shrub zone cut off at both ends by grassland and not going anywhere are no longer cowpaths. The photograph shows the currently used paths in the grassland bowed toward the lower left by encroaching shrubs while faint scars above reveal where the paths once passed. In the grassland these old paths are obliterated by grass; in the shrub zone they remain bare and become broader. The great broad white zones of bare ground both inside and outside the shrubs are curved (not "rectilinear") and can scarcely be explained except as inhibition. Since severe inhibition 6 to 9 m distant from the shrubs is commonplace, with or without transverse cowpaths, it is impossible to ascribe the phenomenon to characteristically narrow cowpaths.

Wells overlooked the fact that we did not credit White-crowned Sparrows (*Zonotrichia leucophrys*) and Golden-crowned Sparrows (*Z. atricapilla*) with contributing to the vegetational patterning. This they do in perceptible degree, but never do they produce a bare area unaided by initial biochemical inhibition. Their contribution consists of grazing more heavily near shrubs for a brief period after initial germination and results in a slight intensification of the patterning.

Steps are being taken to preserve an area of the more instructive patterning. We are desirous of showing this to anyone who will look.

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24 February 1964

Radiocarbon Dating of Mollusk Shells: A Reply

W. Broecker's criticism (*1*) of our hypothesis (*2*) that humus contributions affect the radiocarbon age of fresh-water mollusk shells is based partly upon the misconception that our hypothesis requires oxidation of humus "within the water body *rather than* in the soils of the drainage basin" (italics added). His phrase "rather than" should read "as well as" in order to be in accord with our evidence and stated conclusions. Humus oxidation begins in soils and ground water, of course, but a second-stage oxidation of humus takes place in suspension in river waters and to a lesser extent in lakes; they are not sterile environments. A third-stage humus effect depends upon the nature of the food web and upon the food selectivity of mollusks. We have shown in a separate study of C^{13}:C^{12} ratios (*3*) that river mollusks adapt themselves to digest humus or humus-derived material, which is relatively deficient in both C^{13} and C^{14} (as compared with atmospheric carbon dioxide). Our conclusion that humus is an important source of shell carbon was based largely upon that study, and the radiocarbon data are regarded as supplementary evidence. This was perhaps not sufficiently emphasized.

Because of C^{13} enrichment (about 15 per mil) and C^{14} enrichment (about 30 per mil) in mollusk shell relative to the food web (the major source of metabolic carbon), projections made in order to estimate the probable age of contributing humus should be drawn through points representing the food web (Fig. 1) rather than through those representing shell isotopic composition. Failure to do that, and to allow for carbon fractionation by mollusks, probably explains Broecker's conclusion that "humus of about 4000 years in age is needed in order to yield the observed compositions of river mollusk shells. . . ." Our projection gives a maximum necessary humus age of less than 3000 years (Fig. 1).

We do not dismiss the contribution of inactive carbon from limestones, which Broecker emphasizes so strongly; it should be pointed out, however, that the limestone-dissolution effect is a local one, not generally significant in limestone-free areas. Relative contributions of the several carbon reservoirs probably can be more exactly defined by a detailed study of the C^{13} and C^{14} content of bicarbonate, food web, and mollusk flesh and shell in biologic communities of rivers. We have proposed an investigation to be made in colloboration with Broecker.

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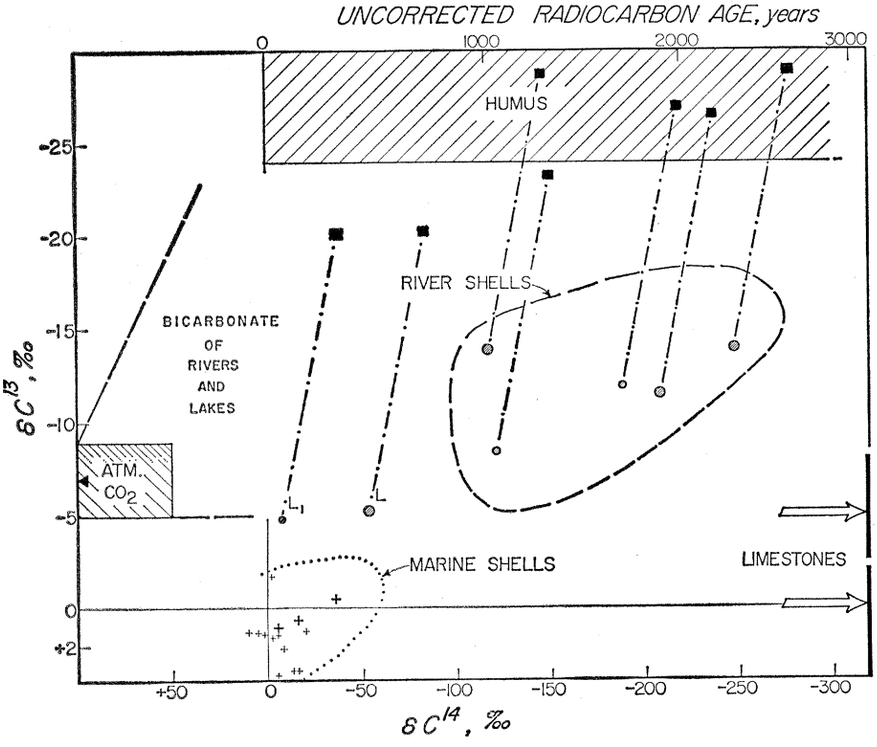

Fig. 1. Carbon isotopic composition and radiocarbon age of mollusk shells. This figure is identical with Fig. 1 in the earlier report by Keith and Anderson (*2*), except for showing fractionation tie-lines and the approximate isotopic compositions of food web (filled squares) to be expected in relation to the analyzed fresh-water shells (circles). Specimens L and L_1 are from lake-water environments.

References

1. W. Broecker, *Science* **143**, 596 (1964).
2. M. L. Keith and G. M. Anderson, *ibid.* **141**, 634 (1963).
3. ———, *Geol. Soc. Am., Spec. Paper* **73**, 185 (1963); *Geochim. Cosmochim. Acta*, in press.

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