Basic equation of radiation dosimetry by TL

$$p = s\exp\left(-\frac{E}{kT}\right) \qquad (1)$$

Let us define N as the concentration of empty traps in the material. During irradiation at a dose rate dD/dt the filled traps are

$$N_f = N - n \qquad (2)$$

where n is the concentration of the remaining empty traps. So the rate of decrease of n can be written as

$$-\frac{dn}{dt} = A \cdot n \frac{dD}{dt} \qquad (3)$$

where A is a constant of the material, called radiation susceptibility.

Making the assumption that no trapped electrons are thermally released during the irradiation (i.e., the filled traps are deep enough to resist to a thermal drainage), Eq.(2) can be integrated as follows, with the initial condition that at $t=0$, $n=N$

$$\int_N^n \frac{dn}{dN} = \int_0^t - A \frac{dD}{dt} dt$$

from which

$$n = N \exp(-A \cdot D) \tag{4}$$

where D is the total irradiation dose received by the material during the irradiation time t.

It is now possible to define the constant A considering that if $D_{1/2}$ is the radiation dose needed to fill half of the empty traps, from Eq.(3) we obatin

$$A = \frac{0.693}{D_{1/2}}$$

The filled traps at the end of the irradiation is given by

$$N_f = N[1 - \exp(-A \cdot D)]$$

The heating phase of the irradiated sample, for obtained thermoluminescence, can be expressed as follows

$$-\frac{dN_f}{dt} = p \cdot N_f = N_f \cdot s \cdot \exp\left(-\frac{E}{kT}\right)$$

and the intensity of thermoluminescence, $I(D,T)$, is then given by

$$I(D,T) = -C\frac{dN_f}{dt} = C \cdot s \cdot N[1-\exp(-A \cdot D)]\exp\left(-\frac{E}{kT}\right) \qquad (5)$$

If $A \cdot D < 1$ for small values of D, 1-exp(-$A \cdot D$) can be approximated to AD and then Eq.(5) becomes

$$I(D,T) = C \cdot s \cdot N \cdot A \cdot D \cdot \exp\left(-\frac{E}{kT}\right) \qquad (6)$$

from which it is easily observed that the TL intensity at a given temperature, i.e., the glow peak temperature, is proportional to the received dose D.

Basic equation of radiation dosimetry by TL

$$p = s \exp\left(-\frac{E}{kT}\right) \quad (1)$$

$$I(D,T) = C \cdot s \cdot N \cdot A \cdot D \cdot \exp\left(-\frac{E}{kT}\right)$$

Linearity of TL signal versus dose

TL dose response

Attribute different doses to the material and subsequently plot either the integrated intensity or the TL peak's maximum intensity versus Dose.

The TL signal is a function (F) of the absorbed dose D. Ideally $F(D)$ shows a linear dose response over a wide dose range at least over the range of interest of the application. However, most materials used in practical dosimetry show a variety of non-linear effects. A pattern that is found frequently as the dose is increased is first a linear response, then a supralinear and finally during the approach to saturation a sublinear response. The

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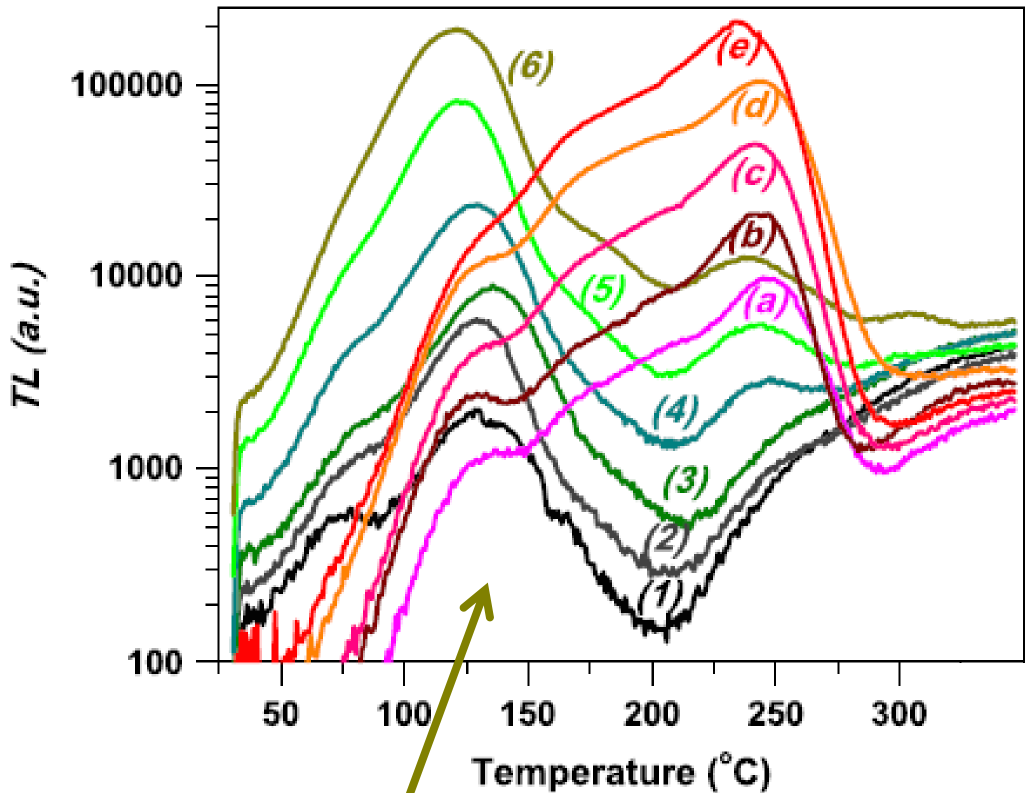


