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MID-WISCONSINAN RADIOCARBON DATES FROM MASTODON- AND MAMMOTH-BEARING SPRINGS, OZARK HIGHLAND, MISSOURI

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From 1966 to 1979, the University of Missouri, the University of Arizona, and the Illinois State Museum conducted extensive interdisciplinary investigations of Late Pleistocene peat deposits associated with springs, some extinct, in the Pomme de Terre River Valley of the Ozark Highland, Missouri (fig 1). Most of the sites are now beneath the waters of the Harry S Truman reservoir. Archaeologic investigations in the area produced a remarkably long sequence of cultural change and development during the Holocene but produced no evidence of human presence in the area prior to 11,000 years ago despite diligent excavation of favorable bone-bearing deposits.

The chronosequence (fig 2) determined by detailed lithostratigraphic and geomorphic studies in conjunction with ^{14}C dating, consists of 7 alluvial terrace deposits of which 4 contain buried lenses of bone-, plant-, and pollen-bearing peat associated with ancient springs (Haynes, 1976; in press; Brakenridge, 1981). The Holocene alluvium consists of the Pippins formation of late prehistoric to historic age and the Rodgers formation containing evidence of as many as six cut and fill cycles. The earliest deposition (R_1) contains Paleo Indian artifacts and is dated to as early as 10,500 BP in Rodgers Rock Shelter which has yielded the most complete archaeologic record in the region (McMillan, 1976a). The next older alluvium is the Boney Spring formation with a date of 13,000 BP at the top, the 13,500-year-old Boney Spring fauna below this (Saunders, 1977), and an organic deposit near the base > 27,000 BP.

The Koch formation contains the Koch spring site where, in 1840, A C Koch recovered one of the best-preserved mastodon skeletons known (McMillan, 1976a). The assembled skeleton now resides in the British Museum of Natural History. The peat lens that contained the bones is between 30,000 and > 32,000 years old, based upon ^{14}C dating of Koch Spring, as discussed below. The Trolinger formation contains three spring sites, all of which have buried peat lenses and complex stratigraphy

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ranging in age from 32,000 to > 57,000 years old. The springs originated by water erupting through several meters of fine-grained floodplain sediments overlying aquifers composed of basal alluvial gravels (Haynes, in press). Loci of the springs appear to be controlled by topographic highs on top of the gravels and/or by fault-controlled feeders.

