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Holocene Stratigraphy of Turkey Creek, A Small Drainage Basin in the Southern Colorado Piedmont

by

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INTRODUCTION

Holocene alluvial stratigraphy is of interest to a variety of studies where chronology and dating of recent geologic events is important. Examples of such studies include research on geologic hazards (floods, landslides, and seismicity) and paleoclimate. The Colorado Piedmont has a widespread and varied Holocene stratigraphic record (Madole, in press), but numerical ages for the various units are few even though nearly four decades have passed since the advent of ^{14}C dating. Furthermore, agreement is poor among the few ^{14}C ages that have been reported (Hunt, 1954; Scott, 1960, 1962, 1963; Van Horn, 1976). The work reported on here is intended to fill some of the chronologic gaps in the Holocene alluvial history of the Colorado Piedmont.

Archeological investigations on Turkey Creek, a small drainage basin adjacent to the east flank of the southern Front Range (Fig. 1), yielded eleven ^{14}C ages that can be applied to dating Holocene alluvial stratigraphy. On Turkey Creek, as on many other piedmont streams, stratigraphic relations are particularly well exposed because of 4 to 6 m of channel incision that has occurred during the past 100 to 150 years. The individual alluvial units are lithologically distinct, and superposition and crosscutting relations of the units clearly establish relative ages. The potential for obtaining numerical ages for the units is high because ^{14}C-datable materials are relatively common in archeological features and buried soils. Eleven ^{14}C ages obtained from archeological work provide a detailed chronology for one alluvial unit and limits for two others. This paper describes the stratigraphy and ^{14}C ages of Holocene alluvial units on a reach of Turkey Creek from about 3.5 km north of archeological site 5PE648 to about 5 km south of the site.

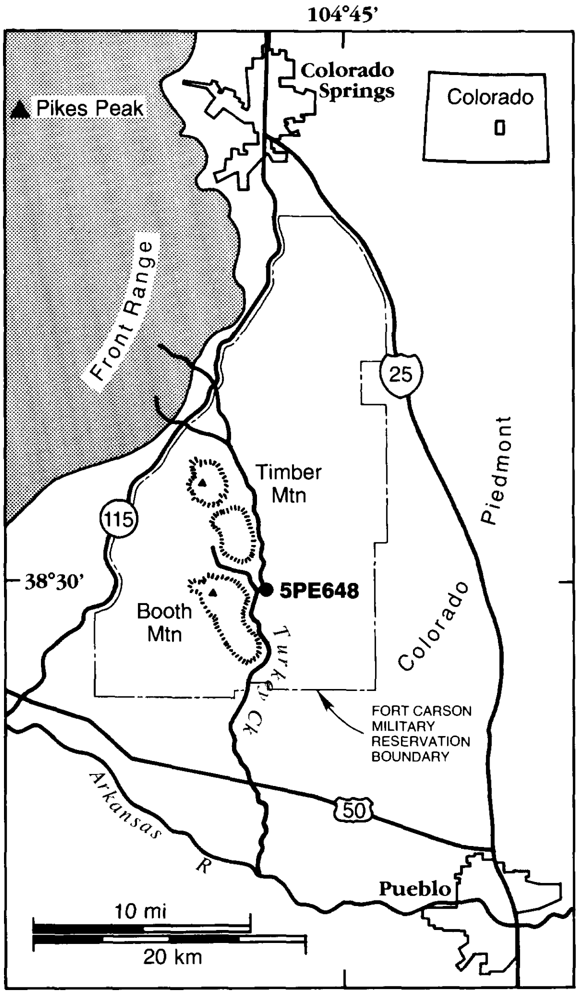

Figure 1. Map showing the location of Turkey Creek and archeological site 5PE648.

STUDY AREA

Turkey Creek is a small stream that heads on the lowermost slopes of the Front Range and flows south for about 50 km through the Colorado Piedmont to the Arkansas River (Fig. 1). The area traversed by Turkey Creek includes one of the more hilly parts of the Colorado Piedmont. In this area, the sedimentary rocks flanking the Front Range are warped into a series of folds that plunge south-southeast (Scott and others, 1978) and merge into plains within about 20-30 km of the mountain front (Fig. 2). These folds are the southernmost manifestation of Front Range geologic structure. Hills, some of which are referred to as mountains (Timber Mountain and Booth Mountain, for example), delineate the trends of the anticlines, and valleys more or less mark the position of the synclines. The summits of Booth Mountain, Timber Mountain (Fig. 1), and the other hills formed by these anticlines are a few hundred meters higher than the plains to the east, but are 1,000 to 2,000 m or more lower than summits in the Front Range just a few tens of kilometers to the west.