Natural salt

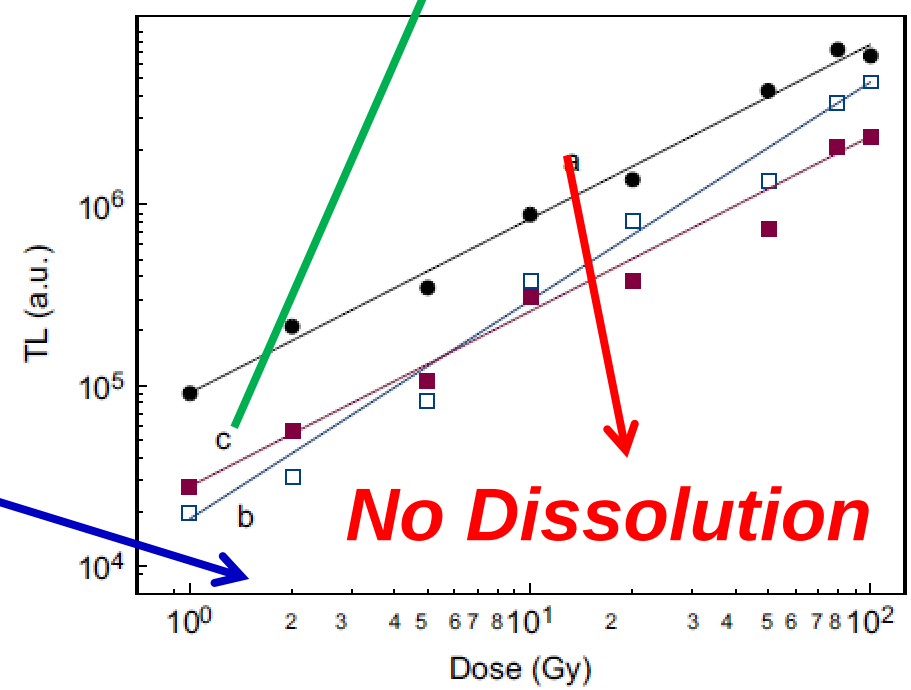
Dissolution

+

Re-crystallization

Glow curves for all doses

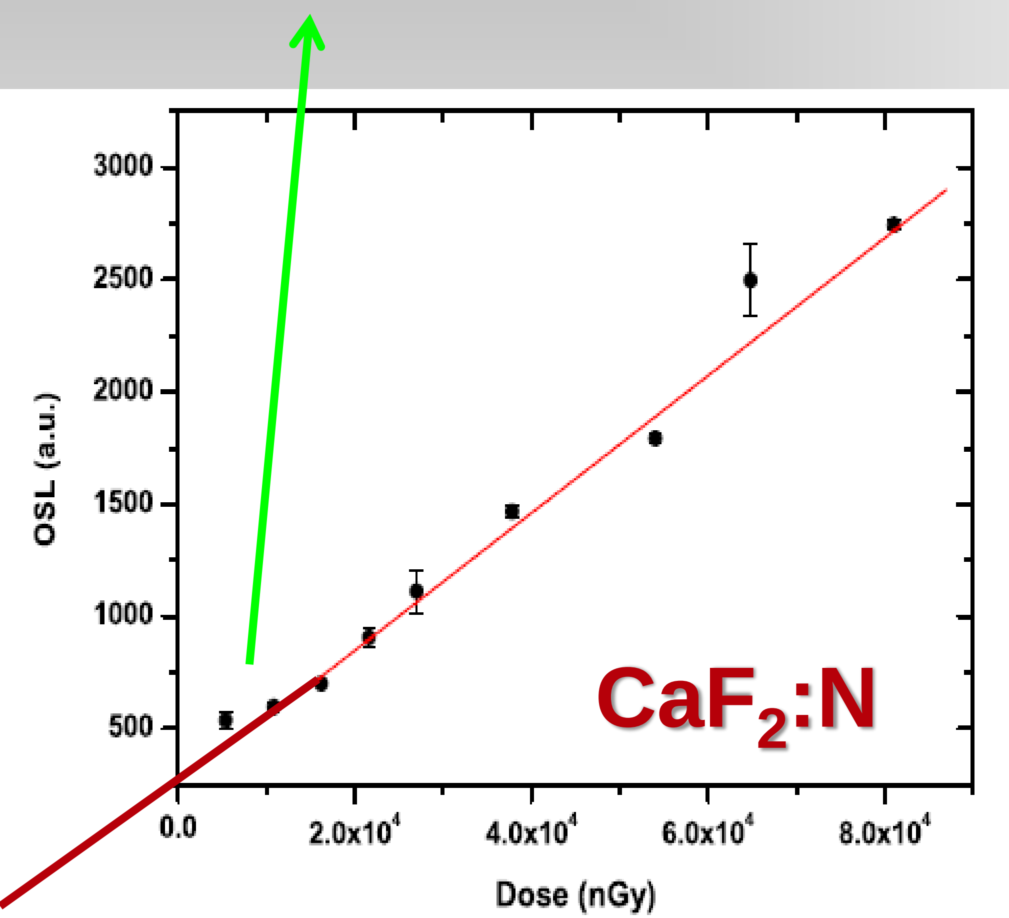
Dose response