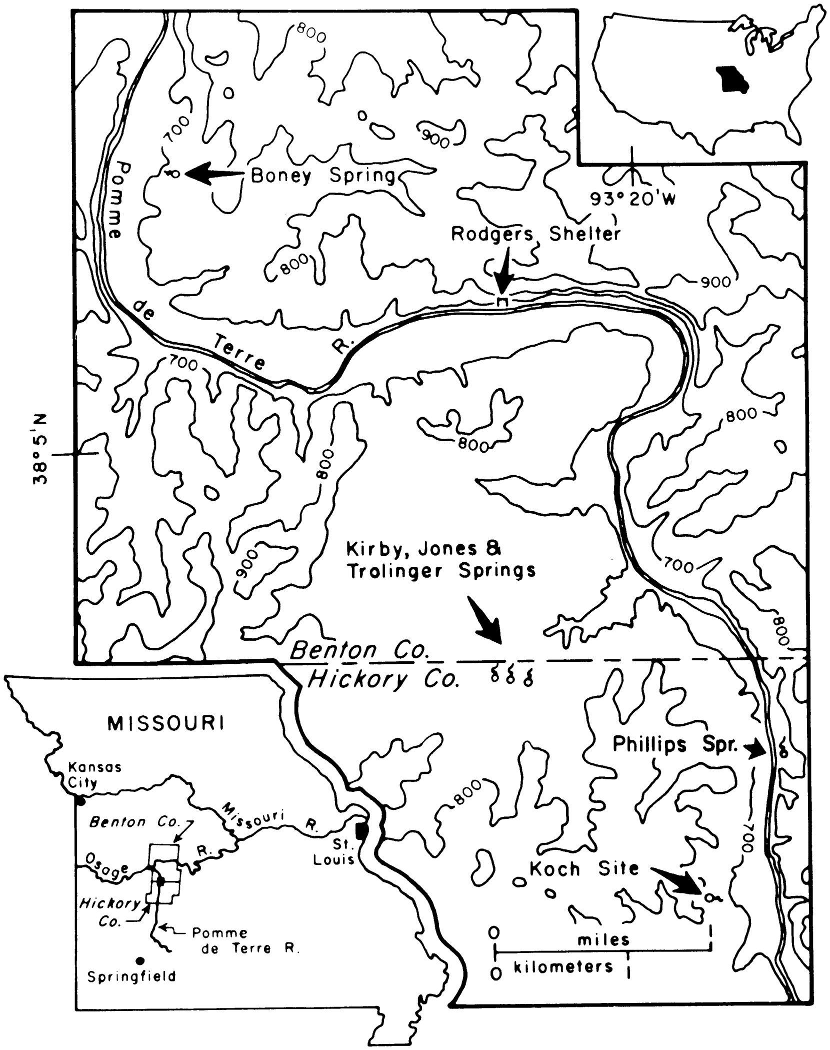

Fig 1. Spring locations, lower Pomme de Terre River, Benton and Hickory counties, Missouri

Hydrostatic pressure causing initial eruption seems to have been due to increased recharge associated with the more mesic parts of the late Pleistocene climatic cycles. Fossil pollen and plant macrofossils indicate that all of the peat lenses formed during the more xeric parts of the cycles when spring discharge was low. ^{14}C dating of the peat deposits or wood contained therein provides a discontinuous time calibration for the alluvial deposits. There appears to be general correlation between the peat deposits and the late Pleistocene interstadials.

TROLINGER SPRING. Previous studies at Trolinger Spring (Wood, 1976; King and Lindsay, 1976) revealed a bone-bearing peat lens overlying white, well-sorted quartz feeder sand, overlain by gray to brown alluvial silty clay, probably of the Boney Spring formation. The peat was subdivided into older (d_3) and younger (e) parts on the basis of sharp but discontinuous contacts within it (Haynes, 1976). ^{14}C dates within both parts ranged from 14,450 ± 500 BP (Gx-1318) to 34,300 ± 1200 BP (A-1080) but were not stratigraphically consistent. This made interpretations of the pollen and faunal data somewhat equivocal (Mehringer et al, 1968; King and Lindsay, 1976; King, 1973). Another potential problem might be churning of the peat by mastodons and other large animals entrapped in the spring as well as by a farm tractor that some local residents claimed had become stuck in the spring bog. Further, humic acids extracted from two peat samples yielded apparent ages much younger than the peat residue fractions, thus raising the question of adequate pretreatment before ^{14}C analysis.

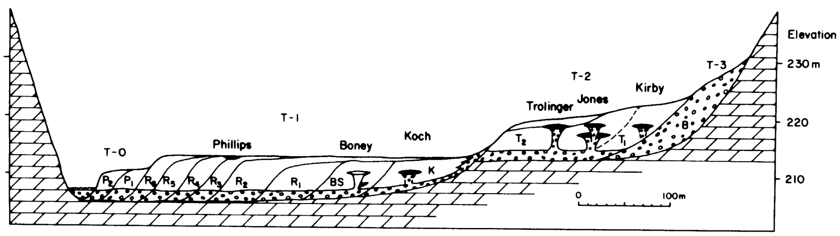

Fig 2. Generalized geologic cross section of alluvial terraces of the Pomme de Terre River valley showing the stratigraphic relationship of the spring sites with peat deposits (black lenses) to the terraces (T-0, T-1, T-2, and T-3). Geologic formations are Pippin (P), Rodgers (R), Boney Spring (BS), Koch (K), Trolinger (T), and Breshears (B).

