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GEOLOGICAL SURVEY

A soils chronosequence at Terrace Creek: Studies of Late Quaternary Tectonism in Dixie Valley, Nevada

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ABSTRACT

Fluvial and lacustrine landforms and their soils provide data that constrain the rates and times of late Quaternary tectonism at the Terrace Creek study site in Dixie Valley, Nevada. The most useful data for describing the terrace and fan chronosequence are stratigraphy, degree of surface dissection, desert-pavement development, and the Harden (1982) quantitative soil-development index. Two older terraces predate the 12,000 year old highstand shoreline of pluvial Lake Dixie, but two younger terraces and two correlative alluvial-fan surfaces postdate the shoreline. Each of the four terraces is truncated by piedmont faulting. At least one Holocene faulting event preceded the 1954 event; maximum Holocene displacement is about 2 m, including the 1954 event.

INTRODUCTION

Purpose

This study examines soil profiles and their associated geomorphic surfaces to constrain ages of faulted and unfaulted alluvial landforms on the west side of Dixie Valley, Nevada (Figure 1). This area experienced surface rupture during the 1954 Dixie Valley earthquake (Slemmons, 1957), but little is known about the rates and patterns of pre-1954 faulting activity. Thompson and Burke (1973) and Wallace (1977) used crosscutting relationships between faults and the shorelines of the late Pleistocene highstands of Lake Dixie and Lake Lahontan (about 12,000 yr. B.P.) to date periods of tectonic activity. This technique is generally limited to situations where fault scarps cut shorelines. In other areas, it is necessary to use auxilliary methods to date offset surfaces adjacent. In this study, we compare soil profiles formed on dated surfaces to those formed on adjacent faulted surfaces. If soil profiles show comparable development, then it is likely that the surfaces are of the same age. On the other hand, significant differences in soil-profile development indicate different surface ages or post-faulting erosion and/or deposition. Thus, we use soil analysis to extend the spatial usefulness of absolute age constraints.

Soils as Geomorphic Time Markers

Analysis of soil-profile development is a powerful tool for relative dating of geomorphic surfaces. Within areas of uniform climate and parent material, the degree of soil development is time dependent. Thus, soil development is indicative of relative surface ages (Birkeland, 1974). A recently published soil-development index has enhanced interpretation of relative soil-profile development by quantifying easily obtained field properties (Harden, 1982). We have utilized the soil-development index as part of our description of a soils chronosequence on a suite of well preserved terrace and fan surfaces at Terrace Creek (Figure 1) on the eastern margin of the Stillwater Range.