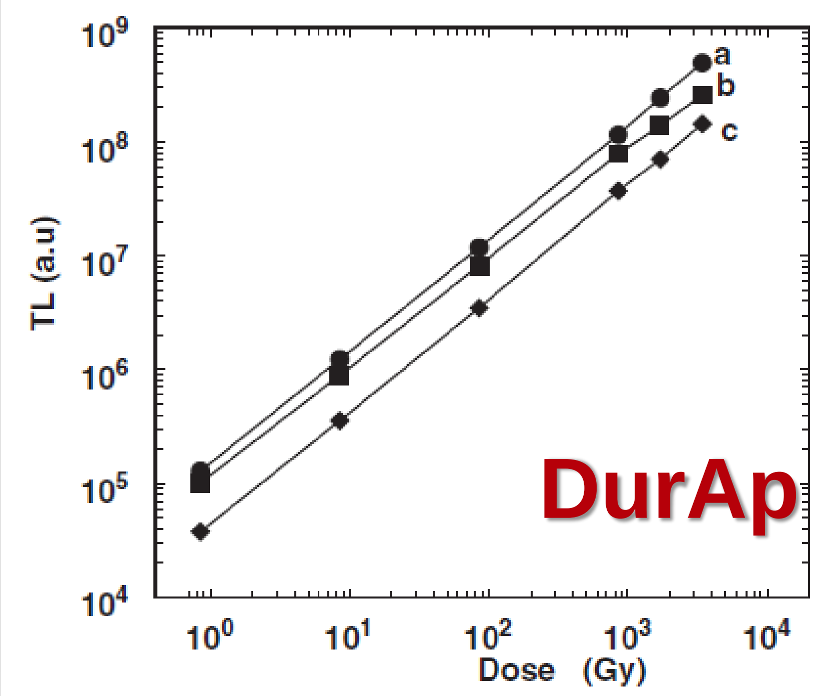


No Dissolution

CaF_2:N versus Durango apatite

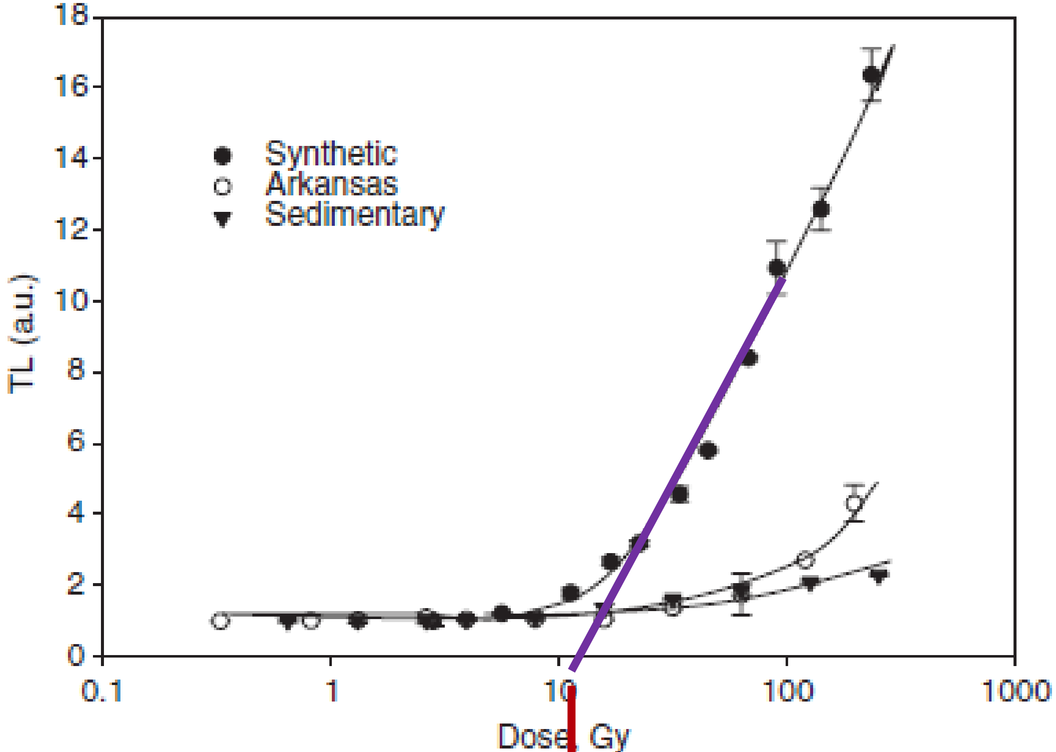
Low dose Supralinearity



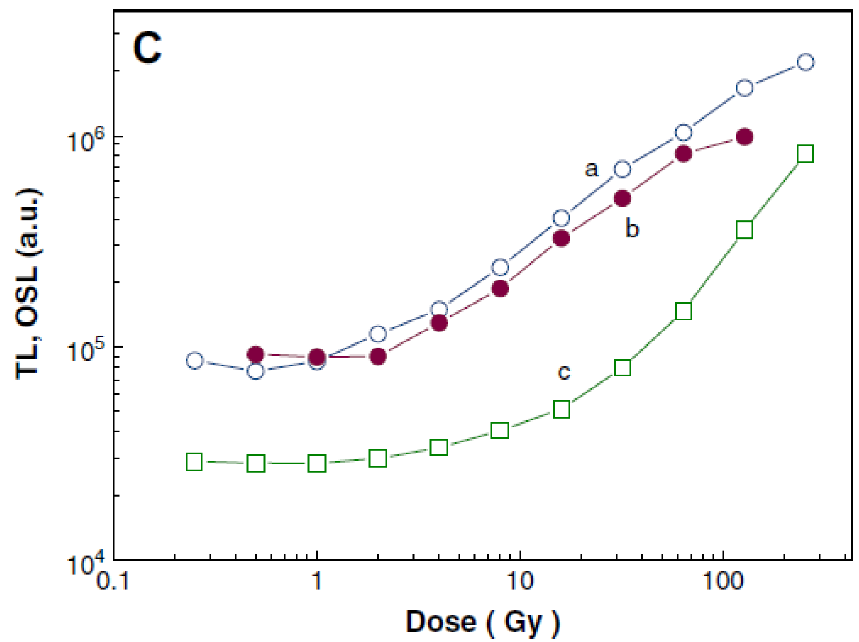


Differences:

