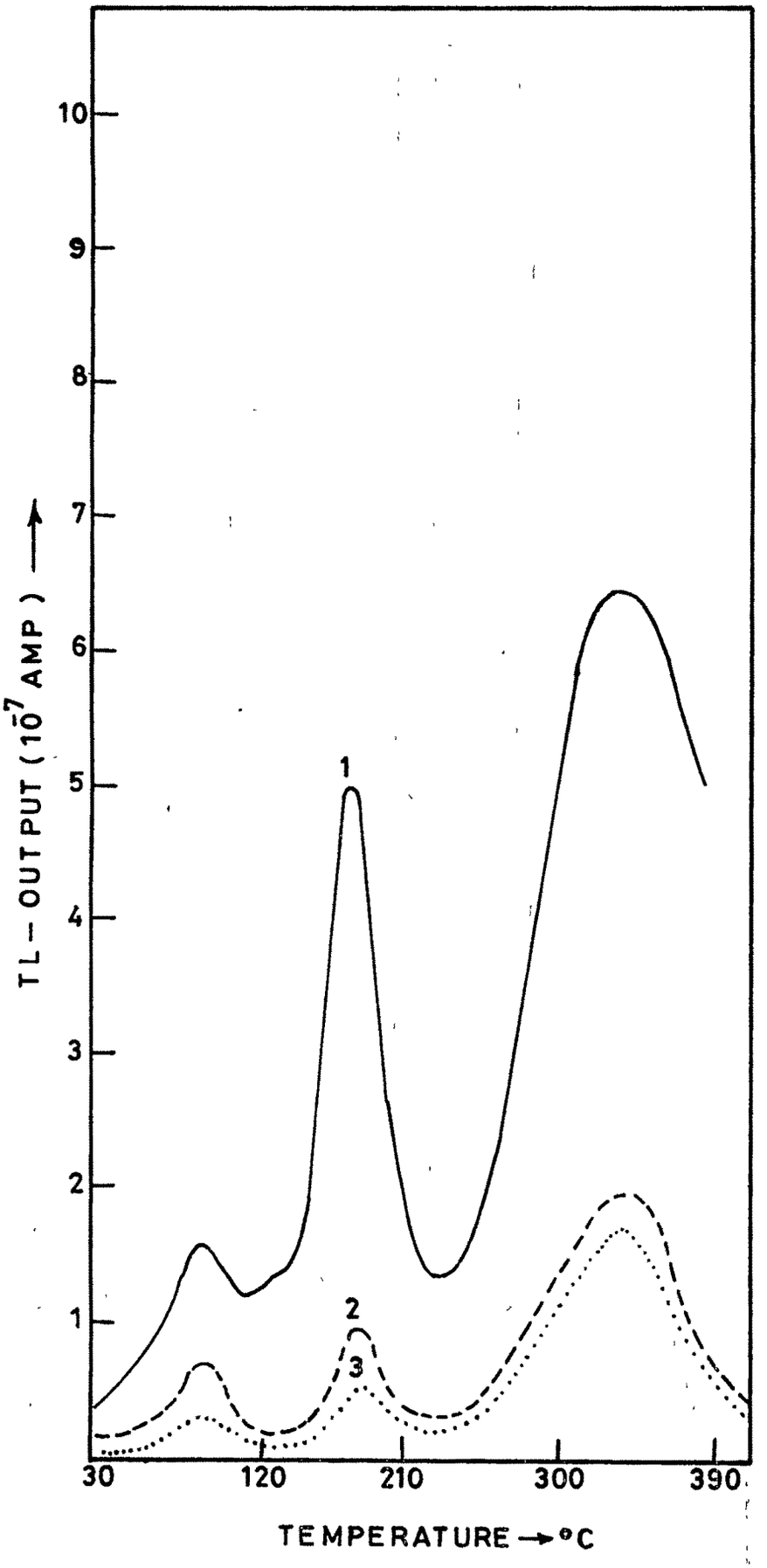
10
9
8
7
6
5
4
3
2
1
TL – OUT PUT (10^{-7} AMP) ⟶
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 27

FIGURE - 28 : TYPICAL TL GLOW CURVES FOR DIFFERENT UV DOSES FOR NaCl:Ca (T).

Curves :

.....	5×10^{2}	Jm^{-2}
-----	1×10^{3}	Jm^{-2}
- - -	2×10^{3}	Jm^{-2}
-.-.-	4×10^{3}	Jm^{-2}
-..-..	5×10^{3}	Jm^{-2}
-.-.-	6×10^{3}	Jm^{-2}
-..-..	1.2×10^{4}	Jm^{-2}
-x-x-	2.4×10^{4}	Jm^{-2}
———	4.8×10^{4}	Jm^{-2}

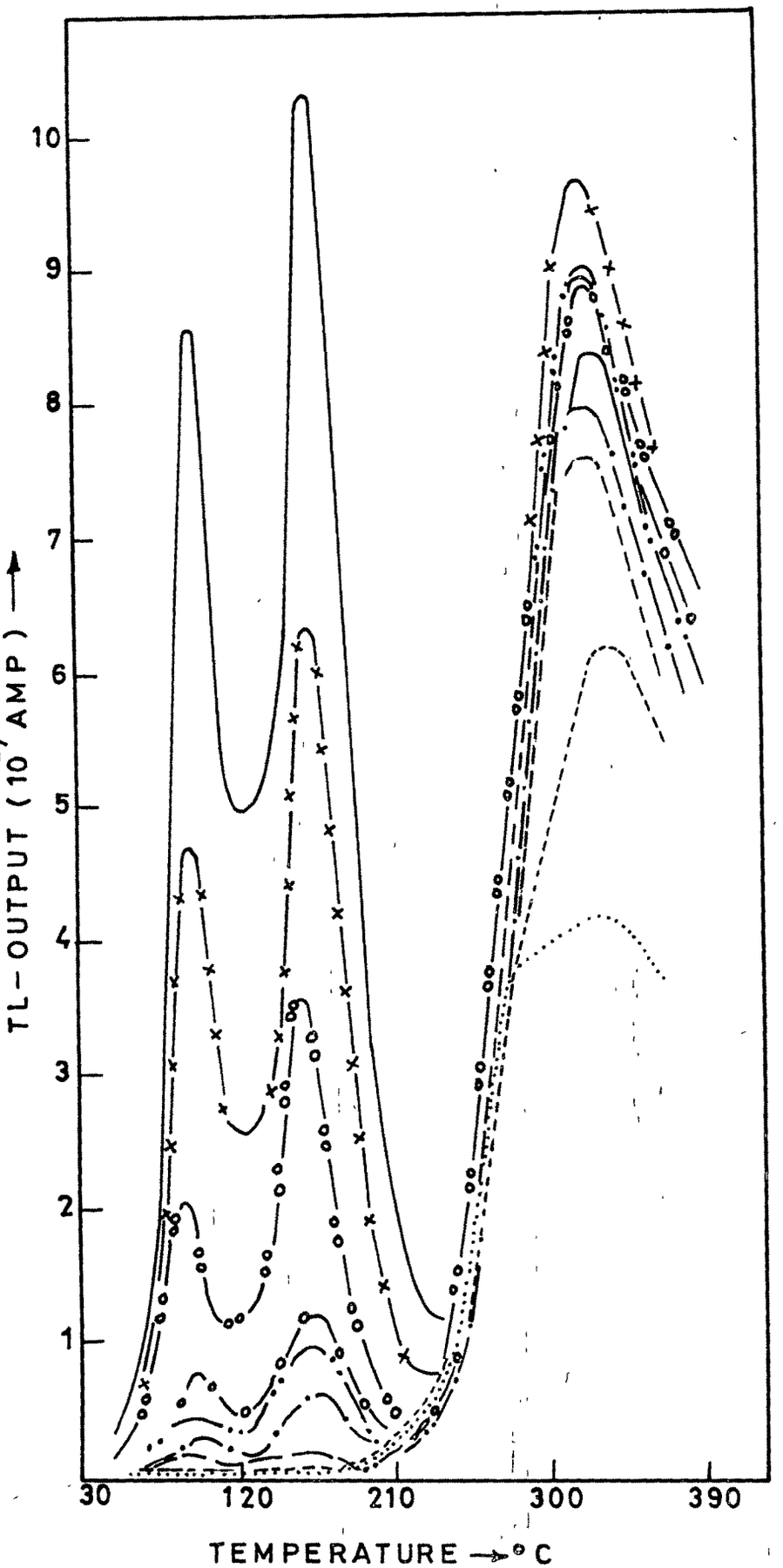
TL-OUTPUT (10^{-7} AMP) →
10
9
8
7
6
5
4
3
2
1
30
120
210
300
390
TEMPERATURE → °C

FIGURE : 28

FIGURE - 29 : GLOW CURVES FOR COMPRESSED SPECIMENS.
After 2.4×10^4 Jm^{-2} exposure dose.

Curves : ..... NaCl, Annealed and quenched from 750° C and compressed.

----- NaCl:Ca (T) compressed.

——— NaCl:Ca (10^{-4} mf), Annealed and quenched from 750° C, and compressed.