Renewed excavations in 1978 and 1979 provided a new opportunity to perform ^{14}C dating with microstratigraphic control (fig 3). A third subdivision (d_3b) was recognized in the peat as well as what appear to be fragments of older peat incorporated as irregular masses in and below its basal part. Samples, carefully collected to obtain representative portions of each subunit, were rigorously pretreated by repeated digestion with hot HCl solution followed by NaOH extraction of humic acids and thorough washing with distilled water. Complete absence of humic acids is indicated when the base extractions become essentially colorless. This required as many as five cycles for some samples, resulting in smaller samples than desired by the Southern Methodist University Radiocarbon Laboratory. The standard deviations are, therefore, larger than desired, but adequate.

The five ^{14}C dates are all between 32,000 and 39,000 years old (table 1), indicating that all of the previous ^{14}C dates on Trolinger peat may have been too young. The five mean values are essentially in reverse stratigraphic order. They fall, however, into two distinct groups (fig 4): one between 32,270 ± 920 BP (SMU-931) and 32,950 ± 1040 BP (SMU-932), the other between 38,020 ± 2850 BP (SMU-935) and 38,880 ± 3750 BP (SMU-934) with an intermediate value of 38,200 ± 1680 BP (SMU-933). The two groups do not overlap at 1 σ, suggesting that the stratigraphic contact between them represents a significant hiatus. The sloping contact suggests that units e and d_3b were deposited after unit d_3a but the ^{14}C dates indicate that the reverse is true. Haynes (1976) suggested that the peaty organic matter around the eye of a cauldron type spring might be expected to accumulate inward as the discharge declined. It is possible that this happened at Trolinger Spring but more samples will have to be dated to substantiate it. Fortunately, more undated samples exist. If this turns out to be the case, the sloping contacts within the peat may be microfaults caused by disturbance and/or compaction rather than depositional contacts.

The presence of 22,000-year-old mastodon bones at the base of the peat (d_3) indicates the probability of some mixing. These are experimental dates on bone collagen and apatite, but they are probably correct (Hassan, ms). They support the suggestion (Haynes, 1976) that, in late Wisconsinan time, one or more mastodons, while seeking water, sank through a peat mat overlying the edge of a pool of water that formed the eye of the spring.

In addition to the peat at Trolinger Spring, we also collected fragments of wood that were encountered during excavation of the outer conduit gravels surrounding the feeder sand (fig. 3). These were possibly swept up during the initial period of spring eruption from the basal gravel and organic layer known to underlie the Breshears Valley in the area of Trolinger, Jones, and Kirby springs (Haynes, in press). ^{14}C analysis of one of these wood fragments (4 Mo 79, oak) in the University of Washington's subterranean counter after rigorous pretreatment at the University of Arizona produced a minimum age of > 55,000 BP (QL-1428) (table 1). This date is presumably associated with the grassland or savanna fauna from the conduit gravels including bear (Ursus), mammoth, horses (Equus, 2 species), extant deer (Odocoileus), and bison (Bison) (Saunders, 1981). A cool interstadial period, dominated by pine and herbs, is indicated by the fossil pollen from the peat at Trolinger Spring (King, 1973; King and Lindsay, 1976; Mehringer, King, and Lindsay, 1970). This is also consistent with the associated fauna of mastodon (Mammut), extinct deer (Sangamona), and woodland muskox (Symbos) (King and Lindsay, 1976; Saunders, 1977; 1981).

KOCH SPRING. Our previous investigations at Koch's original 1840 excavations demonstrated that the mastodon remains came from a buried peat lens (b_2) that dated 31,880 ± 1340 BP (Tx-1412) and 30,880 ± 1320 BP (Tx-1455) (Haynes, 1976). Concern about possibly incomplete humic-acid-removal from these samples prompted us to re-expose the peat lens at Koch Spring in 1978 to recollect large volume samples for analysis by the high-precision counting system at the University of Washington. Bulk samples of the upper and lower halves of the brown peat were collected. The peat contained abundant wood and