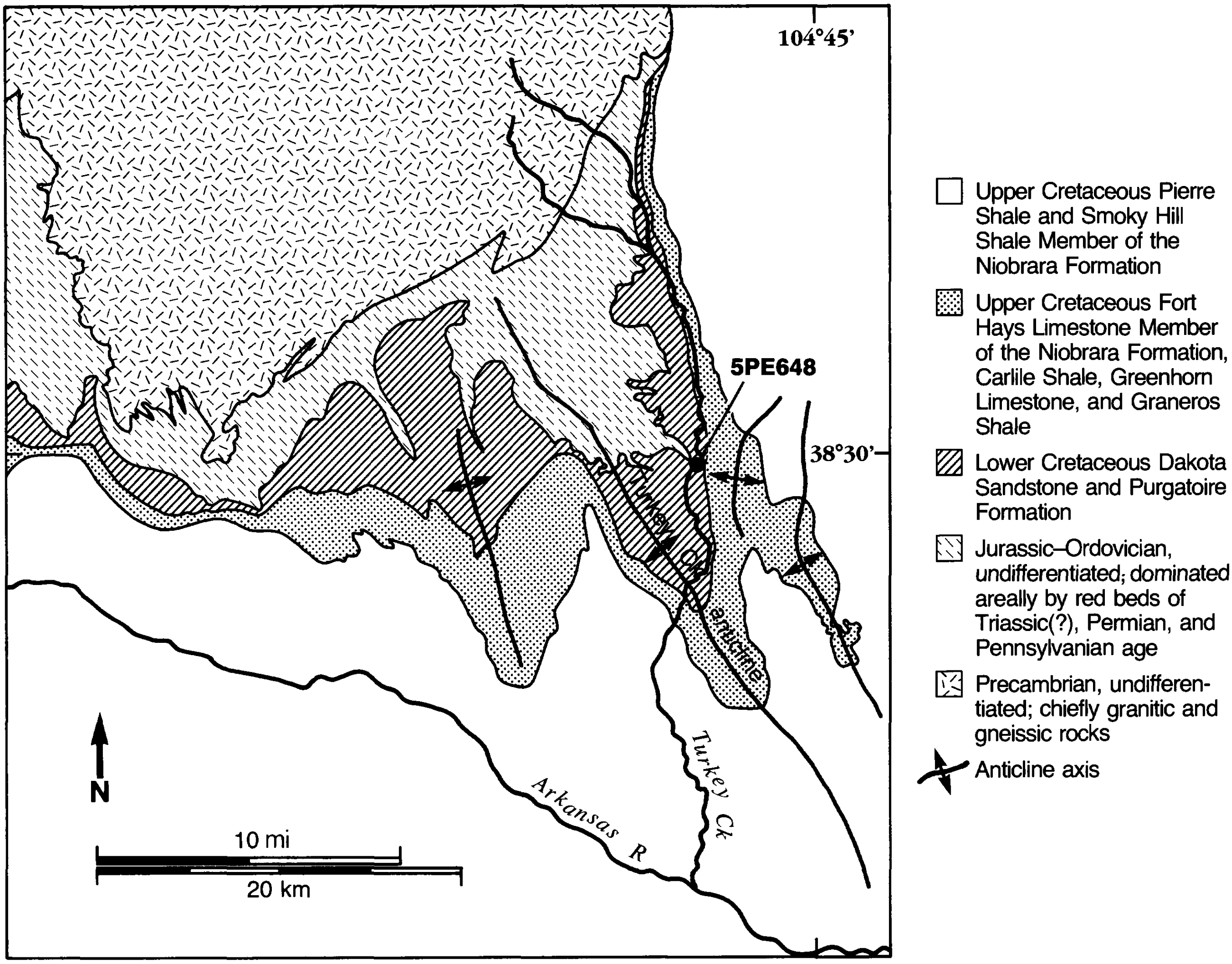

Figure 2. Generalized bedrock geologic map of the southern end of the Front Range and part of the Colorado Piedmont.

Turkey Creek heads in the Front Range, about 8 km west of the mountain front, and flows southward out of the Front Range and along the east flank of the Turkey Creek anticline (Fig. 2). Timber Mountain and Booth Mountain, which are separated by Sullivan Canyon, are the topographic expression of the Turkey Creek anticline. From the mountain front south, nearly to Sullivan Canyon, Turkey Creek valley is shallow and more or less follows the outcrop of the Graneros Shale (Upper Cretaceous). However, beginning a few hundred meters upstream from archeological site 5PE648 (Fig. 2) and extending for about 5 km downstream from the site, Turkey Creek valley is superposed onto the flank of the Turkey Creek anticline, which is underlain by the resistant Dakota Sandstone. This resistant sandstone accounts for the topographic prominence of the Turkey Creek anticline in this area; it also forms cliffs on the east side of the valley that provided shelter for the prehistoric inhabitants of the region.

Where Turkey Creek is superposed onto the Dakota Sandstone, it has cut a relatively deep, somewhat asymmetrical valley. The valley bottom varies in width from about 100 to 300 m, and is incised to depths of 40 to 60 m below the rim of the cliff-like east valley wall. The asymmetrical cross-valley profile reflects geologic structure; Turkey Creek migrated eastward downdip as valley deepening progressed. In time, the tendency to migrate eastward was enhanced by the asymmetrical distribution of sediment deposited on the valley floor by small side-valley tributaries. The volume of sediment entering the valley from the west was much greater than that entering from the east, which tended to keep the creek on the east side of the valley. This pattern of sedimentation has continued to the present, as several small tributaries and related alluvial fans extend into Turkey Creek valley from the west. In comparison, no tributaries enter Turkey Creek valley from the east in the 5 km reach that is entrenched in Dakota Sandstone. Consequently, the east valley wall is steep, marked in places by cliffs, 30-50 m high, whereas the west side of the valley is less steep and more or less reflects the dip of the bedding. The tendency for Turkey Creek to cut against the sandstone cliffs along the east side of the valley led to the formation of the rock shelter, archeological site 5PE648, that provided chronologic control for the Holocene alluvial units of the area.

Remnants of Pleistocene terrace gravel are present locally in Turkey Creek valley, but alluvial terraces are generally absent, except for the valley floor, which has become a low terrace because of channel incision during the past 100 to 150 years. The valley floor varies in width from about 100 to 300 m and is underlain by alluvium from side to side. The thickness of the alluvium is unknown, although as much as 6 m is exposed locally in cutbanks.

STRATIGRAPHY

Three alluvial units are widespread on the valley floor of Turkey Creek (Fig. 3). The units are distinguished on the basis of lithology, stratigraphic relations (superposition and crosscutting relations), position in the landscape, and relative soil development. Unit 1 is the thickest and most extensive alluvial unit, but is covered in most places by unit 2. Unit 2 includes deposits that typically have a combined thickness of less than 1 m, although thickness ranges from 0.25 to 1.6 m. Unit 3 consists of coarse-grained alluvium that was deposited in a relatively narrow channel incised through unit 2 into unit 1. Unit 3 is historic in age, and most is probably less than 100 yr old. Unit 2 is late Holocene in age; unit 1 is middle Holocene and older, and may include sediment as old as latest Pleistocene.

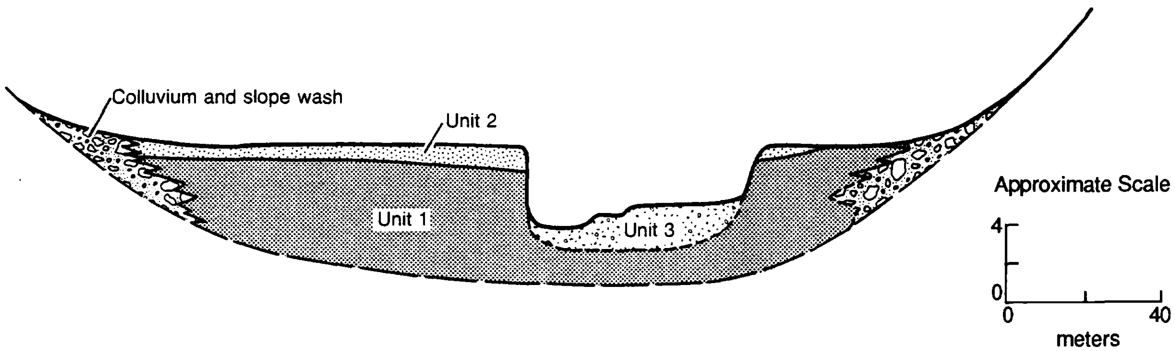

Figure 3. Schematic diagram showing the stratigraphic relations of the three alluvial units on Turkey Creek and valley-side deposits of slopewash and colluvium.