- Dose range
- Intensity
- Shape
- Scale

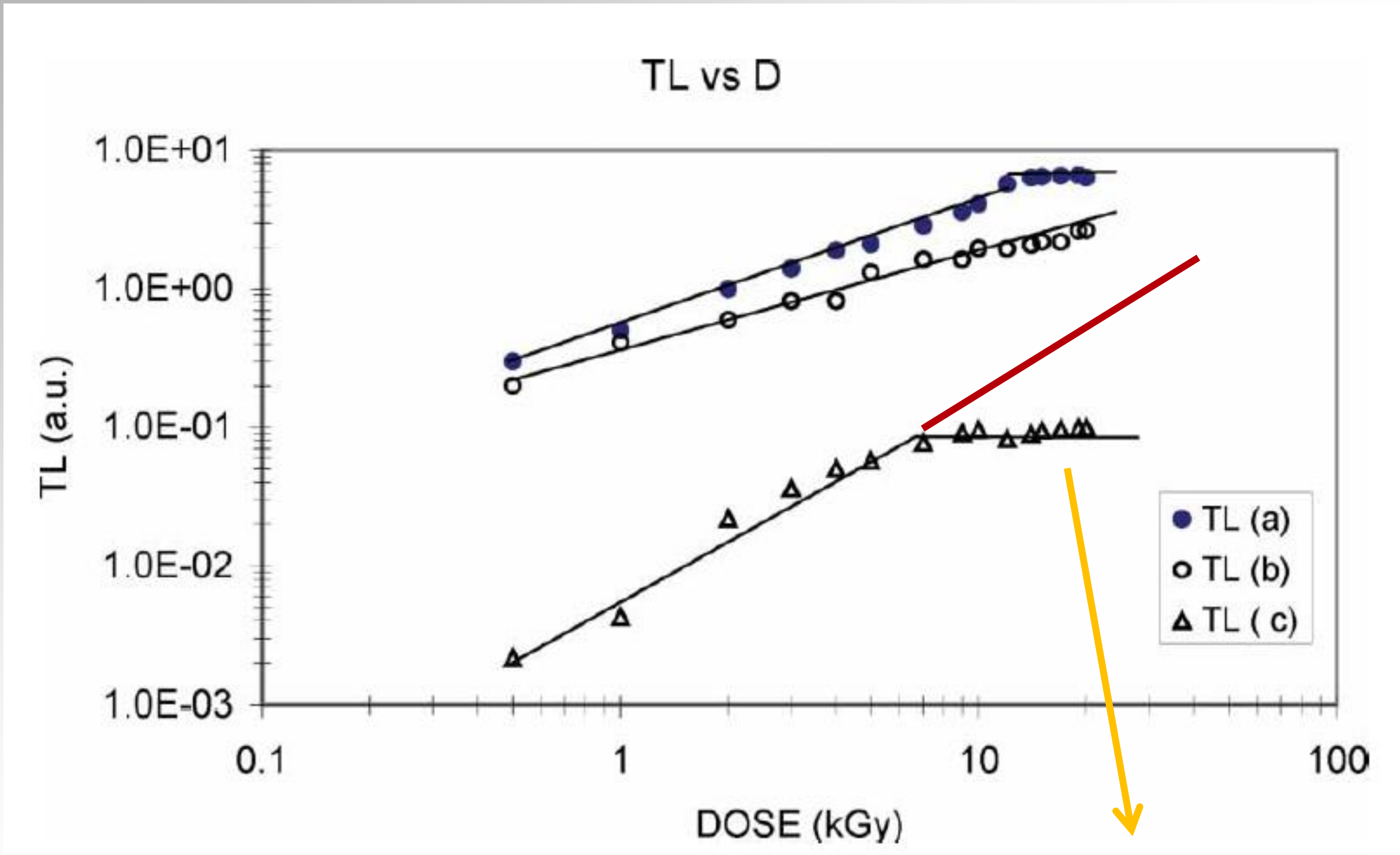


Low dose Supralinearity

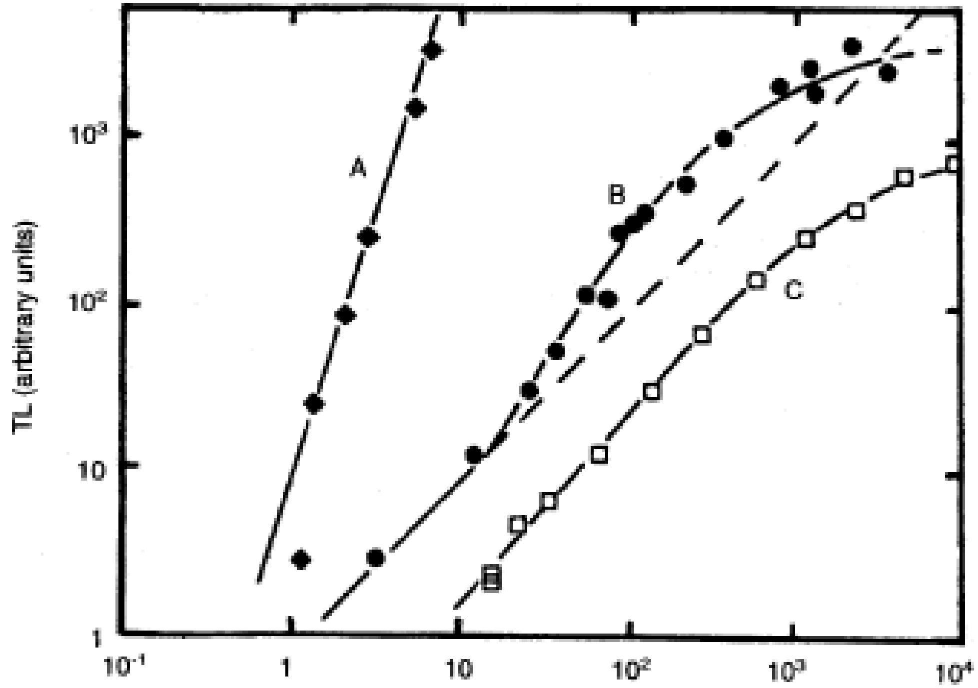


Lowest Detectable Dose Limit Estimation

Saturation Sublinearity: no more empty traps



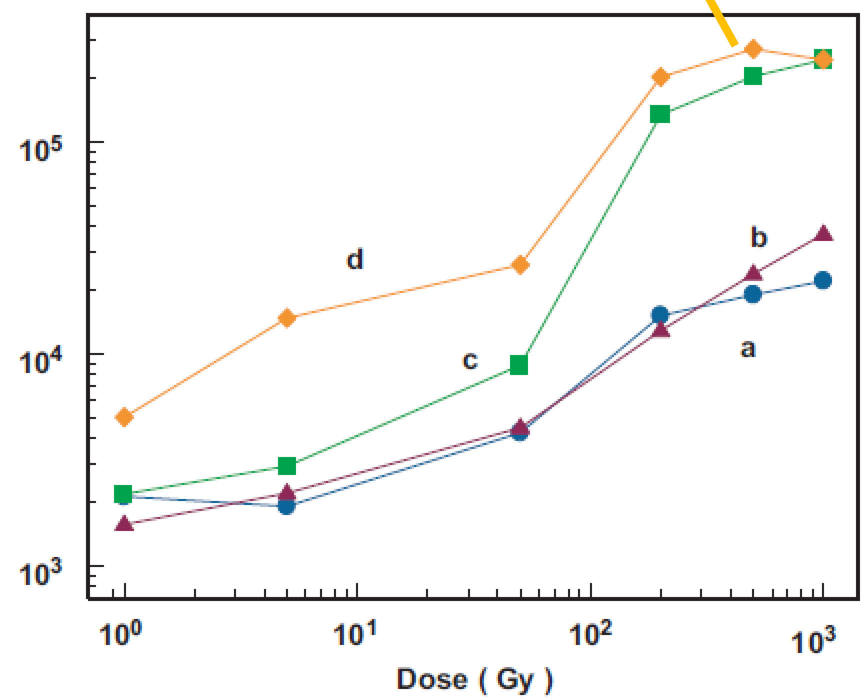
Almost Flat Dose Response

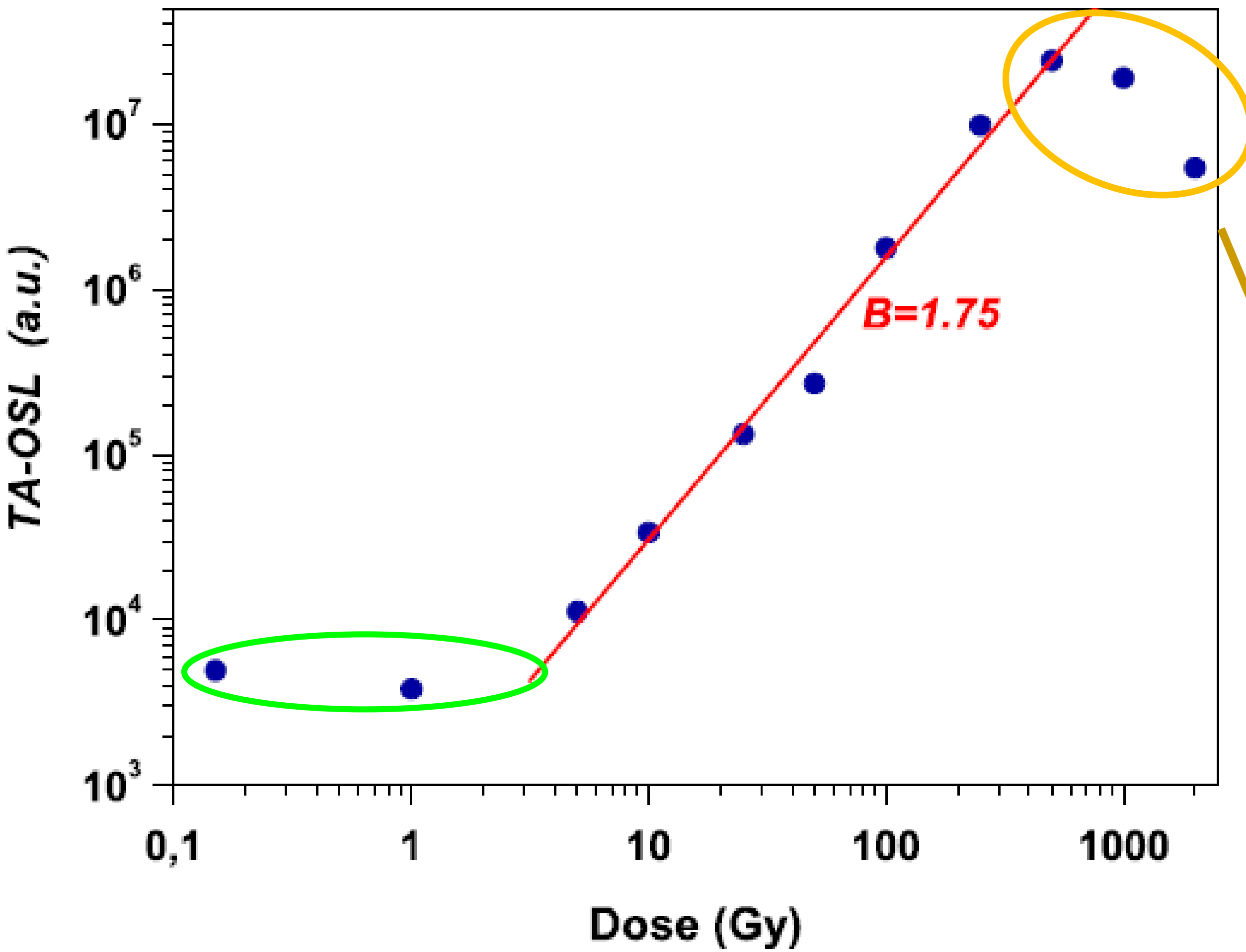


Saturation Sublinearity