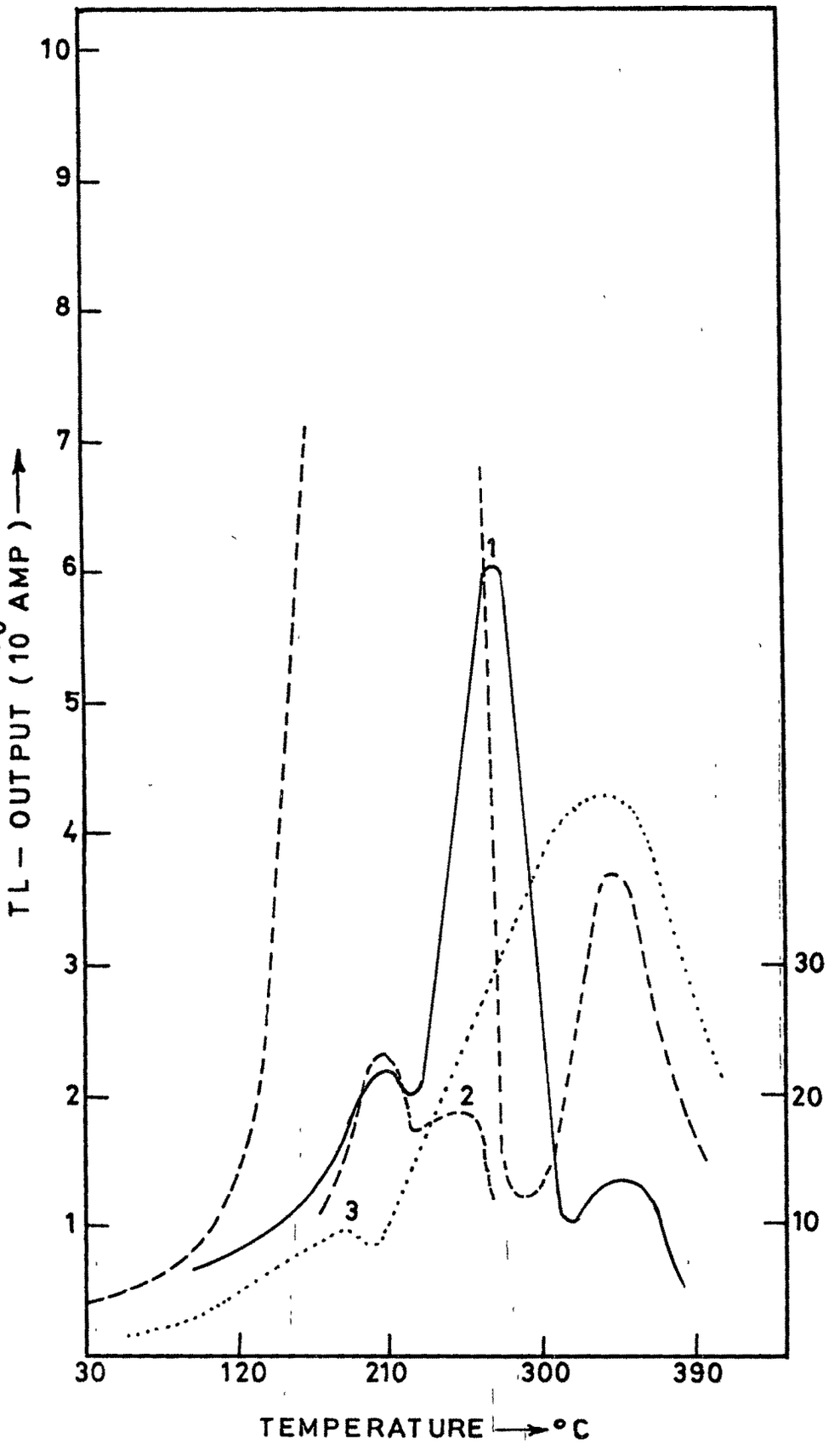
10
9
8
7
6
5
4
3
2
1
TL – OUTPUT (10^{-6} AMP) ⟶
30
20
10
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 29

FIGURE - 30 ; TL GLOW CURVES OF LiF TLD - 100

Curves : ----- 6×10^{3} Jm^{-2} UV dose.

——— 6.5×10^{2} rad Gamma dose.

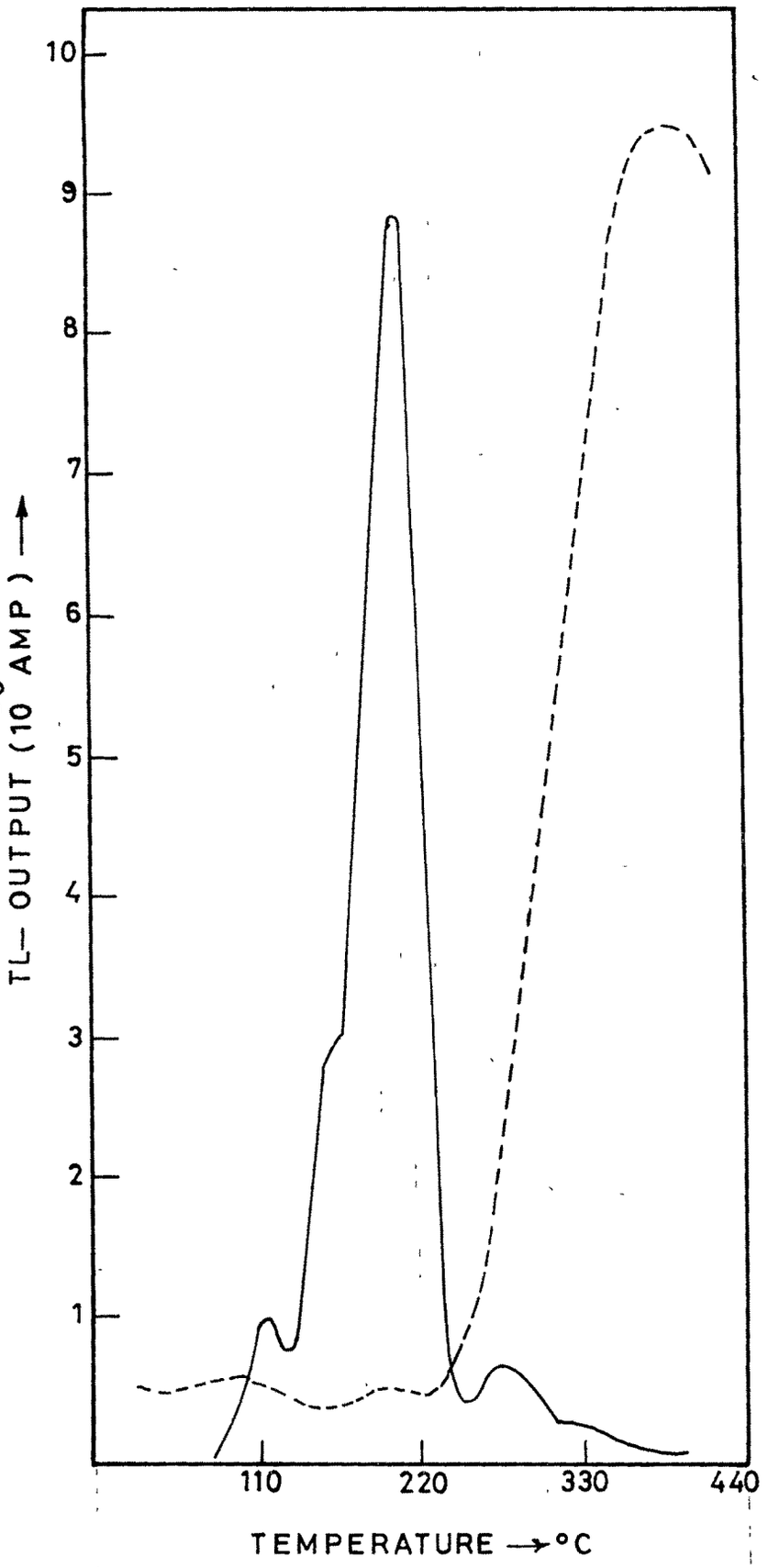

FIGURE : 30

FIGURE - 31 : TL GLOW CURVES OF NaCl.
After 2.4×10^4 Jm^{-2} exposure dose.

Curves : 1 ——— Annealed and quenched from 750° C.

2 ----- Annealed and quenched from 550° C.

3 .....As-obtained from solution.

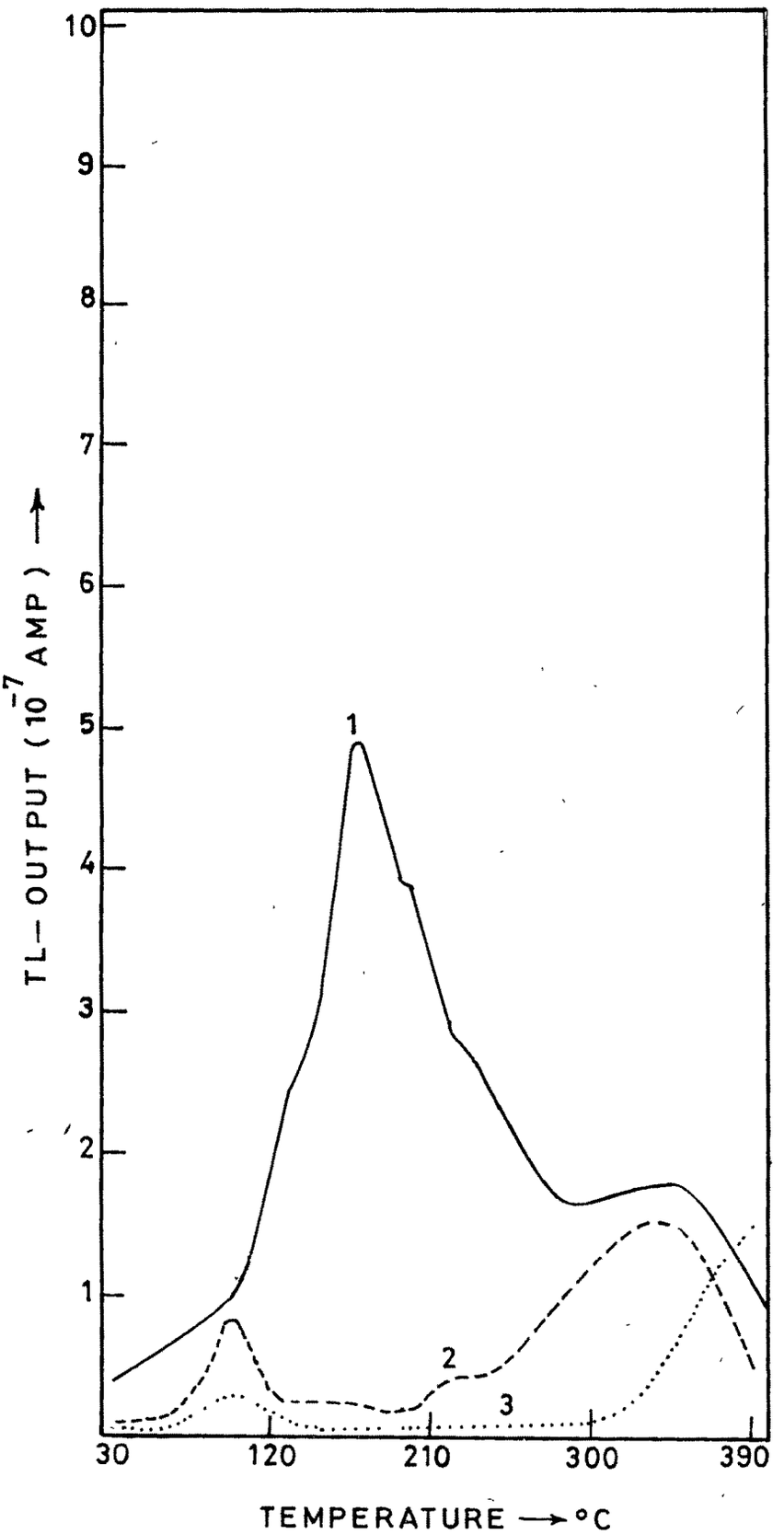
10
9
8
7
6
5
4
3
2
1
TL— OUTPUT (10^{-7} AMP) ⟶
1
2
3
30
120
210
300
390
TEMPERATURE ⟶ °C

FIGURE : 31

FIGURE - 32 : TL GLOW CURVES OF NaCl:Ca (10^{-3} m.f.).
After 2.4×10^{4} Jm^{-2} exposure dose.

