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Geology of the Dry Creek Site; a Stratified Early Man Site in Interior Alaska

ROBERT M. THORSON[1]

Geology Department, University of Alaska, Fairbanks, Alaska

AND

THOMAS D. HAMILTON

U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025

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The Dry Creek archeologic site contains a stratified record of late Pleistocene human occupation in central Alaska. Four archeologic components occur within a sequence of multiple loess and sand layers which together form a 2-m cap above weathered glacial outwash. The two oldest components appear to be of late Pleistocene age and occur with the bones of extinct game animals. Geologic mapping, stratigraphic correlations, radiocarbon dating, and sediment analyses indicate that the basal loess units formed part of a widespread blanket that was associated with an arctic steppe environment and with stream aggradation during waning phases of the last major glaciation of the Alaska Range. These basal loess beds contain artifacts for which radiocarbon dates and typologic correlations suggest a time range of perhaps 12,000–9000 yr ago. A long subsequent episode of cultural sterility was associated with waning loess deposition and development of a cryoturbated tundra soil above shallow permafrost. Sand deposition from local source areas predominated during the middle and late Holocene, and buried Subarctic Brown Soils indicate that a forest fringe developed on bluff-edge sand sheets along Dry Creek. The youngest archeologic component, which is associated with the deepest forest soil, indicates intermittent human occupation of the site between about 4700 and 3400 ^{14}C yr BP.

INTRODUCTION

The Dry Creek archeologic site occupies a prominent loess-covered bluff within the Nenana Valley about 10 km north of the Alaska Range (Figs. 1 and 2). Excavations in 1973 and 1974 revealed that the site contains a well-stratified record of environmental fluctuations and repeated human occupations which span more than 11,000 yr. Five buried paleosol complexes within eolian sediments record arctic steppe conditions of the late Pleistocene (Matthews, 1976) succeeded by a milder forested environment during Holocene time. The Dry Creek site is the first well-documented occurrence in Alaska of deeply buried artifacts and charcoal in primary stratigraphic association with the bones of late Pleistocene mammals. Cultural horizons between 1- and 2-m depth also show strong similarities to the Siberian Paleolithic (Powers and Hamilton, in press), suggesting that the site may have been first occupied during an early phase of late Pleistocene human influx into the New World.

Because of its potential paleoecologic significance and Early Man record, detailed geologic studies of the Dry Creek site were carried out in conjunction with the archeologic excavations. Primary objectives of the geologic program were to (1) document the site's stratigraphy and its lateral variations, (2) determine the genesis of local soils and sediments, (3) date the principal geologic and cultural events represented at the site, and (4) determine the environmental history

[1] Present address: Department of Geological Sciences, University of Washington, Seattle, Washington 98195.

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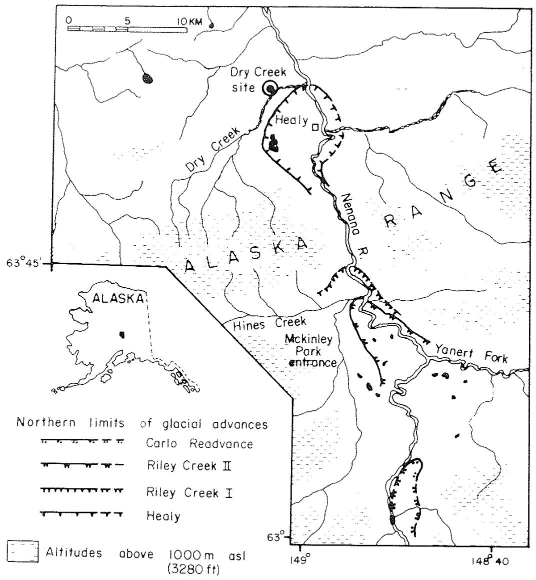

FIG. 1. Location map, Dry Creek archeologic site.

of the area and its probable relations to the successive human occupations.

REGIONAL SETTING

The area around Dry Creek, which occupies a transition zone at about 500-m altitude between the rugged Alaska Range and its more subdued northern foothills (Fig. 3), exhibits a varied and complex Quaternary history. Glacial, glaciofluvial, and lacustrine sediments within the Nenana Valley, alluvial deposits of Dry Creek, and eolian sediments of diverse provenance record the complex succession of environmental changes that occurred here during middle and late Quaternary time.

The Pleistocene glacial sequence of the Nenana Valley was defined by Wahrhaftig (1953, 1958). Wahrhaftig recognized two old and extensive glaciations, Browne and Dry Creek, each of which was followed by major episodes of erosion, weathering, and tectonic uplift of the Alaska Range. The Browne Glaciation is now believed to be of late Pliocene to early Pleistocene age (Wahrhaftig, personal communication, 1974); the Dry Creek Glaciation probably dates broadly from the middle Pleistocene. During the subsequent Healy Glaciation, ice advanced down the Nenana Valley and expanded into a piedmont lobe that terminated about 1 km upvalley from the Dry Creek site (Fig. 1). Outwash from the Healy moraine forms the substrate upon which the site's eolian deposits and paleosols later formed. The Riley Creek Glaciation, which includes the last major ice advances in the Nenana Valley, terminated sometime prior to about 9000 yr BP. The Healy Glaciation is generally considered to be Illinoian in age (Péwé *et al.*, 1965), but it could be as young as early Wisconsinan (Péwé, 1975; Wahrhaftig, personal communication,

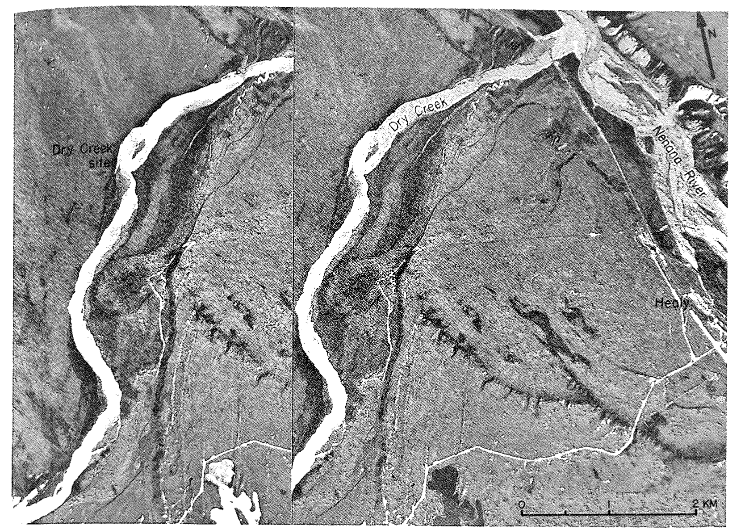

FIG. 2. Stereopair showing Dry Creek site and surrounding area.

1975). A late Wisconsinan age is generally accepted for the Riley Creek Glaciation.

Near its confluence with Dry Creek, the Nenana River presently occupies a relatively narrow (0.3 km), slightly braided flood plain incised within a series of broader outwash terraces of Healy and Riley Creek age. The bedload of the river consists primarily of very well-rounded to subrounded sand- to small-boulder-sized clasts of quartz–mica schist, lithic sandstone and conglomerate, and various volcanic and plutonic rocks. Its suspended load consists largely of rock fragments that impart a gray color in both water and sediments.

From its origin near the north flank of the Alaska Range, Dry Creek flows northeastward for 20 km along a wide, braided flood plain and crosses a small alluvial fan that presently is displacing the Nenana River towards its east bank. Near the head of its valley Dry Creek drains a 10-km-wide belt of the quartz–mica schist which forms the northernmost ridge of the Alaska Range in this region (Wahrhaftig, 1970a, b). Farther north, the creek crosses a narrow belt of Tertiary coal-bearing rocks, continues through poorly consolidated Pliocene gravel deposits, and finally crosses Quaternary deposits of Healy and Riley Creek age. Along the lower 8 km of its course, Dry Creek occupies a complexly braided network of shallow channels that averages 150 m in width and has an average gradient of about 20.7 m km^{-1}. Irregularly shaped cobbles and small boulders of quartz–mica schist account for 80% of its bedload. Most of the remaining clasts are well-rounded igneous and metasedimentary cobbles derived from the Pliocene gravel. Platy sand- to granule-sized coal fragments are also present in the flood plain of the creek downstream from the coal-bearing rocks. Dry Creek's suspended load, which consists almost entirely of platy fragments of weathered schist, quartz, and muscovite, imparts a pale brown color to its sediments.

Dry Creek presently lies within the dis-

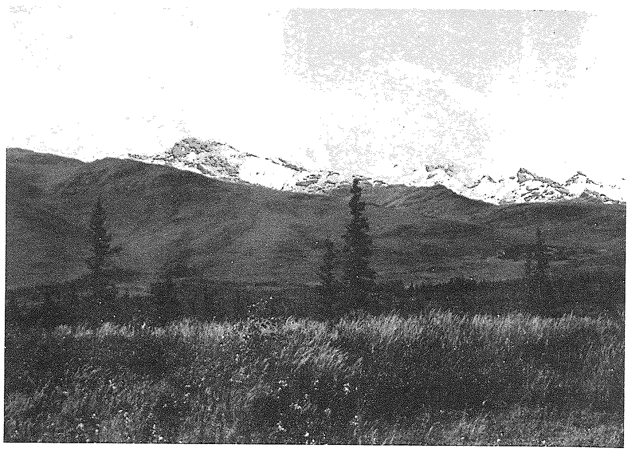

FIG. 3. Forest–tundra ecotone near Dry Creek. North flank of Alaska Range lies beyond forest border.

continuous permafrost zone (Ferrians, 1965), where local environmental factors such as slope angle and orientation, permeability of the substrate, vegetation, and hydrologic regimen control the presence or absence of perennially frozen ground. The presence of a silt cap and insulating vegetative cover generally is required for the maintenance of permafrost around the Dry Creek site. Permanently frozen ground exists about 1.2 to 1.5 m below the surface near the edge of the bluff but may be a shallow as 0.5 m in areas of denser vegetation.