Logarithmic Scale

1. **Why?**
2. **Misleading**



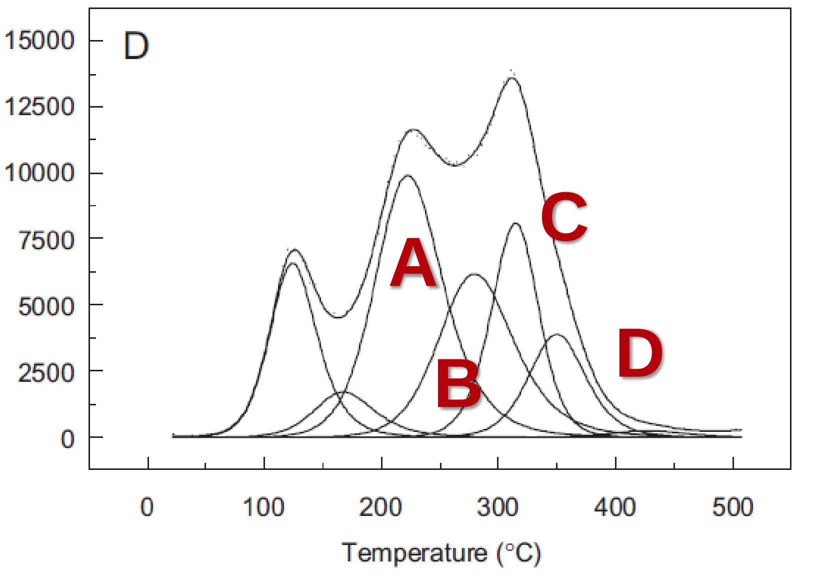


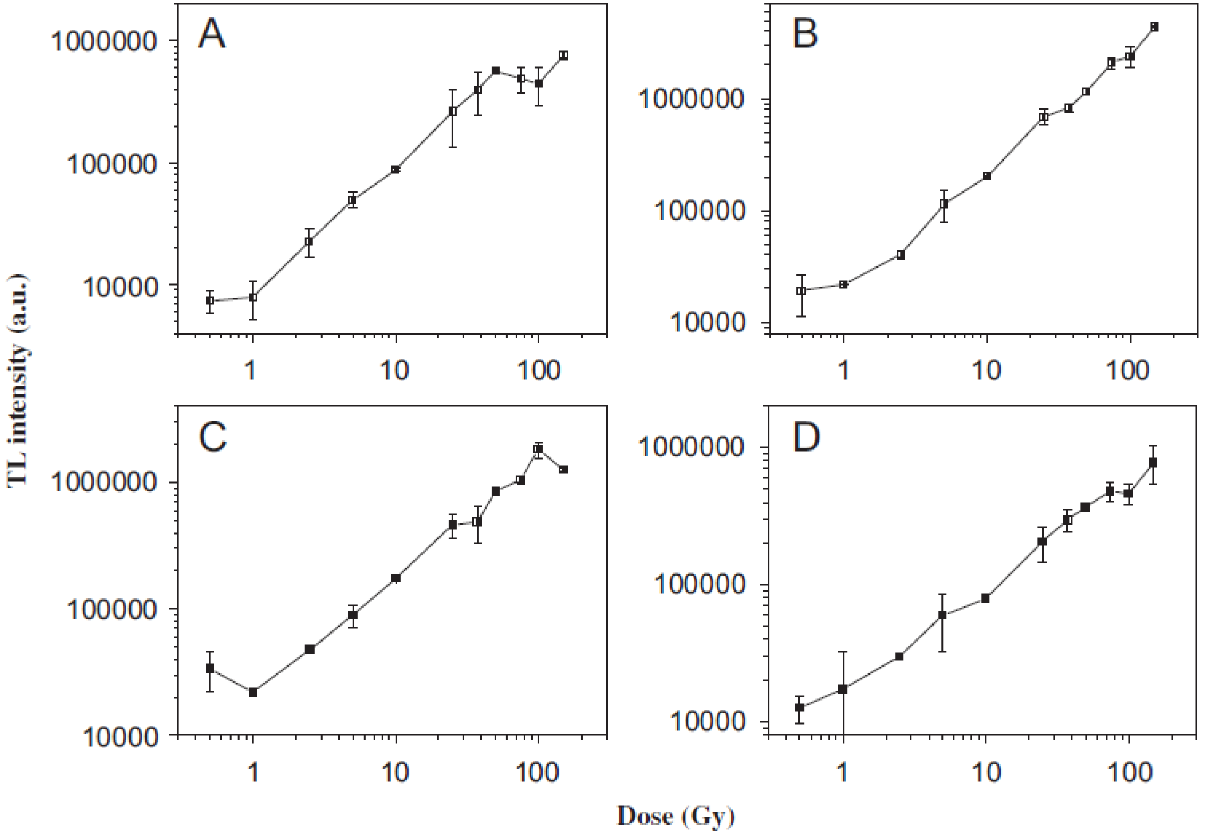
Al_2O_3:C

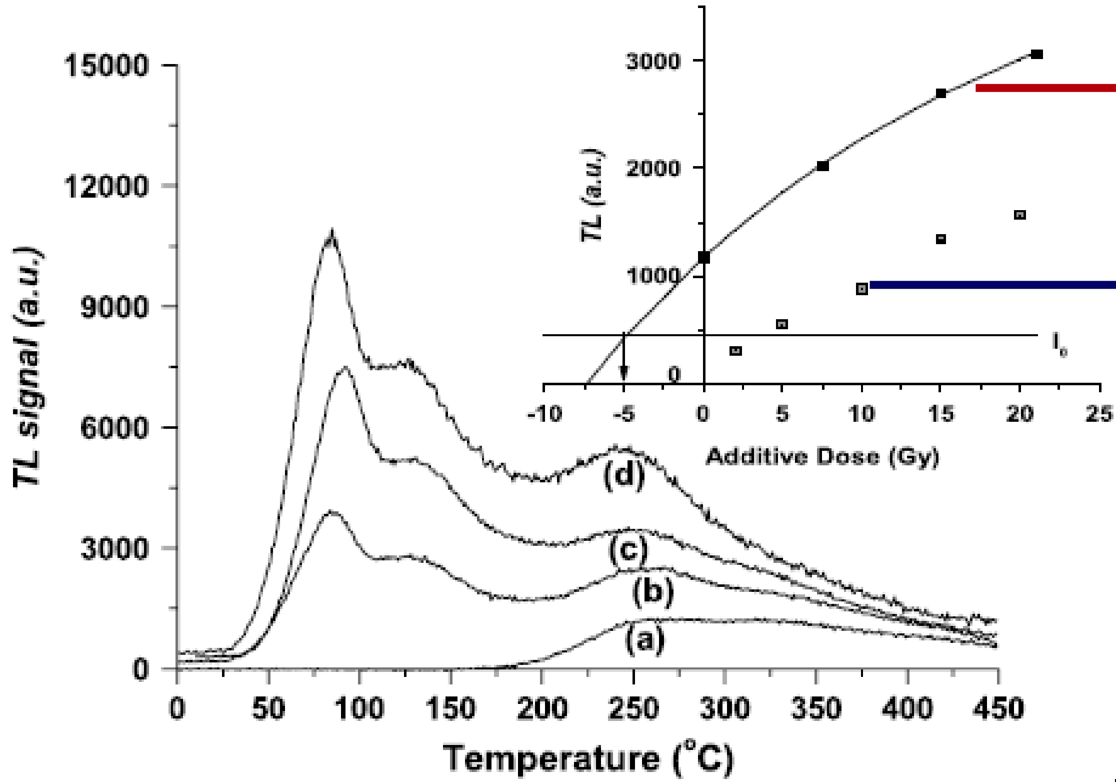
Radiation Damage

Typical Dose Response

Quartz-based materials



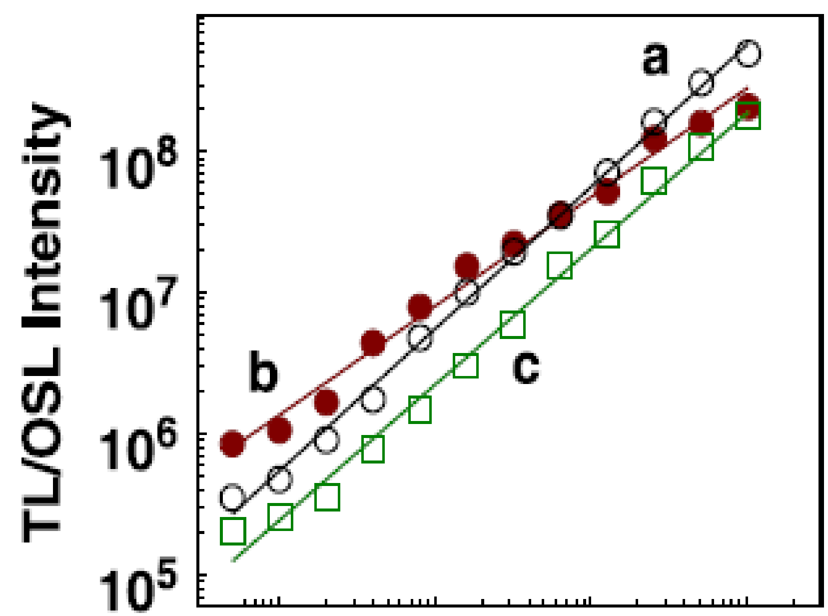


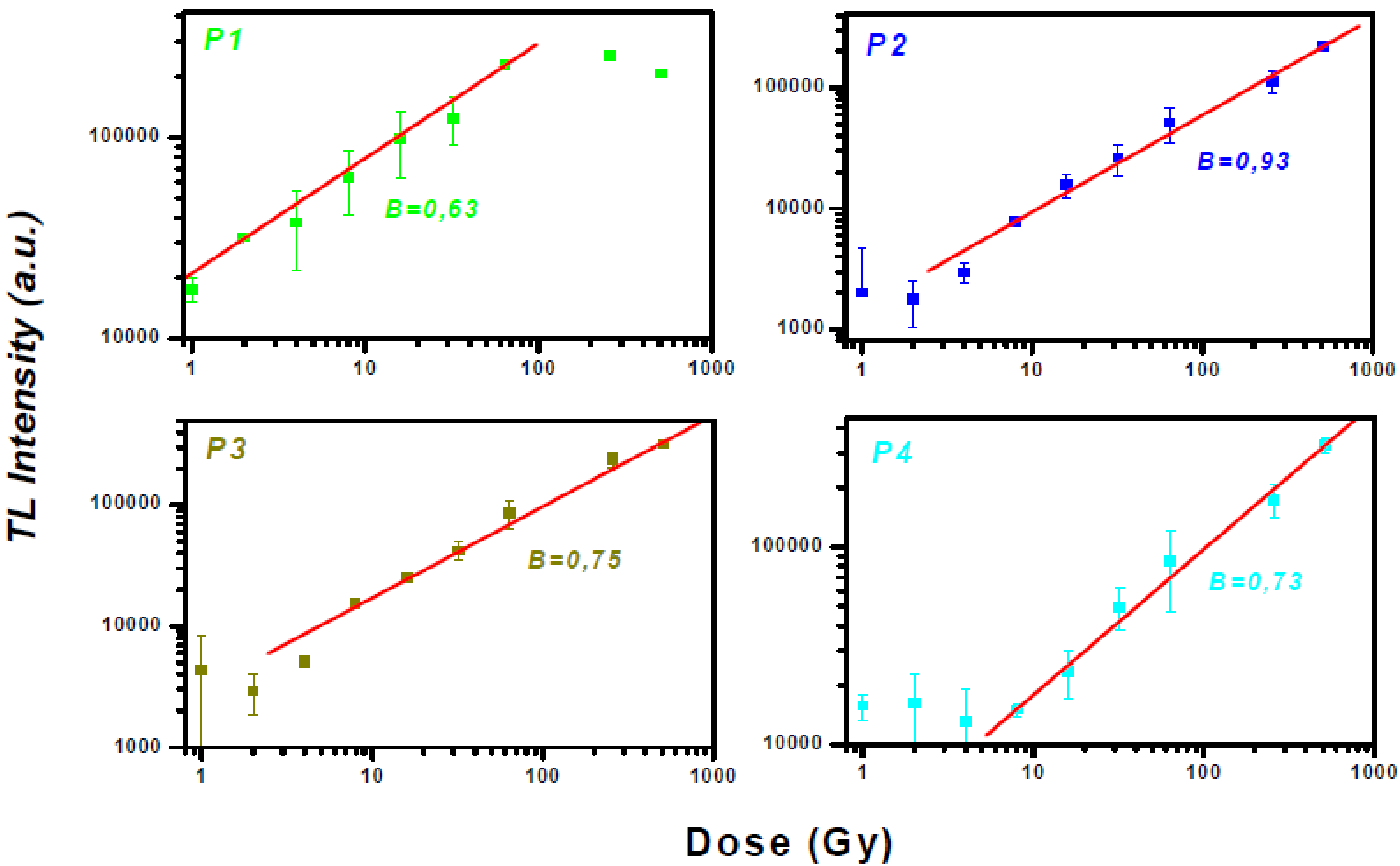


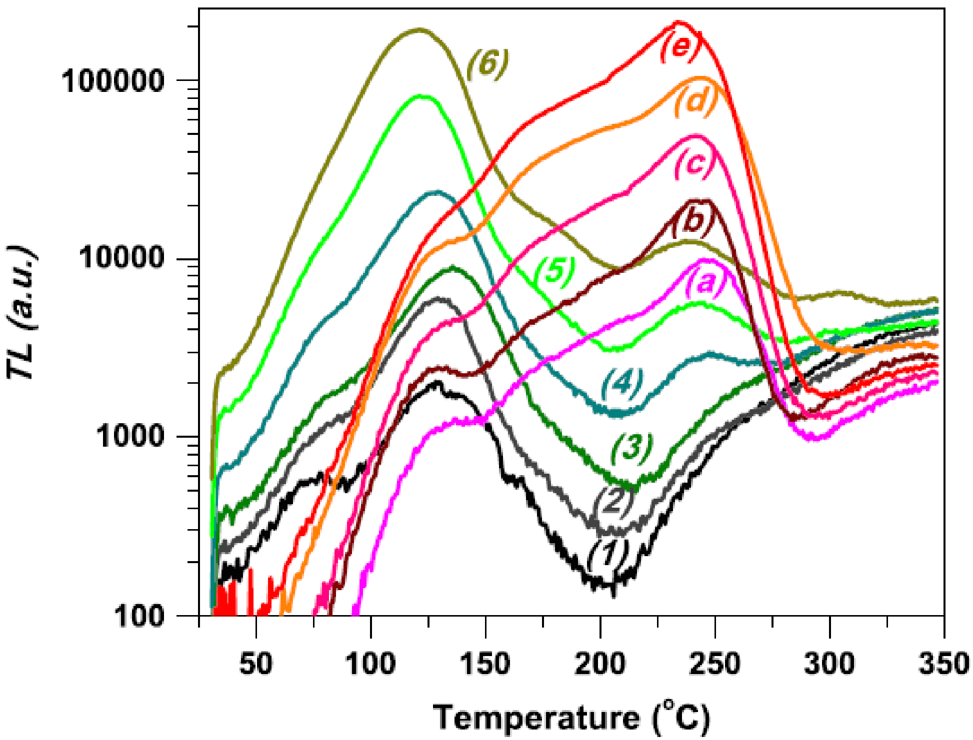
