The effect of optical absorption on luminescence dating

A.G. Wintle and G.A.T. Duller
Institute of Earth Studies, University College of Wales, Aberystwyth, SY23 3DB. UK

Introduction

Knowledge of the thermoluminescence emission spectra of minerals has led to the choice of particular optical filters when trying to enhance the response of a particular mineral relative to another. This approach has been used particularly for fine grained sediments, which cannot be separated by mineralogical techniques (Debenham and Walton, 1983). Although emission spectra for some samples of quartz and feldspar are now available (Huntley et al, 1988), no parallel studies of the optical absorption properties of the minerals have been published. In this paper we discuss the importance of such properties for luminescence dating studies.

Published absorption data for feldspars

Most absorption spectra result from electronic transitions relating to the presence of elements such as iron and manganese in the crystals. These result in characteristic absorption bands in the visible and near infrared region and relate to the colour of the crystal (Rossman, 1988). Electronic transitions between the top of the valence band and the bottom of the conduction band will result in absorption in the W, as well as the production of a luminescence signal as a result of ionization. Spectral measurements indicate absorption in the near UV at wavelengths of less than 320 nm.

Hofmeister and Rossman (1983) consider this absorption to be caused by charge transfer from oxygen to a cation (probably Fe^{3+}). It is characterized by a very steeply rising absorption edge. In their review Hofmeister and Rossman gave several examples of feldspars exhibiting this response (orthoclase, labradorite and amazonite). Figure la reproduces their graph of data from Speit and Lehmann (1976) for a sanidine from the Eifel area of Germany, where the effect of heating the crystal results in the shift of the apparent absorption edge from about 380 nm back to 320 nm. Comparison of these spectra with the absorption spectra of X-ray irradiated crystals shows that irradiated grains have an intense absorption band at about 360 nm.

Effects of absorption in the near UV

i) Because of the need for quartz optics to observe the near UV and because of the difficulty in calibrating the spectrometer response below 350 nm, most emission spectra are only obtained for wavelengths greater than 350 nm. For example, Huntley et al (1988) demonstrated that K feldspar TL is dominated by emission around 400 nm (fig. lb). However, it is possible that the peak at 400 nm is caused by the effect of absorption on an emission peak further into the UV. If selective absorption is occurring, then the relative spectra will differ if the measurements are made on grains of different sizes; less absorption will occur for the signal from fine grain samples than for the <1 mm crushed grains used by Huntley et al. The spectrum will also be affected by past radiation or heat treatments.

ii) A more direct effect of optical absorption may be expected when luminescence dating is carried out using an optical filter which spans the absorption edge, e.g. the Schott UGll whose transmission characteristics are shown in figure lc. The UGll has been used alone and in combination with heat absorbing filters (e.g. Chance-Pilkington HA-3) which restrict its transmission to wavelengths greater than 280 nm. For fine grain sediments, no difference in the EDs obtained using either blue or UV filters have been reported. However, problems with apparent underestimation of ED have been reported when the luminescence of coarse-grained K feldspars has been observed with a UGll filter (Balescu et al, 1991; Dijkmans and Wintle, 1991). Detailed examination of the response of a particular Danish feldspar by Grün et al (1989) suggested that a higher ED was obtained when using a predominantly blue transmitting filter combination (Corning 7-59 and HA3) and they suggested that this could be related to a more stable luminescence signal. More recently Balescu and Lamothe (1991) demonstrated a consistent difference between EDs obtained with ultraviolet filters (Schott UGll or Hoya U340) and with a blue filter (Corning 7-59) for K feldspars from beach deposits in northwest Europe. On the other hand, no difference was observed by the same authors for K feldspars from southern Italy. The magnitude of the discrepancy in the ED values was found to be equivalent to that which would be calculated as being due to the internal dose rate within K feldspar grains - about 40% for the grains in the above study.

The grains involved in the study were relatively coarse (150 - 250 or 250 - 300 μm) and so if the etched grains were effectively only emitting UV light from the surface because of strong absorption, then the ED obtained would relate to that surface layer. The dose to this layer due to the internal potassium of the grain will be smaller than the average to the whole grain.

Comparing the absorption spectrum of natural smoky sanidine (fig la) and the filter combinations that have been used in the dating of potassium feldspars (fig lc) it is clear that the TL signal observed with the UG11 filter (with or without a heat-absorbing filter) will be absorbed within the crystal. Even with the 7-59 filter