Curves : 1———Annealed and quenched from 750° C.

2-----Annealed and quenched from 550° C.

3.....As-obtained from solution.

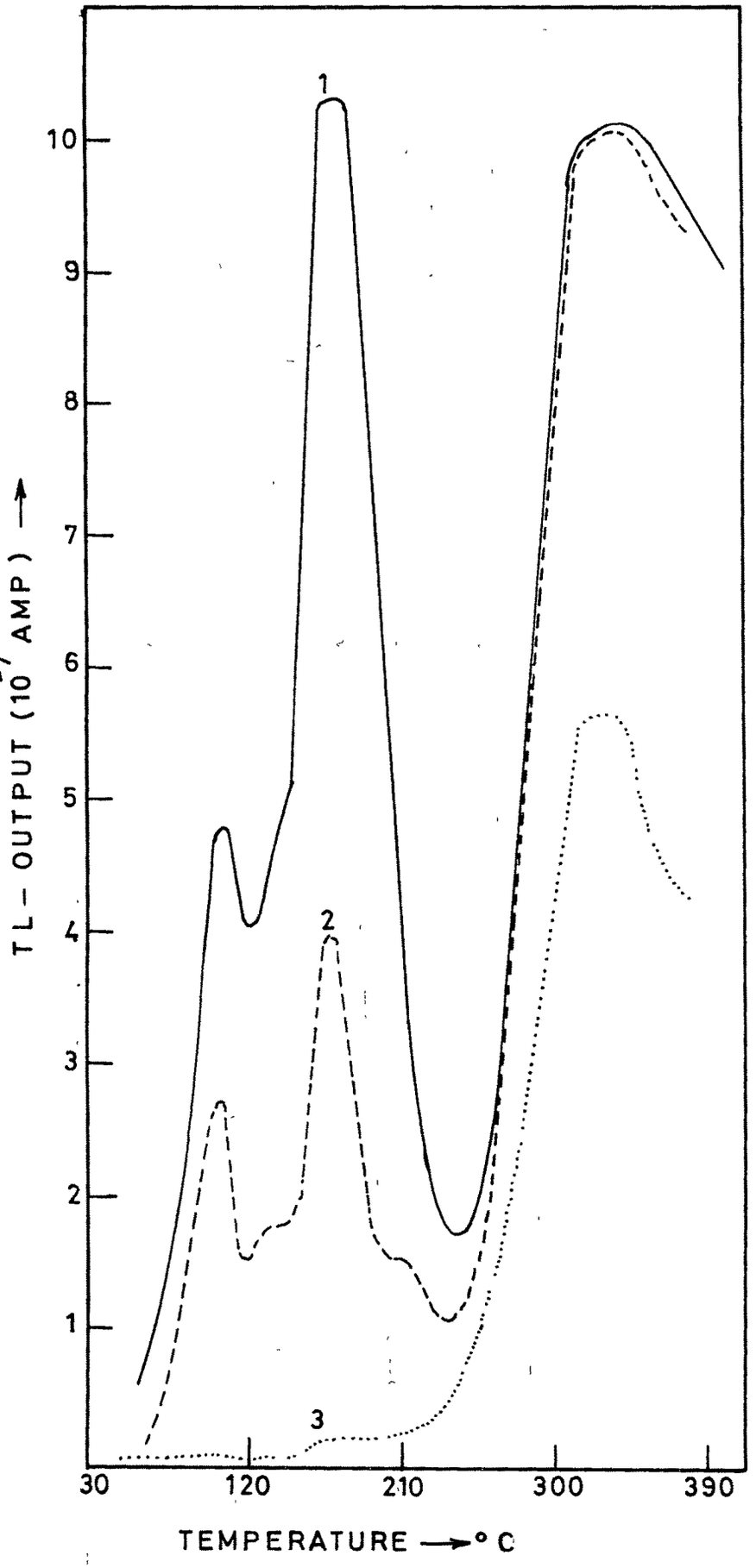
1
2
3
10
9
8
7
6
5
4
3
2
1
TL – OUTPUT (10^{-7} AMP) ⟶
30
120
210
300
390
TEMPERATURE ⟶ ° C

FIGURE : 32

FIGURE - 33 : (A) TL GLOW CURVE OF NaCl:Ca(T) (10^{-3}m.f.)

——— After 6 x 10^{3} Jm^{-2} exposure dose.

(B) TL GLOW CURVE OF LiF TLD-100.

----- After 6 x 10^{3} Jm^{-2} exposure dose.

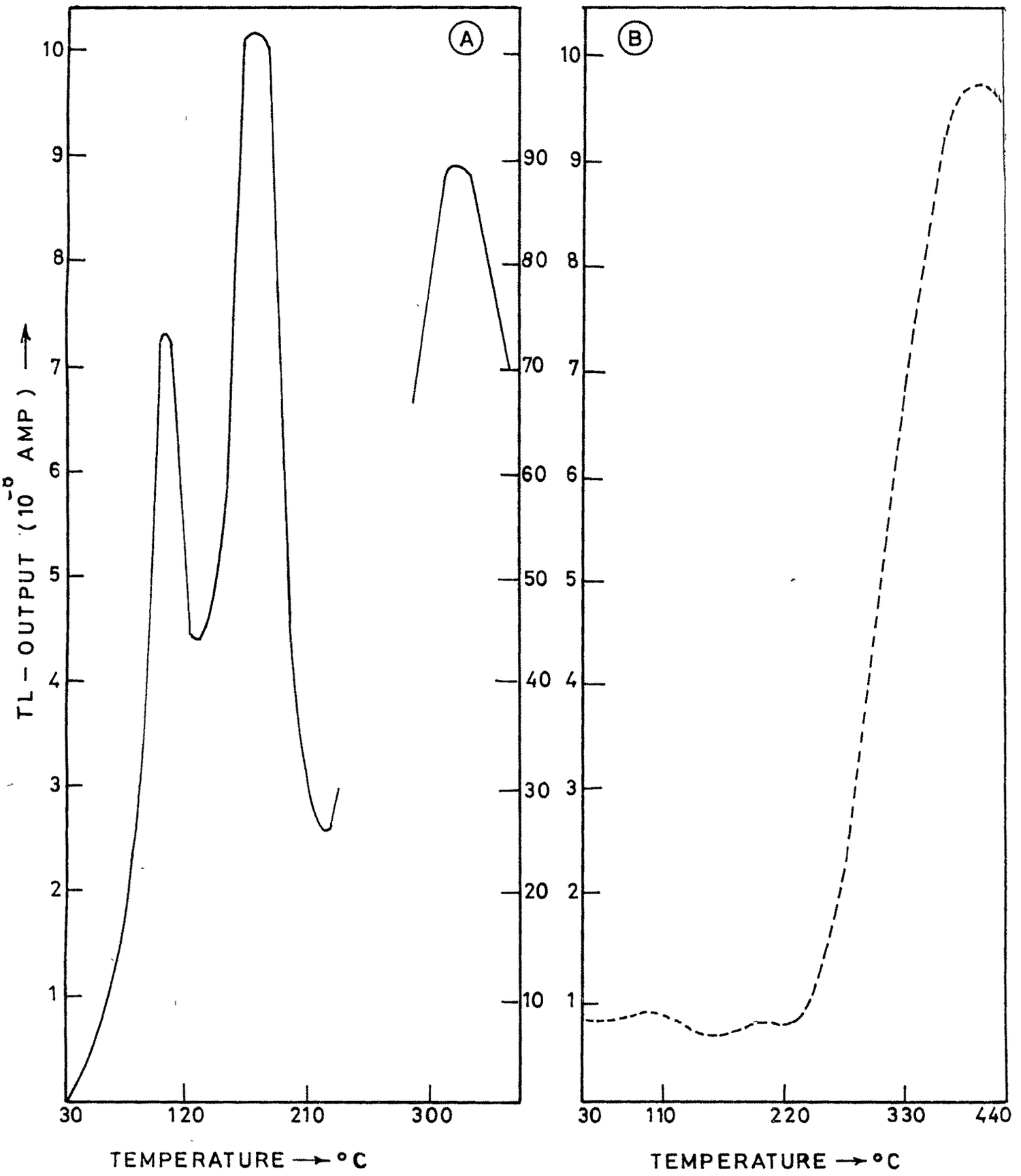
A
B
TL – OUTPUT (10^{-5} AMP) →
10
9
8
7
6
5
4
3
2
1
90
80
70
60
50
40
30
20
10
30
120
210
300
110
220
330
440
TEMPERATURE → °C
TEMPERATURE → °C

FIGURE : 33

FIGURE - 34 : TYPICAL TL GLOW CURVES OF NaCl:Ca(T) After an exposure to different low UV doses.