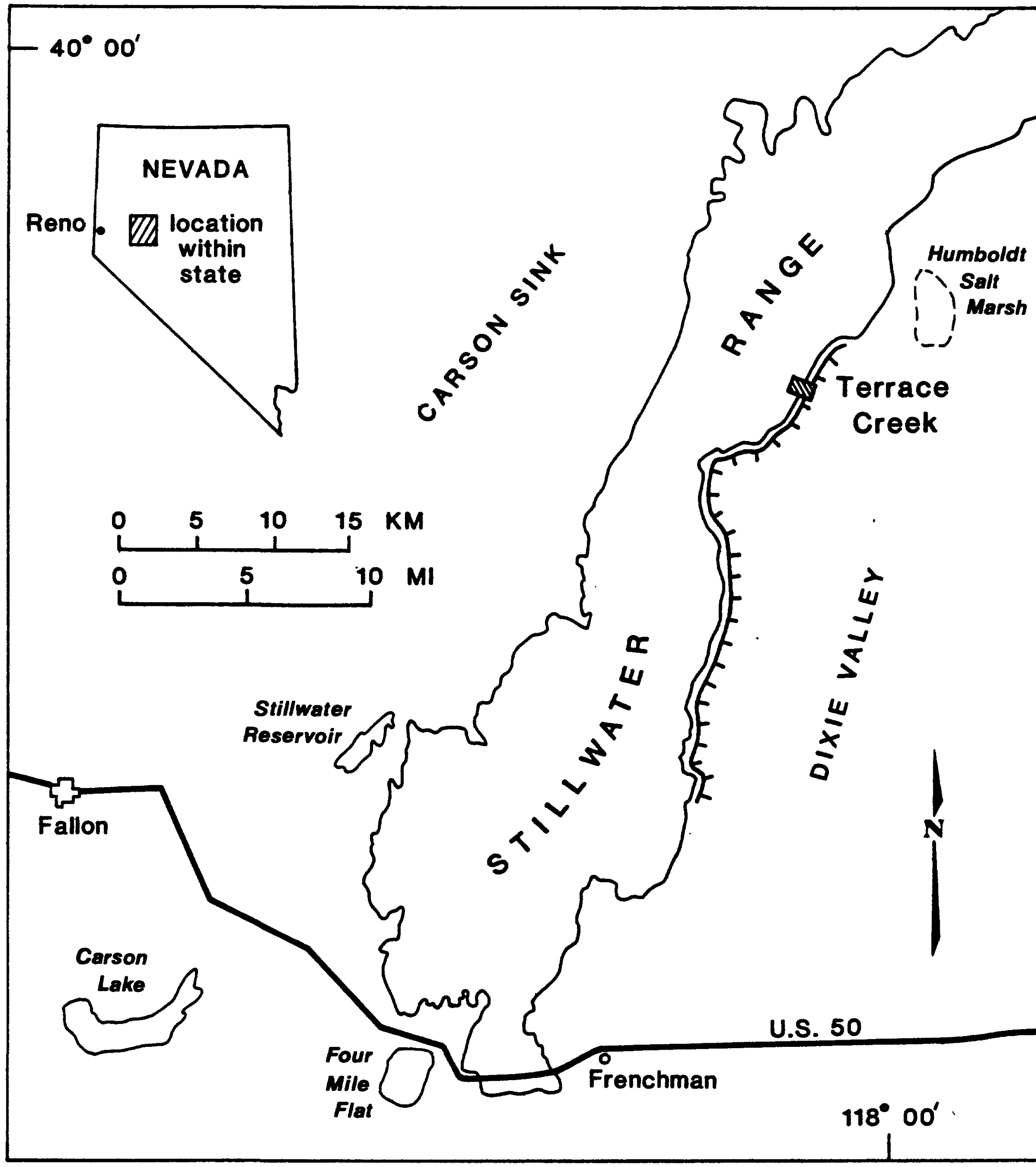

Figure 1: Location of Terrace Creek study area in west central Nevada. Approximate extent of 1954 surface rupture in Dixie Valley is indicated by hachures.

Terrace Creek Site

The site chosen for study (Figures 2 and 3) includes a main valley heading in the Stillwater Range that has four associated terraces and an alluvial fan. The terraces are truncated on the east by one and possibly two fault scarps. Basinward of the fault scarps the alluvial-fan was partially capped by a large debris-flow deposit.

Soil parent materials are composed of mixed alluvium from slate, phyllite, rhyolite, and Tertiary sediments. Soils also have received aeolian silt and salts from the nearby Humboldt Salt Marsh and playa (Figure 1). Annual precipitation in the study area (altitude 1100 m) varies from 12 to 20 cm. Freezing temperatures are common November through March; the average annual number of freeze-thaw cycles is between 120 and 130 (Wallace, 1978). Vegetation is sparse, and includes greasewood (*Sarcobatus baileyi*), shadscale (*Atriplex confertifolia*), burrowbrush (*Hymenoclea salsola*), and cheatgrass (*Bromus tectorum*).

METHODS

Surface Descriptions and Interpretations

Seven alluvial geomorphic units were identified and described using aerial photo interpretation and field studies (Figure 2). Terrace (T) and alluvial-fan (F) surfaces were labelled numerically; increasing numbers correspond to increasing relative ages.

In addition to soil-profile development, relative ages of terrace and fan surfaces were based on the following geomorphic characteristics: a) height above the modern channel, b) truncation or burial of one surface by another surface, c) amount of local stream dissection on individual surfaces, and d) development of desert pavement and rock varnish. These surface characteristics were combined with stratigraphic information to reconstruct the late Quaternary history of the site.

Soil Pedon Selection and Description

Representative soil pedons were described for each stable geomorphic surface while additional soil pits were examined to determine soil variability within individual surfaces. All the soils pits are located on Figure 2 and the representative pedon descriptions are included in the appendix. Pedon locations were selected to minimize the influence of sheetwash erosion or deposition derived from from adjacent higher surfaces. The risers of the T1 and T2 terraces provided additional exposures for determining spatial variations in soil characteristics. Sites on T3 and T4 terraces were selected mainly on the basis of lack of obvious surficial erosion. The T4 surface has been degraded to rounded ridgecrests (Figure 3); therefore, it is unlikely that the truncated soil dates from the time of deposition of the original surface.

