MATTERS ARISING

The rhenium–osmium age of the Galaxy

LUCK, BIRCK AND ALLEGRE[1] have reported new meteoritic data on Re and Os which led to limits to the age of the Galaxy of between 13,000 and 22,400 Myr. Here I point out how these results change if one uses estimates of the s-process contribution to ^{187}Os given by Woosley and Fowler[2].

The isotope ratio used as a galactic chronometer can be written

$$R \equiv \frac{^{187}\mathrm{Os}^*}{^{187}\mathrm{Re}} = \frac{^{187}\mathrm{Os}^*}{^{186}\mathrm{Os}} \Big/ \frac{^{187}\mathrm{Re}}{^{186}\mathrm{Os}}$$

where all values are for the meteorites at formation and $^{187}\mathrm{Os}^*$ is the radiogenic component of ^{187}Os. The s-process component is written in terms of the ratio of neutron capture cross-sections and a correction factor, f, so that

$$^{187}\mathrm{Os}^*/^{186}\mathrm{Os} = (^{187}\mathrm{Os}/^{186}\mathrm{Os})_{\mathrm{total}} - (\sigma_{186}/\sigma_{187})f$$

Let us use from reference 1 the values $^{187}\mathrm{Re}/^{186}\mathrm{Os} = 3.20$ and $(^{187}\mathrm{Os}/^{186}\mathrm{Os})_{\mathrm{total}} = 0.805 \pm 0.011$ (2σ), and from ref. 2 the values $\sigma_{186}/\sigma_{187} = 0.504 \pm 0.034$ (2σ) (ref. 4) and $0.8 \leqslant f \leqslant 1.15$. These quantities give $R = 0.096 \pm 0.041$. Luck *et al*[1]. use a smaller s-process contribution, which gives $R = 0.152$.

A firm lower limit to the age of the Galaxy comes from assuming that all nucleosynthesis of Re occurred in a single burst at time $t = 0$. Then the time T of meteorite formation (4,550 Myr ago[1]) is given by $R = \exp(\lambda T) - 1$, where the decay constant $\lambda = 1.62 \times 10^{-11}$ yr^{-1} (ref.1); the age of the Galaxy is given by $t_0 > T + 4{,}550$ Myr. The value of R used by Luck *et al.* gives $t_0 > 13{,}300$ Myr, but the above revised value gives a lower limit of $10{,}200 \pm 2{,}300$ Myr.

An upper limit to t_0 cannot be obtained without a detailed model of chemical evolution, including gas flows[3]. As a simple example of an older model, the case stated by Luck *et al.* of 'steady-state nucleosynthesis' gave $t_0 = 22{,}400$ Myr with their value of R, but with the above value it gives $t_0 = 16{,}100 \pm 5{,}100$ Myr.

The main points are, as forseen by Woosley and Fowler[2], that uncertainties in the s-process seriously affect the Re–Os chronometer, and that use of the latest estimate of the s-process contribution to ^{187}Os reduces the lower limit to the age of the Galaxy by about 3,000 Myr.

BEATRICE M. TINSLEY
Yale University Observatory,
260 Whitney Ave.,
Box 6666,
New Haven, Connecticut 06511

1. Luck, J.-M., Birck, J.-L. & Allègre, C.-J. *Nature* **283**, 256 (1980).
2. Woosley, S. E. & Fowler, W. A. *Astrophys. J.* **233**, 411 (1979).
3. Tinsley, B. M. *Astrophys. J.* **216**, 548 (1977).
4. Winters, R. R., Macklin, R. L. & Halpern, J. *Phys. Rev.* C (in the press).

Accuracy of thermoluminescence dates

WE congratulate Liritzis and Thomas[1] on the first combined application of thermoluminescence dating and magnetic palaeointensity determination, particularly in view of the disadvantageous magnetic characteristics of the kiln wall material used. It is a pity, however, that the thermoluminescence age errors in their Table 1 have been quoted without qualification, as they are liable to mislead archaeologists and others into expecting a higher accuracy from the technique than it can truly give. As has been learnt with radiocarbon dating, it is important to distinguish between precision of measurement and absolute accuracy. Evidently the errors quoted in Table 1 refer to the former (because the errors quoted for the averages are substantially less than the errors quoted for the individual measurements).