Modern soils of the Dry Creek area can be differentiated into four general groups. Low-Humic Gley soils (*Cryaquepts*[2]), the most common soils forming today, develop in poorly drained areas where near-surface permafrost usually is present. Subarctic Brown Forest soils (*Ochrepts* and *Orthods*) develop on well-drained forested sites that fringe bluff edges and on locally elevated areas where permafrost is generally absent or deep. Bog soils (*Histosols*) develop in closed depressions where permafrost is near the surface. Regosols (*Inceptosols*) occur on freshly abandoned fluvial terraces and on windswept parts of older terraces and moraines.

Modern eolian deposition rates are extremely low throughout most of the Dry Creek area. During intervals of sustained high winds, silt- and clay-sized particles are swept from stream flood plains to form localized dust clouds that usually move northward down the valley. During these episodes an almost undetectable trace of dust is deposited on the ground surface. In contrast, areas near active flood plain margins are being rapidly inundated by local sand accumulation. Along most of the lower 4 km of Dry Creek, gusty winds frequently sweep sand and silt particles across the wide, bare flood plain to accumulate as rapidly aggrading deposits along its margins.

SITE GEOLOGY

The Dry Creek archeologic site extends along the edge of a prominent southeast-facing 25-m bluff that was created by downcutting of Dry Creek through outwash of the Healy Glaciation (Fig. 2). Natural exposures of eolian deposits and paleosols

[2] Terminology follows Soil Survey Staff (1960).

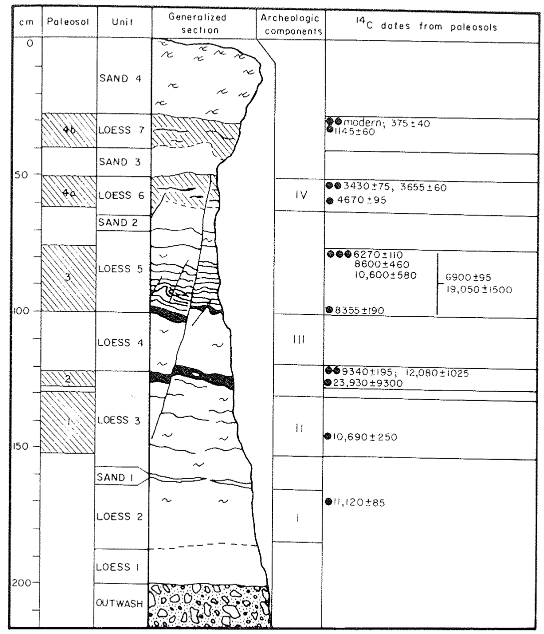

FIG. 4. Generalized stratigraphic section, Dry Creek site. Radiocarbon dates from 1974 test trench and adjacent bluff face.

above the outwash are continuous for nearly 100 m along the bluff because Dry Creek is actively eroding its bank through this stretch. Archeologic test excavations during 1974, which consisted of several test pits and a 15 × 2 m test trench dug perpendicular to the bluff face, afforded an excellent opportunity to study stratigraphic relations at the site. Seven loess units, four sand units, and five buried paleosols overlie the outwash (Figs. 4 and 5, and Table 1). All stratigraphic units with the exception of Sand 3 were continuous along the bluff face and throughout the test trench.

Outwash

At least 25 m of cobble- to small-boulder-sized outwash gravel underlies the eolian sediments at Dry Creek site. The gravel consists primarily of poorly sorted, rounded to subrounded clasts of quartz, schist, metasediments, metavolcanics, and other rocks set in a cleanly washed, coarse, sandy matrix. Average maximum clast diameter is about 20–30 cm, but small boulders 60–80 cm in diameter are fairly abundant. The outwash appears to coarsen upward, but it is capped by about 1 m of slightly finer gravel in which average maximum clast diameters are 15–20 cm. Shallow northward-trending channels cut into the outwash surface suggest that northward-flowing streams were the last to incise the surface.

Prior to deposition of its loess cover, the outwash surface was subjected to physical and chemical weathering. Most of the

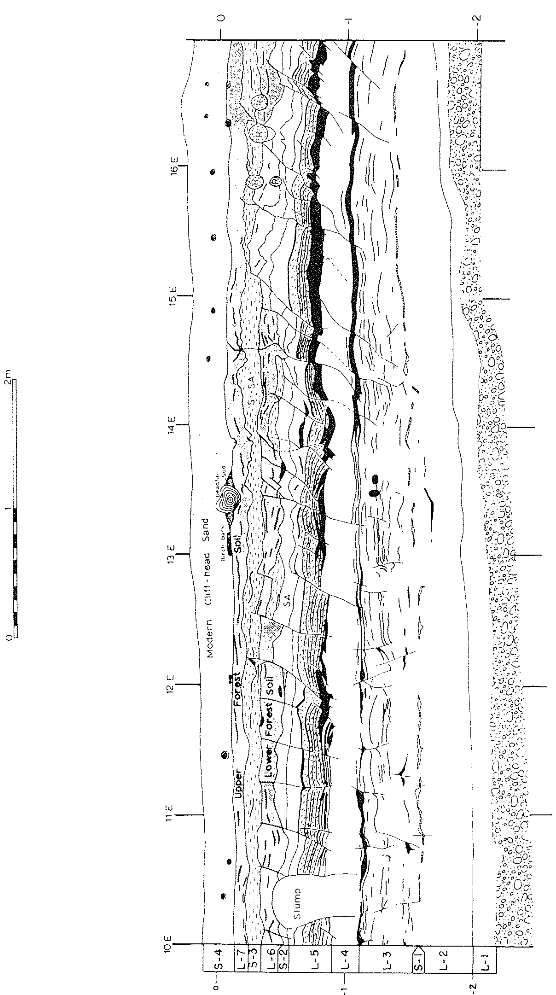

FIG. 5. Straigraphic section along north wall of 1974 test trench. Dry Creek Site. Bluff face is to right.

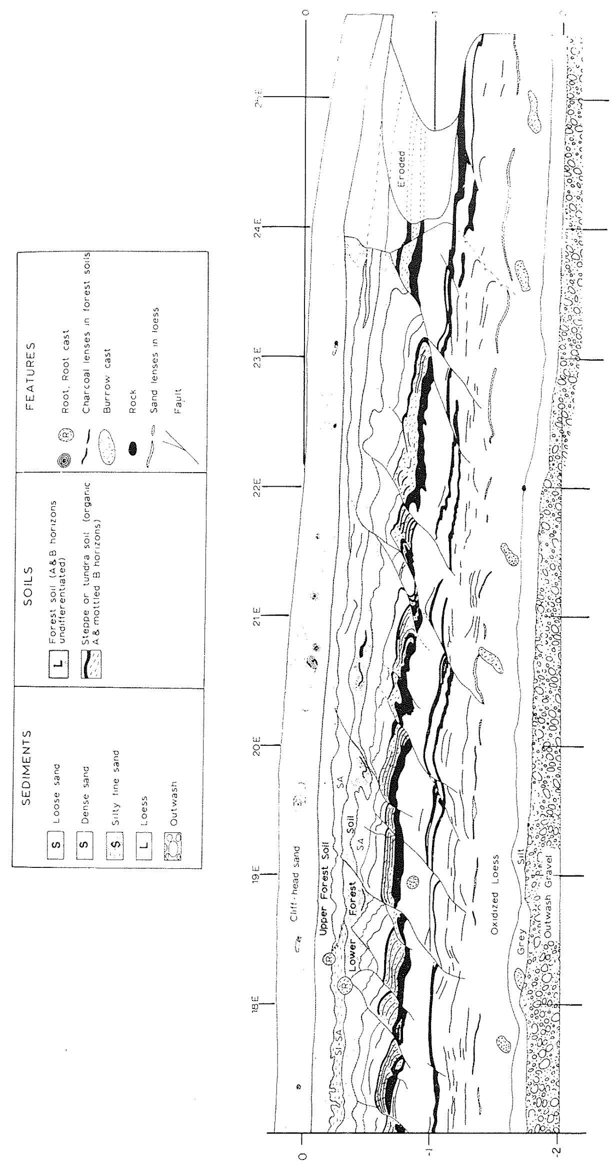

FIG. 5–*Continued*

TABLE 1

GENERAL DESCRIPTION OF STRATIGRAPHIC UNITS, DRY CREEK ARCHEOLOGIC SITE[a]

