Quaternary aminostratigraphy of Mississippi Valley loess: Discussion and reply

Discussion

JOHN J. ALFORD *Department of Geography, Western Illinois University, Macomb, Illinois 61455*

The construction of an aminostratigraphy for the loess of the Mississippi Valley by Clark and others (1989) is of considerable interest because their methodology does show promise of being helpful in establishing interregional correlations. Unfortunately, however, the authors have promised too much too soon. They have claimed that amino acid racemization allows for the circumventing of problems associated with existing methods. The implication is that "stratigraphic position," "soil development," and "lithology" will become secondary in consideration. Ironically, compelling evidence from the traditional methods raises serious question about the reliability of the racemization method of dating in the lower Mississippi Valley.

The case in point concerns the age of the Sicily Island loess. From the top down, the Sicily Island loess is the second loess. In earlier studies, it has been referred to as "Late Sangamon" (Wascher and others, 1947), pre-Peoria (Miller and others, 1985), and was suspected of being a correlative of the Loveland by Snowden and Priddy (1968). Miller and others (1985) tentatively assigned this unit to an early Wisconsinan time slot based upon TL dates obtained by Johnson and others (1984) from the Vicksburg standard section. Thus, the question for earlier investigators was whether this unit was Wisconsinan or Illinoian in age. The rather startling conclusion presented by Clark and others (1989) is that the Sicily Island loess is substantially older than the Loveland and thus might be pre-Illinoian in age.

The key to correctly dating the Sicily Island loess lies in examining the stratigraphy of the lower valley terraces. Macon Ridge is a glacial outwash terrace that lies adjacent to Sicily Island. Several lines of evidence show that this feature is early Wisconsinan in age (Saucier, 1968; Miller and others, 1985). Farther south in southeast Louisiana, the fluviatile Prairie Terrace carries a weak paleosol that is capped by the Peoria Loess. Radiocarbon dates indicate that the top stratum of the alluvium was laid down in mid-Wisconsinan time (Alford and others, 1983, 1985; Autin and others, 1988). The Sangamonian terrace for the region is the Irene Terrace (the Montgomery of Fisk, 1944). This feature carries both the Peoria Loess and the Sicily Island loess. Only on older surfaces is the third loess (Loveland?) present.

These regional relations make it difficult to accept the racemization date of Clark and others (1989). The absence of the Sicily Island loess on the Prairie means that it is older than mid-Wisconsinan, whereas its presence on the Irene Terrace shows that it is post-Sangamon in age. The source for this loess fall was most likely the braided-stream deposits represented by Macon Ridge.

In summary, either the racemization date is wrong, or the Sicily Island loess has been misidentified at its type section by others (not Clark and others) as the "second loess" in the lower Mississippi Valley.

REFERENCES CITED

Alford, J. J., Kolb, C. R., and Holmes, J. C., 1983, Terrace stratigraphy in the Tunica Hills of Louisiana: Quaternary Research, v. 19, p. 55–63.

——1985, Terrace stratigraphy along the lower Red River, Louisiana: Southeastern Geology, v. 26, p. 47–51.

Autin, J. A., Davison, A. T., Miller, B. J., Day, W. J., and Schumacher, B. A., 1988, Exposure of late Pleistocene Mississippi River meander-belt facies at Mt. Pleasant, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 38, p. 375–383.

Clark, P. U., Nelson, A. R., McCoy, W. D., Miller, B. B., and Barnes, D. K., 1989, Quaternary aminostratigraphy of Mississippi Valley loess: Geological Society of America Bulletin, v. 101, p. 918–926.

Fisk, H. N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Vicksburg, Mississippi, U.S. Army Corps of Engineers Mississippi River Commission, 78 p.

Johnson, R. A., Pye, K., and Stipp, J. J., 1984, Thermoluminescence dating of southern Mississippi loess: American Quaternary Association Biennial Meeting, 8th, August 13–15, Boulder, Colorado, Program and Abstracts.

Miller, B. J., Lewis, G. C., Alford, J. J., and Day, W. J., 1985, Loess in Louisiana and at Vicksburg, Mississippi: Friends of the Pleistocene, South-Central Cell, Guidebook, 126 p.

Saucier, R. T., 1968, A new chronology for braided stream surface formation in the lower Mississippi Valley: Southeastern Geology, v. 9, p. 65–76.