The systematic errors inherent in thermoluminescence dating are of a different type from those in radiocarbon but they are, nonetheless, important if comparison is being made with archaeologists' calendar year dates. Whereas the major systematic errors in radiocarbon dates have been worldwide effects—initially, uncertainty about the value of the half life and, more recently, uncertainty about the calibration curve by which radiocarbon years are converted into calendar years—the systematic errors in thermoluminescence dating arise from more intimate effects such as differences between types of fabric measured, burial environments and laboratory techniques.

It is not appropriate here to go into detail, but on the basis of a previous assessment[2,3] and taking into account two additional interfering effects also noted[4,5] specifically in respect of quartz, it seems unlikely that tighter limits than ±5% can at present be placed on the possible systematic error for a thermoluminescence date. This is at the 67% level of confidence. Neglecting any contribution from measurement error, this 5% systematic error limit corresponds to ±200 yr for a date at around 2000 BC, falling to ±150 yr for 1000 BC. More realistically, we would put the best overall error limit that can be achieved for the average date on a group of contemporaneous samples, except in abnormally favourable circumstances, at ±7%, that is, ±300 yr and ±200 yr, respectively.

Obviously it is to be hoped that research will lead to improvement in the accuracy of thermoluminescence dating. One notable obstacle is the uncertainty introduced by possible variation in water content during burial; although techniques have been proposed[6,7] that eliminate this interference, they have not yet reached a better accuracy than that quoted above.

M. J. AITKEN
J. HUXTABLE
Research Laboratory for Archaeology,
6 Keble Road,
Oxford OX1 3QJ, UK

1. Liritzis, Y. & Thomas, R. *Nature* **283**, 54–55 (1980).
2. Aitken, M. J. & Alldred, J. C. *Archaeometry* **14**, 257–267 (1972).
3. Aitken, M. J. *Archaeometry* **18**, 233–238 (1976).
4. Bell, W. T. & Zimmerman, D. W. *Archaeometry* **20**, 63–65 (1978).
5. Sutton, S. R. & Zimmerman, D. W. *Archaeometry* **20**, 66–70 (1978).
6. Zimmerman, D. W. *Specialist Seminar on Thermoluminescence Dating, Oxford 1978, PACT Journal* **3**, 458–465 (1979).
7. Poupeau, G., Sutton, S., Walker, R. M. & Zimmerman, D. W. *9th Congr. Un. intern. Sci. Préhist. Protohist.*, Nice 1976 (in the press).

LIRITZIS REPLIES—I would like to clarify some points. First, the systematic errors in thermoluminescence (TL) dating of well-fired kilns clays are not pronounced (as they are in most other cases), due to the kiln structure; we used the internal part of the well-fired kiln wall or internal part of a fused kiln-surface clay. Second, the dated quartz samples (15 kiln clays and 3 tiles) come from the same fabric type of the respective kiln, and all have been subjected to the same climatological factors, an 'advantage' for precise water uptake and environmental γ-radiation measurements. This mineral similarity was also found from X-ray fluorescence analysis of many samples from the same kiln, and from the TL glow curves.

Third, in general, I agree that the systematic errors of ±5% exist for TL dating, but in the favourable circumstances of studying kiln materials they are much reduced. Fourth, the quoted 67% level of confidence will ensure improved accuracy for archaeologists' estimations. Fifth, some estimated errors (many due to the operator and technique used) cancel themselves out. Therefore, an average date for many contemporaneous samples, in the same burial conditions and weathering as in kiln materials, does make sense and justifiably reduces the overall error. Finally, by taking the 'permitted' average error of many TL dates as an overall error limit of the age of a kiln, the final quoted TL accuracy, as estimated % error, of our report is valid, and the precision obviously better.

YIANNIS LIRITZIS
Physics Laboratory II,
University of Patras,
Patras, Greece

0028–0836/80/350911—01$01.00