We also obtained the equivalent dose (ED) for two very old samples of foraminifera; a 2.6-Myr sample V20-163 (75 cm)[5] and a 3.2-Myr sample DSDP Site 357 (2/5/10-13)[6]. The EDs were obtained experimentally by the additive dose method, which was also used for the ESR measurements by Sato[1]. The TL was measured using a Daybreak TL system with a Corning 4-69 filter (50% transmission between 340 and 580 nm) between the heat absorbing filter and the EMI9635 photomultiplier tube. The TL peak obtained at 275 °C for a heating rate of 5 °C $s^{-1}$ is typical of pure calcite[2]. The foraminifera from V20-163 had already been cleaned and hand picked in ordinary room fluorescent lighting for oxygen isotope analysis but those from DSDP357 were prepared in the dark. They gave ED values of 110 and 250 Gy (11 and 25 krad) respectively.

To see whether an ED of 250 Gy was reasonable for the foraminifera extracted in the dark, radioactivity analyses were carried out to calculate the annual dose rate. $\alpha$ counting[7] of DSDP Site 357 bulk sample gave a total count rate of $0.052 \pm 0.004$ $cm^{-2}$ $ks^{-1}$ which predicts an annual dose rate of 140 μGy (14 mrad). For high carbonate cores, the potassium content is inversely related to the carbonate content[7] and using the value for an 85% carbonate core[6] ($K_2O = 0.2\%$) we get an additional annual dose rate of 70 μGy. The cosmic dose rate is negligible under several kilometres of ocean. These data predict a total dose of 630 Gy (63 krad) for a 3 Myr sample. An additional dose due to the decay of excess $^{230}Th$ must also be included. This was ignored by Sato[1], even though his cores are beneath 4 km of ocean water. $\alpha$ counting of RC8-39[7], a core at a similar water depth (4.33 km), gave a core top count due to excess $^{230}Th$ of 1.8 $cm^{-2}$ $ks^{-1}$ in agreement with $\alpha$ spectrometric measurements. This excess activity will produce an additional ED of about 500 Gy (50 krad) for any sample in the core older than 0.3 Myr. Indeed, this component would give rise to exactly the type of behaviour shown in Fig. 3 of ref. 1.

The ED obtained from TL measurements (250 Gy) is thus considerably less than that predicted from radioactivity data (1,130 Gy). We therefore think that the electron trap responsible for the 275 °C peak may not be sufficiently stable for dating samples as old as 3 Myr. Similar low values of ED were obtained by Sato[1] for samples older than 1 Myr. Sato assumed that the radiation defects responsible for the ESR ($g = 2.003$) signal that he used for dating were the same as those of the 275 °C TL peak, as found experimentally by Valladas *et al.*[4]. Although the 275 °C peak has been attributed with a mean life of $\sim 10^8$ yr at 10 °C (ref. 8), more recent kinetic studies on calcite (N. C. Debenham, personal communication) give a minimum mean life of ~1 Myr. Hence the trend towards a constant value of dose with depth may be due to thermal decay of the defects at ambient temperature, not anomalous fading as he suggested. Another possibility is that diagenetic changes may have occurred in such old foraminifera (N. J. Shackleton, personal communication). Bothner and Johnson[9] also found a saturation of the TL signal with depth. They studied the TL response of foraminifera >74 μm relative to the $\alpha$ activity down a number of cores and found that the thermal decay constant for the TL was $\sim 10^{-6}$ $yr^{-1}$ such that the mean life at ocean bottom temperatures was $\sim 10^6$ yr. They also concluded that this was lower than that obtained from TL studies of limestone. Further ESR and TL studies on constantly deposited foraminifera should produce a more precise determination of the mean life for calcite in the natural environment. This is of wider interest since attempts are being made to use ESR to date stalagmites and bones associated with fossil hominids.

A. G. WINTLE
D. J. HUNTLEY*

*The Godwin Laboratory,*
*Subdepartment of*
*Quaternary Research,*
*Cambridge University,*
*Cambridge CB2 3RS, UK*

* Permanent address: Physics Department, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6.

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SATO REPLIES—The ESR signal of foraminifera may be reduced by optical bleaching, as Wintle and Huntley pointed out, if the samples were stored in light. I prepared two groups of samples consisting of foraminifera of diameter 149–250 μm and 250–503 μm, and gave them a $\gamma$ dose of 40 krad. The ESR signal was reduced by $31 \pm 3\%$ and $24 \pm 3\%$, respectively, using a 7-h exposure to a 100 W tungsten lamp placed 7 cm from the samples. Although reproducibility of the signal intensity shows that the bleaching by short exposures to ordinary room fluorescent lighting is negligible, the samples to be used for dating should be prepared from sediment which has not been exposed to light for a long time.

$\gamma$-ray spectrometry of 11 samples taken from core KH 73-4-7 was performed by M. Sakanoue and K. Komura (personal communication). The equivalent content of $^{238}U$ decreases rapidly with depth from 13.46 p.p.m. at a depth of 6 cm to 0.24 p.p.m. at 140 cm due to the excess of $^{230}Th$ and then remains nearly constant. The mean equivalent content of $^{232}Th$ was 1.67 p.p.m. and the mean potassium content was 0.56%. The annual dose predicted from these data decreases with depth from 0.4 rad $yr^{-1}$ to 0.1 rad $yr^{-1}$ if the effectiveness of $\alpha$-radiation for inducing ESR signal is assumed to be zero. It is improbable that the large contribution of excess $^{230}Th$ to the annual dose is completely compensated by insufficient exposure to $\gamma$ radiation near the sediment–water interface[1]. On the other hand, the rate of decrease in the content of U-series may predict a slow sedimentation rate (3.2 mm $kyr^{-1}$) for the uppermost 70 cm. In future work, it will be necessary to estimate the effect of reduced exposure near the surface of the sediment.

As there is little information about the stability of the signal in foraminifera, further studies on uniform and constantly deposited sediments are needed to evaluate the mean life time.

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TAKAHARU SATO

*Faculty of Engineering Science,*
*Osaka University,*
*Toyonaka, Osaka, Japan*

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