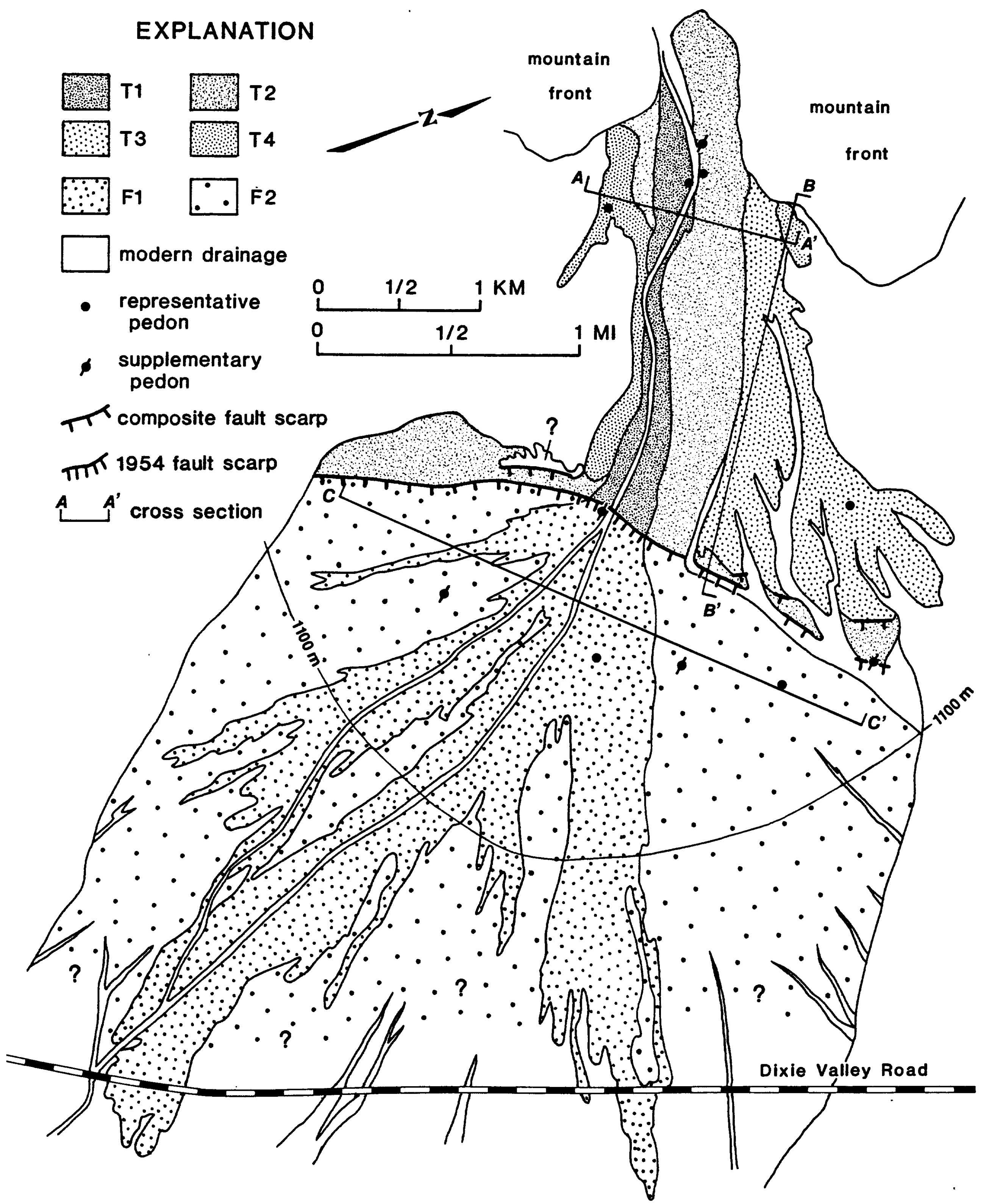

Figure 2: Alluvial geomorphic units of Terrace Creek including locations of soil pits and cross-sections.

Figure 3: Aerial view across Terrace Creek toward the northwest. The dirt road on the F1 surface provides scale. Wide hachures indicate composite fault scarp, narrow hachures indicate 1954 fault scarp. (Photograph courtesy of Robert E. Wallace.)

Soil profiles were described using terminology from the USDA Soil Survey Manual (1981). The only exception was the use of the Av horizon designation to emphasize the presence of thick platy, vesicular horizons commonly occurring beneath desert pavements. In coarse alluvial soils, Av horizons usually form from atmospherically derived silt that accumulates on the soil surface (Gile and Grossman, 1979; Miller, 1971).

Twelve soil properties were described using standard field techniques (Soil Survey Manual, 1981). The most important properties were color, texture, consistence, structure, amount of free calcium carbonate, clay films, and pH. Each of these characteristics varies with time and thus may indicate relative soil age. Values of pH greater than 8.8 were used as indirect evidence of high levels of sodium. Several soil samples analyzed at the University of Arizona Soil and Plant Testing Laboratory confirmed the relationship between high pH and high exchangeable sodium percentage. A texture sample was also analyzed to assist in calibration of field textures. The selection of lab samples was primarily dictated by the need for greater certainty before assigning soils to taxonomic classes. All soils were classified using the USDA Soil Taxonomy (1975).

Soil-Development Index

A quantitative soil-development index was calculated for each representative pedon (see appendix) following procedures described by Harden (1982). The index is based on the premise that many soil characteristics change with time in a given climatic setting. A comparison of the present characteristics of each soil horizon with the characteristics of its presumed parent material allows an interpretation of the strength of soil development. Different soil properties respond to soil formation at different rates. Some rapidly decrease in rate of development while others continue to develop for long time spans. Harden (1982) has normalized numerical descriptions of soil properties for each horizon in order to give the properties equal weight in the index. Thus, a numerical comparison can be made between the degree of profile development of young and old soils.

Eight properties are incorporated in the soil-development index: clay films, texture plus wet consistence, rubification (increase in redness as measured by hue and chroma), structure, dry consistence, moist consistence, color value, and pH. Use of as few as four of these properties have produced index agreement with dated chronosequences (Harden, 1982). The first six properties were used in the present study (see appendix). Color value normally decreases with increasing age as organic carbon accumulates; however it was not used in the index because very little organic carbon has accumulated with time in Dixie Valley. Instead, color value tends to increase with age due to aeolian additions of soluble and semi-soluble salts during the Holocene. pH values have also responded to the influx of salts; therefore they were not considered in the index.

Vesicular (Av) horizons of the soil profiles were not used in index computation because they constitute a younger parent material than the underlying alluvium. In arid and semiarid environments increasing accumulations of soluble salts, calcium carbonate and clays are important indicators of the strength of soil-profile development (Gile and Grossman, 1979). These characteristics are partially incorporated by the soil-development index but they also were used as a qualitative check on soil-development index values.

