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Pre-Settlement Vegetation at Casey's Paha State Preserve, Iowa

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Paha are loess-capped ridges standing 10–30 m above the surrounding plain of the Iowan Surface. Although Iowa was almost entirely covered with prairie and wetlands just prior to Euro-American settlement, the paha are believed to have been forested based on soil types and on early vegetation maps. The objective of this study was to find evidence that paha were forested by measuring the $\delta^{13}C$ value of humin, the fraction of soil organic matter that is insoluble in acid and base. Previous work has shown that humin retains the $\delta^{13}C$ signature of vegetation on a 1000-year time scale, as opposed to the more mobile and soluble humic and fulvic acids that reflect the $\delta^{13}C$ signature of more recent vegetation. Soil samples were obtained from Casey's Paha State Preserve in Tama County from four locations at depths ranging from 5–85 cm. Carbonates were removed with 1.0 M HCl and humic and fulvic acids were removed by repeated application of 0.5 M NaOH. The $\delta^{13}C$ values of the humin fraction (−22.031‰ to −24.358‰) were within or slightly above the upper range of $\delta^{13}C$ values for woody vegetation (−23‰ to −34‰) and well below the range for prairie grasses (−9‰ to −17‰). Although it has been suggested that prairie fires bypassed the paha or that perched water tables maintained the forest, we suggest that the paha forests resulted from activity by Native Americans.

The landform region of northeastern Iowa known as the Iowan Surface is characterized by low relief, long slopes, poorly defined drainage divides and open views to the horizon (Prior 1991; Anderson 1998) (see Fig. 1). The term paha refers to elongated ridges and isolated oblong hills, kilometers in length and standing 10–30 m above the surrounding plain of the Iowan Surface (Ruhe 1969; Prior 1991). The term was adapted from the Lakota language by McGee (1891) who described paha as "the elongated swell of soft and graceful contour, standing apart on the plain, or else connected with its fellows sometimes in long lines, again in congeries, and locally merging to form broad plateaus." Paha are mantled with loess and fine sand and are distinctly oriented in a northwest-to-southeast direction (Scholtes and Smith 1950; Ruhe 1969; Anderson 1972; Hallberg et al. 1978; Fleckenstein 1992; Anderson 1998; Herzberg and Pearson 2001). Eighty percent of the 116 paha occur within 35–80 km of the irregular southern boundary of the Iowan Surface (Prior 1991) (see Fig. 1). The description of paha and speculation as to their origin was an active area of research around the turn of the century (Norton 1895, 1901, 1906; Savage 1905; Shimek 1908; Alden and Leighton 1915).

The modern interpretation of the Iowan Surface is that it resulted from the intense periglacial erosion of the pre-Illinoian till plain that occurred during the coldest part of the Wisconsinan Stage 16,500–21,000 years ago (Prior 1991). The paha that occur at interstream divides are the erosional remnants of the pre-Illinoian till plain. These remnants received a greater deposition of loess than the lower lying erosion surface (Ruhe 1969). Other paha are found parallel to and close to river valleys. These paha presumably accumulated loess from river valleys at a rate that exceeded the rate of periglacial wasting (Prior 1991).

At the present time, paha are often covered by forest and are essentially the only upland woods on the Iowan Surface (Anderson 1998). Just prior to Euro-American settlement of Iowa, trees were confined to river valleys and the farthest northeast corner of the state, the remainder being covered with prairie or wetlands (Prior 1991). However, beginning with McGee (1891), it has been argued that the paha were forested at the time of settlement. Norton (1906) suggested that the paha had a thicker cover of loess than the surrounding plain because the loess was intercepted by the trees on the paha. Scholtes (1955) showed that some of the paha soils developed under grass vegetation and some under woody vegetation, as opposed to the soils of the rest of the Iowan Surface, which developed almost entirely under grass vegetation. Prior (1991) suggested that the fires that maintained the tallgrass prairie bypassed the paha. Fleckenstein (1992) suggested that perched water tables on paha may have supported the paha forest. However, since the paha are simply the erosional remnants of the pre-Illinoian till plain, the stratigraphy of the paha, loess overlying a clay-rich paleosol, is identical to the stratigraphy of the uplands (pre-Illinoian till plain) of the Southern Iowa Drift Plain (Prior 1991) (see Fig. 1). On that basis, perched water tables should be no more common on paha than on the uplands of the Southern Iowa Drift Plain, which was almost entirely prairie just prior to settlement. On the other hand, there is no obvious reason why prairie fires should have bypassed the paha. In the Loess Hills of Iowa (see Fig. 1), as in most other parts of the Midwest, it is the summits that are covered by prairie, while trees occupy the lowlands (Prior 1991). If Prior's (1991) suggestion is correct, then the existence of forests on paha draws attention to an aspect of prairie fire that cannot be reconciled with current knowledge about fire.