Exponential

Linear

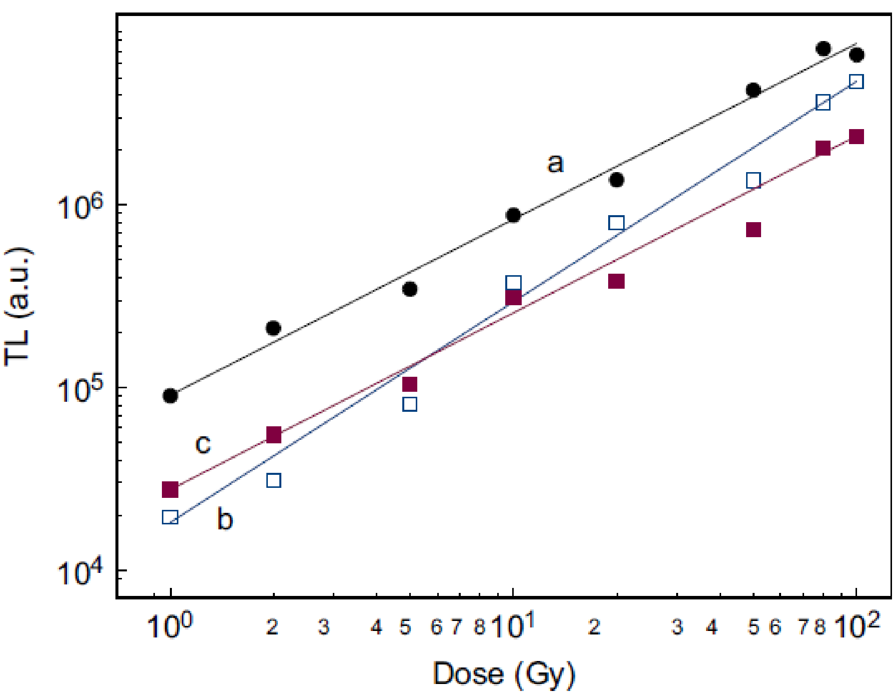
$$I = I_0\left(1 - e^{-D/D_0}\right)$$




P1
B=0,63
P2
B=0,93
P3
B=0,75
P4
B=0,73
100000
10000
1000
1
10
100
1000
TL Intensity (a.u.)
Dose (Gy)

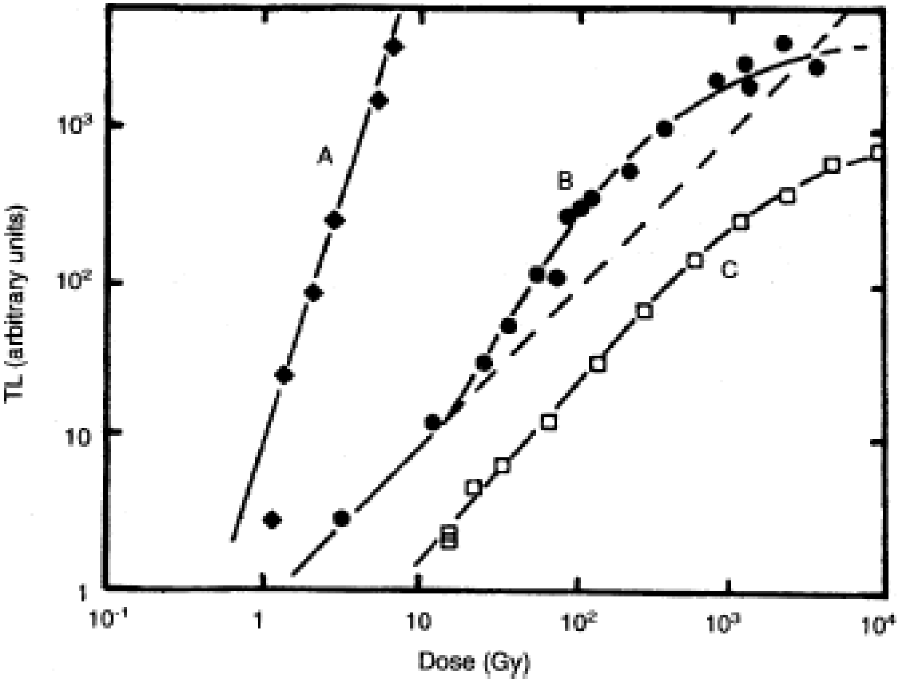


Natural salt



Normalised Dose response – supralinearity index

$$f(D) = \frac{F(D)/D}{F(D_1)/D_1},$$



where $F(D)$ is the dose response at a
D_1 is a low dose at which the dose
linear. The ideal TLD material has $f($
wide dose range. If $f(D) > 1$ the respo
supralinear, if $f(D) < 1$ the respons
sublinear. These features are illustrate
adopted for McKeever et al. [6] and a
in depth in this issue by Horowitz [24] and Horowitz et al. [25], for gamma rays and heavy charged particles, respectively.