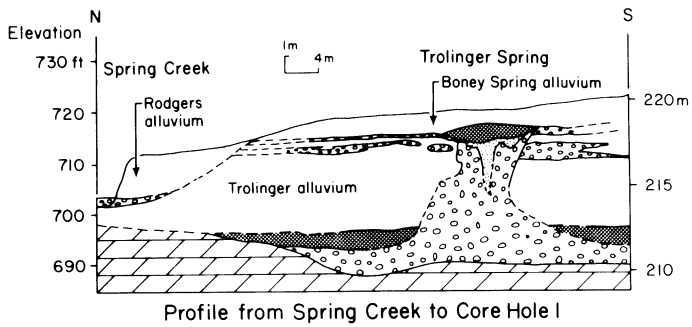

Fig 3. Geologic cross section (length 63m) of Trolinger Spring showing stratigraphic relationship of peat lens (dark stippling), feeder sand (light stippling), and conduit gravel (irregular circles) to alluvium. Lower organic ("peat") layer is an ancient slough.

plant fragments concentrated by screen washing and flotation set up by Illinois State Museum archaeologists at nearby Philips Spring (Kay, 1980). At the University of Arizona these concentrations were given the same pretreatment as described for the Trolinger samples. The stratigraphically consistent results of 30,530 ± 200 BP (QL-1427) over 31,090 ± 150 BP (QL-1429) for these samples (fig 4 and table 1) confirmed the previous dates for the peat lens and presumably, for the Koch mastodon in the British Museum. The lack of apparent mixing of the Koch peat in contrast to the Trolinger peat is perhaps due to the greater distance of the sampling sites from the central area or eye where the maximum concentration of bones and presumably disturbance occurred.

JONES SPRING. Excavations at Jones Spring from 1973-1977 revealed two superimposed lenses of bone-bearing peat (fig 5). The stratigraphy and the mixed and abraded faunal remains and fossil pollen indicate that the upper peat was in part derived from the lower lens when the latter was penetrated and disrupted by conduit sands and gravels during a renewed eruption of spring activity (Haynes, in press). The first generation of ^{14}C dates indicated an age of > 40,000 years for the lower lens and > 35,000 years for the upper lens. A younger age for the upper peat can probably be precluded despite its mixed nature because it is stratigraphically the same age as or older than the peat at Trolinger Spring, < 150m to the northeast.

Table 1. ^{14}C dates from the Pomme de Terre valley

Sample No.	^{14}C date; yrs BP (lab no)	Unit	Spring Location
	Koch Formation		
47 Mo 78	30,530±200 (QL-1427)	Brown peat b_2	Koch
48 Mo 78	31,090±150 (QL-1429)	" " "	"
	Trolinger Formation		
5 Mo 78	32,270±920 (SMU-931)	Black peat d_3a	Trolinger
6 Mo 78	32,950±1040 (SMU-932)	" " "	"
9 Mo 78	38,020±2850 (SMU-935)	" " e	"
8 Mo 78	38,880±3750 (SMU-934)	" " e	"
7 Mo 78	38,200±1680 (SMU-933)	" " d_3b	"
11 JEK 76	48,900±900 (QL-962)	Gray clay	Jones
4 Mo 79	> 55,000 (QL-1428)	Conduit gravel	Trolinger
45 Mo 78	> 57,000 (QL-1426)	Brown peat	Kirby

The basal portion (c_1) of the lower peat lens at Jones Spring is pebbly and contains different ecologic indicators than the overlying portion (c_2). A small log of red cedar (Juniperus virginiana) at the basal contact of the lower peat dated 48,900 ± 900 BP (QL-962) (fig 4 and table 1) and applies