Unit 1

Although the full thickness of unit 1 is not known, as much as 4 m commonly is exposed in cutbanks (Figs. 4A, 4B). Typically, unit 1 consists of 2.5 to 3 m of poorly sorted clayey and silty sand overlying 0.5 to 1 m of clast-supported gravel (Fig. 4A). No evidence of an unconformity was observed between the clayey-silty sand and the gravel; hence, they are tentatively treated as a single unit. The gravel is mostly pebbles and cobbles but locally includes small boulders (25-75 cm in maximum dimension). In many places, the basal gravel is absent or is present only in thin beds and isolated lenses 10-50 cm thick. Nowhere was the bottom of unit 1 observed. Gravel thickness probably varies from one cutbank exposure to another as a function of distance between the location of the cutbank exposure and the axis of the former channel (Fig. 5). Most of the clasts are Precambrian granitic and gneissic rock derived from the Front Range, and sandstone derived locally, mainly from the Dakota Sandstone (Fig. 2). Stratification in the clayey-silty sand part of unit 1 varies from weakly developed to well developed. The better stratified sections generally contain more thin beds of sand and lenses of granule and small pebble gravel, and are interpreted as having formed within or near paleochannels (Fig. 5).

Unit 1 contains much silt and clay; therefore, it is very hard when dry, maintains steep, nearly vertical cutbanks, and has a distinctive coarse columnar structure (Fig. 4). The columnar structure together with the redder (7.5YR) hues of the sediment readily distinguish unit 1 from overlying deposits of unit 2. The redder hues of unit 1 are attributed to sediment provenance; a significant part of the unit was derived from redbeds, mainly Fountain Formation (Pennsylvanian and Permian) and Lykins Formation (Permian and Triassic (?)) (Fig. 2), in the headwater areas of Turkey Creek and some of its larger tributaries.

In most places, the upper contact of unit 1 is marked by a relatively thick but weakly developed soil. The soil profile consists of A/C or A1/A2/C horizons. The thickness of the A horizon varies considerably, from 30 cm to as much as 85 cm, but most commonly is about 40-45 cm. The large range in thickness is probably due both to losses by erosion and to variation in the amount of soil formed on different parts of the valley floor. The soil is interpreted to be a cumulic A horizon because it is much thicker than the typical A horizon in this region, and also because, even though thick, it is

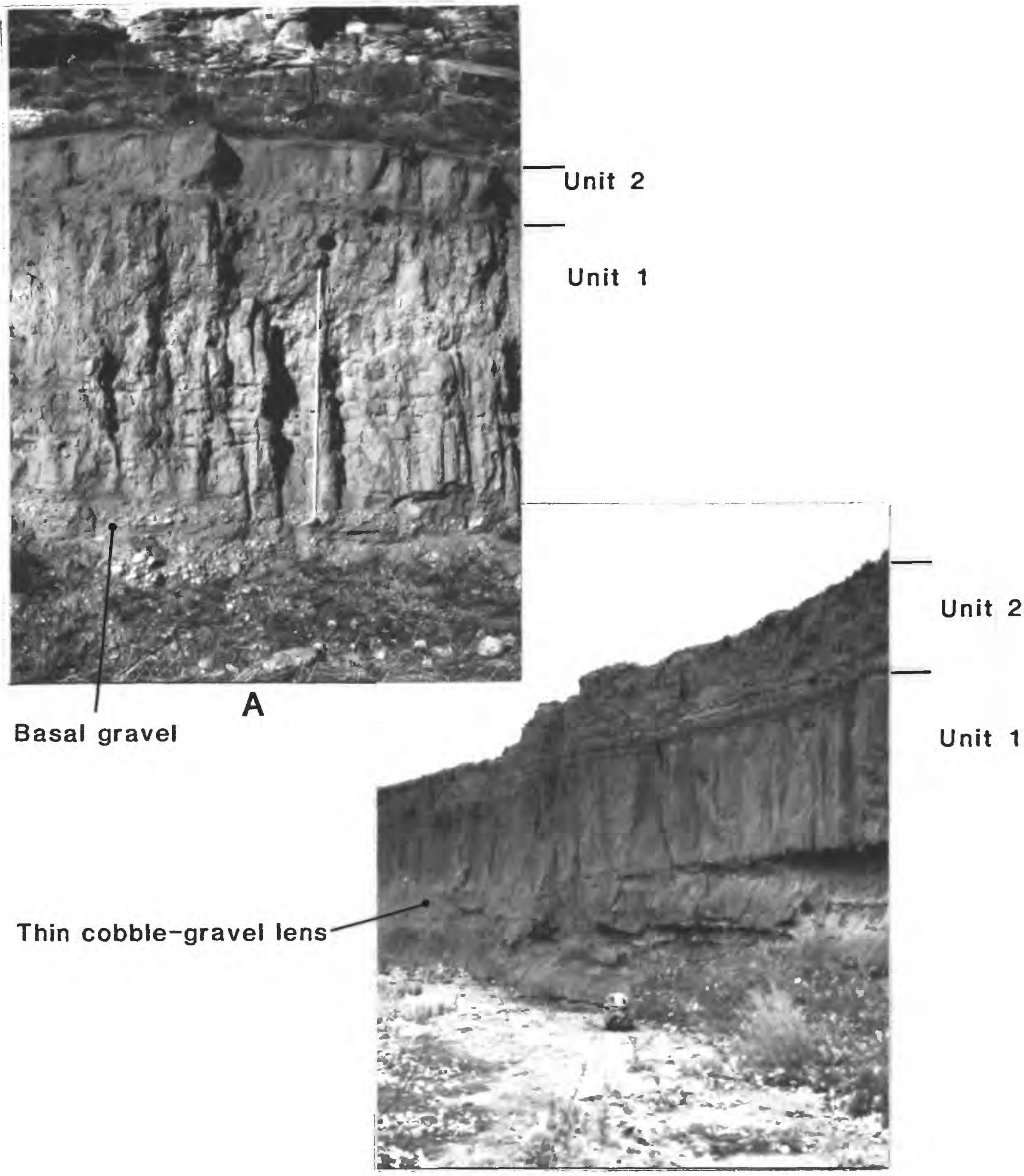

Figure 4. Alluvial units in cutbanks along Turkey Creek near the downstream end of the valley segment entrenched in Dakota Sandstone. A. From 0.6 to 0.7 m of unit 2 overlies 3.5-4.0 m of unit 1, which consists of about 1 m of basal gravel overlain by 2.5-3.0 m of clayey-silty sand. Columnar structure is typical in unit 1; stratification in lower part of unit is enhanced by etching of thin sand beds. Buried soil in top of unit is partly concealed by film of sediment washed down from unit 2. Dakota Sandstone at base of east valley wall is in background (top). B. About 1.5 m of well-stratified unit 2 overlies 4 m of unit 1. Thin lenses of pebble-cobble gravel are present within unit 1 (left center), but are not exposed at base of the unit at this locality.

weakly developed. Cumulic A horizons commonly develop on slowly but progressively aggrading flood plains. Under such conditions, incorporation of humus into the alluvium (A horizon formation) keeps pace with aggradation, and variation in the amount of aggradation from place to place may cause a proportional variation in A-horizon thickness. Nevertheless, some of the variability in thickness of the buried A horizon is due to erosion. In places, the upper boundary of the soil is wavy suggesting that the contact between it and the overlying alluvium (unit 2) is erosional, and locally the contact is also marked by weakly developed stone lines.