RESULTS

Alluvial Geomorphic Unit Descriptions

Tl

Terrace Tl is found preserved along both sides of the active channel upstream from the 1954 rupture and is inset approximately 2 m below T2 (Figures 2 and 3). Stratigraphically, Tl is composed of about 0.5 m of unstratified, poorly sorted debris-flow sediments underlain by water-laid sands and gravels (Figure 4, A-A'). Post-Tl streamflow has eroded the debris-flow material and incised approximately 0.5 m into the water-laid deposits. A backhoe trench across Tl and the active channel shows stratigraphic continuity of the underlying deposits. Consistent with its debris-flow origin, the Tl surficial deposits contain tree trunks, splintered limbs, and occasional boulders. A wood sample has been submitted for radiocarbon dating at the University of Arizona. The surface has no suggestion of bar and swale topography, such as would be associated with braided-stream deposition.

The plant community on Tl is as distinctive as its soil. Burrowbrush and cheatgrass predominate, imparting a yellowish contrast to the greener, greasewood and shadscale dominated vegetation on the higher terraces. Vegetation is sparse but evenly distributed with non-vegetated patches showing no evidence of rock varnish or desert pavement. Dissection by local runoff has been minimal.

The soil on the Tl terrace has formed in the uppermost 0.5 m of debris flow deposits and has textures varying from gravelly to very gravelly loam (15 to 40 percent gravel and cobbles). The substratum, extending from about 0.5 m to greater than 1.5 m, is composed of stratified sand and gravel. The soil lacks a vesicular A horizon. A distinct cambic horizon was recognized by an increase in redness (10YR 6/4 dry in the B horizon compared to 10YR 6/2 dry for the C horizon) and the presence of a weak to moderate angular blocky structure. The presence of a few thin clay films on peds and along pores indicates slight clay translocation. Based on the above properties, the Tl soil was classified as a sandy-skeletal, mixed, mesic Typic Camborthid. It has a soil-development index of 6.1 (Table 1). With the exception of active channels and the Fl fan soil, the Tl terrace soil shows the least development of those sampled.

Table 1. Soil-development index values and approximate surface ages for Terrace Creek chronosequence

Surface	Soil Development Index[1,2]	Approximate Age (yr. B.P.)[3]
T1	6.10	> 30, < 6600
F1	5.22	> 30, < 6600
T2	9.01	> 6600, < 12,000
F2	9.97	> 6600, < 12,000
T3	18.42	>12,000
T4	11.28	?

[1]After Harden (1982).

[2]Soil profile descriptions and computation tables are presented in the appendix.

[3]Age estimates are constrained primarily by crosscutting relationships with the 12,000 yr. B.P. highstand shoreline of pluvial Lake Dixie. A secondary age estimate is based on the assumption that more than 6600 years is needed to form the Typic Natrargids on terrace T2 and fan F2 at Terrace Creek (see Discussion).

SURFACE	REPRESENTATIVE SOILS
T1	Typic Camborthids
T2	Typic Natragids
T3	Typic Paleargids
T4	Typic Haplargids
F1	Typic Camborthids
F2	Typic Natrargids