Unit	Description
Sand 4	Sand with minor silt and clay; light-yellowish-brown (10YR 6/4),[b] very poorly sorted angular to subangular grains; peaty texture, with partially decomposed wood near base. Living spruce trees rooted at sharp lower contact.
Loess 7	Sandy silt with clay; poorly sorted angular grains, commonly with clay and oxide coatings; well-developed reddish-brown (5YR 5/4) buried soil (Paleosol 4b) with charcoal fragments. Gradational lower contact.
Sand 3	Silty sand with minor clay; yellowish-brown (10YR 5/6), poorly sorted angular to subangular grains; thickness variable. Sharp lower contact.
Loess 6	Sandy silt with minor clay; yellowish-brown (10YR 5/4), poorly sorted angular grains, commonly with clay and oxide coatings; contains archeologic Component IV; well-developed reddish-brown (5YR 5/4) buried soil (Paleosol 4a) with charcoal lenses and root casts. Gradual lower contact.
Sand 2	Sand with minor silt; brownish-yellow (10YR 6/6), very poorly sorted angular to subangular grains. Sharp lower contact.
Loess 5	Sandy silt with minor clay, mottled strong brown (7.5YR 5/6) to light olive-gray (5Y 6/2); poorly sorted angular grains, strongly folded and faulted, slightly to strongly deformed by creep and solifluction; altering dark organic, light olive-gray (5YR 6/2), and yellowish-brown (10YR 5/6) horizons (Paleosol 3). Sharp lower contact.
Loess 4	Sandy silt, mottled strong brown (7.5YR 5/6) to light olive-gray (5Y 6/2); poorly sorted angular grains; contains archeologic Component III. Gradational lower contact.
Loess 3	Sandy silt with minor clay, mottled strong brown (7.5YR 5/6) to light olive-gray (5Y 6/2); poorly sorted angular grains; contains archeologic Component II and decomposed bone fragments; nearly continuous dark organic horizons at top of unit (Paleosol 2), discontinuous dark organic horizons occur throughout unit (Paleosol 1). Sharp lower contact.
Sand 1	Medium sand; yellowish-brown (10YR 5/4), discontinuous sand lenses, with very well-sorted subrounded to subangular grains; weakly developed pitted texture on large quartz grains. Sharp lower contact.
Loess 2	Sandy silt with minor clay, mottled yellowish-brown (10YR 5/6) to light olive-gray (5Y 6/2); poorly sorted angular grains which coarsen upward; burrow casts common; contains archeologic Component I. Gradual lower contact.
Loess 1	Silt with minor fine sand; olive (5Y 5/3), very poorly sorted angular grains; upper 10 cm coarsens upward; occasionally contains pebbles intruded from below. Sharp lower contact.
Outwash	Cobbles, pebbles, and sand with minor silt; poorly sorted rounded to subrounded clasts of schist and other metamorphic and plutonic rocks; clasts wind polished at upper contact, and frost cracked, stained, and carbonate encrusted to 30–40-cm depth.

[a] All units are composed primarily of quartz, muscovite, and rock fragments, hence mineralogy is not described individually for each unit.
[b] Munsell colors on field-moist material.

schistose rocks to 0.3-m depth were split along foliation planes by frost action, but rounded, nonfoliate cobbles were only rarely broken. Surface stones were polished and abraded by wind action, but only minor fluting and ventifacting occurred. Most surface cobbles exposed along the bluff edge and along the floor of the test trench were also stained bluish black to brown by heavy iron and manganese oxide accumulations. Accumulation of calcium carbonate forms dense encrustations up to 1 cm thick on the undersides of cobbles to depths of 30 to 40 cm along the bluff edge and for about 4–5 m inland along the test trench.

Eolian Deposits

Fifty samples of eolian sediments from the Dry Creek site were analyzed to determine vertical and horizontal changes in grain-size distribution, grain surface tex-

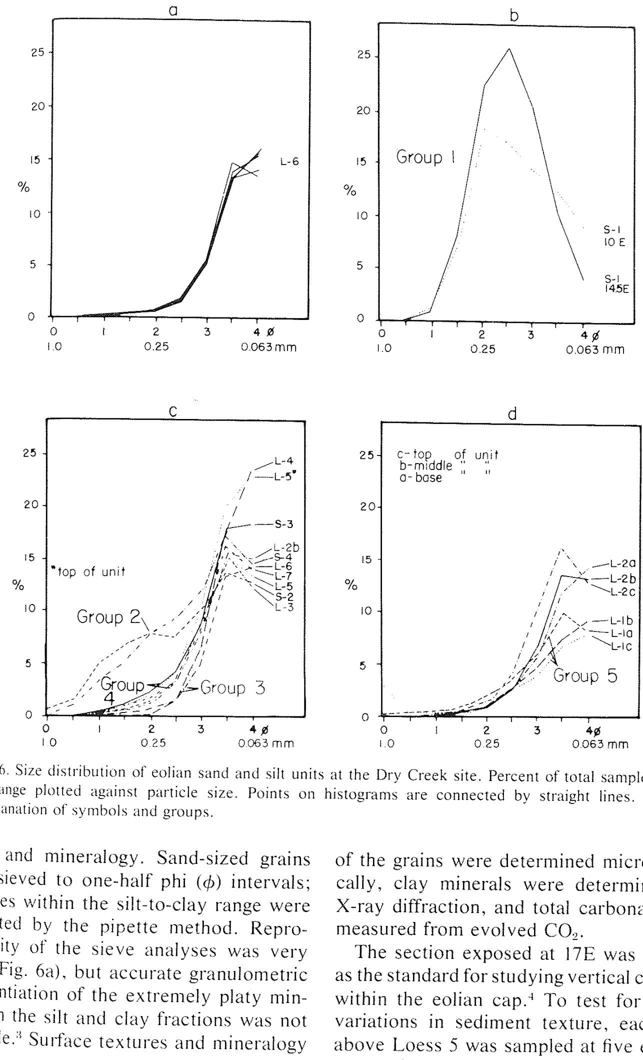

FIG. 6. Size distribution of eolian sand and silt units at the Dry Creek site. Percent of total sample in each 0.5 ϕ range plotted against particle size. Points on histograms are connected by straight lines. See text for explanation of symbols and groups.

tures, and mineralogy. Sand-sized grains were sieved to one-half phi (ϕ) intervals; particles within the silt-to-clay range were separated by the pipette method. Reproducibility of the sieve analyses was very good (Fig. 6a), but accurate granulometric differentiation of the extremely platy minerals in the silt and clay fractions was not feasibile.[3] Surface textures and mineralogy of the grains were determined microscopically, clay minerals were determined by X-ray diffraction, and total carbonate was measured from evolved CO_2.

The section exposed at 17E was chosen as the standard for studying vertical changes within the eolian cap.[4] To test for lateral variations in sediment texture, each unit above Loess 5 was sampled at five equally spaced intervals (24E, 20.5E, 17E, 13.5E,

[3] Histograms were more useful for differentiating the eolian units than cumulative curves because the bulk sediment textures of the loess units were similar.

[4] Locations along the trench wall are designated as distance (meters) east of a base line (see Fig. 5).

TABLE 2

MINERALOGY OF EOLIAN DEPOSITS, DRY CREEK ARCHEOLOGIC SITE[a]

Mineral	Loess 1	Loess Units 2–7	Sand Units 1–4	Nenana River silt	Dry Creek silt
Amphibole	R	VR	VR	R	VR
Apatite	VR	VR	VR	VR	VR
Biotite				VR	VR
Chlorite	VR	C	R	C	C
Epidote	R	R	R	C	R
Garnet	VR	VR	VR	R	R
K-Feldspar[b]	VR	VR		R	
Muscovite	A	VA	VA	A	VA
Opaques	A	C	C	A	C
Plagioclase	VR	VR		VR	
Pyroxene	VR			VR	
Quartz	VA	VA	VA	VA	VA
Rock fragments	A	C	VA	VA	C
Rutile	C	C	C	C	C
Tourmaline	VR	VR	VR	VR	VR
Zircon	R	R		R	R
Zoisite + clinozoisite	R	R	R	C	

[a] VA = very abundant, A = abundant, C = common, R = rare, VR = very rare.
[b] All highly altered grains of low index are included in this group.

and 10E) and units below Sand 2 were sampled at 24E, 17E, and 10E.

None of the loess and sand units showed any identifiable sedimentary structures such as fine-interbedding, cross-stratification, loading, grading, or scour. No trace of horizontal bedding, a feature usually present in local fluvial sequences, was found in any of the units.

Grain Surface Textures

All loess grains viewed under the binocular microscope appear fresh and angular. None show any pitting, etching, or other surface alterations. The larger quartz grains of Sand 1 have a weakly developed pitted texture that is similar to the incipient frosting observed on modern dune sands of the Nenana River flood plain; most grains ranged from subangular to subrounded in outline. The fine grains of Sand Units 2, 3, and 4 are all fresh and angular, and the larger sand grains are fresh but slightly more rounded.

Composition

Loess Units 2 through 7, which are nearly identical in composition, consist principally of quartz and muscovite with accessory metamorphic minerals (Table 2). Loess 1, at the base of the loess cap, is compositionally distinct from the overlying beds. Its slightly lower abundance of muscovite and higher concentration of accessory minerals and dark rock fragments may in part account for its gray color. The sand units typically contain a mineral assemblage less diverse than that of the loess beds. Their larger particles are principally metamorphic quartz and schist fragments. No detectable carbonate minerals were present in units younger than Loess 3, but small amounts (0.2–0.4% of total minerals) were present in the lower 50 cm of the section. Small quantities of detrital amphibole and chlorite were present in every unit, suggesting that the eolian sediments have not been greatly weathered.

Oxidation of iron is responsible for the yellowish-brown color of Loess Units 2 through 5 and the reddish-brown color of Loess 6 and Loess 7. Removal of these oxides with concentrated HCl reveals that primary sediment color is light gray to very pale brown. Removal of oxides from Loess 1 resulted in a slightly darker gray color than for the other loess beds, further suggesting that its gray appearance is in part a primary characteristic.

Samples of fluvial silt from the modern flood plains of Dry Creek and the Nenana River show pronounced compositional differences. Dry Creek silt, which reflects the greenschist–facies rocks of its headwaters, is composed almost entirely of platy quartz and muscovite fragments and contains minor accessory minerals and rock fragments. The gray Nenana River silt, in contrast, contains abundant dark minerals and dark rock fragments and has less muscovite than Dry Creek silt. The sand beds at the Dry Creek site are similar to sediment from the flood plain of Dry Creek and were almost certainly derived from this local source. Loess 1 appears almost identical to Nenana River silt of the same size fraction. The other loess units contain practically all of the minerals present in Nenana River silt but are richer in muscovite and quartz and show lower concentrations of dark fragments and heavy minerals. Enrichment in quartz and muscovite could be due to differential winnowing of Nenana River silt or to influx of some eolian particles from the Dry Creek drainage basin.

