which they escape by a thermal activation process having a probability dependent on a Boltzmann type function $C \exp(-E/kT)$ where C is a constant, E another constant known as the trap depth, k Boltzmann's constant and T the absolute temperature. Such a function gives a very critical temperature dependence; for example, if for a given value of C traps of depth 0.1 eV hold electrons for a mean time of 2×10^3 s, then traps of depth 2 eV give mean lifetimes of 10^{18} s. Thus deep traps in solids form electron storage sites effective for geological times. The simple model is, however, not realistic as Wintle has shown on page 141 of this issue of *Nature*. Electrons leak away from traps at ordinary temperatures on account of what are effectively non-thermal processes. Such effects have been known for a long time in inorganic solids and the transition of electrons from triplet, metastable states in organic molecules to the singlet ground states by direct but forbidden processes is also well known. In 1950 Garlick and Bull (*Proc. phys. Soc. Lond.*, **63**, 1283) reported a non-thermal phosphorescence decay involving loss of trapped electrons in diamond and having a lifetime of 10^5 s. Much later, similar effects in terrestrial labradorite and in lunar soil samples were described (Garlick and Robinson in *The Moon* (edit. by Runcorn, S. K., and Urey, H.), 324 (IAU, 1972).

There is no doubt that the existence of the anomalous loss of trapped electrons from storage sites in minerals and in other samples raises doubts as to the usefulness of the thermoluminescence dating methods. The effect can, however, be a minor one in many samples and the important procedure for anybody wanting to use the technique is to determine the degree of anomalous fading. This can be done, as in the work of Wintle, by studying the room temperature decay of the stored energy over sufficient time periods. It is also wise to take only that part of the thermoluminescence curve, namely the high temperature section, which arises from the release of electrons from relatively deep traps. There always remains the problem that tests for anomalous fading are limited in time scale to weeks or months for practical reasons and so low rates of loss must then be extrapolated to thousands of years or more. High accuracy of correction of dating curves is thus not possible.

It is fitting to add some explanation of the anomalous fading effects in minerals and archaeological specimens. It is now well known in luminescent and semiconducting solids that electron traps and luminescence emission centres are not remote from each other and that direct tunnelling of trapped electrons into centres can occur even at very low temperatures. Such quantum mechanical effects depend strongly on trap-centre separations and on the extent of overlap of wavefunctions for trapping and centre states; the last depend, for example, on trap depth and so for a typical mineral sample, or say pottery sherd, for which a wide distribution of trap depths occur there is a whole range of mean lifetimes for the anomalous leak process for trapped electrons. Thus no simple decay law emerges and in fact it is not surprising that the curve of Fig. 3 of Wintle's communication does not follow a simple exponential form. In the work of my team the common form is that of a power law process, produced by summation of many exponential decays. If Wintle's data of Fig. 3 are replotted on a log-log plot, a sensibly straight line graph results. This indicates, as expected, a wide range of trap depth distributions.

It is also worth pointing out that both in radiological dosimetry, using such thermoluminescent systems as lithium fluoride, and in mineral and archaeological specimen investigations there are other effects which can obscure the stored energy information. One of these is the introduction of surface states on samples by adsorption (of ambient water vapour, for example). Such states can provide leak paths for trapped electrons or even introduce spurious thermoluminescence effects. In most cases handling and operation in dry nitrogen seem to be effective in controlling or eliminating the unwanted disturbances. It must also be admitted that grinding up of samples before thermoluminescence experiments could be an important source of disturbance of electronic states and of new surface states; most experienced workers make control experiments to determine the extent of such effects in every type of sample they investigate.

G. F. J. G.

Aged Sediments

RECENT discoveries have pushed back the radiometric ages of early crustal rocks to the extent that probable ages of at least 3,800 m.y. are now widely accepted. These great ages are normally derived from analysis of such rocks as granites and granite-gneisses. Moorbath, O'Nions and Pankhurst now report on page 138 of this issue of *Nature* results of analyses of supracrustal rocks, including banded ironstones, from the Isua area of West Greenland near Godthaab; they deduce a probable age of $3,760\pm70$ m.y. The geological setting presents familiar problems in these Archaean terrains, because the metasediments occur in a (refolded) syncline among granitic gneisses, and the interpretation of the contact is difficult because of intense deformation; however, the two groups show similar metamorphic grade.

The gneisses yield a whole rock Rb-Sr isochron age of $3,700\pm140$ m.y. The banded ironstones have provided Pb-Pb isochron ages of $3,760\pm70$ m.y.—a remarkable application of this technique to such ancient sediments—and there is evidence of severe uranium depletion at or before this time. These ages are concordant, and the authors discuss the problems arising in a useful maner. Although these are the greatest ages yet reported for water-laid sediments, the "country" gneisses of the Godhaabsfjord area enclose rafts and enclaves of earlier rocks, which include what may well be metasediments of still greater age. The Isua metasediments are therefore at present to be regarded as the oldest to be dated, and their depositional age may well be greater, because the figure of $\sim$3,700 m.y. may well represent a subsequent metamorphic event. It is clear that this early Precambrian cratonic area of the central belt of Greenland deserves still further study to elucidate the time sequence, structural details and sedimentary emplacement among the Archaean rocks.

In addition to these interesting results, the communication also brings out some outstanding new applications of Pb-Pb isochron work.

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