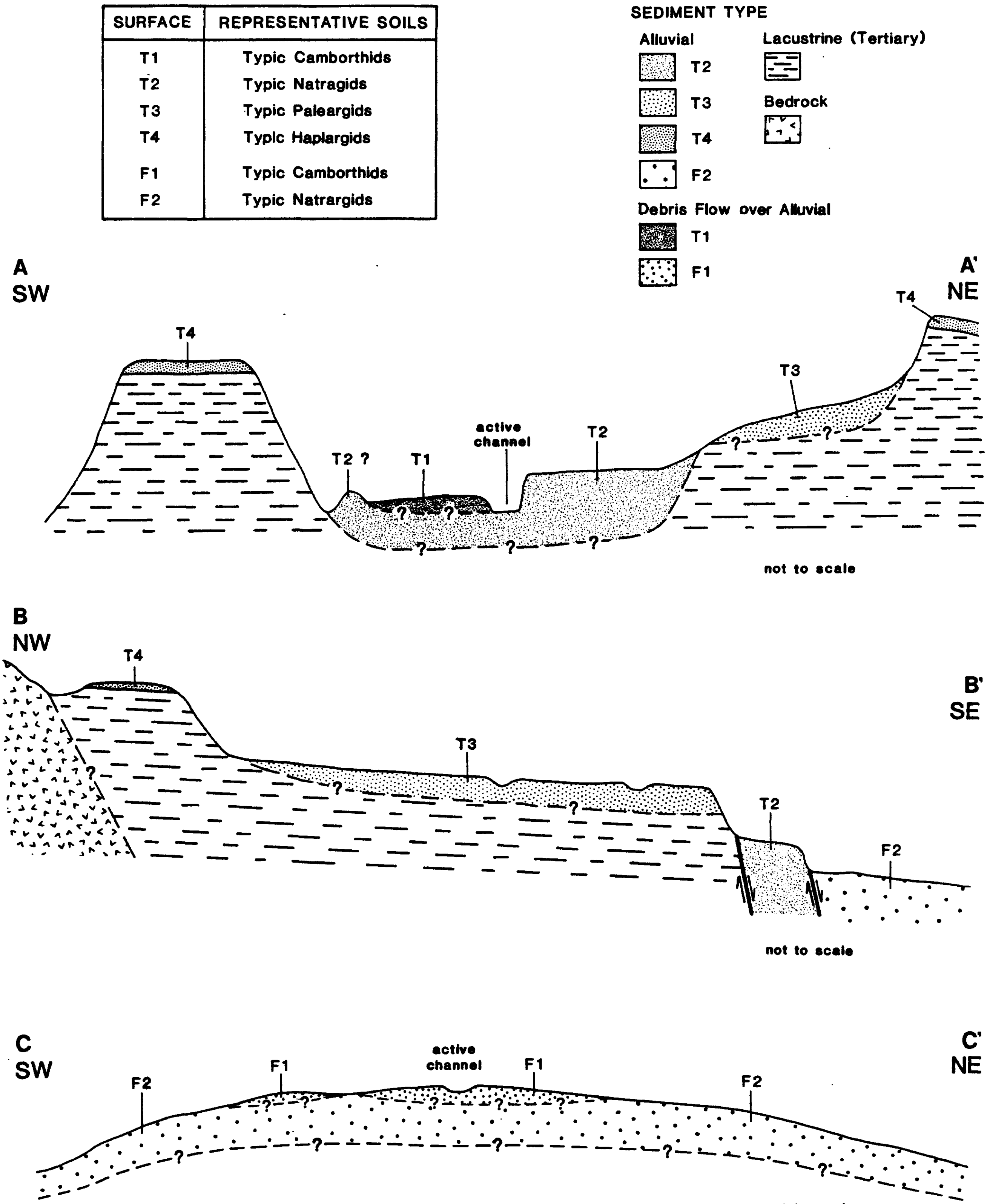

Figure 4: Generalized cross-sections showing topographyic and stratigraphic relationships of terrace and fan units of Terrace Creek. Locations are shown on Figure 2.

F1

Fan F1 is an irregularly shaped area on the medial portion of the alluvial fan basinward of the 1954 fault scarp and apparently correlates with terrace T1. It is laterally continuous with T1, with about 0.75 m of 1954 vertical displacement separating the two surfaces (Figures 2 and 3). Like T1, F1 is capped with debris-flow material (Figure 4, C-C'). The main stream channel has incised into the apex of F1, while at the distal end, parts of the modern drainage debouch over the surface. Stream incision has exposed the contact between the poorly sorted, loamy debris-flow deposits and the underlying water-laid sand and gravel. The thickness of debris-flow materials ranges from less than 0.5 m at the distal end to nearly a meter in the central portion of the fan and then decreases to about 0.75 m at the fan apex.

F1 has the same vegetation, gross surface morphology, and scattering of wood as T1. Likewise, there is no evidence of desert pavement or rock varnish on coarse fragments.

The soil on F1 has formed in debris-flow parent material. The A horizon lacks a significant vesicular horizon. The cambic horizon has evidence of incipient clay movement and an exchangeable sodium percentage of 27.5. Thus, the soil classifies as a loamy-skeletal, mixed, mesic Typic Camborthid. The soil development index is 5.22, similar to the value for the T1 terrace soil (Table 1).

T2

The T2 terrace is extensively preserved as a wide tread on the north side of the main drainage (Figures 2 and 3). T2 is mainly composed of stratified fluvial deposits. It is separated from T3 by a 3 to 10 m riser which increases in height downstream toward the fault zone. A narrow strip of T2 wraps around the basinward margin of T3 on the north and T4 on the south side of the main channel, forming a bench within a two-tiered scarp profile (Figure 4, B-B'). The height of the fault scarp separating T2 and T3 increases rapidly in a northerly direction away from the main channel.

The dominant plants on the T2 terrace are greasewood, shadscale, and cheatgrass which cover approximately 40 percent of the surface. Desert pavement and rock varnish development are moderate. Local surface dissection is slight to moderate with a substantial wash cut along the boundary with T3, parallel to the main drainage.

The soil on T2 terrace has formed in weakly bedded sand and gravel parent material. The strata are cohesive, apparently due to small amounts of silt and clay. Parent material textures are sands, loamy sands, and sandy loams, all of which are very gravelly. Stratification of the parent material contributes to variations in soil textures. The soil has an Av horizon and clay accumulation in the B horizon. The lower part of the B horizon has large amounts of sodium, indicated by a pH of 9.2 and an exchangeable sodium percentage of

44. The combination of illuviated clay and high levels of exchangeable sodium define a natric horizon; the soil is a loamy-skeletal, mixed, mesic Typic Natrargid. The soil development index for T2 is 9.01 (Table 1). This places the soil development and age between that of T1 and T3.

F2

The F2 surface comprises the main area of the alluvial fan at Terrace Creek (Figures 2, 3, and 4, C-C'). The mountainward limit of the F2 fan is delineated by a 2 to 3 m high fault scarp, separating F2 from the T2 terrace. The distal boundary of F2 appears to grade laterally into more recent deposits, resulting from fluvial reworking by local drainages that head on the fan. The surface of F2 has bar and swale topography formed by braided streams. Stratified alluvium is the dominant sediment but poorly sorted debris-flow lobes also occur on parts of the fan surface.

Vegetation covers approximately 50 percent of the surface and, like T2, includes greasewood, shadscale, and cheatgrass. Desert pavement and rock varnish are moderately well-developed, as is dissection by drainages heading on the fan.

The representative soil on F2 formed in stratified sand and gravel parent material. It has a well-developed Av horizon and an argillic horizon that contains strong evidence of clay illuviation and high sodium content (with a pH of 8.8 and an exchangeable sodium percentage of 13.5). Thus, the soil on F2 may be classified as a loamy-skeletal, mixed, mesic Typic Natrargid. The soil-development index of 9.97 is similar to the 9.01 value for the soil developed on T2 (Table 1).