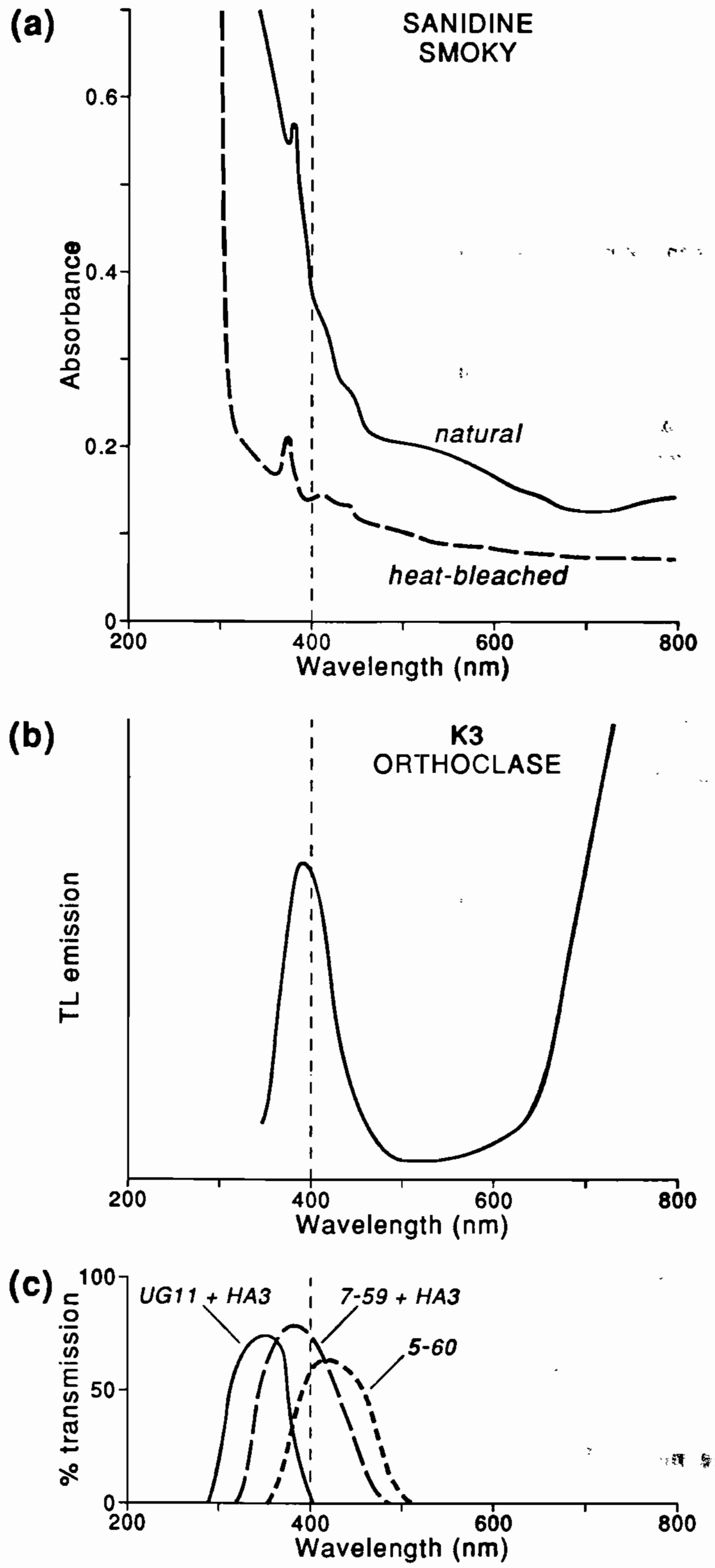

Figure 1. (a) Absorption spectra for smoky sanidine taken from Hofmeister and Rossman (1983); (b) emission spectrum for potassium feldspar (K3 orthoclase) from Huntley et al (1988); c) transmission characteristics of filters commonly used in TL dating studies. The vertical dashed line at 400 nm indicates the wavelength below which absorption is likely to affect luminescence measurements.

some absorption is likely and this was suggested by the results presented by Grün et al (1989). However, Mejdahl's use of a Corning 5-60 filter (Kolstrup et al, 1990) would result in little absorption of the signal from 300 µm grains. This is demonstrated by the agreement between the ages that he obtains for quartz and feldspar separates from the same sample.

Obviously different feldspars will show individual absorption characteristics and some examples are given by Hofmeister and Rossman (1983). The absorption properties of individual feldspar grains used in dating studies could be studied with a microscope uv-visible spectrophotometer, but the exact position of the absorption edge also depends upon crystal orientation. A simpler solution is to use filters which transmit above 400 nm.

References

Balescu, S. and Lamothe, M. (1991) The blue emission of K-feldspar coarse grains and its potential for overcoming TL age underestimation. *Quaternary Science Reviews*. in press.

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.

Debenham, N.C. and Walton, A.J. (1983) TL properties of some wind-blown sediments. *PACT* **9**, 531-538.

Dijkmans, J.W.A. and Wintle, A.G. (1991) Methodological problems in thermoluminescence dating of Weichselian cover sand and Late Holocene drift sand from the Lutterzand area, E. Netherlands. *Geologie en Mijnbouw* **70**, 21-33.

Grün, R., Packman, S.C. and Pye, K. (1989) Problems involved in TL-dating of Danish cover sands using K-feldspar. Synopses from *Workshop on Long and Short Range Limits in Luminescence Dating*. Occasional paper 9 of the Research Laboratory for Archaeology, Oxford.

Hofmeister, A.M. and Rossman, G.R. (1983) Color in feldspars. *Reviews in Mineralogy* **2**, 271-280.

Huntley, D.J., Godfrey-Smith, D.I., Thewalt, M.L.W. and Berger, G.W. (1988) Thermoluminescence spectra of some mineral samples relevant to thermoluminescence dating. *Journal of Luminescence* **39**, 123-136.

Kolstrup, E., Grun, R. Mejdahl, V., Packman, S.C. and Wintle, A.G. (1990) Stratigraphy and thermoluminescence dating of Late-Glacial cover sands in Denmark. *Journal of Quaternary Science* **5**, 207-224.

Rossman, G.R. (1988) Optical Spectroscopy. *Reviews in Mineralogy* **18**, 207- 243.

Speit, B. and Lehmann, G. (1976) Hole centers in the feldspar sanidine. *Physica Status Solidi* **36A**, 471-481.

PI Reviewer's Comments (Helen Rendell)

The absorption of UV TL emissions by feldspars, as discussed in this paper, represents at least a partial explanation of the age underestimates obtained from large grain potassium feldspars. The dosimetry implications are likely to be strongly dependent on grain size. Other explanations of underestimation relating to long-term signal instability or the methods used for the calculation of the new internal beta dose distribution still need to be explored more fully.