Curves :

..... 5×10^2 Jm^{-2}

----- 1×10^3 Jm^{-2}

-.-.- 2×10^3 Jm^{-2}

-..-..4×10^3 Jm^{-2}

——— 5×10^3 Jm^{-2}

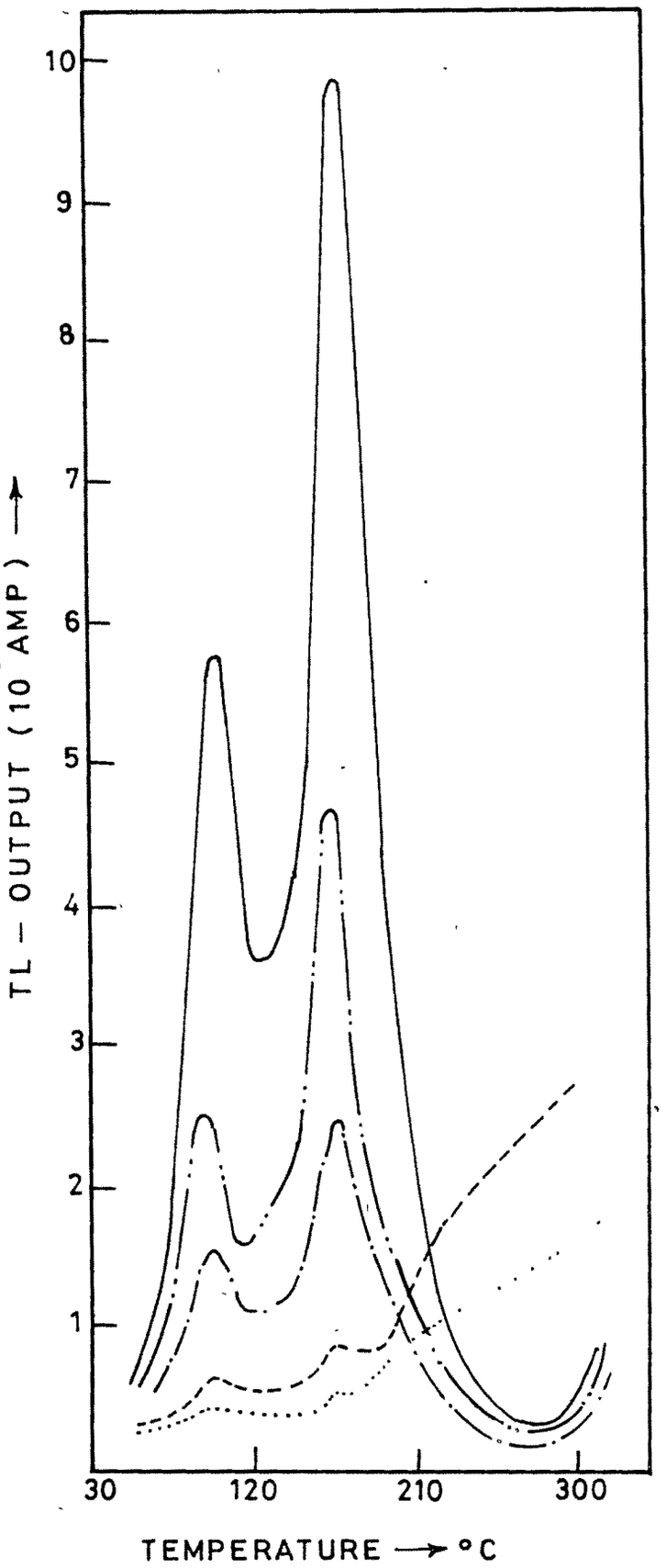

FIGURE : 34

FIGURE - 35 : TL OUTPUT AT PEAK II OF NaCl:Ca(T) AS A FUNCTION OF INCIDENT LOW UV DOSE (Jm^{-2}).

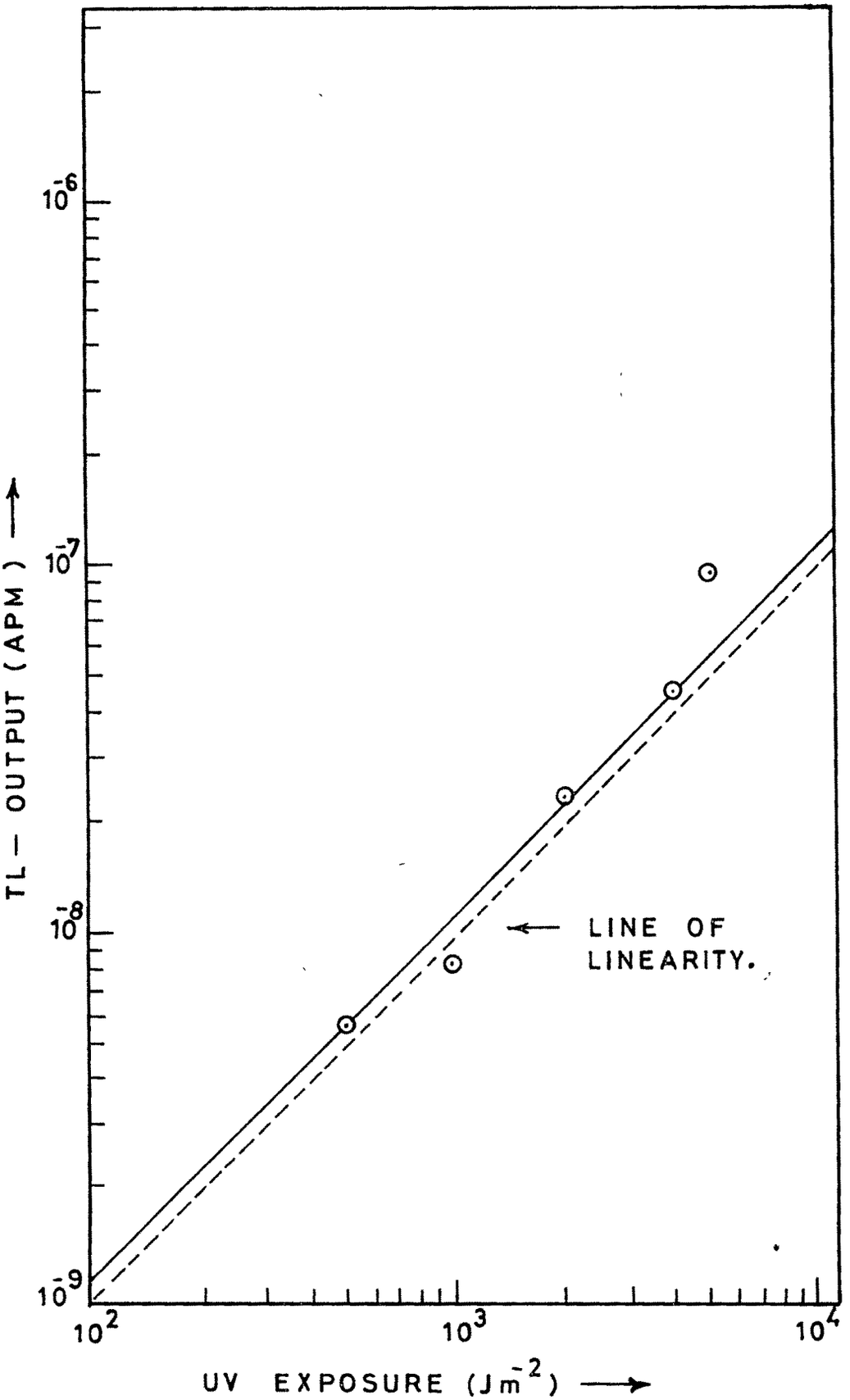
TL – OUTPUT (APM) ⟶
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{2}
10^{3}
10^{4}
LINE OF LINEARITY.
UV EXPOSURE (Jm^{-2}) ⟶

FIGURE : 35

FIGURE - 36 : TYPICAL TL GLOW CURVES OF NaCl:Ca(T). After an exposure to different high UV doses.

Curves : ..... 3×10^3 Jm^{-2}

----- 6×10^3 Jm^{-2}

-.-.- 1.2×10^4 Jm^{-2}

-..-..2.4×10^4 Jm^{-2}

——— 4.8×10^4 Jm^{-2}

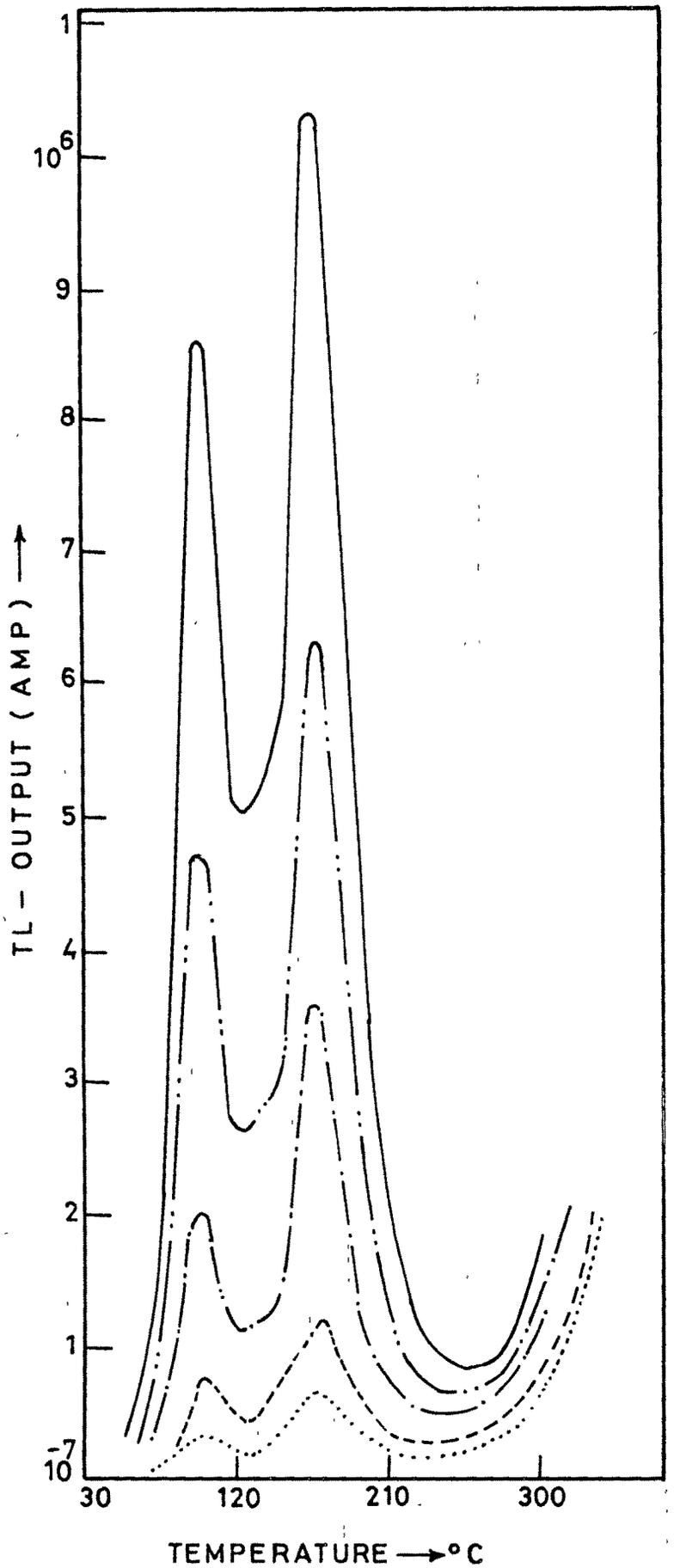
1
10^6
9
8
7
6
5
4
3
2
1
10^-7
TL - OUTPUT (AMP) ⟶
30
120
210
300
TEMPERATURE ⟶ °C

FIGURE : 36

FIGURE - 37 : TL OUTPUT AT PEAK II OF NaCl:Ca(T) AS A FUNCTION OF INCIDENT HIGH UV DOSE (Jm^{-2}).