Most of unit 1 is probably middle to early Holocene in age. Detrital charcoal concentrated from the uppermost 10-15 cm of unit 1 at site 5PE648 had a ^{14}C age of 4,050 ± 120 B.P. (Beta-24247), and detrital charcoal from an interval about 20-30 cm deeper had an age of 4,400 ± 80 B.P. (Beta-24248) (Christian J. Zier, written commun., 1988). Except for the uppermost part, the age of unit 1 is unknown. The basal gravel of unit 1 may be Pleistocene in age. Coarse gravel such as this is dominant in deposits of Pleistocene age along streams draining from the glaciated part of the Front Range. A study of

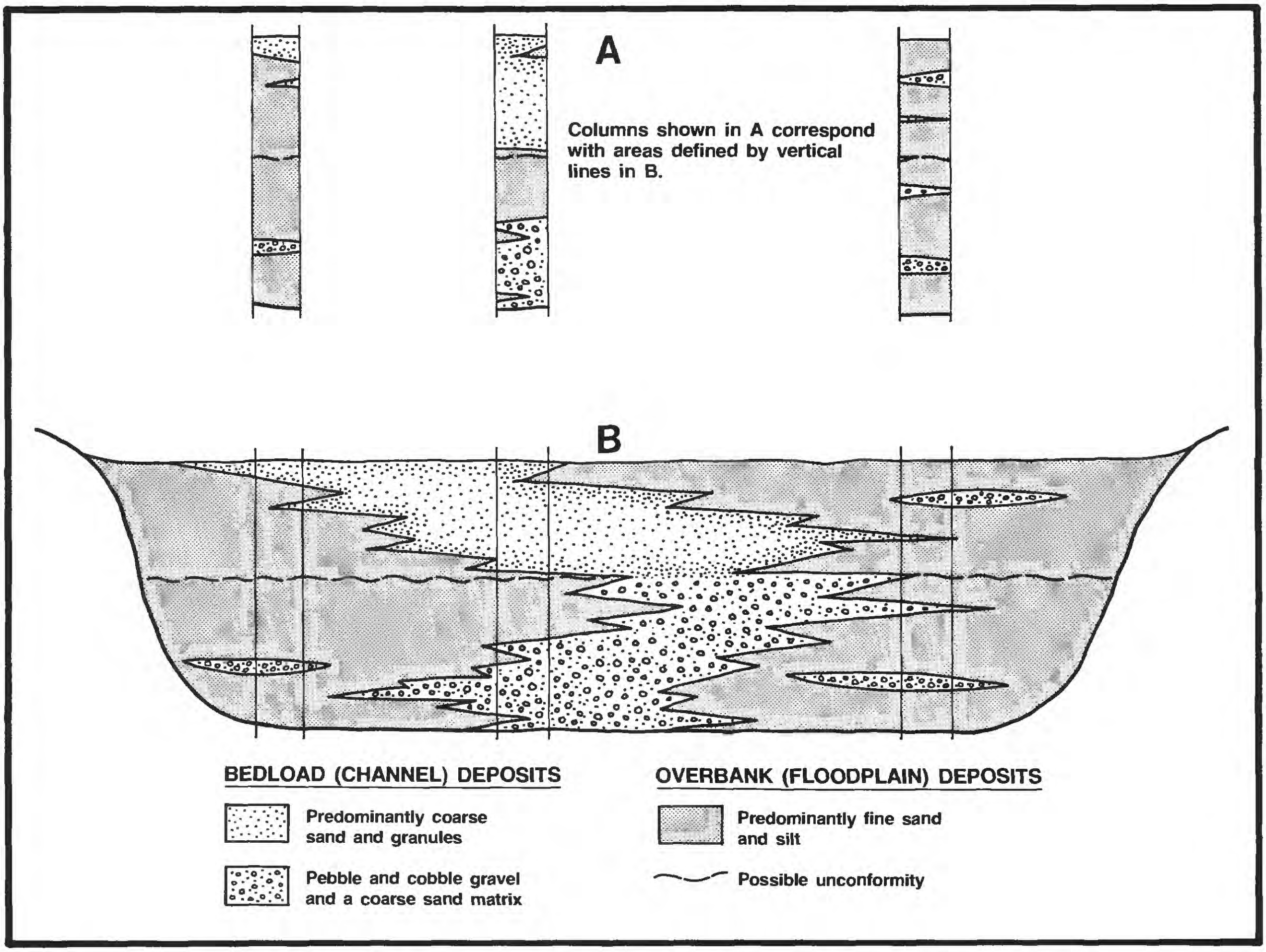

Figure 5. Diagram of an alluvial valley fill, such as unit 1, showing how vertical sequences of alluvium in isolated cutbank exposures (A) may vary considerably, yet be part of a coherent body of bedload (channel) and overbank (flood-plain) sediment (B) deposited by a stream that shifted laterally as it aggraded.

such deposits on Clear Creek west of Denver led Baker (1974) to conclude, on the basis of engineering hydraulics, that the coarse gravel in this area would have been transported only by the "influx of large quantities of glacial meltwater". This conclusion followed from calculations which showed that transport of the coarse gravel would have required sustained discharges ten times greater than that of the largest flood during 120 years of record. Although Turkey Creek did not receive an influx of glacial meltwater, discharges were probably greater during times of glaciation because the climatic change that caused glaciers to form in the higher parts of the Front Range is likely to have caused an increase in precipitation and/or reduction in evapotranspiration in the Colorado Piedmont.

Unit 2

Unit 2 overlies unit 1 over most of the valley floor of Turkey Creek (Figs. 3, 4A, 4B, 6A, 6B). Unit 2 comprises deposits of two different ages that are treated as a unit because their combined thickness is generally less than 1 m and their separation requires detailed field work. Most of unit 2 is grayish-brown to brown calcareous sand that over much of the area grades downward to a basal unit of sand (Fig. 6) that appears to be pink or light reddish brown partly because of the somber colors of the soils that bound it above and below. The basal sand is of 7.5YR hue, whereas the overlying and underlying soils are 10YR gray and gray brown. The basal sand of unit 2 is generally better sorted and coarser than the gray-brown sand in the upper part of the unit. Unit 2 is typically less than 75 cm thick, but ranges in thickness from about 25 cm to 1.6 m. The thickest deposits of unit 2 are in paleochannels in the axial part of the valley (Fig. 6B) and in small alluvial fans that extend onto the valley floor from tributaries and side-valley rills. Stratification is distinct in areas near former channels (Figs. 3, 4B, 5), but elsewhere is weak to absent. Where the unit is well stratified, individual beds of sand and silty sand range in thickness from 2 to 30 cm, but most are 5-10 cm thick. Beds of well-sorted slightly "pink" sand that are common in the lower part of the unit enhance the stratification because of their color and better sorting.