Granulometry

Grain-size distribution curves fall into five natural groups (Fig. 6), which are reflected also in lateral variability of the units (Figs. 7 and 8). All of the loess beds consist of sandy silt with minor clay and exhibit little or no variability inland from the edge of the bluff. Particle accretion probably was due to gravitational settling of airborne silt, and the virtual absence of grains larger than medium sand suggests that Dry Creek was not an active local source area. The sand units are more variable in grain size, ranging from silty fine sand to medium sand, and they exhibit significant lateral facies changes that reflect variations in wind com-

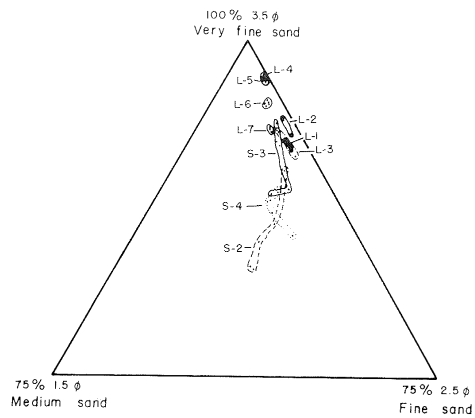

FIG. 7. Lateral variability in bulk sediment textures of eolian units at the Dry Creek site. Tight groupings indicate similar bulk sediment textures throughout the length of the test trench; wide groupings indicate bulk textures change inland from the bluff edge.

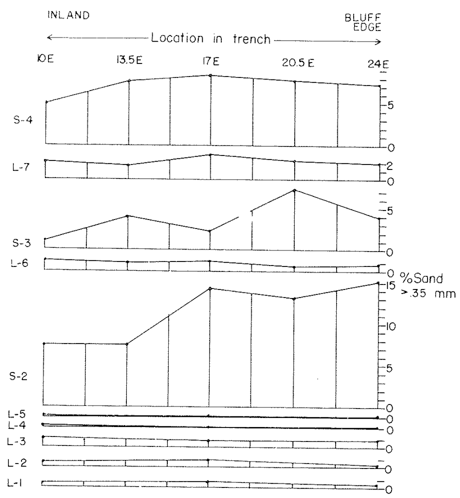

FIG. 8. Histograms showing change in percent of medium to coarse (greater than 0.35 mm) sand fraction vs location in 1974 test trench at the Dry Creek site.

petence inland from the bluff edge. Locally strong winds, sweeping particles from the Dry Creek flood plain up the bluff face and progressively dropping the coarsest grains, probably account for most of this variation.

Sand 1 (Group 1) consists of more than 25% medium sand and is the coarsest eolian sediment at the site. Its unusually good sorting (Fig. 6b) suggests that it is not an *in situ* deflation product but represents a deposit from which both the finest and coarsest grains have been selectively removed. Fines could easily have been winnowed by deflation, but physical transport of the sediment as a unit is required to explain the excellent sorting and lack of coarse sand. Sand 1 probably was deposited from an actively moving sand sheet during a time when strong surface winds swept the bluff.

Sand 2 and *Sand 4* (Group 2) are much coarser grained than any of the other units except Sand 1 and are the most poorly sorted of any group (Fig. 6c). Both units become thinner and finer inland from the bluff edge. Their high lateral variability is equaled only by Sand 3. Sand 4 is the modern sand sheet which is accreting today near the edge of the bluff where Dry Creek is eroding its bank. Sand 2 clearly accumulated in a similar environment in which gusty winds, sweeping up an unvegetated slope, redeposited particles derived from the floodplain of Dry Creek and the exposed bluff face.

Loess Units 4, 5, and 6 (Group 3) are best sorted among the loess beds (Fig. 6c). They show virtually no lateral change in texture or thickness inland from the bluff edge and appear to have accumulated as part of a widespread and nearly homogeneous blanket derived largely from the flood plain of the Nenana River.

Sand 3 and Loess Units 2, 3, and 7 (Group 4) are intermediate in character between Groups 2 and 3. Sand 3, although similar to Sand 2 and Sand 4, is finer grained and better sorted. Either the bluff was more protected from surface winds during the time of its deposition, or the active flood

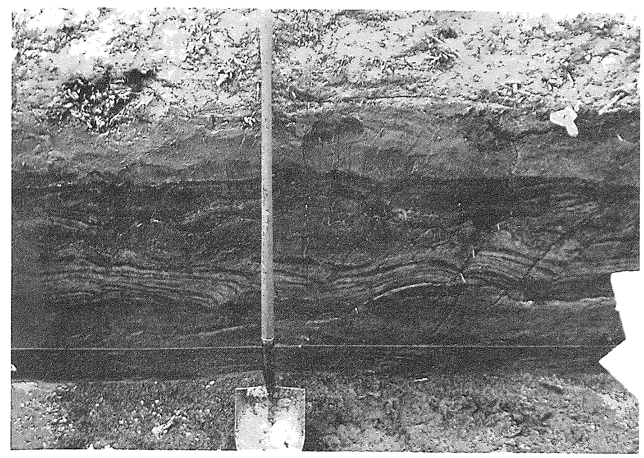

FIG. 9. Paleosols exposed between 13E and 15E in 1974 test trench, Dry Creek site.

plain of Dry Creek was more distant from the site. Loess beds 2 and 3 are similar to the loess units of Group 3, but their slightly coarser grain size and higher lateral variability suggest that they accumulated when source areas were closer or more exposed. Loess 7, which contains more medium to coarse sand than the other loess units (Fig. 8), may consist in part of sediment derived from Dry Creek.

Loess 1 (Group 5) shows as little lateral variability as the other loess beds but is comparatively fine grained, poorly sorted, and compositionally distinctive. Possibly it was derived from the Nenana River prior to the last major episode of erosion of the bluff. Loess 1 coarsens progressively upward into Loess 2 (Fig. 6d).

Paleosols

Deposition of loess and sand was interrupted by five episodes of soil formation (Figs. 4, 5, and 9). The three oldest paleosol complexes are immature tundra soils (Cryepts) that do not form in the Dry Creek area today. They typically consist of dark organic A horizons overlying mottled loess but locally have yellowish-brown (10YR 5/6) incipient B horizons and light-olive-gray (5Y 6/2) leached horizons. Paleosol 1, the oldest soil complex, consists of a series of thin, dark, discontinuous organic horizons, which become more numerous and strongly developed toward the rear of the test trench (Fig. 5). Paleosol 2, commonly with two organic horizons but locally more complex, is much more strongly developed and continuous than Paleosol 1. Paleosol 3 is a very complex sequence of well-developed organic horizons that commonly alternate with light-gray and yellowish-brown horizons. A strongly developed soil at its base is succeeded upward by at least eight less prominent soils. This sequence is remarkably continuous and uniform throughout the test trench and is broken only by secondary structural deformation (Fig. 5).

The uppermost two paleosols are typical of the Subarctic Brown Forest soils (Ochrepts and Orthods) presently forming in the boreal forest of interior Alaska. These soils are relatively thick and continuous, with prominent reddish-brown (5YR 5/4) oxidized horizons that contain many layers and pods of charcoal. Paleosols 4a and 4b have approximately the same thickness and show similar degrees of development. Root casts within both soils indicate that a forest cover was present during their formation; abundant charcoal suggests that the forest cover periodically burned. Paleosols 4a and 4b merge into one composite soil profile where Sand 3 wedges out to the southwest along the bluff face. The B horizon of Paleosol 4b appears nearly uniform throughout the test trench, but the B horizon of Paleosol 4a changes inland from the bluff edge. It is uniformly oxidized near 24E but becomes more complex to the northwest along the test trench. At 10E it appears to be a composite soil horizon and shows many properties similar to Low-Humic Gley soils. Paleosol 4a appears more poorly drained than 4b, suggesting that northward erosion of the bluff edge may have occurred since original forest soil formation.

Structural Deformation

The dominant structural features in the eolian sediments at the Dry Creek site are normal faults with dip–slip displacements of up to 50 cm (Fig. 5). Their dips are nearly vertical at the inner end of the test trench but decrease progressively to about 30° near the bluff edge. Most strike across the trench floor perpendicular to its walls and parallel to the bluff face. Although major faults within the trench exhibit as much as 3-m net dip–slip, no net vertical offset has occurred. Each small fault block apparently rotated clockwise in response to sudden lateral spreading of the loess cap toward the open bluff face. Many faults are traceable from Sand 1 upward into or through Paleosol 4a, which is broken by 25 faults with offsets up to 20 cm along the north wall of the test trench (Fig. 5). Extensional movement and faulting of the loess cap probably occurred at about the same time of deposition of Sand 3. They possibly were caused by vigorous shaking of the bluff during a high-intensity earthquake (George Plafker, personal communication, 1976).

Where exposed along the face of the bluff, Paleosol 3 exhibits asymmetric and overturned folds, drag structures, and other features that suggest solifluction directed northeastward toward the margin of the Healy terrace. These features are most pronounced near the terrace edge, where slopes exceed 3° but still are evident farther to the southwest on slopes as gentle as 1°. Comparable structures which show less intense deformation occur along the walls of the test trench in the interval between 19E and 25E, where both the modern ground surface and Paleosol 3 slope at an angle of about 3.5° toward the face of the bluff (Fig. 5).

During excavation through Paleosol 3, the floor of the test trench exhibited regularly spaced concentric rings of alternating dark organic and lighter colored mottled silt which formed structures 30–50 cm in diameter (Fig. 10). In section along the trench walls, these structures form broad but shallow convex-upward undulations in the individual soil horizons of Paleosol 3. Because of their approximately circular outlines and regular size and spacing, the structures probably represent small frost hummocks that were active at the time of formation of Paleosol 3. Lines of hummock-like structures are separated from each other by discontinuities about 5–10 cm wide which extend parallel to the trench, suggesting that stretching and segmentation of the surface organic mat also occurred at this time. This deformation may have been caused by solifluction toward the terrace edge.