The latest Pleistocene shoreline of Lake Dixie was at an altitude of 1100 m (Mifflin and Wheat, 1979). The toe of the Terrace Creek alluvial fan extends at least 20 m below the highstand lake level. There is, however, no topographic, vegetation, or soils evidence of a shoreline on the fan, which implies that F2 is less than 12,000 years old. In contrast, Burke (1967) mapped a prominent shoreline at 1080 m just 2 km north of Terrace Creek on Mississippi Canyon Fan.

T3

The T3 terrace has the largest areal extent of the four terraces but appears to be preserved only on the north side of the trunk drainage (Figures 2 and 3). There is a remnant surface at a similar elevation to T3 on the south side (marked by "?" in Figure 2). However, its relationship to T3 is uncertain because it only has a thin (1 m) veneer of alluvium overlying Tertiary sediments. In contrast, T3 consists of a thicker wedge of alluvium, increasing basinward from several meters to possibly several tens of meters. T3 is underlain by Tertiary sediments (Figure 4, B-B'). A color contrast delineates the sedimentary contact where colluvium is absent from stream-cut scarps.

Dissection of T3 is substantial. Several well-developed local drainages have deeply incised a sub-dendritic drainage net into the terrace, dividing the remaining surface into a series of connected remnants. The original surface is preserved only on about 25 percent of T3. Most of the stable surface is covered by a well-developed, interlocking desert pavement with a strongly developed rock varnish. Vegetation covers approximately 30 percent of the stable surface and includes shadscale, greasewood, and cheatgrass.

Most T3 soils have been truncated by sheet wash and gully erosion and therefore are not representative of the original surface. Relatively stable sites, selected for pedon description, contain a soil with a thin vesicular A horizon and a prismatic, argillic horizon which is redder (7.5YR 6/4 dry) than B horizons on the other terraces. The lower part of the Btk horizon and upper part of the Ck horizon contain calcium carbonate coatings 2-10 mm thick on gravel clasts, compared with 1-2 mm thick coatings in soils of lower terraces. Soil pH decreases with depth from 8.8 to 7.8. The vesicular A horizon has the highest pH due to aeolian addition of salts. The clayey argillic horizon has an abrupt boundary with the overlying Av horizon which helps to classify this soil as a fine, montmorillonitic, mesic Typic Paleargid. A soil-development index of 18.4 indicates that it is the most strongly developed soil at Terrace Creek (Table 1).

T4

The highest terrace present at Terrace Creek is preserved as small erosional remnants on both the north and south sides of the main drainage (Figures 2 and 3). The same surface can be traced, by projecting altitudes, for several kilometers south of Terrace Creek. At Terrace Creek, areas of smooth, reasonably well-preserved surfaces are limited to several square meters at the crest of several ridgetops. On the south side, a remnant of T4 consists almost entirely of erosional slopes, with the basinward portion of the unit degraded to almost the same altitude as T3. Stratigraphically, T4 is distinctive, consisting of 2-3 m of sand and gravel alluvium capping fine-grained Tertiary sediments (Figure 4, A-A').

Desert pavement and rock varnish are well-developed on the more stable portions of this surface. Vegetation covers about 30 percent of the stable surface and consists mainly of greasewood, cheatgrass and shadscale.

The original soil on T4 formed in alluvial parent material. Due to sheetwash and gully erosion, only remnants of this soil remain. In places, all alluvial parent material has been eroded and soils are now forming in fine textured Tertiary sediments. The representative pedon for this surface was dug on a summit of T4. It is unlikely, therefore, that this degraded soil approximates the original, stable soil for this surface. The representative soil has an argillic horizon with evidence of clay accumulation and low sodium content. It also has 2-10 mm calcium carbonate coatings on pebbles and 10-20 percent of the Btk horzion has soft segregations of calcium carbonate 20-55 mm in diameter. The soil on T4 was classified as a coarse-loamy, mixed, mesic Typic Haplargid and has a soil-development index of 11.28 (Table 1). Although the development index indicates a closer age affinity to the soil on T2 than on T3, the morphology of calcium carbonate accumulation is similar to that of T3. In any case, truncation of this soil limits its usefulness in a chronosequence, and a complete description will be made on a correlative surface to the north or south of Terrace Creek.

DISCUSSION

Tentative Quaternary Geologic History at Terrace Creek

The T4 surface was originally a continuous pediment, cut into uplifted Tertiary sediments, extending for several kilometers along the mountain front south of Terrace Creek. Formation of this extensive equilibrium surface indicates a lengthy period of tectonic quiescence compared to later episodes of base-level change. The severe degradation of this formerly extensive surface, and its position high above and bracketing all subsequently formed surfaces (Figures 2 and 3) indicates a significantly greater age than the next younger surface.

T3 records a history of downcutting into the pedimented Tertiary sediments, lateral beveling with concurrent destruction of T4, and subsequent aggradation. The pediment-alluvium contact appears to diverge from the terrace tread in the basinward direction (Figure 4, B-B'), suggesting a period of base-level fall. Subsequently, climate-induced processes and/or mountain-front tectonism led to backfilling, creating the wedge of alluvium that underlies the T3 terrace tread.