The older part of unit 2 is thicker and more extensive than the younger part. The younger part forms a thin cover (generally less than 50 cm) along valley sides and on alluvial fans that extend onto the valley floor of Turkey Creek from side canyons. Also, 30-70 cm of the younger sediment commonly blankets a narrow area adjacent to the present stream. The two parts of unit 2 are distinguished chiefly by differences in degree of soil development. The older part of the unit is characterized by an A/C soil profile wherein the A horizon, although weakly developed, is commonly 30 to 40 cm thick. In the younger part of the unit, soil development is barely present. At the most, it consists of a simple A horizon, 6-8 cm thick, that is weakly defined by a minimal amount of humus; it also is essentially unleached of $CaCO_3$.

The stratigraphic relations of the two parts of unit 2 are exposed in cutbanks in the vicinity of site 5PE648. Approximately 1.5 m of the older part of unit 2 underlies the site, and is overlain locally by as much as 20 cm of the younger part of unit 2 (chiefly sheetwash and fan alluvium) derived from rills along the valley wall. As at many other localities, the base of the older part of unit 2 at site 5PE648 contains "pinkish"-brown sand overlying a paleosol developed in unit 1. Strata of the older part of unit 2 slope from site 5PE648 toward the valley axis where they are buried by as much as 70 cm of mainstream alluvium of the younger part of unit 2. This

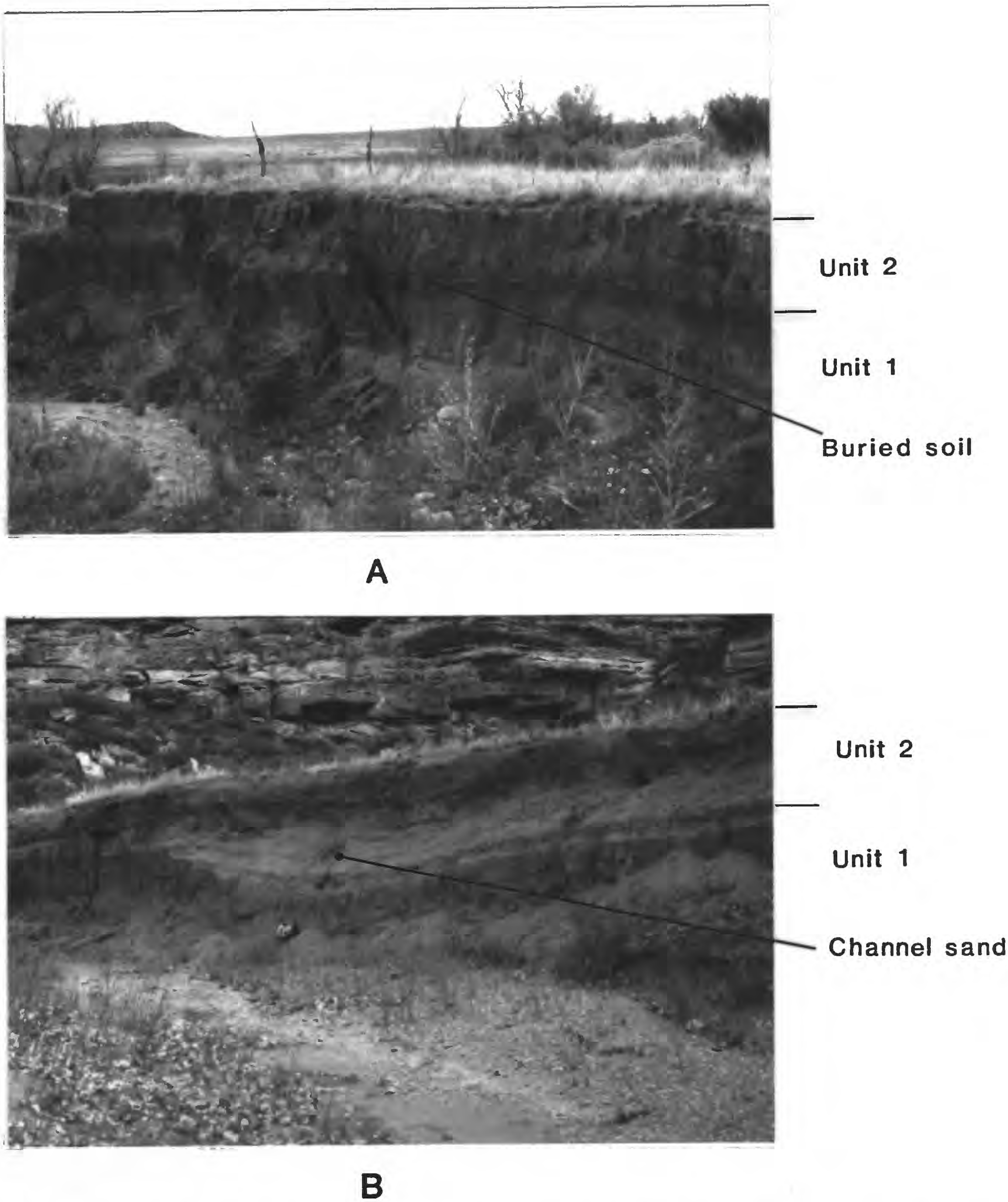

Figure 6. Alluvial units in cutbanks along Turkey Creek. A. View southeast just south of Rt. 8 showing 1.2 m of unit 2 overlying unit 1. Prominent buried soil marks upper contact of unit 1; a thin buried A horizon also is present about midway up in unit 2 (most visible at left center). Stratification below buried soil is typical of unit 1. B. More than 1 m of "pinkish" sand in lower part of unit 2 fills paleochannel on unit 1 in cutbank near the lower end of valley segment entrenched in Dakota Sandstone. Thickness of basal "pinkish" sand at left is more typical than thickness in paleochannel, but caving of sand in paleochannel is typical because sand is coarser and better sorted than other alluvium. The color of the basal sand is distinct partly because it is bounded by dark soils, the surface soil in the upper part of unit 2 and the buried soil in the upper part of unit 1. Dakota Sandstone at the base of the east valley wall is in background.

stratigraphic relationship is exposed immediately downstream from site 5PE648 in a cutbank oriented approximately normal to the valley axis. Mainstream alluvium of the younger part of unit 2 also is exposed in the west bank of Turkey Creek opposite site 5PE648.