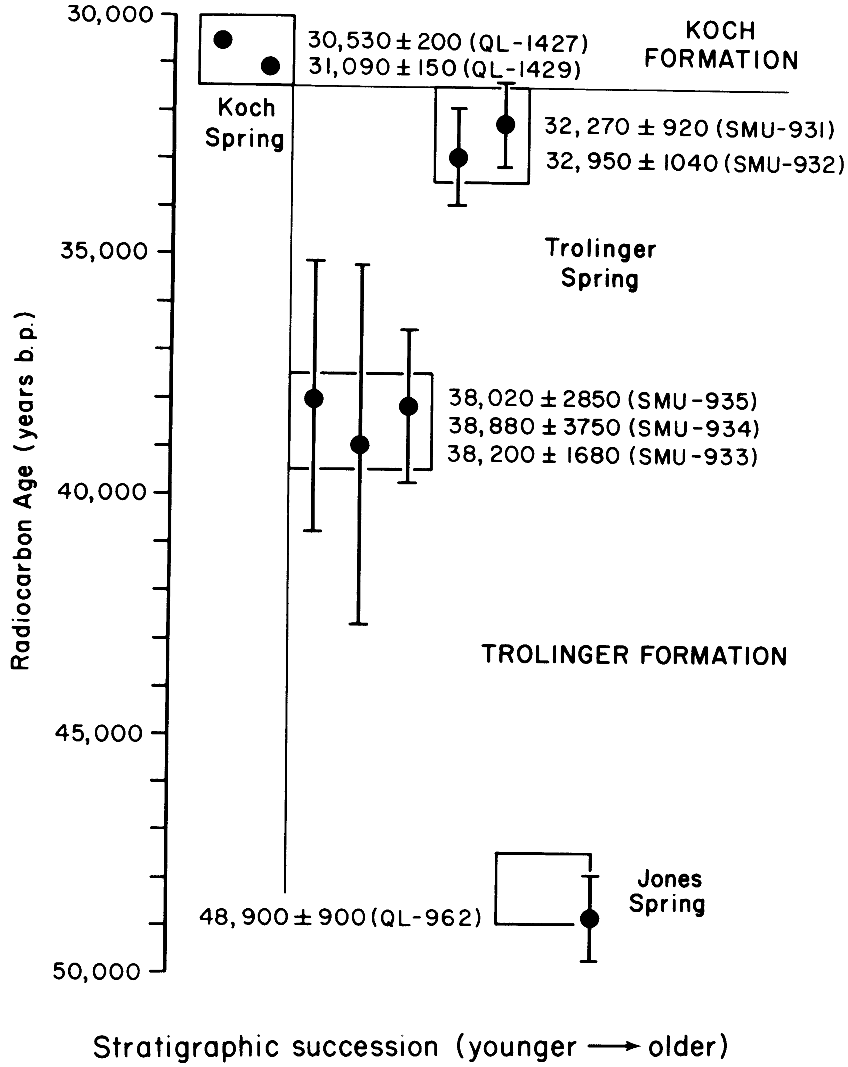

Fig 4. ^{14}C age determinations versus stratigraphic succession for the Koch and Trolinger formations

to a warm c_1 fauna including mastodon, grazers such as mammoth (Mammuthus), camel (Camelops), and giant bison (Bison latifrons), as well as alligator (Alligator) and large turtles. The associated plant macrofossils reflect warmer interstadial vegetation. A change to cooler interstadial conditions in the overlying c_2 is indicated by a fauna containing a smaller bison (B antiquus) and woodland muskox (Symbos or Bootherium). The upper peat lens at Jones is too mixed to provide a reliable faunal assemblage or a reproducible pollen record.

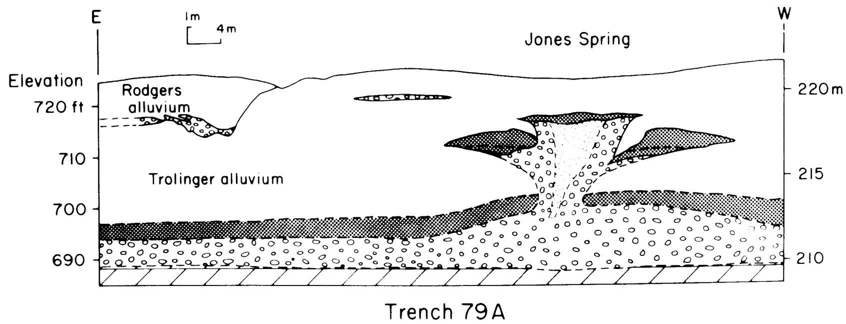

Fig 5. Geologic cross section (length 81m) of Jones Spring showing stratigraphic relationship of peat lenses (dark stippling), feeder sand (light stippling), and conduit gravel (irregular circles) to alluvium. Lower organic ("peat") layer is an ancient slough.