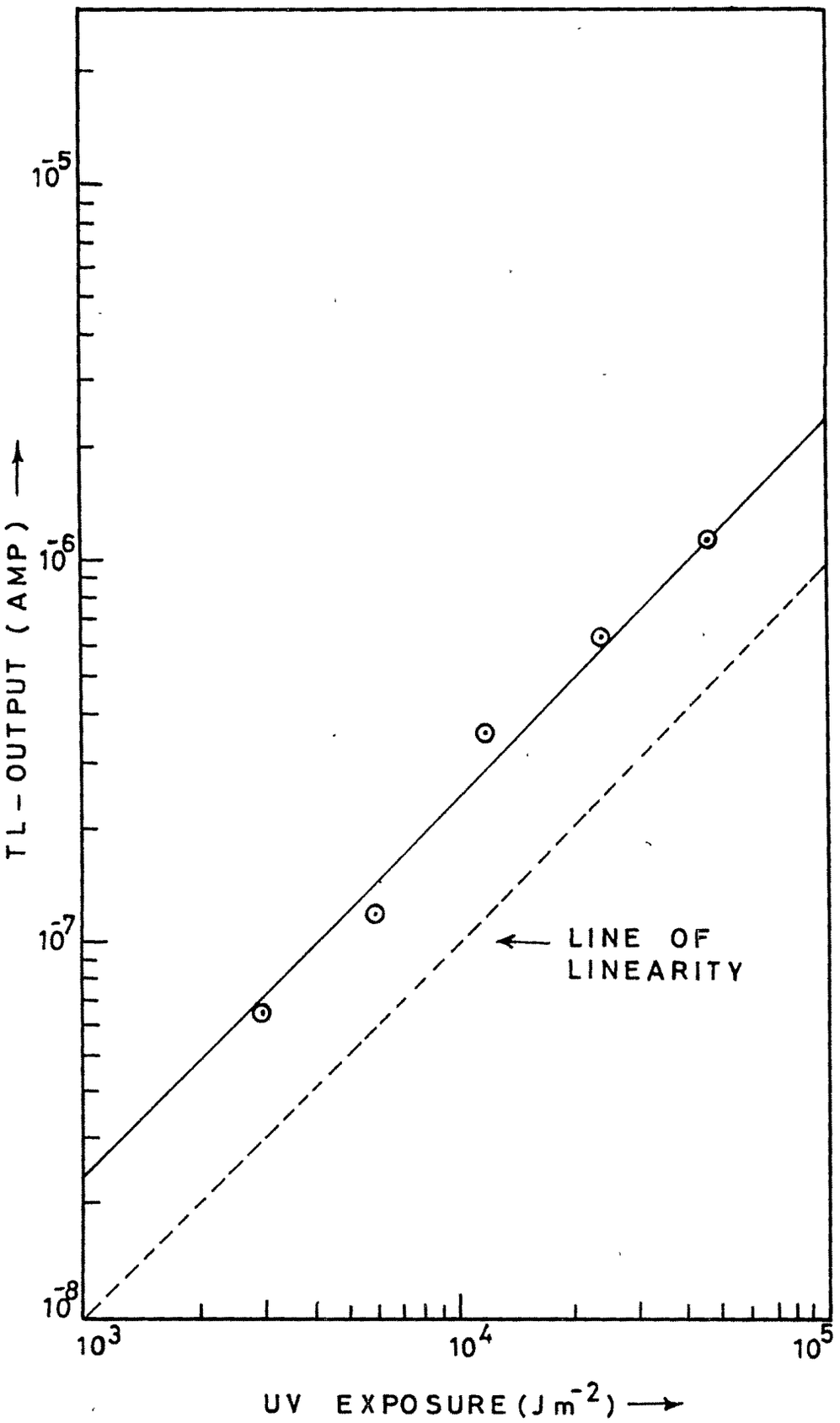
TL-OUTPUT (AMP) ⟶
10^{-5}
10^{-6}
10^{-7}
10^{-8}
LINE OF LINEARITY
10^{3}
10^{4}
10^{5}
UV EXPOSURE ($J\,m^{-2}$) ⟶

FIGURE : 37

FIGURE - 38 : TL YIELD OF NaCl:Ca(T) AS A FUNCTION OF UV DOSE (Jm^{-2}).

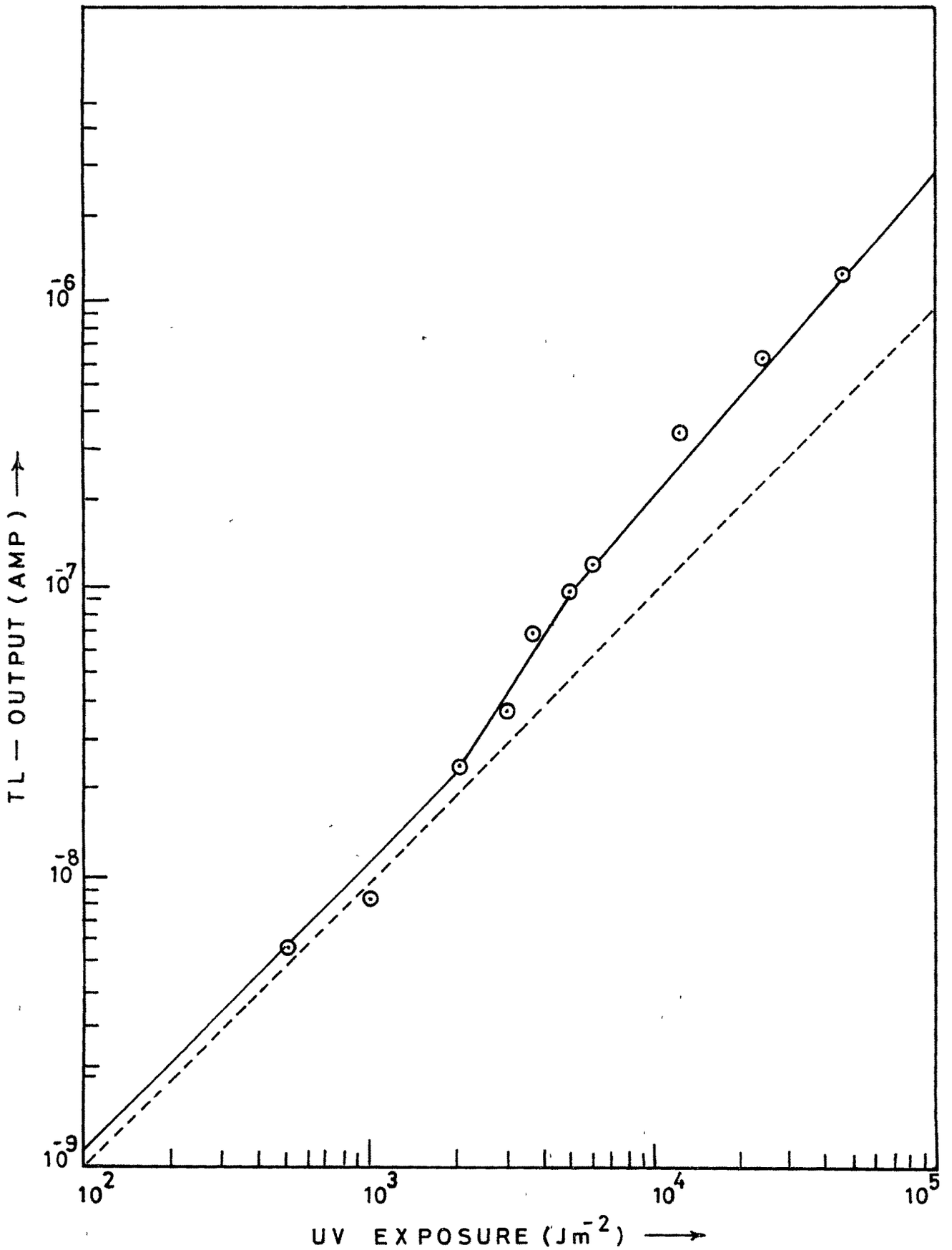

FIGURE : 38

FIGURE - 39 : TYPICAL TL GLOW CURVES OF NaCl:Ca(T).

Curves : ——— 6×10^3 Jm^{-2} UV dose.

----- 1 rad Gamma dose.

