Ancient TL

Mejdahl, V., Shlukov, A., Shakhovets, S., Voskovskaya, L. and Lyashenko, H., 1992. *The effect of shallow traps: a possible source of error in TL dating of sediments.* Ancient TL 10(2): 22-25.

The effect of shallow traps: a possible source of error in TL dating of sediments

Vagn Mejdahl[§], A.I. Shlukov[†], S.A. Shakhovets[†], L.T. Voskovskaya[†] & H.G. Lyashenko[†]

§ The Nordic Laboratory for Luminescence Dating, The Department of Geology, University of Aarhus, DK-8000 Aarhus C, Denmark.
† INFORM-GEO Co. Ltd., Society of Geology of Russia, 10, 2 Roshinskaya, Moscow, 113191, Russia.

In a recent TL dating study of Eemian and Early Weichselian deposits in Denmark (Kronborg and Mejdahl 1989) severe underestimates of ages were encountered, e.g. ages of 80-90 ka for typical Eemian deposits with an expected age around 125 ka. The same result was obtained with optically stimulated luminescence (Mejdahl unpublished). Similar underestimates for deposits of comparable ages have been reported by Balescu et al. (1991) for K- feldspars from interglacial beach sands. A small part of the underestimate, perhaps 10 ka for ages around 100 ka, might be ascribed to thermal fading (Mejdahl 1988a, 1989). In addition, it has been found that the use of a particular filter, Schott UG11, could cause underestimates (Balescu and Lamothe (1992), Balescu et al. (1992), Grün et al. (1989) and Wintle and Duller (1991)). In the measurements of the Danish sediments where a blue filter, Corning 5-60, was used rather than the UG11 filter the large difference between measured and expected ages is still unexplained.

Wintle and Packman (1988) and Shlukov et al. (1992) pointed out that a substantial underestimate of luminescence ages might result from the large difference between natural dose rates and those used in laboratory irradiation of samples combined with presence of shallow traps in the minerals. When minerals are irradiated in nature such traps maintain only a very small equilibrium population of trapped charge, but during laboratory irradiation they become filled and may go into saturation. If the shallow traps saturate at a lower dose than that required for saturation of the deeper traps used for dating, additional charges become available for the deeper traps with the result that from a certain dose level the growth of the luminescence signal with dose will be faster for laboratory irradiation than for irradiation in nature.

In the present work potassium feldspar was studied. After laboratory irradiation this mineral has a TL peak at about 150 °C (heating rate 8 °C/s) in addition to the two characteristic peaks at around 230 °C and 330 °C present in laboratory irradiated as well as natural samples (see e.g. Bøtter-Jensen et al. 1991, fig.4, and Mejdahl 1990, figs.7 and 8).

The situation arising in dating experiments is illustrated in fig.1 where the natural growth curve has been simulated (fig.1, B) by holding the samples at a temperature of 130 °C during laboratory irradiation (60Co gamma), thus keeping the traps corresponding to the 150 °C peak empty as in nature. After the irradiation the samples were kept at a temperature of 100 °C for one week in order to eliminate the effect of anomalous fading. It is seen that when a growth curve obtained by laboratory irradiation of samples held at room temperature (fig.1, A) is used for estimating the palaeodose rather than the "natural" growth curve (fig.1, B) then the palaeodose will be underestimated, especially when using the regeneration technique. A growth curve for the 150 °C peak is shown in fig.2. It is interesting to note that this peak shows initial sublinear growth, but does not appear to saturate until about 900 Gy. This is well above the dose level at which curves A and B in fig.1 deviate.

Shlukov and Sakhovets (1987) and Shlukov et al. (1992) in a study of quartz circumvented the dose rate problem as well as the problems of thermal fading and "radiation fading", i.e. the eviction of charges from traps caused by irradiation (also called radiation quenching), by constructing a natural "master curve" which in its simplest form is an exponential function:

$$S = S_o \, (1 - \exp(-D/D_s)) \quad (1)$$

where
S is the luminescence signal. S_o is the signal at saturation. D is palaeodose. D_s is a parameter to be determined.