Snowden, J. O., and Priddy, R. R., 1968, Geology of Mississippi loess: Mississippi Geological Economic and Topographic Survey Bulletin, v. 111, p. 1–203.

Wascher, H. L., Humbert, R. P., and Cady, J. G., 1947, Loess in the southern Mississippi Valley: Identification and distribution of the loess sheet: Soil Science Society of America Proceedings, v. 12, p. 389–399.

MANUSCRIPT RECEIVED BY THE SOCIETY JULY 31, 1989
MANUSCRIPT ACCEPTED FEBRUARY 26, 1990

Reply

PETER U. CLARK *Department of Geosciences, Oregon State University, Corvallis, Oregon 97331-5506*
WILLIAM D. McCOY, ERIC A. OCHES *Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts 01003*
ALAN R. NELSON *U.S. Geological Survey, M.S. 966, P.O. Box 25046, Denver, Colorado 80225*
BARRY B. MILLER *Department of Geology, Kent State University, Kent, Ohio 44242*

Alford favors an early Wisconsin age for the "Sicily Island loess" in Louisiana, based on its regional relations to soils and fluvial terraces in the southern Mississippi Valley. He argues that the "racemization *date*" (a common misnomer; we reported only aIle/Ile *ratios* and inferred relative age from them) which indicates that the "Sicily Island loess" at its type locality is pre-Wisconsin must be wrong. Much of the disagreement in the age of this unit, however, may stem from problems in identifying and correlating the "Sicily Island loess" beyond its type area. We suggest that "Sicily Island loess" elsewhere in the lower Mississippi Valley may be younger than the unit exposed at the type section. This hypothesis could be

The article discussed appeared in the *Bulletin*, v. 101, p. 918–926.

confirmed by amino acid analyses of shells from other sections. In response to Alford's comment concerning the reliability of aminostratigraphy, we discuss further the potential of these methods for solving stratigraphic problems in the Mississippi Valley. We also present data that support our conclusion that "Sicily Island loess" in its type area is pre-Wisconsin. This unit, however, may not be as old as we previously proposed; it may be correlative to the "Third loess" at Crowley's Ridge, Arkansas, which has been correlated with pre-Wisconsin Loveland Silt identified elsewhere in the Midwest, and "Chinatown silt" in Illinois, rather than older.

The primary basis for correlating "Sicily Island loess" beyond its type section is stratigraphic position. At its type section, "Sicily Island loess" overlies gravel of the Citronelle Formation that is probably early Pleistocene or older (Saucier, 1990) and underlies noncalcareous loess that is correlated with Peoria Loess (Miller and others, 1985). Miller and others (1985, 1986), Schumacher and others (1987), and Miller (1990) correlated "Sicily Island loess" at its type section with the pre–Prairie Terrace, post–Montgomery (= Irene) Terrace loess in southern Louisiana (Touchet and Daniels, 1970), the pre-Vicksburg loess at the Vicksburg section in Mississippi (Krinitzsky and Turnbull, 1967), and the "Third loess" on Crowley's Ridge, Arkansas. The soil developed in "Sicily Island loess" at its type section is significantly less well developed than are soils developed in loess units elsewhere in the lower Mississippi Valley that have been correlated to "Sicily Island loess" by Miller and others (1985, 1986), Schumacher and others (1987), and Miller (1990). For this reason, soil development cannot be the primary basis for correlation of this unit from its type area with these other units. Similarly, thickness-distance relationships cannot be used for correlation because "Sicily Island loess" is anomalously thick in its type area with respect to regional patterns of thickness of the unit mapped by Miller and others (1985, 1986).

The debate over an early Wisconsin or pre-Wisconsin age for "Sicily Island loess" is not restricted to Clark and others (1989). As discussed by Alford, an early Wisconsin age for loess units correlated to the "Sicily Island loess" in southern Louisiana is suggested by the relationship of these units to the Montgomery (= Irene) Terrace of Sangamon age and by thermoluminescence (TL) ages from pre-Vicksburg loess in Mississippi (Pye and Johnson, 1988). Other workers, however, have argued that the "Third loess" on Crowley's Ridge is correlative to pre-Wisconsin Loveland Silt (West and others, 1980; Rutledge and others, 1985; McKay and Follmer, 1985; Guccione and others, 1986). Furthermore, the ages of the Prairie and Montgomery (= Irene) Terraces are not as well constrained as suggested by Alford (compare Saucier, 1990).