The objective of this study was to find evidence for the existence of forest on paha prior to settlement. All fieldwork was carried out at Casey's Paha State Preserve in northeastern Tama County (see Fig. 1). Casey's Paha is a 71-ha preserve, which includes about 800 m of an approximately 4-km long paha (Herzberg and Pearson 2001) (see Figs. 2–3). The 1832–1859 Government Land Office Vegetation Map of Tama County (Anderson 2000) shows the paha covered by "grove," the river valleys filled in with "timber," and the surrounding area covered

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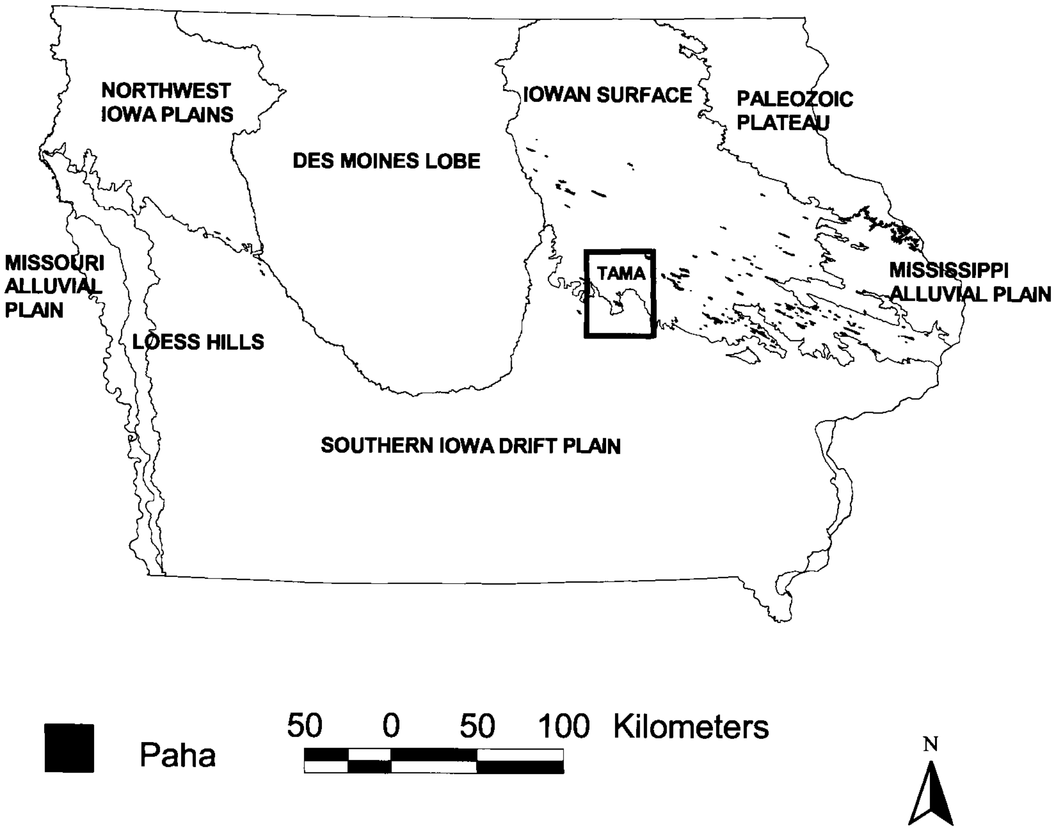

Fig. 1 Paha ridges superimposed on the major landform regions of Iowa (Kohrt and Prior 2006a, 2006b). Casey's Paha State Preserve is located in the northeast corner of Tama County.