Other Secondary Alterations

Fossil animal burrows, marked by casts about 10–20 cm in diameter, are abundant below Sand 1 and are locally present in Loess 3 and Loess 4 (Fig. 5). They are most abundant near the edge of the bluff and are not evident inland from about 17.5E in the test trench. The fossil features strongly resemble the modern burrows of ground squirrels (*Citellus* sp.), which are common

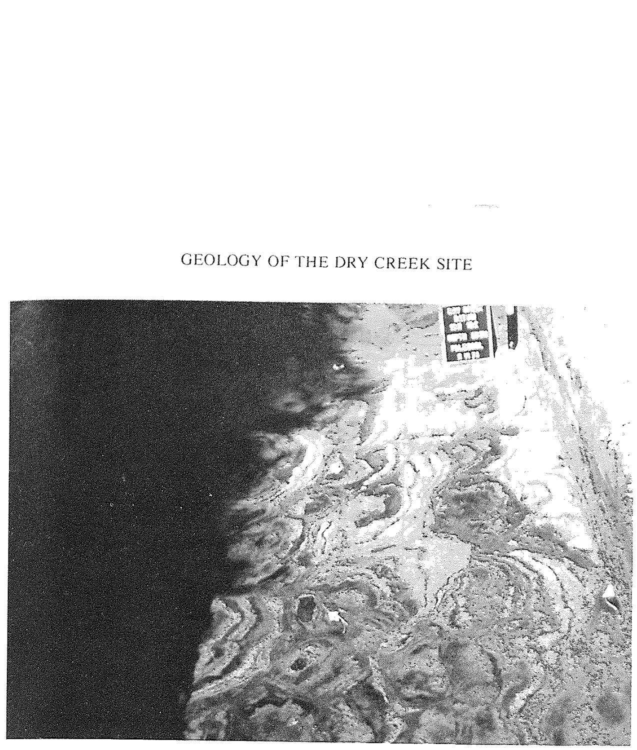

FIG. 10. Surface of Paleosol 3 exposed on floor of 1974 test trench, Dry Creek site.

near the present bluff edge where permafrost is absent or occurs at relatively great depth. Because of (1) their marked decrease in abundance above Sand 1, (2) backfilling with gravel derived from the underlying outwash, (3) oxidation and weathering of the burrow fill, and (4) decomposed state of the incorporated organic matter, most of the fossil burrows appear to date from Loess 2 and (or) Sand 1 time. Permafrost probably was absent from the thin loess cap that existed during this interval, and the Dry Creek site probably lay close to the bluff edge that existed then.

Fossil plant rootlets are most abundant in Loess 6 and Loess 7, where they are associated with Paleosols 4a and 4b. The remaining loess units contain fewer rootlets, and rootlets are least abundant in the sand beds. The state of preservation of plant rootlets ranged from extremely fresh in Sand 4 to thoroughly decomposed and usually carbonized in units below Sand 2.

Loess Units 1 through 5 and Sand Beds 1 through 3 exhibit yellowish-brown to light-gray mottling. The gray (10YR 7/1) zones, which usually surround fossilized grass rootlets, are evenly dispersed throughout brighter colored (10YR 5/6) oxidized zones. Sand 4 is accumulating too rapidly to allow marked oxidation; Loess 6 and Loess 7 are so thoroughly oxidized by recent soil development that any original mottling is obscured.

Relatively high percentages of clay are associated with the paleosols, owing largely to selective transport of the finest particles during times of greatly reduced loess accumulation that accompany pedogenesis. Typically the loess and sand units contain very poorly crystalline clays that include illite, kaolinite, mixed-layer vermiculite, and a small amount of chlorite. All of the tundra soils and the intervening mottled loess units contain these four minerals as well as lepidocrocite(?), which indicates the oxidation of ferrous compounds and the destruction of gley (Allan, 1969). Oxidizing soil environments probably followed the formation of the tundra soils.

Archeologic Components

Waste flakes and artifacts, associated with vertebrate faunal remains and strati-

TABLE 3

ARCHEOLOGIC MATERIALS AND FAUNAL REMAINS, DRY CREEK SITE[a]

Component	Stratigraphic position and depth below datum (cm)	Lithic material: Bifaces and fragments	Blades	Blade-like flakes	Burins (?)	Choppers	Flake cores	Hammerstones	Microblades	Microblade cores	Points and fragments	Retouched flakes	Scrapers	Stones	Waste flakes	Total lithic objects	Artifact distribution	Faunal remains
IV	Loess 6 60–65								3		2				140	145	Separate concentrations at bluff edge and about 10 m inland	None found
III	Loess 4 100–120	1	3	1											573	578	Separate concentrations at bluff edge and several m inland	None found
II	Loess 3 130–160[b]	6	5	3		2		1	11	2	1	6	7	21	1716	1781	Microblades, cores, anvil stones, and bifaces near bluff edge; hearth, artifacts, and flaking debris about 10 m inland	Molars (*Equus* sp.) Teeth in mandibular fragment (Bison sp.) Bone fragment (genus unk.) Large bone fragment (proboscidean ?)
I	Loess 2 170–190	1		1	2	1	1					3	6	10	282	307	Throughout trench; two flake clusters near bluff edge	Rib fragment (genus unk.) Bone fragments (genus unk.)

[a] Archeologic data modified from Powers and Hamilton (in press); faunal identifications provided by R. D. Guthrie, University of Alaska. Material collected during 1973 and 1974.
[b] 95% of the remains occurs between 145- and 155-cm depth.

graphically displaced pebbles to small boulders, indicate four distinct levels of prehistoric human occupation within the eolian sediments at the Dry Creek site (Fig. 4 and Table 3). Component I, the oldest artifact assemblage, consists of clusters of waste flakes, 15 recognizable stone implements, 3 highly decayed and unidentifiable bone fragments, and 10 rocks, one of which has been fire-cracked. Component II, the major archeologic horizon at the site, consists of 44 tools or fragments, 10 specimens of bone from horse, bison, and possibly mammoth,[5] 2 anvil stones, 19 other rocks, and a huge number of waste flakes. The cultural materials of Component II are most abundant (1) along the present edge of the bluff and (2) around a hearth of large cobbles and small boulders near the rear of the trench. This distribution suggests that the edge of the bluff may have been utilized as a lookout point associated with tool manufacture, whereas the area farther inland was used for domestic purposes and tool finishing (Powers and Hamilton, in press).

Components III and IV consist of smaller and less diverse cultural assemblages which contain no bones or large stones and few recognizable implements. As with Component II, cultural materials tend to occur in separate concentrations near the present edge of the bluff and 5–10 m inland.

Artifacts from Components I, II, and probably III appear to be typologically close to the late upper Paleolithic Diuktai Culture of northeastern Siberia (Powers and Hamilton, in press). Diuktai sites date back to at least 18,000 ^{14}C yr BP in central Siberia but probably are no older than 13,000 or 12,000 yr in Kamchatka and along the arctic coast (Powers, 1973). The Diuktai Culture persisted until about 10,000 ^{14}C yr BP. The faunal remains associated with Component II, while supportive of a late Pleistocene age for this horizon, are inconclusive. The highly decayed proboscidean(?) bone fragment cannot be definitely identified, and both horse and bison could have persisted into Holocene time within refugia in Alaska (Guthrie, personal communication, 1976).

Radiocarbon Dates

Eighteen samples from the Dry Creek archeologic site have been dated by Robert Stuckenrath at the Smithsonian Institution Radiocarbon Laboratory (Fig. 4 and Table 4). With only one exception (SI-1933B), all dates are on material which was identified as charcoal and given nitration pretreatment for complete removal of all uncharred cellulose. All samples were from well-defined buried paleosols or charcoal lenses, hence the incongruous series of dates is puzzling. Two samples (SI-1544 and SI-1938) yielded dates of 19,050 ± 1500 and 23,930 ± 9300 ^{14}C yr BP, which are considered questionable owing to very small sample size and resulting high counting errors (Stuckenrath, personal communication, 1974). A third sample SI-1936, dated 12,080 ± 1025 yr BP) also has a very high counting error and may be equally questionable. Sample SI-2328 (dated 7985 ± 105 yr BP) was obtained from a test pit where correlations with the basic site stratigraphy are less certain than for sample locations along the 1974 test trench and the adjacent bluff face. The remaining 15 dates provide a somewhat more consistent time frame for the site.

The radiocarbon dates for Components I and II suggest that initial human occupation of the Dry Creek site began more than 11,000 yr BP and continued intermittently until perhaps 10,000 yr ago. The one acceptable date for Paleosol 2 suggests that this soil complex formed probably about 10,000 to 9000 yr ago. Of the six dates from Paleosol 3, the three with smallest counting errors, which are mutually consistent as well as compatible with the

[5] The highly decayed proboscidean(?) bone cannot be definitely identified (Guthrie, personal communication). If proboscidean, it probably is mammoth because mastodon remains are rare in central Alaska (Guthrie, 1968).