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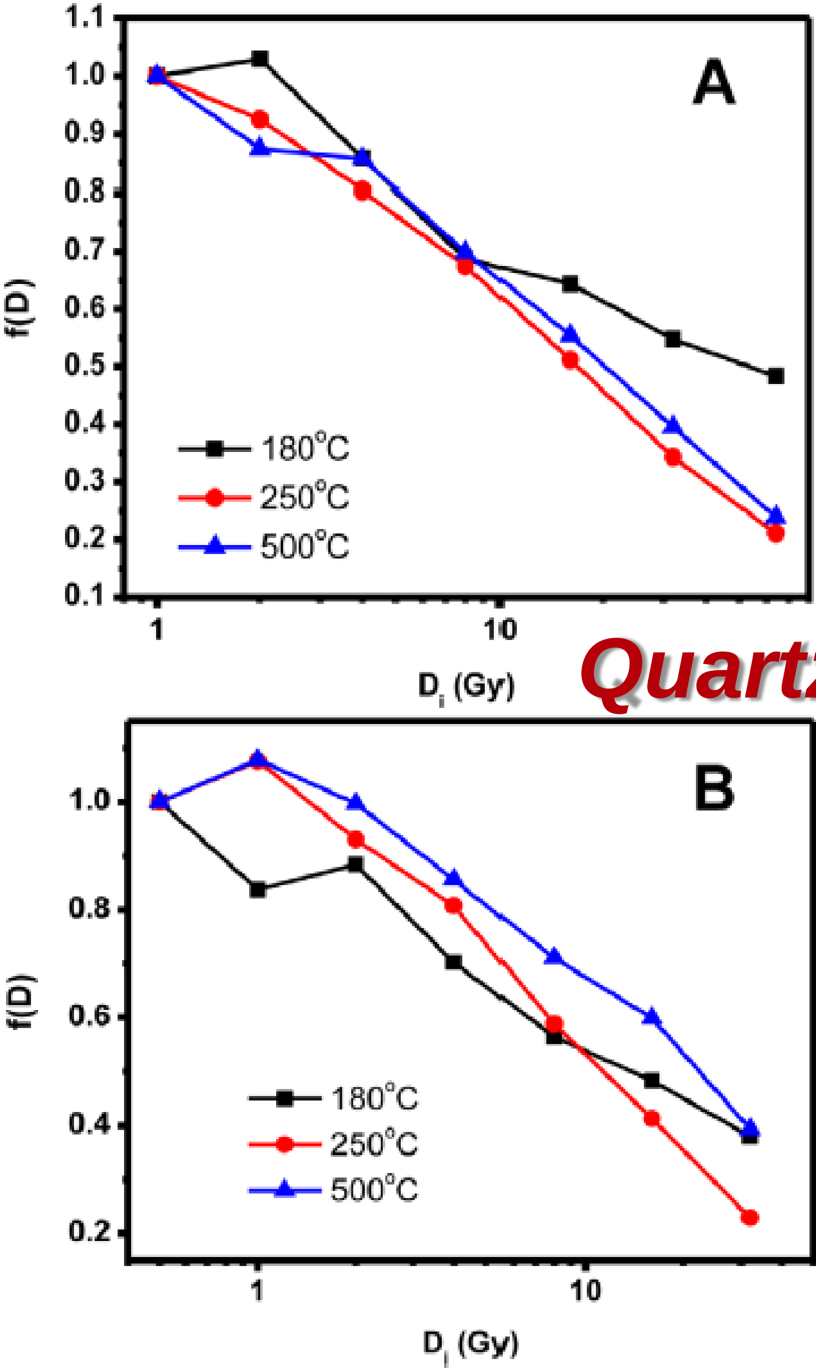
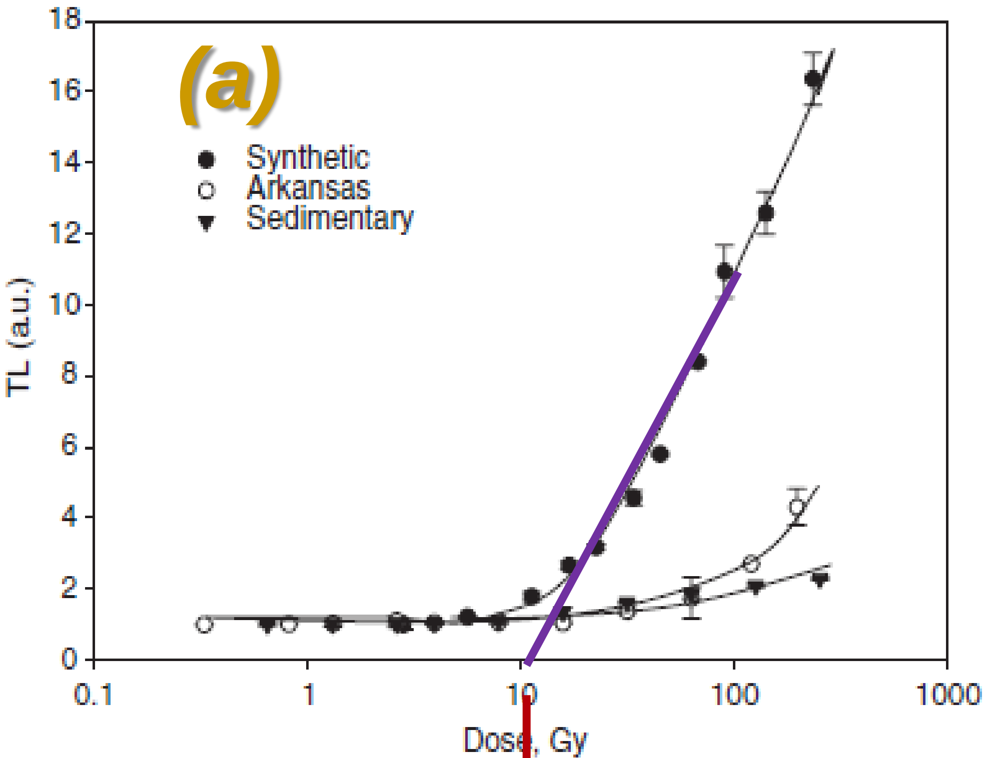
supralinearity index examples



Quartz

Detection Limits: Low



Lowest Detectable Dose Limit Estimation

(b)

The lower limit of detection is important in low dose measurements where the signal of an irradiated TLD is almost the same as the signal of the background. It is defined as the smallest absorbed dose that according to an analytical process can be detected at a specified confidence level.

BGK measurement, Finding error

$$Error = \sqrt{BGK}$$

Dose corresponding to signal = BGK+3Error