The expression (1) was found to be valid for a specific mineral from a certain region. S_o was determined by measuring the signal from infinitely old samples (about 30 Ma) from the region and D_s was determined by measuring the signal from a sediment of known age. The method assumes that minerals from different sediments have the same growth characteristics and that the signal was bleached to its minimum value at the time of deposition.
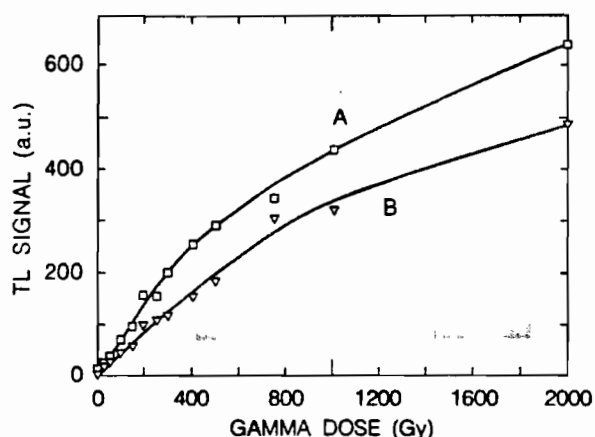
Figure 1.
TL growth curves for the 330 °C peak in K-feldspar samples from a Danish site, Stensigmose (R-909008). Natural samples were exposed to a Philips fluorescent lamp, TL05 for 50 h and irradiated with ^{60}Co gamma radiation at a dose rate of about 70 Gy/min. The samples used for curve A were irradiated at room temperature and those for curve B at a temperature of 130 °C. Prior to the TL measurements the samples were kept at 100 °C for one week in order to eliminate the effect of anomalous fading.
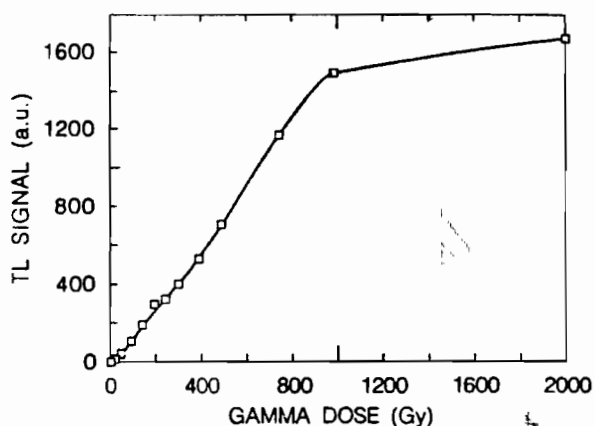

Figure 2.
TL growth curve for the 150 °C peak in a K-feldspar sample from Stensigmose.

The approach in the present paper, which deals with K-feldspar in the 100-300 μm range extracted from natural sediments, was to attempt to suppress the 150 °C peak by holding the samples at an elevated temperature during irradiation, thereby simulating the natural situation. This idea was proposed by Wintle and Packman (1988) in a study of fine-grain loess samples. Using a range of temperatures up to 123 °C and a dose of about 130 Gy they studied the shape of the resulting glow curves, but

found no effect beyond a glow curve temperature of 270 °C. As suggested by A.G. Wintle (personal communication) it is conceivable that the dose used was too low for a clear effect to be seen.

The suppression of the 150 °C peak by irradiating a sample at 130 °C is illustrated by comparing the glow curves in figs.3 and 4. Two natural samples of K-feldspar (lab.no. R-909008) from a Danish site, Stensigmose were exposed to a Philips fluorescent lamp, TL05 for 50 h and then given a gamma dose of 200 Gy. One sample was irradiated at room temperature and the other at a temperature of 130 °C. TL glow curves for the two samples measured immediately after the irradiation are shown in figs. 3 and 4, respectively. The heating rate was 8 °C/s and the filters used were BG39 and HA3. The effect of suppressing the 150 °C peak is clearly seen. 130 °C was chosen as the lowest temperature that would cause an effective suppression of the 150 °C peak. It was verified that holding the samples at 130 °C caused no draining of the higher temperature peaks over the period of irradiation.

The effect of holding samples at an elevated temperature during irradiation was tested on a series of K-feldspar samples of different ages from the Thule area, Greenland (Kronborg and Mejdahl 1990). Figs.4 and 5 show plots of palaeodoses and TL ages, respectively, obtained by irradiating samples at 130 °C against the values obtained by irradiating at room temperature. The irradiation was carried out at a dose rate of about 70 Gy/min using a Co-60 gamma source. Palaeodoses were measured by means of the partial bleach technique of Mejdahl (1988b).

The regression lines for the dose and age plots have the equations:

$$Y = 0.87 + 1.35X \quad (2)$$

and

$$Y = 0.70 + 1.35X \quad (3)$$

respectively, i.e. they are almost identical. The correlation coefficients are high, 0.978 for both plots, but it should be emphasized, nevertheless, that with only nine points the results must be regarded as preliminary. It should be noted that even though the regression lines have been extrapolated to intercept the axes, the relationships cannot without further studies be extended to regions above and below those covered by the points.