Six ^{14}C ages of charcoal show that the older part of unit 2 at site 5PE648 ranges in age from about 2,000 to 1,000 B.P. (Christian J. Zier, written commun., 1988). Charcoal from near the base of the unit had an age of 1,910 ± 90 B.P. (Beta-24246) and charcoal from near the top had an age of 1,150 ± 60 B.P. (Beta-24243). Also, detrital charcoal concentrated from about the middle of the unit in the cutbank adjacent to site 5PE648 yielded an age of 1,870 ± 50 B.P. (Beta-24242).

Stratigraphic relations and ^{14}C ages of unit 2 in Turkey Creek valley are similar to those of alluvial units at archeological sites in three small drainage basins along the mountain front farther north. The three sites are at Dutch Creek (5JF463), Leyden Gulch (5JF367), and Van Bibber Creek (5JF10), all in Jefferson County in the Denver area. At the Dutch Creek site, an alluvial unit about 90 cm thick began to aggrade sometime after 2700 ± 70 B.P. (Beta-22217) but before 1980 ± 50 B.P. (Beta-21192) (^{14}C ages provided by Debra Angulski, Colorado State Highway Department, oral commun., 1987), and continued to aggrade for an undetermined length of time after 1980 ± 50 B.P. The 1980 ± 50 yr age is from about the middle of the 90-cm-thick alluvial unit. At Leyden Gulch, a hearth excavated into a thick cumulic A horizon, a possible correlative of the paleosol in the upper part of unit 1 at Turkey Creek, yielded a ^{14}C age of 2,380 ± 50 B.P. (Beta-15091) (Debra Angulski, Colorado State Highway Department, oral commun., 1987). Subsequently, the hearth and A horizon were buried by as much as 1.3 m of alluvium that is probably correlative with unit 2 at Turkey Creek. Similarly, at the Van Bibber Creek site, a hearth was constructed in an occupation zone about 2,140 ± 145 B.P. (I-3818) (Nelson, 1969), and then was subsequently buried by about 50 cm of sediment, of which all but the upper 8 cm was deposited prior to 1,050 ± 250 B.P. (W-616).

The very weak degree of soil development in the younger part of unit 2 at Turkey Creek suggests that the time elapsed since this part of the unit ceased to be deposited is probably on the order of a few centuries. Possibly deposition of this part of the unit largely ceased when 4 to 6 m of channel incision during the past 150-100 years made overbank flooding infrequent. The younger part of unit 2 is correlated with an episode of deposition that occurred between about 800 and 100 yr B.P. in drainage basins similar in size to that of Turkey Creek from southern Utah (Graf, 1987) to western Oklahoma (Ferring, 1986; Madole, 1986a, 1988).

Unit 3

Unit 3 is poorly sorted, gravelly alluvium that was deposited in the incised channel of Turkey Creek (Fig. 3). The gravel includes all sizes from pebbles to small boulders. The total thickness of the alluvium is unknown, but it is probably 2-3 m. The bed of Turkey Creek, which during normal runoff is 2.5-4 m wide, is on unit 3. The creek is flanked by two low surfaces (Fig. 3), one about 0.5-1 m above stream level, the other about 1-1.5 m above stream level. The higher level is the upper surface of unit 3, the lower level is a surface cut in unit 3 that, in many places, is covered by flood and point-bar deposits. Both surfaces are subject to frequent flooding; in effect, they are the flood plain, and neither shows much soil development. Modern channel deposits, consisting of cobble and boulder gravel in the riffles and sand in the areas between riffles, are considered to be part of unit 3.

The majority of clasts in unit 3 are granitic and metamorphic rock, and sandstone is common, especially where Turkey Creek flows along outcrops of Dakota Sandstone on the east side of the valley. Unit 3 is coarser than the other units, except for the gravel in the basal part of unit 1 from which much of unit 3 was probably derived. Unit 3 is interpreted to be largely a lag deposit composed of the coarse constituents reworked mainly from the lower part of unit 1. Incision of Turkey Creek, probably within the past 150-100 yr, established conditions favorable for transport and deposition of coarse-grained alluvium. Stream incision to depths of 4 to 6 m provided access to coarse detritus in the lower part of unit 1 and confined runoff to a narrow channel. The relatively deep, narrow channel made it possible for Turkey Creek to transport coarser sediment during times of high runoff.

Most of unit 3 probably was deposited during the past century. Presumably, channel incision in Turkey Creek valley coincided approximately with an episode of channel incision that was widespread in the Colorado Plateau, southern part of the Basin and Range, and the Southern High Plains (summarized by Graf, 1983), and in the Osage Plains (Madole and others, in press) between 150 and 100 yr ago. The lack of soil development in unit 3 and absence of trees as old as 100 years on the unit supports this age assignment.

GEOLOGIC HISTORY AND PALEOENVIRONMENTS

The valley of Turkey Creek, like many streams in the Colorado Piedmont, was probably established on a cover of Tertiary sediment, graded to the Front Range, that has since been removed by erosion. As the cover of horizontally bedded Tertiary fluviatile rocks was eroded, the course of ancestral Turkey Creek was lowered onto folded rocks of Paleozoic and Mesozoic age. Over most of its course, Turkey Creek adjusted to the structural grain of the folded rocks, following the trend of softer units, such as the Graneros Shale (Upper Cretaceous). In the vicinity of site 5PE648, however, the course of Turkey Creek was lowered onto the resistant Dakota Sandstone (Lower Cretaceous) (Fig. 2). Superposition of Turkey Creek onto eastward-dipping beds of Dakota Sandstone on the flank of the Turkey Creek anticline set the stage for development of a canyon-like valley segment and development of rock shelters along sandstone cliffs on the east side of the valley.

During most of Quaternary time, Turkey Creek was eroding and progressively deepening its valley. Regional uplift of the Front Range and the adjoining Great Plains in latest Miocene and Pliocene time caused fluvial degradation and canyon cutting throughout the region, on the plains and in the mountains, that has continued to the present (Trimble, 1980; Madole and others, 1987). Along the larger valleys, especially those heading near the summit of the Front Range, valley deepening was periodically interrupted by episodes of aggradation associated with climatic changes that, in the higher parts of the Front Range, led to the formation of glaciers and extensive perennial snowfields. In these valleys, the episodes of aggradation are recorded by terrace deposits that mark the levels of former valley floors. However, such a sequence of terrace deposits is not preserved in Turkey Creek valley, and remnants of older fluvial deposits are almost entirely absent where the valley is cut in Dakota Sandstone. The scarcity of Pleistocene terrace deposits along Turkey Creek is probably the result of the small size of the drainage basin and the location of the basin in an area where sediment influx related to snowmelt and deglaciation was insignificant. Most of the comparatively small volume of alluvium deposited along Turkey Creek valley during these intervals of aggradation apparently was subsequently eroded. Therefore, the preserved stratigraphic record of Turkey Creek, at least in the vicinity of site 5PE648, begins with unit 1, which is latest Pleistocene (?) to middle Holocene in age.