All relative dating and correlation methods include assumptions. The basic assumption in using the degree of soil development to correlate soil-bearing units is that the climate, parent material, vegetation, and topography are closely similar at the sites of the correlated units. Correlation by stratigraphic position assumes that all major depositional events are represented in the sections compared. Lithology and color can be used to correlate units if it is assumed that key units have unique or characteristic lithologic properties.

Aminostratigraphy assumes that the extent of racemization in a carbonate shell varies only with the integrated effective diagenetic temperature (EDT) history of the shell, with taxonomy, and with age. Within a limited geographic area where the temperature history of all sites is assumed to be nearly the same, the extent of racemization (in this study, expressed as the ratio of alloisoleucine to isoleucine, aIle/Ile) should not vary for samples of the same taxa of equal age. Where independent dating control exists, the effect of different EDT's at different sites can be evaluated, and aminostratigraphic correlations can be made over a larger geographic area.

AIle/Ile ratios show a significant age difference between the "Sicily Island loess" at its type locality and the younger Peoria Loess. We reported a mean aIle/Ile ratio of 0.44 ± 0.01 from shells of the gastropod *Helicina* from the "Sicily Island loess" at its type section. In addition, we have since measured aIle/Ile ratios in additional samples of *Helicina* from "Sicily Island loess" at the type section and nearby sections that yield aIle/Ile values ranging from 0.40 to 0.50. One set of samples gave ratios of 0.53 ± 0.05 in *Helicina*, but this unusually high average is likely due to a higher effective temperature as a result of relatively shallow (only about 2 m) burial. What is important in this discussion is that aIle/Ile ratios of *Helicina* from the "Sicily Island loess" have not been found to be lower than 0.40. For comparison, aIle/Ile ratios measured on *Helicina* sampled from late Wisconsin Peoria Loess from the same latitude as Sicily Island range from 0.14 to 0.17.

It is possible that the "Sicily Island loess" is older than the "Chinatown silt" and the "Third loess" at Crowley's Ridge, but it is very unlikely that it could be younger. In Clark and others (1989), we argued that the north-south gradient of aIle/Ile ratios measured on well-dated samples from Peoria Loess could be used as a measure of expected change in ratios measured on older samples. According to this argument, the "Sicily Island loess" would be older than the "Third loess" at Crowley's Ridge, Arkansas, and "Chinatown silt" in Illinois. In subsequent work, we have measured aIle/Ile ratios on a number of additional samples from Peoria Loess, the "Third loess" at Crowley's Ridge, and "Sicily Island loess" (Fig. 1). In addition, we have plotted isochrons on our plot of aIle/Ile values against current mean annual temperature (M.A.T., Fig. 1), showing the expected latitudinal gradient in aIle/Ile ratios assuming that the differences in EDT's between sites are the same as the differences in MAT's. An EDT gradient calculated from radiocarbon-dated shells collected from late Wisconsin Peoria Loess is less steep than the current MAT gradient (Oches and others, 1989, 1990). Therefore, the use of the MAT gradient is conservative in this context; that is, it tends to predict a greater difference in aIle/Ile ratios between samples of the same age from different latitudes. Similarly, the assumption of a linear kinetic model (Wehmiller, 1981) is conservative in this context. AIle/Ile ratios measured on samples of *Hendersonia* and *Helicina* (shown by Clark and others, 1989, to racemize at the same rate) from the "Chinatown silt," the "Third loess" at Crowley's Ridge, and the "Sicily Island loess" fall close to a single isochron, suggesting possible equivalence in age. The correlation of the "Sicily Island loess" is somewhat uncertain, however, because it is not known if the high aIle/Ile ratios from the unit are beyond the "linear" segment of the *Helicina* kinetic curve (compare Wehmiller, 1981); if so, "Sicily Island loess" could be older than the other units on that isochron.

Alford concludes that either the "racemization date is wrong, or the Sicily Island loess has been misidentified at its type section." Subsequent analyses have supported the aIle/Ile ratios originally reported in Clark and others (1989). Furthermore, aminostratigraphic relationships with other Mississippi Valley loess units thought to be pre-Wisconsin indicate that the "Sicily Island loess" at its type section is the same age or older than those units, not younger. Therefore, we support the possibility that "Sicily Island loess" may have been miscorrelated beyond its type section, as suggested by Alford. Alford's correlations of "Sicily Island loess" at its type section with early Wisconsin loess on the Montgomery Terrace and "pre-Vicksburg loess" at the Vicksburg section rely on the completeness of the stratigraphic record. If one or more pre–Peoria Loess units are missing at the type section of "Sicily Island loess," however, as suggested by our data, then the assumption of a complete stratigraphic record is invalid. Alternatively, we suggest that if the correlations are correct, some correlative loess units might be older than early Wisconsin. There is little numerical age control on the Montgomery (= Irene) Terrace, and some components of the Prairie Terrace may be older than middle Wisconsin (Saucier, 1990).