The validity of the method on a regional basis was confirmed by extensive tests on sediments from the great Russian plain. Detailed studies of sediments from other regions including Caucasus, The Carpathians, The Urals, Altai and The Far East revealed certain regional
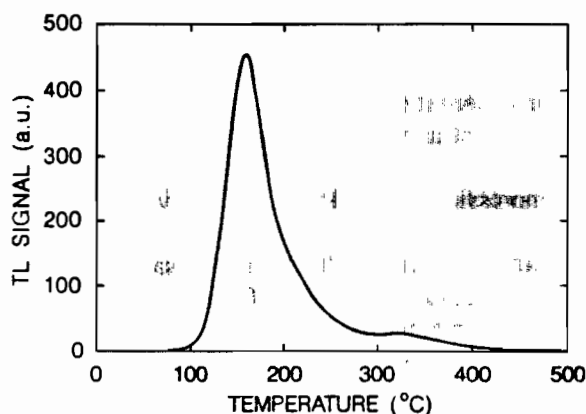
Figure 3.
TL glow curve for a K-feldspar sample from Stensigmose, Denmark (R-909008). The sample was exposed to the Philips TL05 lamp for 50 h and then given a gamma dose of 200 Gy at room temperature. The TL signal was measured immediately after the irradiation. Heating rate 8 °C/s, filters BG39 and HA3.
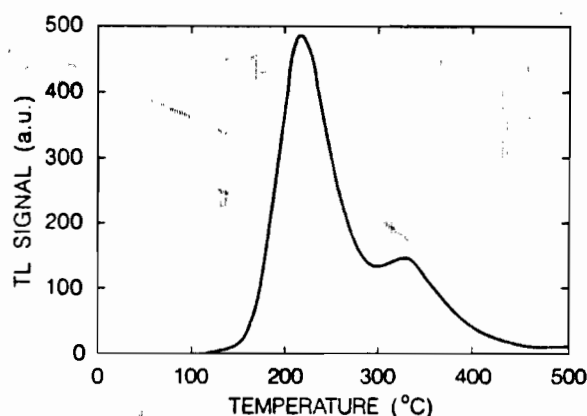

Figure 4.
TL glow curve for a K-feldspar sample from Stensigmose, Denmark (R-909008). Experimental conditions as in fig.3 except that the sample was held at 130 °C during gamma irradiation.
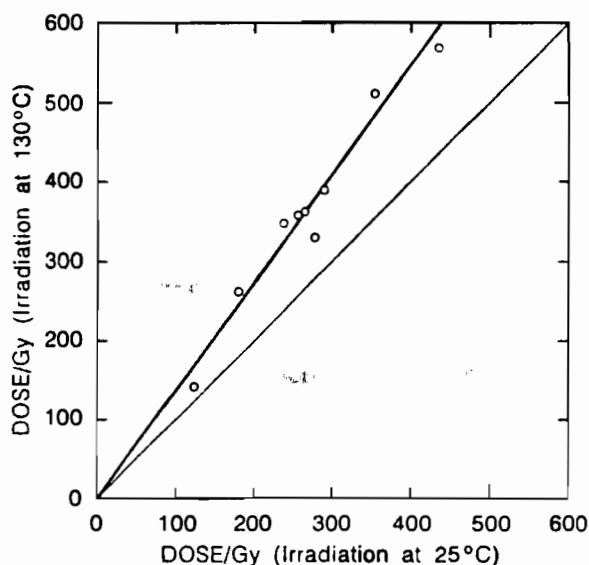

Figure 5.
Plot of palaeodoses for K-feldspar samples obtained by holding samples at 130 °C during gamma irradiation against those obtained by irradiation at room temperature for a series of samples from the Thule area, Greenland.
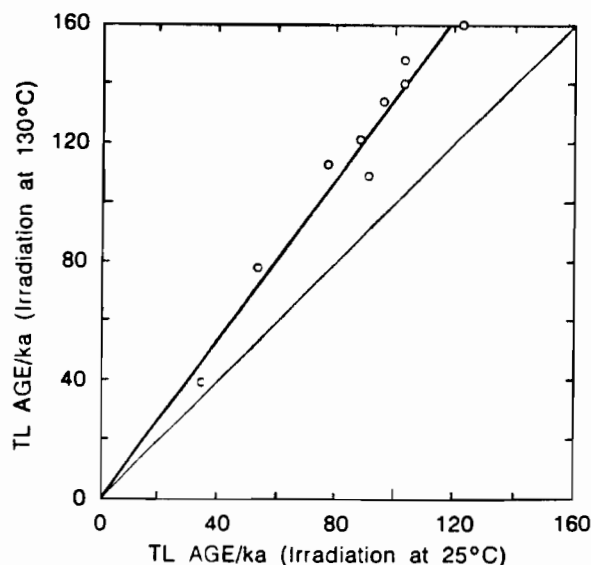

Figure 6.
Plot corresponding to fig. 5, but with TL ages rather than palaeodoses.

variations, e.g. in saturation levels. A general relationship appeared to be: the younger the massif, the lower the saturation level.