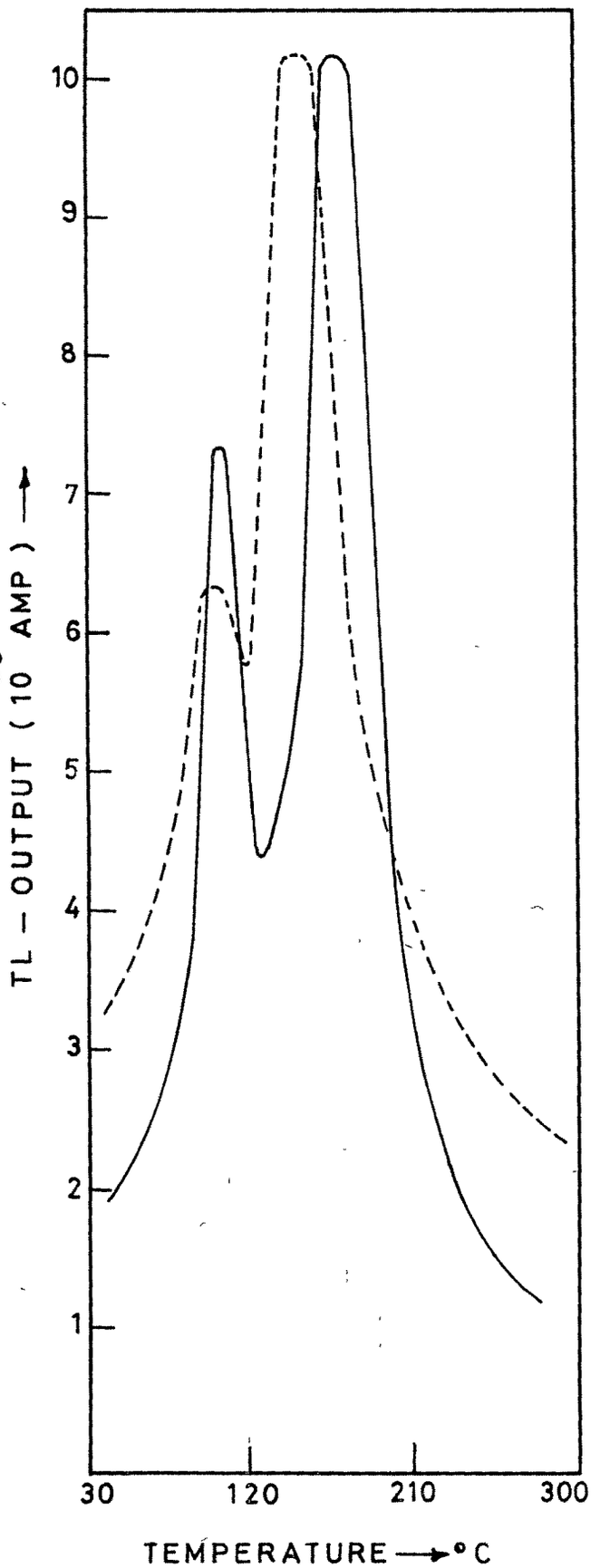

FIGURE : 39

FIGURE - 40 : TL OUTPUT OF NaCl:Ca (T).
After 2.4×10^4 Jm^{-2} exposure dose,
AS A FUNCTION OF POST IRRADIATION
(DECAY) DURATION OF 1 HOUR TO 200
HOURS.

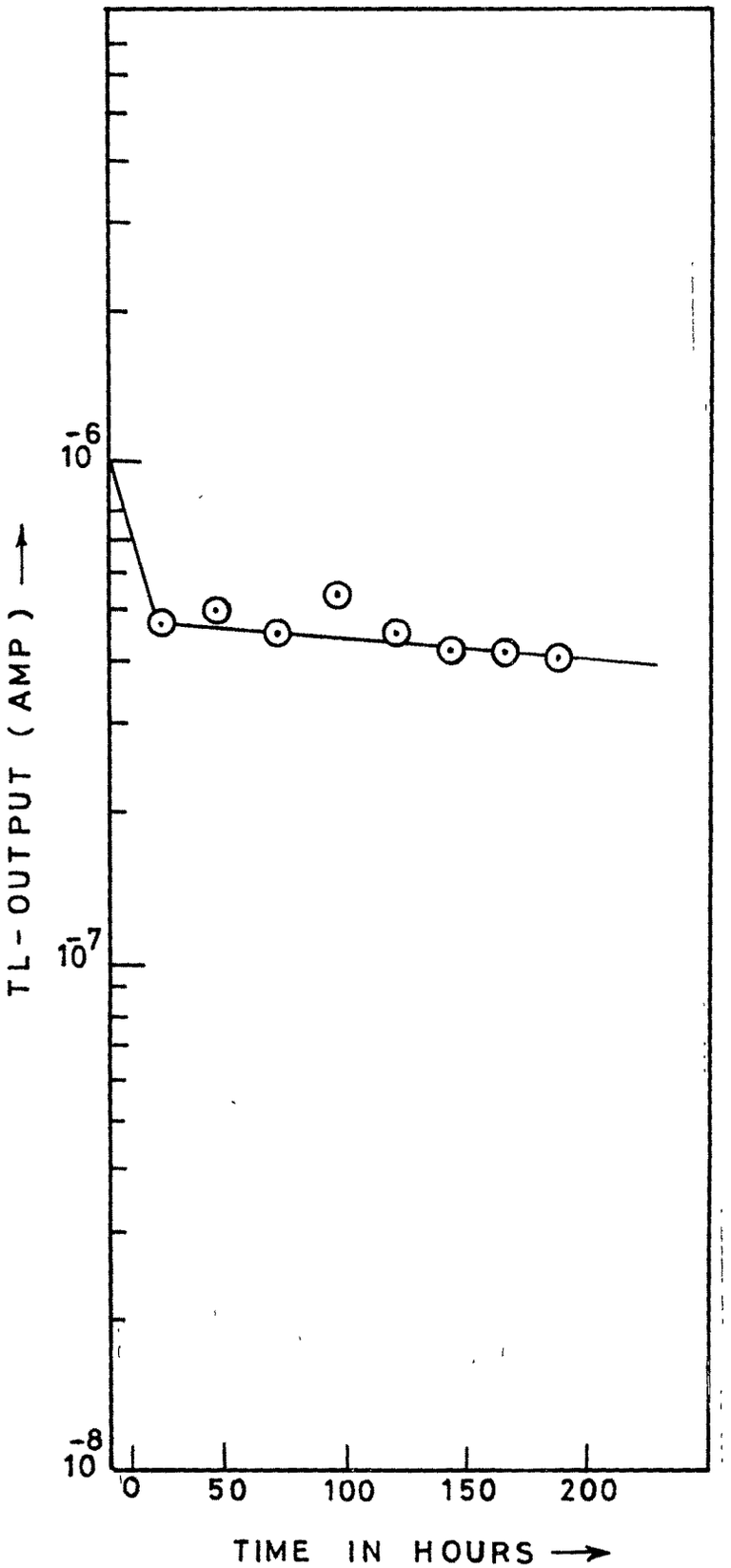

FIGURE : 40

FIGURE - 41 : TYPICAL TL GLOW CURVES OF NaCl:Ca(T) After an exposure to different Gamma low doses.

Curves : ..... 500 m rad

---- 1 rad

-.-.-2 rad

——— 3 rad

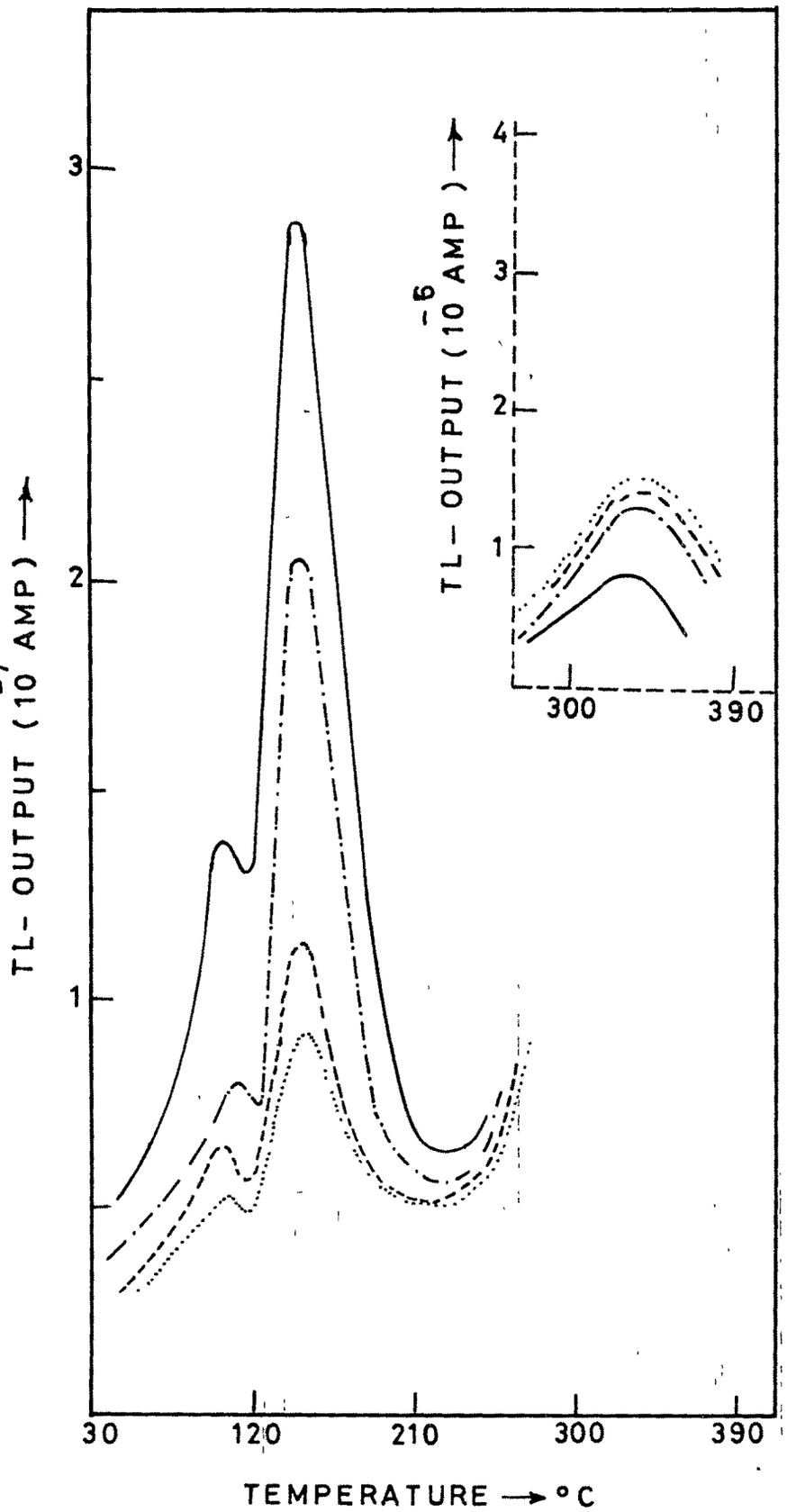
TL- OUTPUT (10^-7 AMP) →
1
2
3
30
120
210
300
390
TEMPERATURE → °C
TL- OUTPUT (10^-6 AMP) →
1
2
3
4
300
390

FIGURE : 41

FIGURE - 42 : TL OUTPUT AT PEAK II OF NaCl:Ca(T) AS A FUNCTION OF INCIDANT GAMMA LOW DOSE IN 'rad'.