KIRBY SPRING. The oldest ^{14}C date from this region is > 57,000 BP (QL-1426) (table 1) for a brown peat layer at Kirby Spring occurring 300m west of Jones Spring. The date agrees with previous dates in excess of 25,000 (Gx-2720), 27,000 (Gx-2719, and 37,000 BP (Tx-2719) (Haynes, 1976). Fossil bones including those of probosicideans are thought to have been removed from here in the late 1800's, but the character of the fauna is unknown (McMillan, 1976b). Fossil pollen, on the other hand, provided a useful record of herbaceous pollen dominance and more xeric conditions than those of today. We believe this deposit is interglacial, probably Sangamon, or stage 5e of the sea floor oxygen isotope record (Shackleton and Opdyke, 1973).

CONCLUSIONS

Correlations of the Pomme de Terre paleoecologic record with the glacial chronologies of the Great Lakes areas is frustrated by the lack of ecologic indicators and ^{14}C dates from the deposits occurring between the peat lenses. Only the alluvium at Boney Spring proved adequate in this regard and revealed an obvious correlation of alluvial clays (C_4 and D, Haynes, 1976) with the Woodfordian Substage of the Wisconsinan Stage of Frye, Willman, and Glass (1968). The underlying peat (C_3) is a logical correlative of the Farmdalian Substage, based on both age (22,000 - 27,000 BP) and interstadial pollen record.

If we consider the previous ^{14}C dates from the Trolinger peat too young, then the Koch peat provides the next younger dates of 30,000 to 31,000 BP for an interstadial interval. This could be equivalent to the last part of the Plum Point interstade of Dreimanis and Goldthwait (1973). Possibly, the entire interval, 22,000 BP - 31,500 BP, in the Ozark Highland is one of interstadial climatic conditions and thus coincides with the Plum Point of the eastern Great Lakes region. The pollen record from Boney Spring indicates gradual rise in the spruce maximum ca 20,000 BP whereas pollen profiles from both Trolinger and Koch peats show a very abrupt spruce appearance at their tops. A possible explanation is that the spruce pollen in the latter two deposits is intrusive into the top of the peats and actually reflects the vegetation at the beginning of deposition of the overlying clays. The accessibility of Trolinger peat to animals 22,000 years ago is demonstrated by the age of the ^{14}C-dated mastodon bones. The overlying clay (f_2) is considered to be backwater deposits of the Boney Spring formation carried into the abandoned meander of the Breshears Valley by flood waters from the Pomme de Terre River.

The next oldest ^{14}C dates are from 32,000 to 39,000 BP from the Trolinger Spring peat with a possible intermediate hiatus. Again, the pollen and fauna indicate cool interstadial conditions. This chronology leaves little room for significant cold stadials between 22,000 and 39,000 years ago, and leads to the possibility that this period represents the intermediate climate indicated by the early part of Stage 2 and the later part of Stage 3 of the sea floor oxygen isotope record (Shackleton and Opdyke, 1973). Episodes of renewed spring discharge indicated within the microstratigraphy of the spring sediments, such as subfeeders, may represent the smaller climatic fluctuations in the oxygen isotope curve.

The initial eruption of Jones and Trolinger Springs may have occurred during Stage 4 when a cold episode almost as severe as that of Stage 2 occurred. If this correlation is correct, the basal fauna and pollen record from the lower peat at Jones Springs would fall somehwere in Stage 5 after 5e, which, as already suggested, is the likely correlative of the pollen record from Kirby Spring and possibly represents a Sangamonian flora.

ACKNOWLEDGMENTS

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