Because there are no data points for doses smaller than 100 Gy, the magnitude of the corrections (if any) for young feldspar samples is unclear. TL dating results for Late-Glacial feldspar samples from the Nordic region obtained by Mejdahl (1991a) indicate that there should

be no systematic age underestimate for samples of this age. However, Grün et al. (1989) and Dijkmans et al. (1992) reported age underestimates for similar sands. It is unclear whether these uncertainties were caused by the effect examined in the present paper or by the choice of filters (Wintle and Duller 1991).

For feldspar samples older than 100 ka it is to be expected that thermal fading will constitute a significant source of error (Mejdahl 1988b, 1989).

The results shown in figs. 5 and 6 demonstrate that the effect of shallow traps could well be the main cause of the underestimates encountered. The figures further indicate that a simple linear correction procedure should apply, at least over a certain part of the dose and age ranges. Obviously, more extensive tests are required to verify the general validity of this approach, especially whether the same relationships are valid for other regions. The possibility of a sensitivity change as a result of the heating should also be investigated.

It should be noted that because the effect discussed in the present paper relates to trap filling and not to any particular method of releasing the luminescence signal, it may be expected to affect OSL dating as well.

Acknowledgement.

References.

Balescu, S. and Lamothe, M. (1992) The blue emission of K-feldspar coarse grains and its potential for overcoming TL age underestimation. *Quaternary Science Reviews* 11, 45-51.

Balescu, S., Packman, S.C. and Wintle, A.G. (1991) Chronological separation of interglacial raised beaches from Northwestern Europe using thermoluminescence. *Quaternary Research* 35, 91-102.

Balescu, S., Packman, S.C., Wintle, A.G. and Grün, R. (1992) Thermoluminescence dating of the Middle Pleistocene raised beach of Sangatte (Northern France). *Quaternary Research* 37, 390-396.

Bøtter-Jensen, L., Ditlefsen, C. and Mejdahl, V. (1991) Combined OSL (infrared) and TL studies of feldspars. *Nuclear Tracks and Radiation Measurements* 18, 257-263.

Dijkmans, J.W.A., Mourik, J.M. van and Wintle, A.G. (1992) Thermoluminescence dating of eolian sands from polycyclic soil profiles in the southern Netherlands. *Quaternary Science Reviews* 11, 85-92.

Grün, R., Packman, S.C. and Pye, K. (1989) Problems involved in TL dating of Danish cover sands using K-feldspars. In *Long and Short Range Limits in Luminescence Dating*. The Research Laboratory for Archaeology and the History of Art, Oxford University. Occasional Publication 9.

Kronborg, C. and Mejdahl, V. (1989) Thermoluminescence dating of Eemian and Early Weichselian deposits in Denmark. *Quaternary International* 3/4, 93-99.

Kronborg, C. and Mejdahl, V. (1990) Thermoluminescence dating of marine sediments from Saunder's Island and Quarmat. In (S. Funder ed.) "Late Quaternary stratigraphy and glaciology in the Thule area, Northwest Greenland". *Geoscience* 22, 33-36.

Mejdahl, V. (1988a) Long-term stability of the TL-signal in alkali feldspars. *Quaternary Science Reviews* 7, 357-360.

Mejdahl, V. (1988b) The plateau method for dating partially bleached sediments by thermoluminescence. *Quaternary Science Reviews* 7, 347-348.

Mejdahl, V. (1989) How far back: life times estimated from studies of feldspars of infinite ages. In *Long and Short Range Limits in Luminescence Dating*. The Research Laboratory for Archaeology and the History of Art. Oxford University. Occasional Publication 9.

Mejdahl, V. (1990) A survey of archaeological and geological samples dated in 1989. *Geoskrifter No. 34*, University of Aarhus, Department of Earth Sciences, 40 pp.

Mejdahl, V. (1991) Thermoluminescence dating of Late-Glacial sand sediments. *Nuclear Tracks and Radiation Measurements* 18, 71-75.

Shlukov, A.I. and Shakhovets, S.A. (1987) Kinetic studies of quartz thermoluminescence as applied to sediment dating, *Ancient TL* 5, No. 1, 11-15.

Shlukov, A.I., Shakhovets, S.A., Voskovskaya, L.T. and Lyashenko, M.G. (1992) Criticism of standard TL dating technology. Accepted for publication in *Nuclear Instruments and Methods*.

Wintle, A.G. and Duller, G.A.T. (1991) The effect of optical absorption on luminescence dating. *Ancient TL* 9, 37-39.

Wintle, A.G. and Packman, S.C. (1988) Irradiation of loess samples at elevated temperatures. *Ancient TL* 6, 22-23.

PR Ann Wintle