by prairie (see Fig. 2). The first soil survey of Tama County did not distinguish between paha soils and the soils of the surrounding plain (Aandahl and Simonson 1950; Scholtes and Smith 1950; Scholtes 1955). However, the more recent soil survey clearly distinguishes between alfisols (soils developed under deciduous forest) on the paha and mollisols (soils developed under prairie) on the surrounding plain (Wisner 1995; USDA 1999) (see Fig. 3). By coring trees on Casey's Paha, Duvick (1990) found many trees showing a strong release effect in 1935, implying widespread tree cutting at that time. The oldest tree found on Casey's Paha was a white oak (*Quercus alba*) with estimated germination date of 1762. Casey's Paha is located within the 269-ha Hickory Hills Recreation Area, which was purchased by the Black Hawk County Conservation Board in 1974. The state preserve was dedicated in 1989 (Herzberg and Pearson 2001). Casey's Paha is currently covered by forest with sparse prairie grasses. A flora survey will be completed by the summer of 2008 (J. A. Pearson, pers. comm.)

The objective of finding evidence for pre-settlement forest was addressed by measuring the $\delta^{13}C$ value of soil humin collected from Casey's Paha. The $\delta^{13}C$ value is defined by

$$\delta^{13}C = \frac{R_{sample} - R_{standard}}{R_{standard}},$$

where $R = {}^{13}C/{}^{12}C$. Since plants that follow the C_3 photosynthetic pathway (woody plants, cool-season grasses and forbs) discriminate against ^{13}C more strongly than plants that follow the C_4 photosynthetic pathway (dominant prairie grasses), C_3 plants will show lower $\delta^{13}C$ values ($-23‰$ to $-34‰$) than C_4 plants ($-9‰$ to $-17‰$) (Bender 1971; Smith and Epstein 1971). The ability of stable carbon isotopes to distinguish between soils that host C_3 and C_4 vegetation has been well-documented (Wang et al. 1993; Bekele and Hudnall 2003; Henderson et al. 2004; Miller et al. 2007). All soil contains humus, which derives from the decomposition of vegetation. Humus can be subdivided into humic acids, fulvic acids and humin. Fulvic acids remain in solution at all pH values, humic acids will precipitate in acidic solutions, while humin is insoluble in both acids and bases (Webb et al. 2004). Humin is the least mobile fraction, has the slowest turnover time, and reflects the $\delta^{13}C$ value of the oldest vegetation. Webb et al. (2004) showed that the $\delta^{13}C$ value of humin reflects the vegetation occurring on a 1000-year time scale.

METHODS

Two soil cores, 100 m apart, were extracted from the summit of Casey's Paha with a slide hammer soil probe with diameter 7/8″ (2.22 cm). Two additional soil cores were extracted from the base of the paha, 80 m down slope from the location of each summit core. Soil samples were removed from each core corresponding to depths 5–10 cm, 20–25 cm, 35–40 cm, 50–55 cm, 65–70 cm and 80–85 cm. Soil samples, which were collected under subzero air temperatures, were frozen within two hours and thawed prior to preparation for analysis.

Samples were prepared for analysis by removing, first, carbonates and second, humic and fulvic acids, following the