The T3 soil contains a well-developed sodium-free argillic horizon which indicates that the T3 surface stabilized during a period of greater effective moisture which enhanced leaching and weathering, and that playas were not present to supply salts. Holocene aridity allowed playa-derived, aeolian salts to accumulate above the relatively impermeable argillic horizon. Thus the soil shows the imprint of two climatic regimes which we tentatively conclude occurred during the full-glacial times of the latest Pleistocene and during the post-glacial times of the Holocene.

Contrasting the T3 surface with the T2 surface indicates that the T3 terrace is considerably older. The T3 soil has a larger soil-development index value and it has much greater total mass of clay and calcium carbonate per unit column of pedon. T3 also has a more tightly packed desert pavement and greater dissection than T2.

The downstream divergence of T2 and T3 was caused by a base-level fall. Faulting truncated T3 and caused the entrenchment that preceded deposition of T2. Without information on the depth to Tertiary sediments, we are unable to determine the total amount of entrenchment and subsequent backfilling by T2 alluvium. Basinward of the T3 scarp, T2 was deposited as an alluvial fan partially burying the scarp to depths inversely related to distance from the fan apex. It is unclear whether the fault scarp between T3 and T2 follows an original fault trace or is the product of fluvial or lake shore modification of a scarp produced along the recently active fault between T2 and F2.

Prior to faulting, T2 and F2 were probably a continuous aggradational geomorphic unit. Two lines of evidence support this interpretation. First, the soils on both surfaces are similar. They are both Typic Natrargids and their soil-development index values differ by 0.96, which is much less than the differences between values for the next lower or higher terrace soils (Table 1). The difference between T2 and F2 soil values is due to normal soil variability that is a function of spatial variations of parent material, water infiltration, and vegetation rather than a difference in surface ages. Second, similarities in the degree of dissection by local drainage and development of rock varnish and desert pavement also indicate age equivalence.

The lack of a 12,000 yr. B.P. highstand shoreline of Lake Dixie on the Terrace Creek alluvial fan constrains the maximum age of F2 and T2, implying that F2 was deposited after pluvial Lake Dixie receded. It appears that net aggradation has occurred since the latest Pleistocene. Bull (in prep.) have found that climatic perturbations at the Pleistocene-Holocene transition has been responsible for widespread alluvial-fan and valley aggradation in the southwestern United States. It is likely that geomorphic process responses associated with increased aridity, increased storm intensity, and decreased vegetation cover on the hillslope subsystem caused aggradation at Terrace Creek.

It is more difficult to constrain the minimum age of the T2-F2 surface. However, a study by Alexander and Nettleton (1977) showed that a weakly developed Natrargid has formed in Dixie Valley in less than 6600 years. The more strongly developed Natrargids at Terrace Creek would require greater time for profile development. Therefore, it is likely that the T2-F2 surface stabilized early in the Holocene.

The Tl and Fl units are clearly correlative, having been offset 0.75 m by the 1954 surface rupture. The variation in soil-development indices for these surfaces (6.10 to 5.22, respectively) can therefore be attributed to normal soil variability on surfaces of the same age. We have yet to make a statistical analysis of variance for soil-development data.

The probable sequence of events leading to formation of the Tl-Fl unit is as follows. A large debris flow was deposited in the canyon and onto the medial one-third of the fan (Figures 2 and 3). This event placed the fluvial system in disequilibrium and subsequent downcutting shifted the area of modern deposition in the downfan direction.

The Tl-Fl surface is probably quite recent but there is no evidence available to closely constrain its maximum age until the detrital wood has been ^{14}C dated. The surface must be at least thirty years old because it is cut by the 1954 fault. The soils lack Av horizons indicating that there has not been enough time for aeolian accumulations. On the other hand, the soils have cambic horizons requiring a moderate but unknown amount of time for formation. Because they lack natric horizons, the soils are probably less than 6600 years old.

Constraints on Faulting Activity

It appears that at least two and possibly several faulting events have occurred along the primary fault trace during the Holocene, with the latest surface rupture being the 1954 event. Calculations from preliminary scarp profile data at Terrace Creek (Pearthree and Knuepfer, personal communication) indicate that about 2.0 m total vertical surface displacement separates T2 and F2. The 1954 event resulted in about 0.75 m of displacement and 1.25 m occurred in one or more events during the Holocene.

Soils data presented in this report may be useful for constraining ages of faulted surfaces in other parts of Dixie Valley. If a T3 correlative surface is found preserved on both sides of an active fault, estimates of longer term rates of late Quaternary vertical displacement would be possible.

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APPENDIX

SOIL-PROFILE DESCRIPTIONS AND TABULATIONS OF SOIL DEVELOPMENT INDEX PARAMETERS

T1 Terrace

Representative Pedon: sandy-skeletal, mixed, mesic Typic Camborthid

A1 - 0 to 10 cm; light brownish gray (10YR 6/2) gravelly sandy loam, brown (10YR 4/3) moist; massive; very hard, firm, slightly sticky and plastic; few fine roots; 15 percent gravel; slightly effervescent; mildly alkaline (pH 7.8); clear smooth boundary.

Bw - 20 to 30 cm; light yellowish brown (10YR 6/4) gravelly loam, dark yellowish brown (10YR 4/4) moist; moderate medium angular blocky structure; hard, firm, slightly sticky, plastic; common fine roots; 2 percent gravel and 5 percent cobbles; few thin clay films on ped faces and in pores; strongly effervescent; moderately alkaline (pH 8.4); clear smooth boundary.