Unit 1 was deposited in a channel that probably was eroded during Pinedale full-glacial conditions, which peaked at about 19,000-18,000 B.P. and ended prior to 12,000 B.P. (Madole, 1986b). The inferred age for channel excavation is based on unpublished data from studies elsewhere in Colorado and Utah, and on published studies at widely scattered localities in the central and western United States (for example, Brakenridge, 1981; Ferring, 1986; Fleming and others, in press; Madole, 1986a). Judging from unit 1, much of Holocene time, and possibly some of latest Pleistocene time, has been characterized mainly by aggradation. Cobble beds in the basal part of unit 1, which locally include small boulders, are a major reason for inferring that the lower part of the unit may be of late Pleistocene age.

Stratigraphic relations, archeological data, and eleven ^{14}C ages indicate that the upper part of unit 1 was deposited prior to about 4,000 B.P. and that the older part of unit 2 was deposited between about 2,000 and 1,000 B.P. Deposition of unit 2 coincides approximately with a time of expanded cirque glaciers and snowfields in the higher part of the Front Range (Fig. 7), which

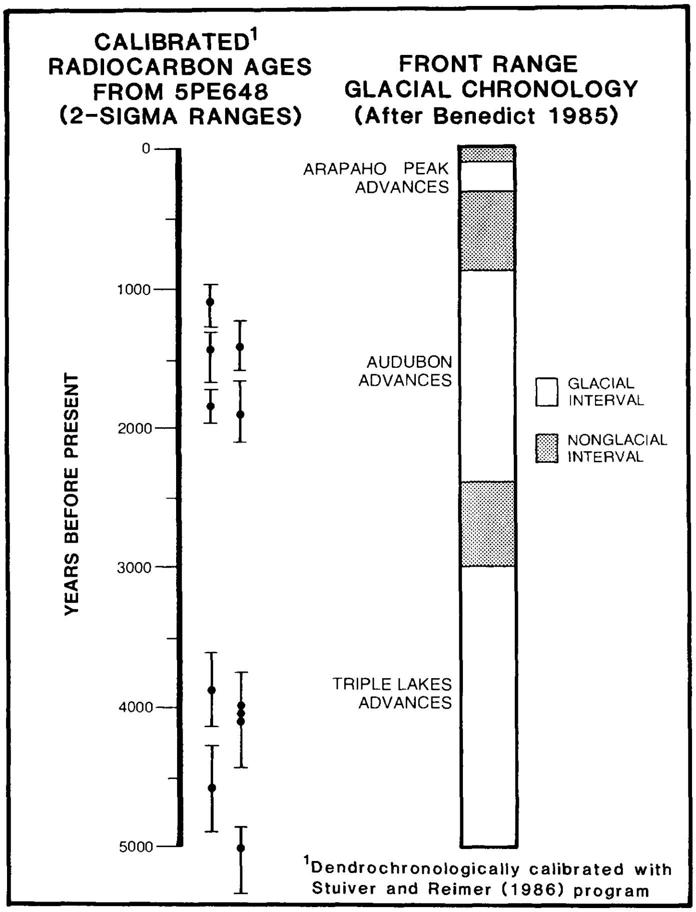

Figure 7. Diagram showing the chronologic relations of the alluvial units at site 5PE648 and the Audubon and Triple Lakes glacial advances of Benedict (1973, 1981, 1985). Vertical lines shown with the calibrated ages represent the two-sigma analytical error for each age determination. Because of inflections in the calibration curve, one of the radiocarbon ages (triple dots at about 4000 B.P.) corresponds to three different calibrated ages.

was initially identified by Benedict (1968) and subsequently referred to as the Audubon glacial advances (Benedict, 1973, 1981, 1985). Integrating a variety of age data, Benedict (1985) revised slightly the limiting dates of the Audubon glacial advances to 2400 and 950 yr B.P. (Fig. 7).

Olyphant (1985) reconstructed aspects of Holocene climate in the Front Range on the basis of the distribution of lithofacies of glacial and periglacial origin. He concluded that the Audubon glacial advances could be accounted for by small changes in climate from that of the present, and that the likely cause of the glacial advances was a deterioration in summer climate resulting from increased cloudiness and cooler temperatures. Olyphant's work supports Benedict's (1973) conclusion that summers were cooler in the Front Range during the time of the Audubon glacial advances than at present. Olyphant (1985) attributes the climatic change of this time to a weakening of the westerlies, both in winter and summer. This weakening of the westerlies would allow a greater penetration of moist air into the southwestern states, as described by Bryson and Wendland (1967). An expansion into the Colorado Rocky Mountains of maritime air would produce summers that were cloudier, wetter, and cooler. Also, the potential for heavy, wet snowstorms on the east slope, such as are common at present during the late winter and spring, may have become greater (Olyphant, 1985). The impact of even short-term shifts of this kind have been evident in Utah in recent years as a series of wetter years have contributed to replenishment of playa lakes, the rise of the Great Salt Lake, and widespread landsliding.

During the time that unit 2 was deposited, most of the valley floor was flood plain, and was aggrading slowly. Coarse sediment like that of unit 3, or the basal part of unit 1, is not present in unit 2. Sediment, mostly less than 2 mm in size, was deposited over the entire valley floor, which suggests that the channel of Turkey Creek was not incised as it is at present. During intervals of high flow, Turkey Creek overtopped banks, which presumably were low, and flooded across the valley floor. In most places, scouring prior to deposition of unit 2 apparently was minimal and the soil that had developed in unit 1 was preserved intact (Figs. 4, 6). Judging from the amount of overbank sediment that was deposited, about 1 to 1.5 m in 1000 yr, the flood-plain surface aggraded at an average rate of about 1 to 1.5 cm per decade. Also, the weak but relatively thick A horizon in the older part of unit 2 suggests that sedimentation was more or less evenly distributed through time and was slow enough that soil formation kept pace with alluviation. If sedimentation had occurred in a few large events, it would have tended to produce a sequence of thin buried soils.

The soil in the upper part of unit 1 began forming by at least 4 ka and continued to develop until buried by unit 2 at about 2 ka. The degree of soil development exhibited in this A/C profile and the degree to which the soil is preserved over the valley floor indicates that stability prevailed generally during the period 4 ka to 2 ka. During this time, the valley floor was neither extensively eroded nor deeply buried by sediment from either the valley sides and tributary valleys or mainstream overbank flooding. Comparison of the Holocene alluvial stratigraphy of Turkey Creek with the record of cirque glaciation shows that deposition of unit 2 and at least the upper part of unit 1 coincided with times when cirque glaciers and perennial snowfields expanded along the summit of the Front Range (Fig. 7).