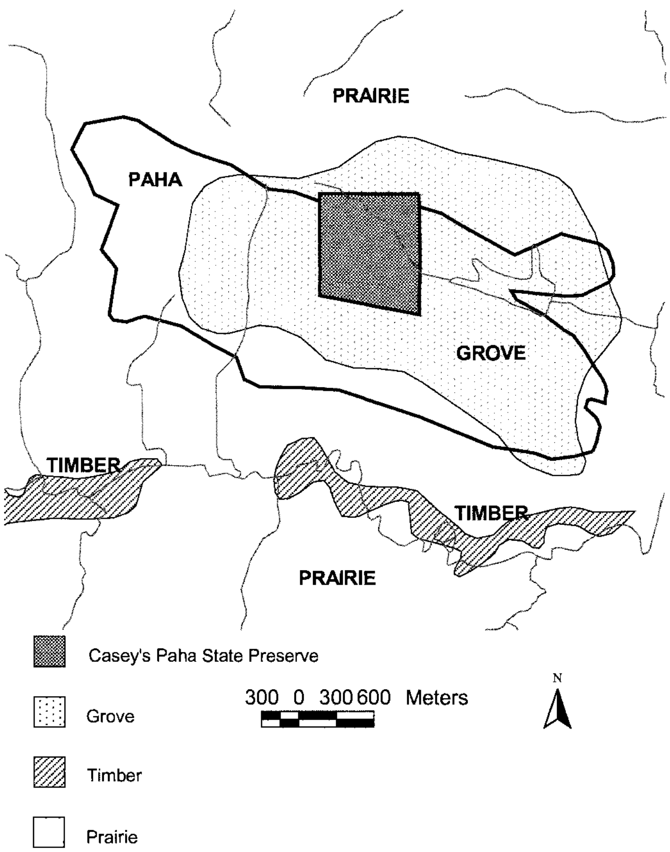

Fig. 2 Casey's Paha State Preserve superimposed on the 1832–1859 Government Land Office vegetation map (Anderson 2000) and stream map of Tama County (Korpel et al. 2000). The entire paha is the region enclosed by the bold elliptical shape (Kohrt and Prior 2006b).

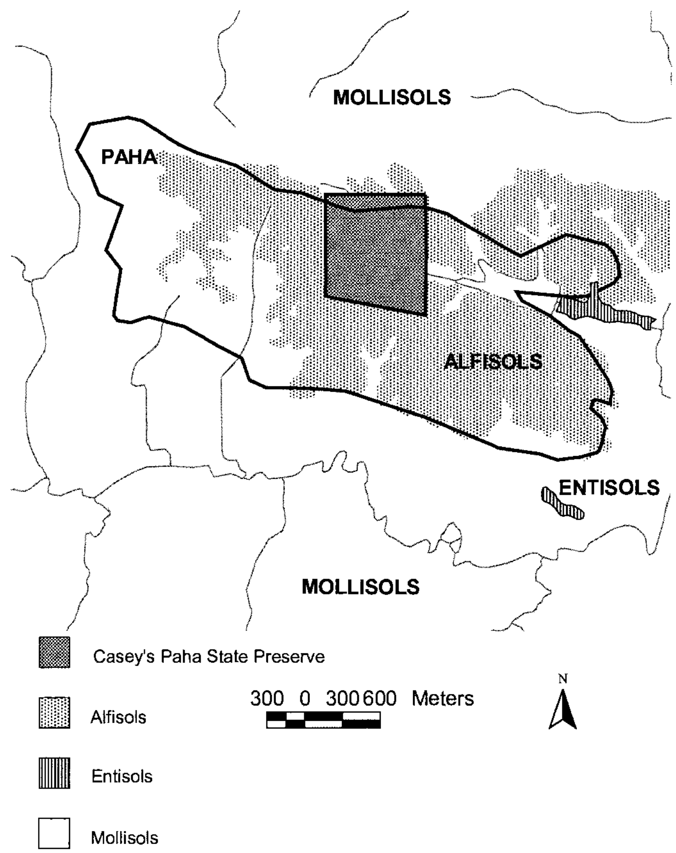

Fig. 3 Casey's Paha State Preserve superimposed on the soil order map (USDA 1999) and stream map of Tama County (Korpel et al. 2000). The entire paha is the region enclosed by the bold elliptical shape (Kohrt and Prior 2006b).

procedure of Webb et al. (2004). Each soil sample, which weighed approximately 45 g, was dried at 105°C and then crushed to a fine powder. After homogenization, 5 g of sample was removed and placed in a 50-mL centrifuge tube, and 1.0 M HCl was added until the solution maintained pH = 1. Samples were soaked in the solution until visual effervescence ceased, indicating the dissolution of carbonates. The excess solution was poured off and the sample was rinsed twice with distilled water to remove any remaining acid.

Humic and fulvic acids were removed by adding 25 mL of 0.5 M NaOH and an atmosphere of N_2 gas, and allowing the mixture to react overnight on a nutator mixer. The mixture was then centrifuged for 15 minutes and the supernatant (humic and fulvic acids) was poured off. The procedure was repeated until the supernatant appeared pale yellow. Webb et al. (2004) found that extraction of humic and fulvic acids by 0.5 M NaOH or by 0.1 M NaOH + 0.1 M $Na_4P_2O_7$ yielded the same results. Following extraction of the humic and fulvic acids, 1.0 M HCl was added to the residue of humin and mineral matter until pH = 7. Samples were kept in a N_2 atmosphere prior to analyses of stable carbon isotopes.