TABLE 4

RADIOCARBON DATES FROM THE DRY CREEK AREA, ALASKA

Laboratory no.[a]	^{14}C yr BP	Stratigraphic and archeologic association[b]
		Dry Creek archeologic site (Fig. 4)
SI-1933A	Modern	Paleosol 4b
SI-1933B	375 ± 40	Paleosol 4b (peat and roots)
SI-2333	1145 ± 60	Paleosol 4b
SI-2332	3430 ± 75	Paleosol 4a; Component IV
SI-1934	3655 ± 60	Paleosol 4a; Component IV
SI-1937	4670 ± 95	Paleosol 4a; Component IV
SI-2331	6270 ± 110	Paleosol 3
SI-1935C	6900 ± 95	Paleosol 3
SI-2328	7985 ± 105	Paleosol 2? (test pit)
SI-1935B	8355 ± 190	Paleosol 3
SI-2115	8600 ± 460	Paleosol 3
SI-2329	9340 ± 195	Paleosol 2; Component II
SI-1935A	10,600 ± 580	Paleosol 3
SI-1561	10,690 ± 250	Paleosol 1; Component II
SI-2880	11,120 ± 85	Loess 2; Component I
SI-1936	12,080 ± 1025	Paleosol 2
SI-1544	19,050 ± 1500	Paleosol 3
SI-1938	23,930 ± 9300	Paleosol 2
		Lower Dry Creek (Fig. 12)
SI-1941	960 ± 65	Upper paleosol, Sect. 14
SI-1940	3035 ± 55	Middle paleosol, Sect. 14
SI-1939	3880 ± 55	Basal paleosol, Sect. 14
I-8263	4760 ± 205	Middle paleosol, Sect. 8
I-8264	5995 ± 275	Basal paleosol, Sect. 8
		Other
AU-94	9060 ± 160	Peat from 2-m depth at base of closed depression above Carlo outwash in deep roadcut along Fairbanks–Anchorage Highway (63°39.5′N, 148°15′W)
W-49	10,560 ± 200	Peat from about 3-m depth in lacustrine sediments south of Riley Creek II terminal moraine at mile 347.2 of the Alaska Railroad (Wahrhaftig, 1958)

[a] SI = Smithsonian Institution, I = Teledyne Isotopes Inc., AU = University of Alaska, W = U.S. Geological Survey.

[b] All dates are on charcoal except where otherwise noted.

acceptible older dates, suggest a possible time range of perhaps about 8500 to 6000 yr BP for this soil complex. The remaining dates from Paleosol 3 appear to be anomalously old. The three dates from Paleosol 4a mark the development of forest on the present bluff edge, perhaps about 4700 yr BP, and suggest an age on the order of about 4700–3400 ^{14}C yr BP for Component IV. Dates from Paleosol 4b indicate that loess accumulation and forest soil development persisted until very recent time at the Dry Creek site and that Sand 4 is a very young deposit which formed rapidly. This inference is confirmed by ring counts of less than 150 yr on living trees rooted in Paleosol 4b and by fresh to partly decomposed wood and birch bark within Sand 4.

The anomalous radiocarbon dates, many of which are clearly too old, may reflect contamination of the site by dead carbon derived from nearby coal-bearing rocks.

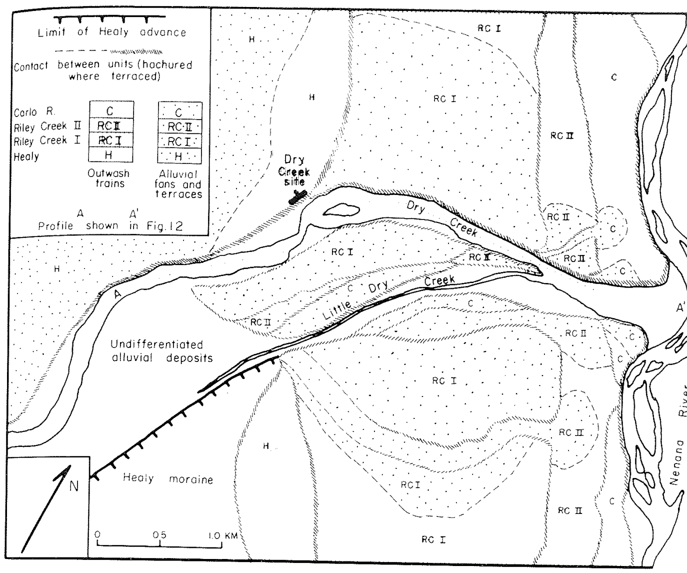

FIG. 11. Late Quaternary deposits and geomorphic units, Dry Creek area.

Coal and lignite particles could be deposited at the site as part of the general loess fallout or may have been contributed as ash from burning coal or lignite seams. Suspect dates occur on samples taken deep within the 1974 test trench as well as along the exposed bluff face, hence contamination must have occurred during formation of the paleosols. As indicated by the large counting errors, many samples that apparently contained abundant charcoal yielded very little residual carbon after pretreatment for removal of humic contaminants. This "charcoal" appears to be composed largely of humic material, as has been reported for charcoal samples from New Zealand loess beds (Bailey, 1971; Bailey *et al.*, 1975). If windblown particles of dead carbon had been transported to the site at a nearly constant rate, then those samples that yielded the smallest insoluble residue of charcoal after pretreatment would show the greatest age anomalies. The largest samples, with smallest counting errors, should yield the most nearly accurate dates.

REGIONAL GEOLOGY

Glacial Deposits

The massive Healy end moraine complex, which extends to within about 1.5 km of the Dry Creek site, consists largely of redeposited fluvial gravel derived from the Alaska Range (Fig. 11). Rounded clasts of pebble to small-boulder size are dominant, with occasional subangular to subrounded boulders up to 1–2-m diameter also present. The flanks of the moraine are relatively steep, averaging 12–15°, but its broad (20–30 m) crest has been appreciably flattened by frost action, deflation, and other postdepositional processes. Many surface boulders exhibit unweathered wind-abraded faces, which commonly are faceted or fluted on their upvalley sides. Several large water-filled kettles are still present on Healy drift, but smaller kettles have been drained or filled since deglaciation. The outwash terrace associated with the Healy ice front, which forms the prominent bluff at the Dry Creek site, is traceable for 35 km down the Nenana Valley (Wahrhaftig, 1958).

During the subsequent Riley Creek Glaciation ice tongues did not extend down the Nenana Valley beyond the range front. Three possible advances of Riley Creek time are suggested by outwash-terrace profiles (Wahrhaftig, 1958, pp. 48–55) and by our own examination of drift limits of the Riley Creek Glaciation. During the first advance (Riley Creek I) the Nenana Valley glacier probably extended into the narrow Nenana Canyon, terminating about 2 km north of the entrance to McKinley Park. This possible ice limit is marked by (1) abrupt deflection of the Nenana River to a position along its east valley wall (Fig. 1), (2) abrupt narrowing of the inner gorge of Nenana Canyon downstream, (3) concentrations of large erratic boulders along both valley sides and in the river bed, (4) till remnants that appear to interfinger with outwash and fan sediments along the west valley side, and (5) abrupt northward rise in height of the till surface as if it were ascending to a moraine crest. The inferred end moraine of Riley Creek I age has been largely destroyed within the steep-sided Nenana Canyon, but discontinuous lateral moraine remnants, ice-marginal drainage channels, and concentrations of erratic boulders are traceable southwestward into extensive hummocky ground moraine west of the McKinley Park entrance. This moraine is younger in appearance than the Healy moraine. Minor surface irregularities are more pronounced, solifluction is less extensive, and exposed boulders are less weathered. The oldest and highest of the Riley Creek outwash terraces forms a broad (1.8 km) nearly level surface immediately east of the Dry Creek site and 28 m below it (Figs. 11 and 12). This terrace extends about 14 km downvalley from Dry Creek (Wahrhaftig, 1958).

A subsequent glacial advance (Riley Creek II) terminated about 2 km south of Nenana Canyon and formed the prominent drift sheet described by Wahrhaftig (1958). After reaching its outer limit, the glacier stagnated across a broad zone that includes the lower 4–6 km of Yanert Fork and adjacent parts of the Nenana Valley (Fig. 1). Fresh kame and kettle terrain is widespread at this locality. Kettles exhibit little post-glacial filling, and gravel is exposed around much of their rims. Moraine ridges have flanking slopes as steep as 21–24° and crests as narrow as 1–3 m. Soil profiles on moraine crests and kame summits are weakly developed, with oxidized horizons seldom exceeding 20 cm depth. The outwash terrace of Riley Creek II age forms a broad bench about 0.4 km wide near Dry Creek and stands 12 m below the lowest part of the Riley Creek I terrace in this locality. It is traceable for about 18 km downvalley from Dry Creek (Wahrhaftig, 1958).

Moraines marking the Carlo Readvance of the Riley Creek Glaciation are less well defined than those of the preceding two advances. Carlo drift is morphologically comparable to Riley Creek II drift and forms a broad terminal zone about 3 km north of Carlo. Deposits of this glacial event have not been recognized elsewhere in the Alaska Range, hence its paleoclimatic significance is uncertain. Gravel terraces ascribed to the Carlo Readvance extend along the Nenana River for about 23 km downvalley from Dry Creek. Near the mouth of Dry Creek the terraces stand about 7 m above the modern flood plain of the Nenana River and are about 6 m lower than the Riley Creek II terrace (Figs. 11 and 12).

Only two radiocarbon dates of 10,560 ± 200[6] and 9060 ± 160 ^{14}C yr BP are available from the Nenana Valley glacial deposits (Table 4). The older date represents an episode of ice wastage after the Riley Creek II advance but before Carlo time (Wahrhaftig, 1958); the younger date provides a minimum limit on Carlo outwash. Riley Creek II deposits appear morphologically and stratigraphically comparable to drift elsewhere in Alaska that dates between 14,000 and 13,000 yr BP (Schmoll *et al.*, 1972; Hamilton and Porter, 1975). Carlo drift must date from about 10,000 ± 500 yr BP if the above radiocarbon dates and interpretations are valid. Riley Creek I drift probably represents the late Wisconsinan glacial maximum, as inferred by Wahrhaftig and others; Healy drift is early Wisconsinan or possibly pre-Wisconsinan in age.