CONCLUDING REMARKS

The alluvial units on Turkey Creek record a succession of environmental changes that occurred in a small drainage basin during Holocene time. Episodes of alluviation alternated with episodes of stability or erosion. The sedimentary characteristics and stratigraphic relations of the alluvial units (Figs. 3, 4, 6) provide clues as to the magnitudes and directions of the environmental changes. This report infers that these changes are related to climate. However, a considerable difference of opinion exists as to the significance and the causes of changes recorded by Holocene alluvial stratigraphic sequences (Karlstrom and Karlstrom, 1987). One school of thought favors regional climatic change as the dominant control, whereas another school favors nonclimatically controlled adjustments within the fluvial system. Still other researchers favor combinations of extrinsic (climate) and intrinsic (process) controls, including impacts from human activities, to explain alluvial stratigraphic sequences. Several unanswered questions fuel the controversy, but central to all arguments is the need for many widely distributed, well-dated alluvial stratigraphic sequences.

REFERENCES CITED

Baker, V. R., 1974, Paleohydraulic interpretations of Quaternary alluvium near Golden, Colorado: Quaternary Research, v. 4, no. 1, p. 94-112.

Benedict, J. B., 1968, Recent glacial history of an alpine area in the Colorado Front Range, U.S.A.--II. Dating the glacial deposits: Journal of Glaciology, v. 7, no. 49, p. 77-87.

_____ 1973, Chronology of cirque glaciation, Colorado Front Range: Quaternary Research, v. 3, p. 584-599.

_____ 1981, The Fourth of July Valley--Glacial Geology and Archeology of the Timberline Ecotone: Ward, Colorado, Center for Mountain Archeology, Research Report No. 2, 139 p.

_____ 1985, Arapaho Pass--Glacial Geology and Archeology at the Crest of the Colorado Front Range: Ward, Colorado, Center for Mountain Archeology, Research Report No. 3, 197 p.

Brakenridge, G. R., 1981, Late Quaternary floodplain sedimentation along the Pomme de Terre River, southern Missouri: Quaternary Research, v. 15, p. 62-76.

Bryson, R. A., and Wendland, W. M., 1967, Tentative climatic patterns for some late glacial and post-glacial episodes in central North America, <u>in</u> Mayer-Oakes, W. J., ed., Life, Land and Water: Winnipeg, Manitoba, University of Manitoba Press, p. 271-298.

Ferring, C.R., 1986, Late Holocene cultural ecology in the southern plains--Perspectives from Delaware Canyon, Oklahoma: Plains Anthropologist, Memoir 21, p. 55-82.

Fleming, R. W., Schuster, R. L., and Johnson, R. B., in press, Physical properties and mode of failure of the Manti landslide, Chapter B in The Manti landslide, Utah: U. S. Geological Survey Professional Paper 1311.

Graf, W.L., 1983, The arroyo problem--Palaeohydrology and palaeohydraulics in the short term, in Gregory, E.W., ed., Background to Palaeohydrology: John Wiley and Sons, p. 279-302.

_____ 1987, Late Holocene sediment storage in canyons of the Colorado Plateau: Geological Society of America Bulletin, v. 99, p. 261-271.

Hunt, C. B., 1954, Pleistocene and recent deposits in the Denver area, Colorado: U.S. Geological Survey Bulletin 996-C, p. 91-140.

Karlstrom, E.T., and Karlstrom, T.N.V., 1987, Late Quaternary alluvial history of the American west--Toward a process paradigm: Geology, v. 15, no. 1, p. 88-89.

Madole, R. F., 1986a, The Meers fault--Quaternary stratigraphy and evidence for late Holocene movement, in Donovan, R.N., ed., The Slick Hills of southwestern Oklahoma--Fragments of an aulacogen?: Oklahoma Geological Survey Guidebook, 24, p. 55-67.

_____ 1986b, Lake Devlin and Pinedale glacial history, Front Range, Colorado: Quaternary Research, v. 25, no. 1, p. 43-54.

_____ 1988, Stratigraphic evidence of Holocene faulting in the mid-continent --The Meers fault, southwestern Oklahoma: Geological Society of America Bulletin, v. 100, p. 392-401.

_____ in press, Colorado Piedmont, in Chapter 10--Northern Great Plains, in Morrison R.B., ed., Non-Glacial Quaternary Geology in the Conterminous United States: Boulder, Colorado, Geological Society of America Centennial Special Volume K-2.

Madole, R. F., Bradley, W. C., Loewenherz, D. S., Ritter, D. F., Rutter, N. W., and Thorn, C. E., 1987, Rocky Mountains, Chapter 7, in Graf, W. L., ed., Geomorphic Systems of North America: Boulder, Colorado, Geological Society of America Centennial Special Volume 2, p. 211-257.

Madole, R. F., Ferring, C. R., Guccione, M. J., Hall, S. A., Johnson, W. C., and Sorenson, C. J., in press, Osage Plains and Interior Highlands, Chapter 12, in Morrison, R. B., ed., Non-Glacial Quaternary Geology in the Conterminous United States: Boulder, Colorado, Geological Society of America Centennial Special Volume K-2.

Nelson, C.E., 1969, Salvage archaeology on Van Bibber Creek, site 5JF10: Southwestern Lore, v. 34, no. 4, p. 85-106.

Olyphant, G. A., 1985, Topoclimate and the distribution of neoglacial facies in the Indian Peaks section of the Front Range, Colorado, U.S.A.: Arctic and Alpine Research, v. 17, no. 1, p. 69-78.

Scott, G.R., 1960, Quaternary sequence east of the Front Range near Denver, Colorado: Rocky Mountain Association of Geologists, Guide to the Geology of Colorado, p. 206-211.

______1962, Geology of the Littleton quadrangle, Jefferson, Douglas, and Arapahoe Counties, Colorado: U.S. Geological Survey Bulletin 1121-L, p. L1-L53.

______1963, Quaternary geology and geomorphic history of the Kassler quadrangle, Colorado: U.S. Geological Survey Professional Paper 421-A, p. A1-A70.

Scott, G.R., Taylor, R.B., Epis, R.C., and Wobus, R.A., 1978, Geologic map of the Pueblo 1° x 2° quadrangle, south-central Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1022, scale 1:250,000.

Stuiver, M., and Reimer, P.J., 1986, A computer program for radiocarbon age calibration: Radiocarbon, v. 28, no. 2B, p. 1022-1030.

Trimble, D. E., 1980, Cenozoic tectonic history of the Great Plains contrasted with that of the Southern Rocky Mountains--A synthesis: Mountain Geologist, v. 17, p. 59-69.

Van Horn, Richard, 1976, Geology of the Golden quadrangle, Colorado: U.S. Geological Survey Professional Paper 872, 116 p.