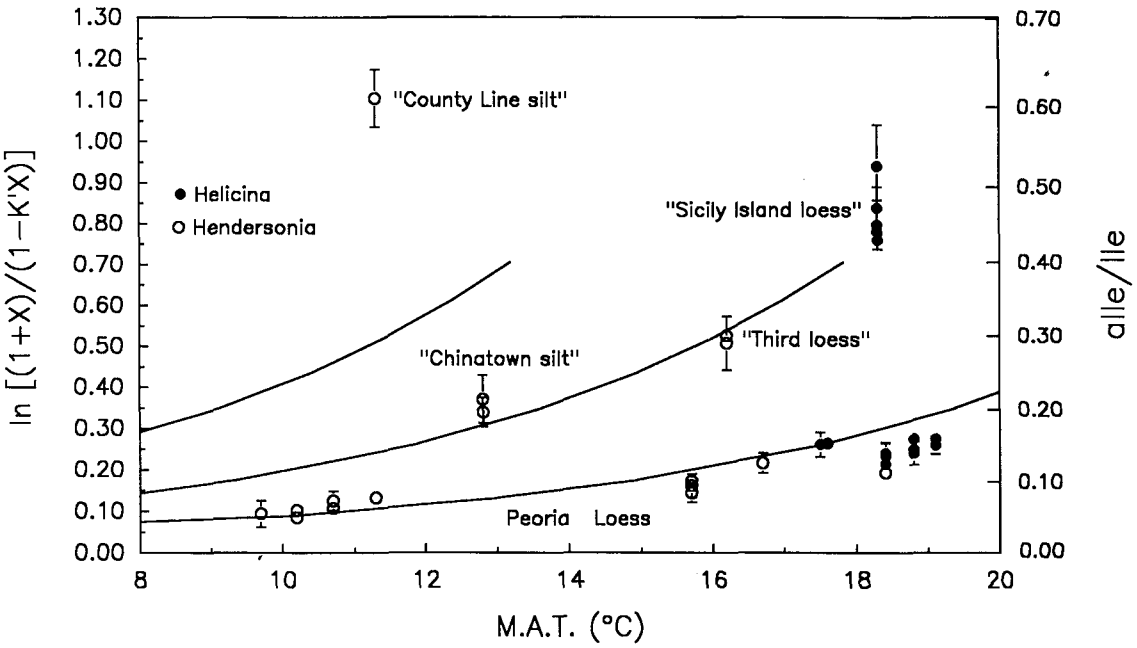

Figure 1. AIle/Ile values (total acid hydrolysate) measured on *Hendersonia* (open circles) and *Helicina* (closed circles) from Peoria Loess and pre-Peoria Loess units in the Mississippi Valley plotted against mean annual temperature (M.A.T.). The function on the left vertical axis transforms aIle/Ile ratios to provide a scale whereby equal intervals of time are represented (at least to a value of 0.6), assuming constant diagenetic temperature. (X in the transformation function refers to the measured aIle/Ile ratio; K′ refers to the reciprocal of the equilibrium constant of the isoleucine epimerization reaction.) Note that the scale on the right is not linear in this representation. Solid lines represent three arbitrary isochrons calculated using kinetics of epimerization of *Hendersonia* (E. A. Oches and W. D. McCoy, unpub. data). The absolute age of each isochron is dependent on effective diagenetic temperature (EDT), which is unknown for all of the pre-Peoria Loess samples and many of the Peoria Loess samples. Note that the "Third loess" is the same as the Loveland Silt referred to in Clark and others (1989). The "County Line silt" is magnetically reversed (Miller and others, 1989).

Finally, TL ages from the "pre-Vicksburg loess" at the Vicksburg section (Pye and Johnson, 1988) may be only minimum ages, because the accuracy of TL ages >75–100 ka is not well constrained (Forman, 1989).