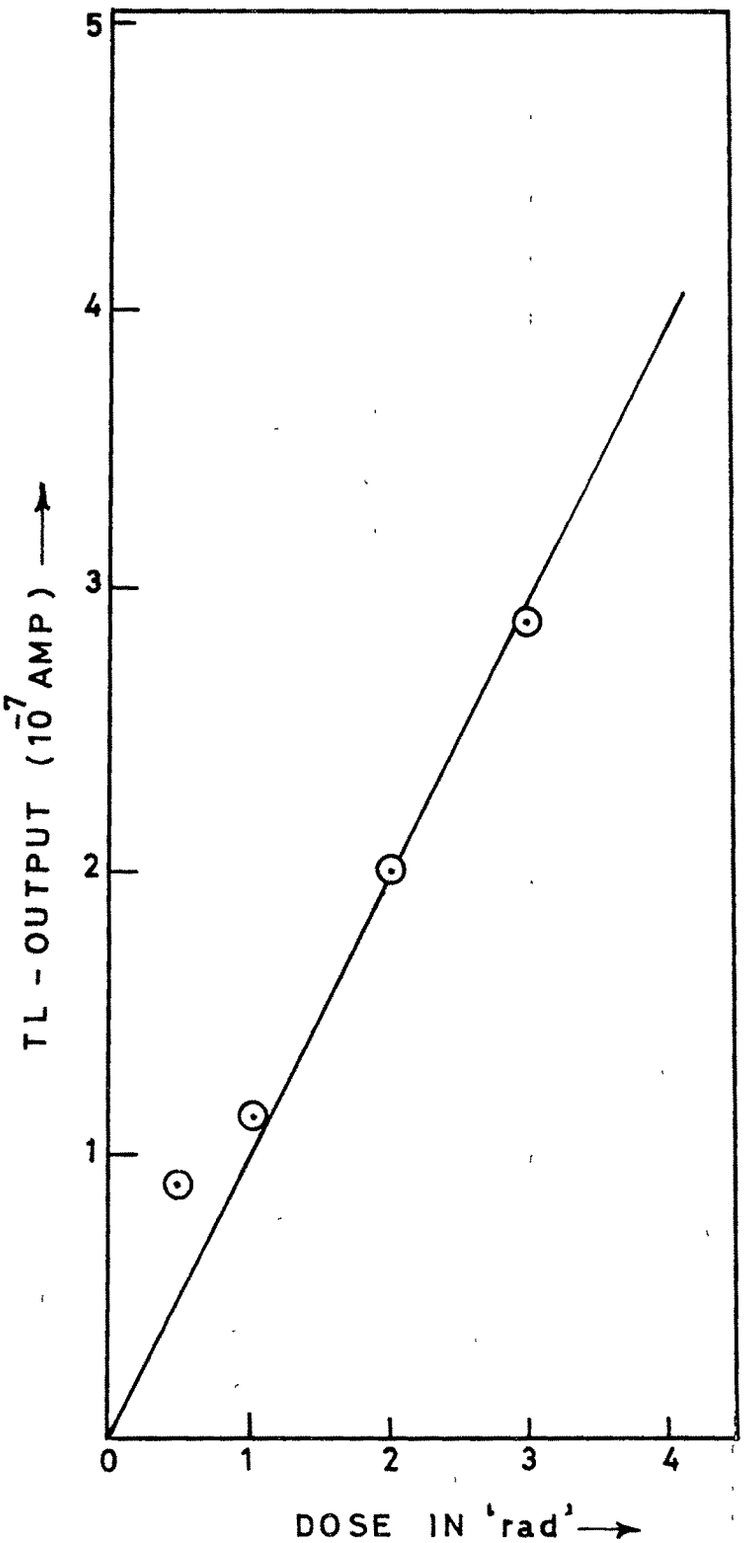

FIGURE : 42

FIGURE - 43 : TL OUTPUT AT PEAK II OF NaCl:Ca(T) AS A FUNCTION OF INCIDANT GAMMA LOW DOSE IN 'Gy'.

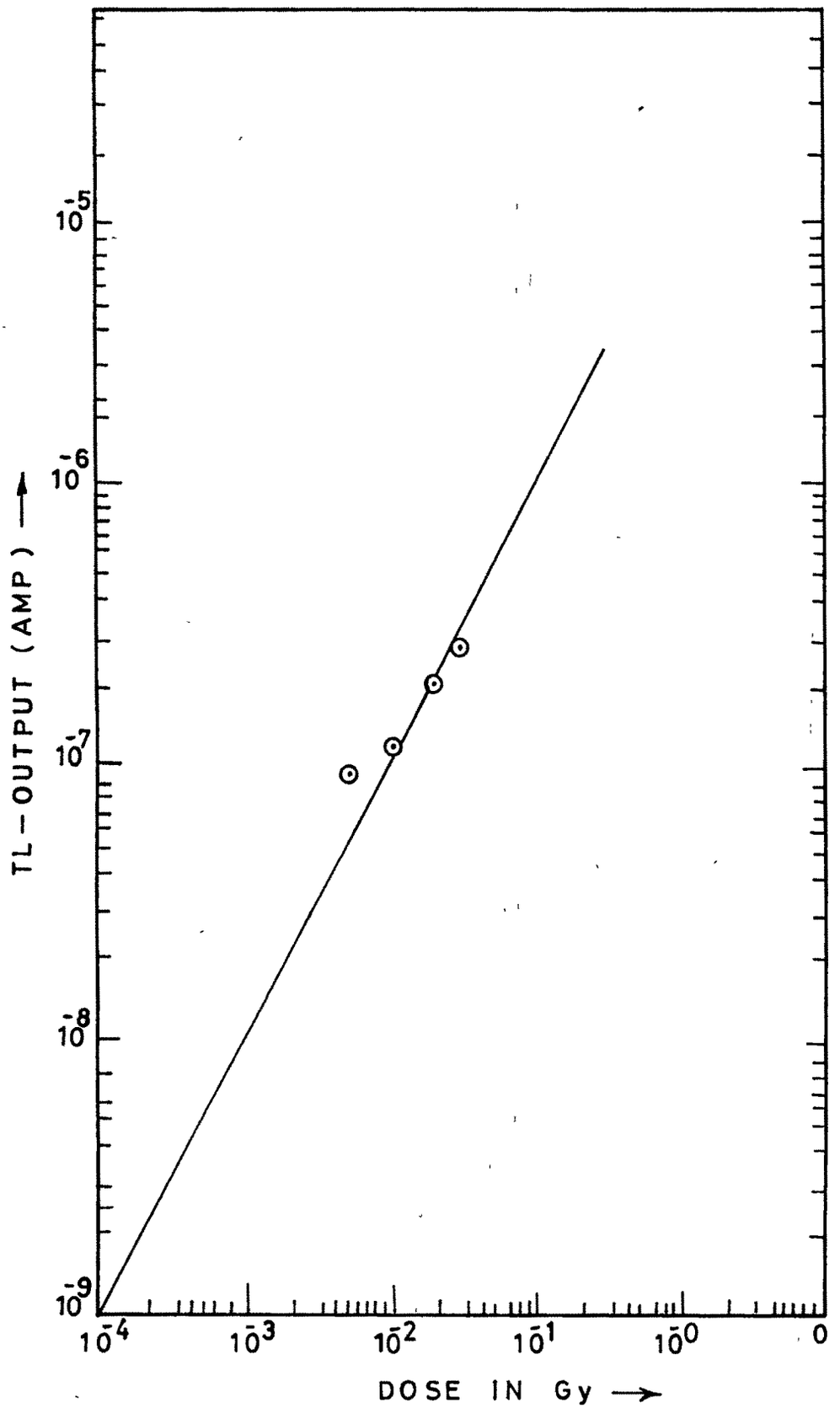
TL – OUTPUT (AMP) →
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻⁴
10⁻³
10⁻²
10⁻¹
10⁰
0
DOSE IN Gy →

FIGURE : 43

FIGURE - 44 ; INTRINSIC TL SENSITIVITY OF NaCl:Ca(T)
AS A FUNCTION OF UV IN Jm^{-2} '——'
AND GAMMA DOSE IN Gy '-----'.

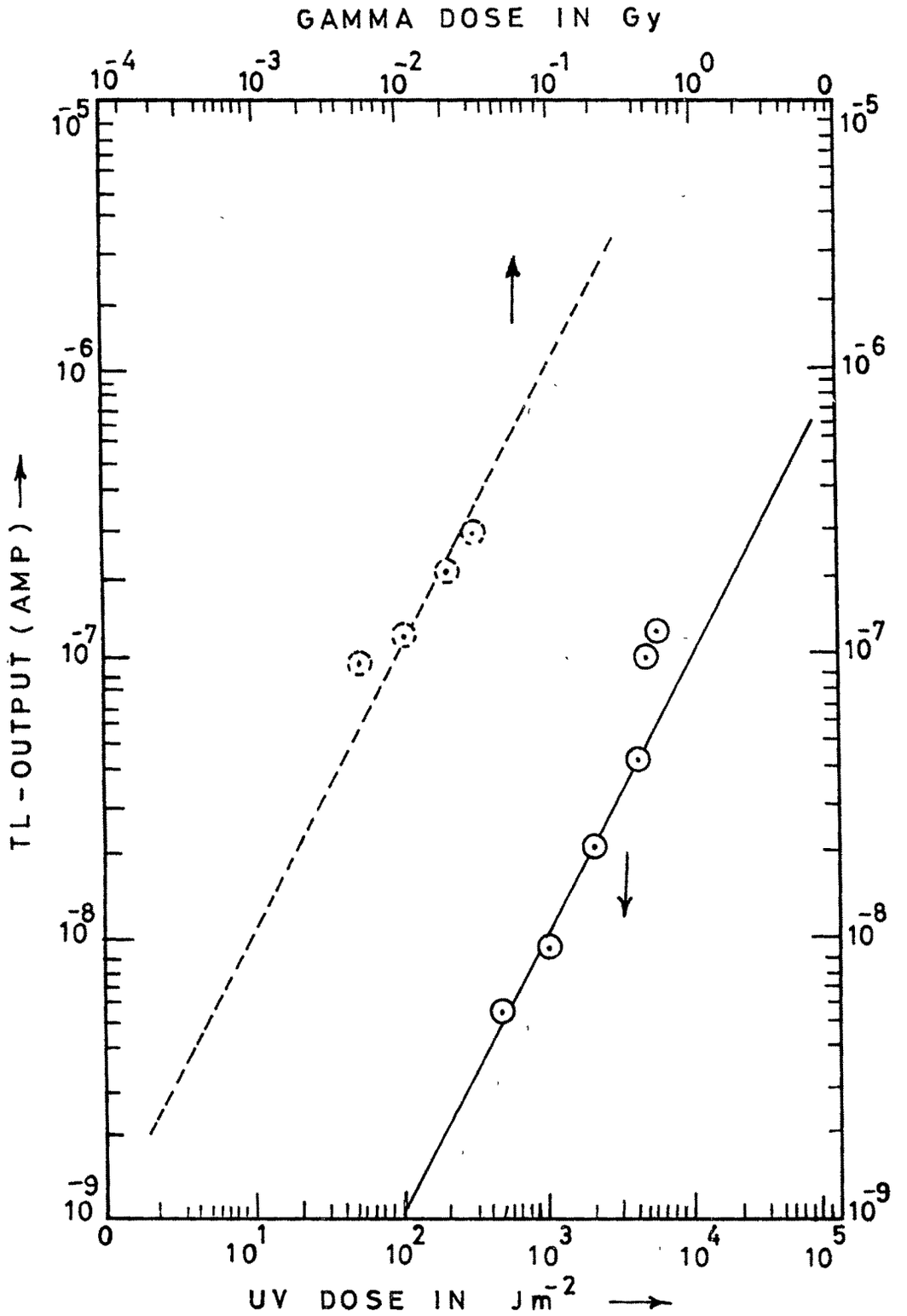
GAMMA DOSE IN Gy
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
0
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
TL - OUTPUT (AMP) ⟶
0
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
UV DOSE IN Jm^{-2} ⟶

