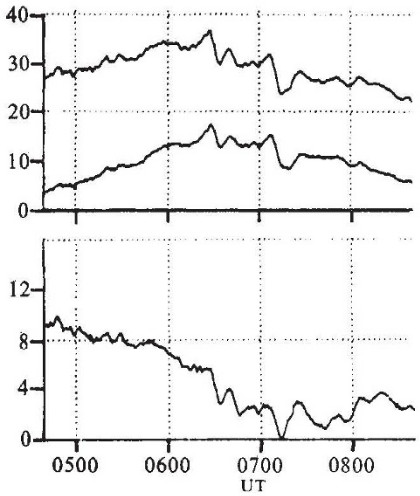

Fig. 1 The declination records for Grahamstown and Hermanus, and the Grahamstown–Hermanus difference curve, plotted on the same scale as used by Lilley and Woods[1]. All records are plotted relative to arbitrary zeros.

that the magnetic field in South Africa was slightly disturbed during the interval 0620–0640 UT when the eclipse occurred in Australia. The 0711 event mentioned by Lilley and Woods is also present although the relative amplitude is smaller than in Australia. The Grahamstown–Hermanus difference graph shows a rapid variation at 0628 UT compared to 0638 UT in Australia. The event reported by Lilley and Woods could, therefore, have been a small eastward travelling disturbance. One should, however, be careful not to attribute all sudden changes in the difference curves to a phase shift. High frequency variations at site J are clearly more damped than the corresponding variations at site H. The form and smoothness of the difference curves are in fact determined to a large extent by the relative frequency responses at the two sites, and not by phase shifts, except in the case of the S_q variations. Similar effects can be seen in the Hermanus–Grahamstown comparison. High frequency response at Hermanus is markedly lower than at Grahamstown.

We conclude that the event reported by Lilley and Woods is a manifestation of a minor magnetic disturbance. The variations observed at the Gnangara observatory in Western Australia should give more information on the suggested eastward travelling event.

G. L. M. SCHEEPERS
Magnetic Observatory of the CSIR,
PO Box 32,
Hermanus 7200,
South Africa

LILLEY AND WOODS REPLY—We accept Scheepers' evidence for some widespread minor magnetic activity at the time of the eclipse in south-east Australia. If the source currents for this activity flowed in the overhead ionosphere they (like the S_q currents) may be perturbed by lowered ionospheric conductivity in an eclipse shadow, and we are now examining the data from our line of instruments for such an effect. We agree with Scheepers that such an ionospheric effect may be difficult to distinguish from local differential induction.

F. E. M. LILLEY
D. V. WOODS
Research School of Earth Sciences,
Australian National University,
Canberra, Australia

Climatic interpretation of $\delta^{18}O$ and δD in tree rings

THERE has been considerable interest[1–5] in, and some controversy[5–7] over the use of the stable isotopes of oxygen and hydrogen in tree rings as measures of past climate. We point out here that variations in isotopic values from the whole ring (or a number of rings) may be in part a function of variations in ring width. As a consequence, whole ring isotope estimates of past climate will not be independent of ring width estimates of past climate. This is a direct result of the relative constancy of either early- or late-wood width in many tree species and of the differences in isotopic composition between early and late wood.

In many species of tree, much of the variation in ring width from year to year is in either the early-wood or the late-wood part of the ring. For instance, in oak[8] and elm (D. Brett, personal communication) the width of the early wood is approximately constant, while in most conifers the late-wood width is approximately constant[4]. Early wood and late wood generally have different isotopic composition. The cellulose analyses of Epstein and Yapp[5] and Wilson and Grinsted[4] both show differences of up to 50‰ in δD. The latter authors show lighter isotopic values in the early wood which they attribute to temperature-dependent fractionation effects. Epstein and Yapp[5] disagree with this interpretation. Their analyses show that early-wood isotopic values may be either lighter or heavier than those of the late-wood depending on the location of the tree, and their work suggests that late-wood is isotopically lighter (for Douglas Fir) in regions where there is winter snow cover.

Epstein and Yapp[5] note that "... differences in early- and late-wood δD could cause sampling problems...". We elaborate here on one way which such problems might arise, and on their possible implications. Approximate constancy of early- or late-wood width, and isotopic variation across a ring, when considered together, necessitate a relationship between ring width and the isotopic value ($\delta^{18}O$ or δD) of the whole ring. If E is the early-wood width, L the late-wood and W ($=E+L$) the total ring width, and if δ_E, δ_L and δ_w are the corresponding mean stable isotope ($\delta^{18}O$ or δD) values, then

$$\delta_W = \delta_E + (\delta_L - \delta_E)\, L/W \tag{1}$$

or

$$\delta_W = \delta_L - (\delta_L - \delta_E)\, E/W \tag{2}$$

These alternative expressions for δ_W arise from the fact that δ_W is a weighted average of δ_E and δ_L. They both contain a term proportional to W^{-1} and thus imply a direct functionation dependence of δ_W on W. The sign of the relation between δ_W and W depends on the sign of $\delta_L - \delta_E$ and on whether the tree has relatively constant E or relatively constant L.

As ring width is determined partly by climate (although the relation is often complex[9]), these results imply a dependence of δ_W on climate which would occur even if δ_E and δ_L were constants. Thus, at least a part of any δ_W–climate relationship may be attributable to ring width variations.

Whether this 'ring width effect' contributes significantly to variations in δ_W depends on the magnitude of variations in δ_E, δ_L and either E/W or L/W. For oak, where E is approximately constant and equation (2) is the appropriate expression, Eckstein and Schmidt[8] give ring width data where E/W varies from 0.23 to 0.63 over the period 1880 to 1969. Since $\delta_L - \delta_E$ may be as high as 50‰ for δD, equation (2) shows that the ring width effect could give δD variations for single whole rings of up to 20‰.

Expected variations in $\delta^{18}O$ of whole rings due to the ring width effect are difficult to estimate because no suitable early-wood and late-wood isotopic data is available. The values would depend on whether precipitation or temperature-dependent fractionation effects are dominant in controlling tree ring isotopic composition, a subject on which there is considerable disagreement. If precipitation effects dominate then $\delta^{18}O$ variations of order 2.5‰ could be expected as a result of the ring-width effect. If fractionation effects dominated then even greater variations in $\delta^{18}O$ could occur.

Gray and Thompson[1] and Libby *et al.*[2] have found significant correlations between whole ring isotopic values and mean annual temperatures. Their results may be partly due to the ring width effect. Gray and Thompson's[1] data show a $\delta^{18}O$ range of about 3‰ with lower values corresponding to cooler mean annual temperatures. In their case we expect L to be relatively constant. If $\delta_L - \delta_E < 0$, as suggested by the results of Epstein and Yapp[5], then δ_W should be lower for narrower rings (see equation (1)), and hence, most probably, for colder years. Since Gray and Thompson use 5-yr means, the magnitude of variations due to the ring-width effect could be as much as 1.5‰