[6] This date was reported as "820 ± 160 years after the Two Creeks advance" by H. E. Suess (Wahrhaftig, 1958, p. 46), hence it could be as old as 11,000 ^{14}C yr BP.

Fluvial Deposits

Healy-age alluvium deposited by Dry Creek merges eastward into outwash derived from the Nenana River. Imbrication of clasts indicates that sediment transport was northward, directly downvalley from the ice front that stood less than 1 km from the present channel of Dry Creek (Fig. 11). Numerous poorly defined northeast-trending channels incised the Healy terrace to 3–5-m depth after outwash deposition had ceased. A deeper channel complex farther to the northwest indicates that Dry Creek subsequently flowed west of the site during an early stage of post-Healy downcutting.

Dry Creek subsequently built three successive alluvial fans on outwash terraces of Riley Creek age (Figs. 11 and 12). The oldest and largest fan, which formed during Riley Creek I time, is about 3 km wide and at least 15 m thick near its apex. The two younger fans (Riley Creek II and Carlo) are about 1.2 and 0.5 km wide, respectively, and lie 12 and 19 m below the Riley Creek I fan. All three aluvial fans are composed primarily of cobble- to silt-size, poorly sorted, subrounded schist fragments and well-rounded cobbles derived from older outwash and alluvium. Bedding is generally irregular and discontinuous, with numerous cut-and-fill structures and poorly defined fining-upward sequences 20 cm thick. No wood fragments were found in these deposits through more than 3 km of nearly continuous exposure. Since driftwood is common along the present flood plain of Dry Creek and in banks along the margins, its apparent absence in older alluvium suggests that trees and shrubs were rare or absent during Riley Creek time. In all other respects, modern alluvium along Dry Creek appears identical to alluvium of Riley Creek age.

During Riley Creek I glaciation, Dry Creek aggraded its channel between the Healy moraine front and the bluff at Dry Creek site, creating a wide alluvial plain (RC I in Fig. 11). Channel scars and terraces indicate that Dry Creek subsequently became confined to a channel near the present course of Little Dry Creek (Fig. 11). Riley Creek II alluvial deposits are widespread along this channel but are absent from the present channel of Dry Creek, which probably was abandoned during Riley Creek II time. Alluvium of Carlo age also occurs predominantly along the channel of Little Dry Creek.

Near the mouth of Dry Creek, a narrow northeast-trending gorge was incised through Riley Creek II deposits by a probable distributary stream that built a small alluvial fan on the adjacent Carlo surface. This channel must have been cut when Dry Creek followed its present course, to which it returned sometime prior to the end of Carlo time. Although several low terraces upstream from the gorge suggest that Dry Creek continued to occupy this channel during parts of the Holocene, widespread and continuous low alluvial terraces along Little Dry Creek indicate that this probably was the principal channel during most of post-Carlo time.

Alluvium and outwash of Healy and Riley Creek age exhibit striking differences in secondary modification, suggesting that an appreciable time interval elapsed between them. Healy surfaces contain abundant frac-

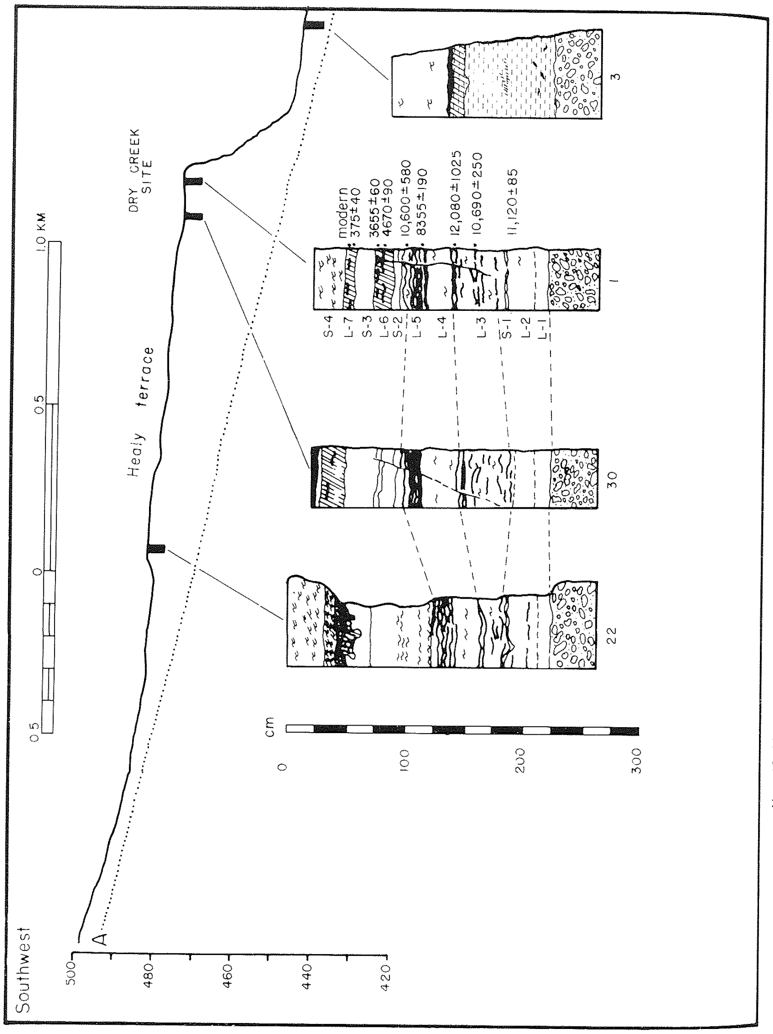

FIG. 12. Topographic profile and selected stratigraphic sections, lower Dry Creek.

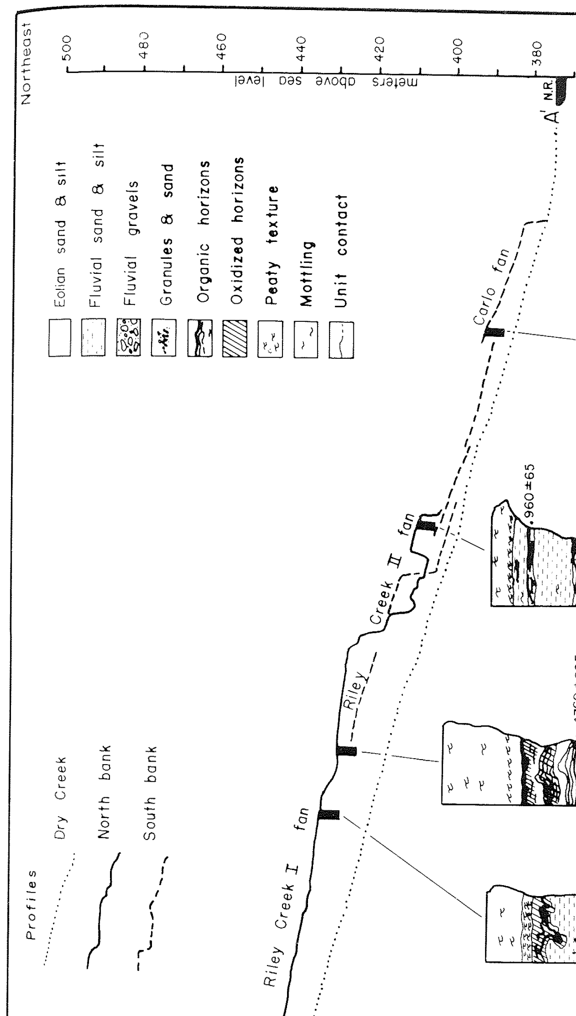

FIG. 12—Continued

tured stones, common wind polish, and a few ventifacts, but frost shattering and wind abrasion are negligible on younger surfaces. Heavy oxide staining and carbonate encrustation also are generally restricted to surfaces of Healy age.

Sediments that cap the Riley Creek II and younger terraces consist primarily of finely bedded micaceous fluvial silt, sand, and inversely graded granule layers, with minor interbeds of eolian sandy silt and paleosols (e.g., Section 14 in Fig. 12). The fluvial sediments are evenly and horizontally bedded, nearly devoid of organic material, frequently occur on nearly horizontal exposures away from active slopes, and stand as high as 11 m above the channel floor of Dry Creek. Three charcoal samples from Section 14 yielded dates of about 3880, 3035, and 960 yr BP (Table 4), indicating that these widespread fluvial sediments were probably deposited as overbank sediments during at least three episodes of extensive flooding along lower Dry Creek during late Holocene time.

Eolian Deposits and Paleosols

Twenty-five measured sections of the sediments that cap the banks of lower Dry Creek provide data on regional changes in loess accumulation and paleosol formation. Most exposures consist of 1–2 m of loess with interstratified tundra soils and sand lenses, overlain by well-developed Subarctic Brown and (or) Low-Humic Gley soils and modern bluff-edge sand sheets. Eolian sand and silt units throughout the area are compositionally identical to those at Dry Creek site. Loess layers range from almost pure silt to silty sand and generally coarsen toward the Nenana River. Seven representative stratigraphic sections are shown in Fig. 12.