FIGURE : 44

FIGURE - 45 : INTRINSIC TL SENSITIVITY OF NaCl:Ca(T) IN EQUIVALENT GAMMA DOSE IN Gy AS A FUNCTION OF UV EXPOSURE IN Jm^{-2}.

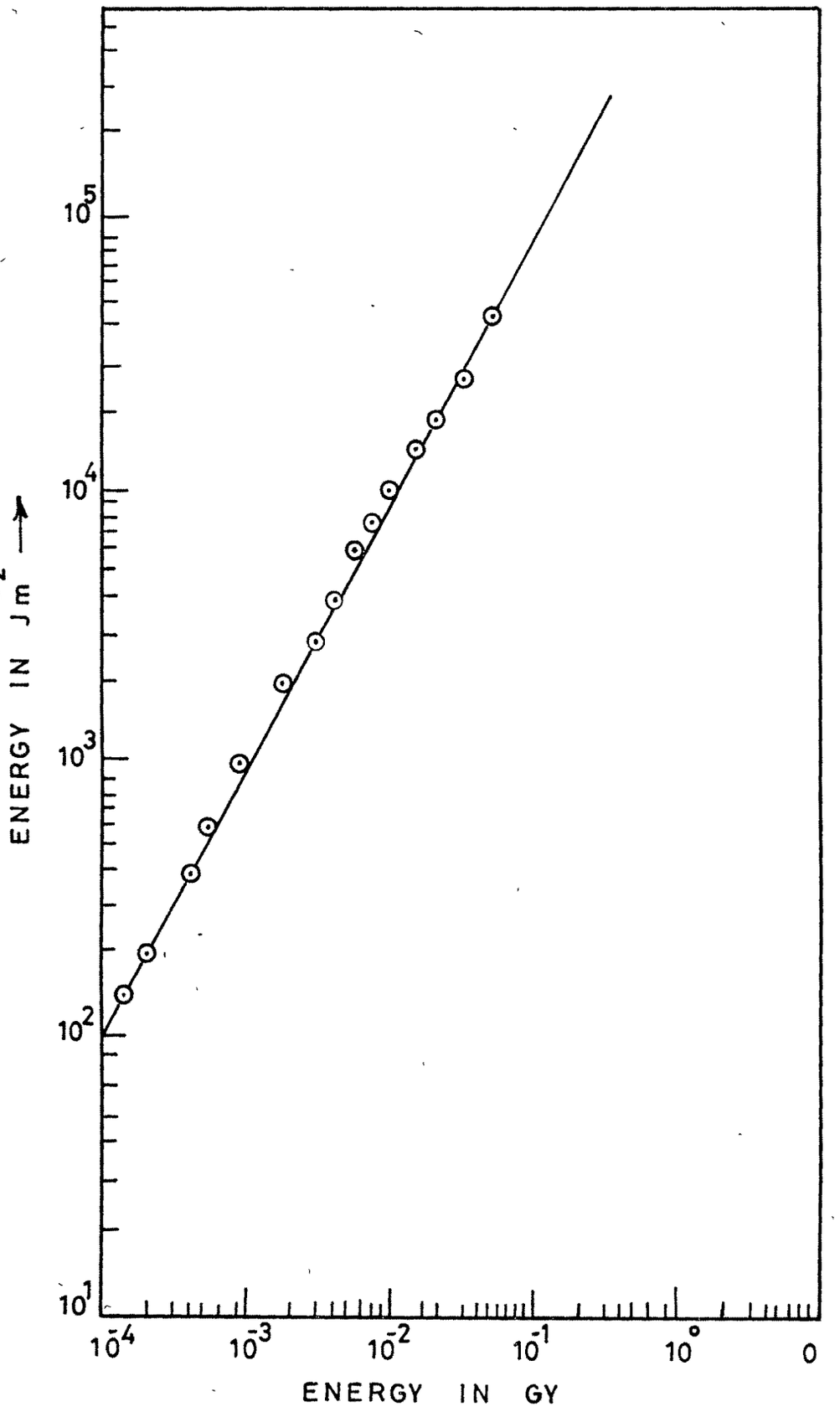
ENERGY IN Jm^{-2}
10^5
10^4
10^3
10^2
10^1
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
0
ENERGY IN GY

FIGURE : 45

FIGURE - 46 : TL GLOW CURVES FOR COMPRESSED SPECIMEN

(A) NaCl, Annealed and quenched from 750° C and Pressed.

(B) NaCl:Ca (10^{-4} m.f.), Annealed and quenched from 750° C and Compressed.

(C) NaCl:Ca(T) Tablet.

Curves : ..... POWDER FORM

——— PELLET FORM.

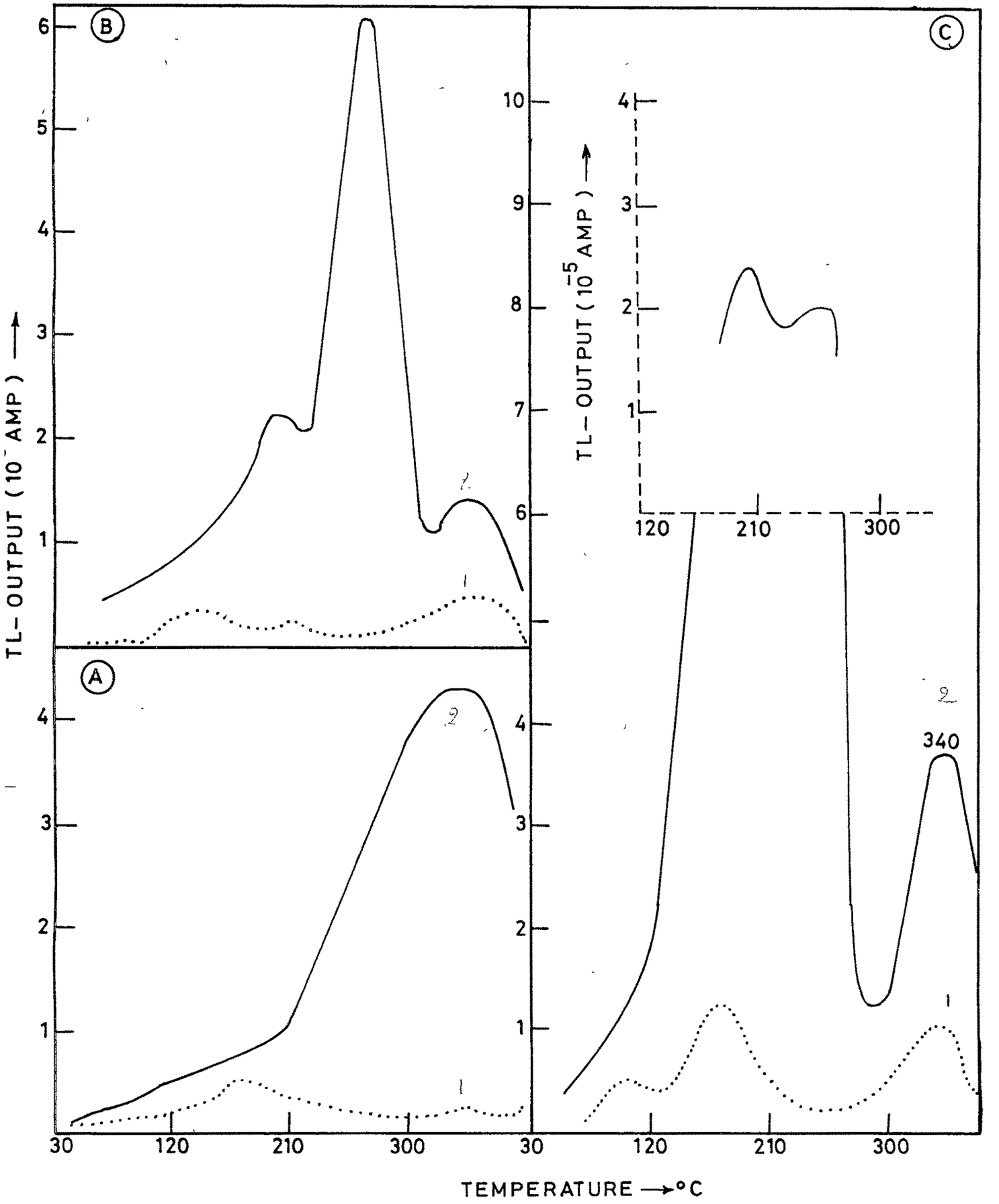
B
C
A
TL- OUTPUT (10⁻ AMP) ⟶
TL- OUTPUT (10⁻⁵ AMP) ⟶
1
2
340
30
120
210
300
TEMPERATURE ⟶ °C

FIGURE : 46