ACKNOWLEDGMENTS

We thank Whitney Autin for discussion and Dan Muhs and Steve Forman for reviews. The generation of data reported has been supported by National Science Foundation ATM86-12455 and ATM86-12621.

REFERENCES CITED

Clark, P. U., Nelson, A. R., McCoy, W. D., Miller, B. B., and Barnes, D. K., 1989, Quaternary aminostratigraphy of Mississippi Valley loess: Geological Society of America Bulletin, v. 101, p. 918–926.

Forman, S. L., 1989, Applications and limitations of thermoluminescence to date Quaternary sediments: Quaternary International, v. 1, p. 47–59.

Guccione, M. J., Prior, W. L., and Rutledge, E. M., 1986, The Tertiary and Quaternary geology of Crowley's Ridge: Geological Society of America Meeting, Southeastern and South-Central Sections, Memphis, Tennessee, Guidebook, p. 1–37.

Krinitzsky, E. L., and Turnbull, W. J., 1967, Loess in Mississippi: Geological Society of America Special Paper 94, 64 p.

McKay, E. D., and Follmer, L. R., 1985, A correlation of lower Mississippi Valley loesses to the glaciated Midwest: Geological Society of America Abstracts with Programs, v. 17, p. 167.

Miller, B. B., McCoy, W. D., Palmer, D. F., Plevniak, J., and Marlette, P., 1989, The "County Line" assemblage: Oldest Quaternary biota from Illinois?: Geological Society of America Abstracts with Programs, v. 21, p. A281.

Miller, B. J., 1990, Pedology, *in* Morrison, R. B., ed., Quaternary nonglacial geology; conterminous United States: Boulder, Colorado, Geological Society of America, Decade of North American Geology, v. K-2 (in press).

Miller, B. J., Lewis, G. C., Alford, J. J., and Day, W. J., 1985, Loesses in Louisiana and at Vicksburg, Mississippi: Friends of the Pleistocene, South-Central Cell, Guidebook, 126 p.

Miller, B. J., Day, W. J., and Schumacher, B. A., 1986, Loesses and loess-derived soils in the lower Mississippi Valley: American Society of Agronomy Meeting, New Orleans, Louisiana, Guidebook, 144 p.

Oches, E. A., McCoy, W. D., and Clark, P. U., 1989, Amino acid paleotemperature estimates for the Last Glacial Maximum, lower Mississippi Valley: Geological Society of America Abstracts with Programs, v. 21, p. A210.

Oches, E. A., Clark, P. U., McCoy, W. D., and Miller, B. B., 1990, Isoleucine epimerization in Quaternary gastropods from Mississippi Valley loess: Stratigraphic correlations and paleotemperature trends: Illinois State Geological Survey Guidebook (in press).

Pye, K., and Johnson, R., 1988, Stratigraphy, geochemistry, and thermoluminescence ages of lower Mississippi Valley loess: Earth Surface Processes and Landforms, v. 13, p. 103–124.

Rutledge, E. M., West, L. T., and Omakupt, M., 1985, Loess deposits on a Pleistocene age terrace in eastern Arkansas: Soil Science Society of America Journal, v. 49, p. 1231–1238.

Saucier, R. T., 1990, Geomorphology, stratigraphy, and chronology, *in* Morrison, R. B., ed., Quaternary non-glacial geology of the conterminous United States: Boulder, Colorado, Geological Society of America, Decade of North American Geology, v. K-2 (in press).

Schumacher, B. A., Miller, B. J., and Day, W. J., 1987, A chronotoposequence of soils developed in loess in central Louisiana: Soil Science Society of America Journal, v. 51, p. 1005–1010.

Touchet, B. A., and Daniels, R. B., 1970, A post-Montgomery, pre-Prairie age loess near Ville Platte, Louisiana: Southeastern Geology, v. 12, p. 83–93.

Wehmiller, J. F., 1981, Kinetic model options for interpretation of amino acid enantiomeric ratios in Quaternary mollusks: Comments on a paper by Kvenvolden et al. (1979): Geochimica et Cosmochimica Acta, v. 45, p. 261–264.

West, L. T., Rutledge, E. M., and Barber, D. M., 1980, Sources and properties of loess deposits on Crowley's Ridge in Arkansas: Soil Science Society of America Journal, v. 44, p. 353–358.

MANUSCRIPT RECEIVED BY THE SOCIETY FEBRUARY 26, 1990
MANUSCRIPT ACCEPTED FEBRUARY 26, 1990