Exposures from the Healy terrace (Sections 1, 22, and 30 in Fig. 12) exhibit broadly comparable stratigraphy. Gray basal silt in each section grades upward into yellowish-brown loess with interstratified tundra soils. Sand 1 at Dry Creek site is absent from Section 30 but is present farther west in Section 22. Paleosols 1 and 2 probably correlate with the discontinuous organic horizons that underlie better defined organic horizons in Sections 22 and 30. These two sections also show a well-defined tundra soil complex that overlies loess containing negligible organic matter; this sequence probably correlates with Paleosol 3 and Loess 4 at the Dry Creek site. The striking similarity shown by basal parts of all three sections suggests that variations in rates of loess accretion and tundra soil formation were caused by regional rather than by local environmental changes. In contrast, the upper units show greater variability. Sand 3 wedges out along the bluff face southwestward from the Dry Creek site, causing Paleosols 4a and 4b to merge into a single composite Paleosol (Section 30). Comparable soils in Section 22 are poorly drained Low-Humic Gleys. Modern bluff-edge sand sheets are present only where Dry Creek is actively eroding its bank. These contrasts indicate that stratigraphic variations above Paleosol 3 at the Dry Creek site probably were controlled by local drainage conditions and by distance from the active channel of Dry Creek.

Sediments that cap the alluvial fan of Riley Creek I age exhibit marked compositional variations. Near the upstream end of the fan these deposits lie only 5–13 m above the modern channel floor of Dry Creek and consist largely of fluvial sand and silt (Section 3, Fig. 12). Near the downstream end, they stand higher above Dry Creek, cap gravel terraces that are incised 1–4 m into the fan, and consist primarily of eolian deposits. This extreme variance within the sediment cap might have been caused either by scour during incision of the fan during late Riley Creek time or by overbank deposition at the upstream end of the fan during later periods of flooding along Dry Creek. Section 6, which is representative of the main body of the fan, consists of finely bedded and congeliturbated fluvial silt which brackets a very coarse eolian sand and underlies congeliturbated sandy silt, forest soil, and a bluff-edge sand sheet. Section 8, closer to the outer edge of the fan, exhibits the following sequence: (1) loess with discontinuous organic horizons, (2) a tundra soil complex, (3) two forest soils separated by sand, and (4) a modern bluff-edge sand sheet. This sequence is similar to the succession above Loess 2 at the Dry Creek site, but radiocarbon dates indicate that it probably is not time-equivalent. If valid, the dates from Section 8 suggest that loess accretion and tundra soil formation began shortly before 6000 ^{14}C yr BP on the eroded fan surface and that tundra vegetation on the fan was contemporaneous with a narrow bluff-edge forest fringe at the Dry Creek site about 4700 yr ago.

Sediments that cap Riley Creek II deposits (e.g., Section 14 in Fig. 12) consist largely of finely bedded alluvium deposited by Dry Creek, apparently during repeated episodes of extensive flooding during late Holocene time. Only three small loess and paleosol units, the oldest of which formed about 3880 yr ago are interbedded with the fluvial sediments in Section 14.

The sediment cap above Carlo and younger deposits along lower Dry Creek typically consists of 0–10 cm of fluvial silt and granules overlain by 5–20 cm of modern bluff-edge sand (e.g., Section 26 in Fig. 12). Incipient soils, consisting of partly decomposed organic matter and showing slight oxidation, commonly are present above the fluvial silt. As with the Riley Creek II surface, the dearth of eolian sediments might be the result of scouring during floods.

SUMMARY OF GEOLOGIC AND ENVIRONMENTAL HISTORY

During the Healy Glaciation, Dry Creek became established in its present course as an ice-marginal stream that skirted the Healy moraine front. It joined with the Nenana River to form a broad valley train, one remnant of which underlies the Dry Creek archeologic site. Subsequent glacier recession was associated with downcutting of the Nenana River and its tributaries. At this time, the emerging Healy terrace near the Dry Creek site became isolated as a narrow erosion remnant between Dry Creek to the west and the Nenana River to the east. Dry Creek, which initially flowed northward to join the Nenana River 2 km downvalley from the site, later shifted or was pirated to its present course along the front of the Healy moraine.

The outwash near the edge of the Dry Creek bluff subsequently was subjected to wind abrasion, frost shattering, oxidation, and carbonate deposition. Oxidation occurs widely at the top of Healy outwash along the bluff and also is evident in roadcuts and test pits into the Healy moraine. Frost-shattered clasts, subsurface carbonate accumulations, and wind-polished stones appear to be restricted to a relatively narrow zone peripheral to the bluff edge at the Dry Creek site. These three weathering processes may have occurred at a later date than the oxidation, perhaps under more intense periglacial conditions and at a time when the edge of the bluff had retreated close to its present position.

During the episode of alluviation associated with Riley Creek I glacier expansion, the Nenana River eroded westward to within about 0.2 km of the Dry Creek site and later was displaced about 2.5 km to the east by the growing fan of Dry Creek (Fig. 11). The northwest margin of the fan extends to the base of the Dry Creek bluff, which must have been eroded back to nearly its present position at this time. Fan sediments of Riley Creek I age lack obvious frost shattering, carbonate accumulation, and wind polishing, hence these features on the Dry Creek bluff may have formed during alluviation of the fan.

Readvancing glaciers in the Alaska Range caused renewed alluviation of the Nenana River during Riley Creek II time. The outwash train built up to within 17 m of the

Riley Creek I level and extended to within 2 km of the Dry Creek site. Dry Creek built a relatively small alluvial fan, incised within the Riley Creek I deposits, which extends northeastward 0.5 km across the Riley Creek II terrace of the Nenana River (Fig. 11). The creek appears to have occupied the Little Dry Creek channel at this time.

The three basal loess units at the Dry Creek archeologic site appear to represent a nearly continuous episode of loess accretion. Loess 1 grades compositionally upward into Loess 2, probably owing to dilution of windblown silt from the Nenana River flood plain by increasing amounts of silt from the alluvial fan of Dry Creek. Both loess units coarsen progressively upward, further suggesting expansion of nearby source areas along Dry Creek. Fossil grass rootlets, abundant burrow casts, and the absence of soil horizons suggest that Loess 2 accumulated rapidly and that arctic steppe vegetation covered the area at this time. Loess 3 is virtually identical to Loess 2 in composition, grain size, and presence of fossil grass rootlets. It lacks the abundant burrow casts of the underlying loess and contains discontinuous thin lenses of organic silt that appear to represent the A horizons of very immature tundra soils (Paleosol 1). Loess 3 is physically separated from Loess 2 by the thin and discontinuous Sand 1, which probably was transported to the site during a brief interval of time from a nearby source such as the bluff face.

The earliest known human occupations of the Dry Creek site (Components I and II) occurred during the deposition of Loess units 2 and 3. Both components are characterized by similar assemblages of cultural materials, and both are associated with poorly preserved bones of extinct herbivores. The margin of the bluff probably lay close to its present position at this time, making the site an attractive lookout point for hunters. A 20-km segment of the Nenana Valley as well as extensive lowlands to the west would have been visible from the site. Loess Units 1, 2, and 3 and the two associated archeologic components probably accumulated during a major glacial–alluvial episode of the Riley Creek Glaciation. A Riley Creek II or Carlo age for these deposits seems more likely than Riley Creek I because (1) the interval of frost weathering and wind abrasion prior to the deposition of Loess 1 appears to correspond to Riley Creek I time, (2) the well-sorted character of the loess suggests that its source area probably was not immediately adjacent to the bluff on an active Riley Creek I fan, (3) radiocarbon dates suggest that deposition of Loess 3 may have ended about 10,000 ^{14}C yr ago, and (4) human occupation may have occurred within the time span of about 12,000 to 10,000 yr ago if the radiocarbon dates from Components I and II are valid.

Paleosol 2, which formed on Loess 3, marks a significant pause in eolian deposition about 10,000 to 9000 ^{14}C yr BP. It was followed by accretion of Loess 4 and by renewed human occupation of the site (Component III) about 9000 to 8500 yr ago. A possibly correlative early Holocene loess unit, derived from the Alaska Range, has been reported from several parts of the Tanana Valley in central Alaska. Post-Wisconsinan loess may have been deposited about 8500 yr ago in the Fairbanks area (Matthews, 1974), and possibly is represented by an episode of rapid silt deposition in Birch Lake between about 9200 and 8500 ^{14}C yr BP (Ager, 1975, p. 41).

Loess 5 is separated from Loess 4 by the well-developed basal organic horizons of the Paleosol 3 complex, which may have formed about 8500 to 8000 yr BP. Thinner but uniform and continuous organic horizons occur throughout Loess 5, suggesting a slow rate of loess influx to the site and little disturbance of the aggrading ground surface during a time span of perhaps 2000 yr. After its formation, Paleosol 3 was strongly deformed by solifluction and probably by frost heaving. This deformation, coupled with the presence of gleyed horizons and well-preserved thin organic horizons, suggests that a rise in the local permafrost table and the development of a heavier insulating sod cover occurred during the genesis of Paleosol 3. Arctic steppe may have been replaced by a more poorly drained tundra assemblage, and the site may have become less suitable for human occupation.

Sand Units 2 through 4 and the intervening loess units and paleosols were deposited during the past 4000–5000 ^{14}C yr under environmental conditions markedly different from those of the older soils and sediments at the Dry Creek site. Dry Creek must have occupied its modern channel at the base of the bluff during intervals when the sand sheets accumulated; it may have followed the Little Dry Creek channel when the intervening loess beds and paleosols formed. The sandy deposits provided a well-drained substrate for spruce forest, which may have grown as a narrow (40–60-m) fringe along the edge of the bluff. Archeologic Component IV, which occurs within the lower forest soil, differs typologically from the older components.

Human occupation at the Dry Creek site clearly is divisible into two major periods. The three lowest components (I–III) date from about 8500 to more than 11,000 ^{14}C yr BP and were associated with late-glacial conditions in the Alaska Range and a probable arctic steppe biome beyond the range front. Periodic episodes of tundra soil formation probably occurred during more poorly drained conditions; no evidence has been found for human occupation of the site at these times. The later period of human occupation (Component IV) occurred within the interval of about 3400–4700 ^{14}C yr BP when a forest soil was forming locally. Use of the site apparently was not as intensive as it was during the older occupations.

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