Stable carbon isotope analyses were carried out in the Department of Geological and Atmospheric Sciences at Iowa State University. Samples were first freeze-dried overnight. Aliquots of 30 to 90 mg of the residue were weighed out and analyzed for stable isotopes of carbon via pyrolysis at 1100°C in a Costech elemental analyzer fitted to a ThermoFinnigan Delta Plus XL isotope ratio mass spectrometer. Analytical precision and accuracy were determined on the basis of repeated analysis of two internal lab standards calibrated against the internationally accepted V-PDB standard. Overall uncertainty was better than 0.08.

RESULTS AND DISCUSSION

For all samples from depths 65–70 cm or deeper, there was insufficient carbon for measurement of $\delta^{13}C$. On the summit of the paha, there was insufficient carbon for depths of 35–40 cm or greater (see Table 1). The difference between organic matter content on the summit and base is consistent with drier conditions on the summit of the paha. For all samples, the $\delta^{13}C$ values were within or slightly above the range of values for C_3 vegetation (−23‰ to −34‰) and far lower than the values for C_4 vegetation (−9‰ to −17‰) (see Table 1). By comparison, Wang et al. (1993) found $\delta^{13}C$ values for soil organic matter from native prairie (Kaslow Prairie State Preserve) near Pocahontas, Iowa, in the range −19‰ to −16‰. The fact that the $\delta^{13}C$ values for Casey's Paha were in or slightly above the upper range for C_3 vegetation could be consistent with the recent addition of C_4 vegetation and the incomplete removal of humic and fulvic acids.

Table 1. $\delta^{13}C$ values of soil humin at Casey's Paha State Preserve.

Depth (cm)	Summit of Paha		Base of Paha	
	Core A	Core B	Core C	Core D
5–10	−24.358‰	−23.328‰	−22.641‰	−23.567‰
20–25	−23.953‰	−23.041‰	−22.543‰	−23.328‰
35–40	–[a]	–	−22.031‰	−22.815‰
50–55	–	–	−22.145‰	–
65–70	–	–	–	–
80–85	–	–	–	–

[a]Dashed line indicates insufficient carbon was present for measurement of $\delta^{13}C$.

For all soil cores, the $\delta^{13}C$ value increased with depth with the exception of a small decrease from 35–40 cm to 50–55 cm in one core from the base of the paha (see Table 1). All changes with depth exceeded the analytical uncertainty of 0.08. This result is also consistent with incomplete removal of humic and fulvic acids. The $\delta^{13}C$ values of the humic and fulvic acids reflect the more recent vegetation. Since the humic and fulvic acids are more mobile than the humin fraction, the carbon fraction with higher $\delta^{13}C$ value is leached downward.

CONCLUSIONS

The chief result of this study is further evidence that the paha were forested prior to Euro-American settlement of Iowa. We now return to the question as to whether prairie fires could have detoured around the paha. Fires follow the pathway of dry fuels, which are much more abundant in prairie than forest. On this basis, once paha have become forested, they will tend to remain forested. On the other hand, it is not clear why this scenario would not apply to the Loess Hills or the Southern Iowa Drift Plain, in which the uplands were not forested at the time of Euro-American settlement. Another factor is that flat topography increases susceptibility to fire (Wells 1970; Woodcock 1992). The flat topography of the Iowan Surface may have promoted the detouring of fires around the paha. This would not occur in the Loess Hills or the Southern Iowa Drift Plain since flat topography is largely absent in those landform regions. At the present time, there is no evidence that isolated hills on a flat surface will be protected from fire. It is important to point out that when explanations involving natural phenomena do not suffice, it is reasonable to look at the possible effects of human activity. Klinger (2006) has documented the cultivation and protection of giant sequoia (*Sequoia giganteum*) (for religious purposes?) and many species of oak trees by California Indians. We are suggesting that such an explanation might be appropriate for the paha of Iowa.

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