C - 30 to 46 cm; light brownish gray (10YR 6/2) very gravelly loam, dark grayish brown (10YR 4/2) moist; massive; very hard, firm, slightly sticky, plastic, few fine roots; 35 percent gravel and 5 percent cobbles; strongly effervescent; moderately alkaline (pH 8.0); abrupt wavy boundary.

2C - 46 to 216 cm ; pale brown (10YR 6/3) very gravelly sand, brown (10YR 4/3) moist; single grain; loose, nonsticky, nonplastic; slightly effervescent; mildly alkaline (pH 7.8).

T1 Terrace - Quantified Soil Field Properties

Horizon	Al	Bw	C	2C
Texture	0	0	0	--
Dry Consistence	0	0	0	--
Moist Consistence	0	0	0	--
Structure	0	30	0	--
Rubification	10	40	0	--
Clay film	0	35	0	--

Normalized Data

Texture	0	0	0	--
Dry Consistence	0	0	0	--
Moist Consistence	0	0	0	--
Structure	0	.5	0	--
Rubification	.05	.21	0	--
Clay film	0	.12	0	--

Index Results

Sum of normalized properties	.05	.83	0	--
Divide by no. of properties	.05	.28	0	--
Multiply by horizon thickness	.5	5.6	0	--
Soil-development index	6.1 index-cm			

Fl Fan

Representative pedon: loamy-skeletal, mixed, mesic Typic Camborthid

Al - 0 to 18 cm; pale brown (10YR 6/3) gravelly loam, brown (10YR 4/3) moist; massive; hard, firm, slightly sticky, plastic; few fine roots; 20 percent gravel and 5 percent cobbles; strongly effervescent; moderately alkaline (pH 8.2); clear smooth boundary.

Bw - 18 to 33 cm; pale brown (10YR 6/3) gravelly loam, brown (10YR 4/3) moist; moderate medium angular blocky structure hard, firm, slightly sticky, plastic; common fine roots; 15 percent gravel and 5 percent cobbles; few thin clay films in pores and on ped faces; strongly effervescent; moderately alkaline (pH 8.2); clear smooth boundary.

BCn - 30 to 51 cm; light brownish gray (10YR 6/2) gravelly loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common fine roots; 25 percent gravel, 5 percent cobbles; strongly effervescent; strongly alkaline (pH 8.8); clear wavy boundary.

Ck1 - 51 to 76 cm; pale brown (10YR 6/3) very gravelly loam, brown (10YR 4/3) moist; massive; slightly hard, firm, slightly sticky, slightly plastic; few fine roots; 35 percent gravel and 5 percent cobbles; few thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; moderately alkaline (pH 8.2); clear smooth boundary.

Ck2 - 76 to 97 cm; pale brown (10YR 6/3) very gravelly loam, brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky, slightly plastic; few fine roots; 35 percent gravel and 5 percent cobbles; few thin (1-2 mm) calcium carbonate coatings on coarse fragment; strongly effervescent, mildly alkaline (pH 7.6); clear smooth boundary.

2Ck3 - 97 to 140 cm; pale brown (10YR 6/3) very gravelly sand, brown (10YR 5/3) moist; massive; loose, loose, non-sticky, non-plastic; few fine roots; 40 percent gravel and 10 percent cobbles; few thin (1-2 mm) calcium carbonate coatings on coarse fragments; slightly effervescent; mildly alkaline (pH 7.8).

Fl Fan - Quantified Soil Field Properties

Horizon	Al	Bw	BCn	Ckl	Ck2	2Ck
Texture	10	10	0	0	0	--
Dry Consistence	10	20	0	0	0	--
Moist Consistence	10	10	0	10	0	--
Structure	0	30	20	0	0	--
Rubification	0	0	0	0	0	--
Clay film	0	35	0	0	0	--

Normalized Data

Texture	.11	.22	0	0	0	--
Dry Consistence	.10	.10	0	0	0	--
Moist Consistence	.10	.10	0	.10	0	--
Structure	0	.50	.33	0	0	--
Rubification	0	.12	0	0	0	--
Clay film						

Index Results

Sum of normalized properties	.31	.93	.33	.10	0	--
Divide by no. of properties	.05	.16	.06	.02	0	--
Multiply by horizon thickness	.90	2.40	1.50	.42	0	--
Soil-development index	5.22 index-cm					

T2 Terrace

Representative pedon: loamy-skeletal, mixed, mesic Typic Natrargid

Av - 0 to 13 cm; light gray (10YR 7/3) sandy loam, brown (10YR 5/3) moist; moderate thick platy structure; slightly hard, friable, sticky, plastic; many medium and fine vesicular pores; 10 percent gravel; strongly effervescent; moderately alkaline (pH 8.4); clear smooth boundary.

Btn - 13 to 23 cm; pale brown (10YR 6/3) gravelly clay loam, brown (10YR 5/3) moist; moderate thick platy breaking to moderate angular blocky structure; hard, firm, sticky, plastic; few fine and medium roots; 15 percent gravel and 5 percent cobbles; few, moderately thick clay films on ped faces; strongly effervescent; strongly alkaline (pH 8.8); clear smooth boundary.

Btkn - 23 to 36 cm; light yellowish brown (10YR 6/4) very gravelly sandy clay loam, dark yellowish brown (10YR 4/4) moist; moderate fine angular blocky structure; very hard, firm, sticky, plastic; few fine roots; 45 percent gravel and 5 percent cobbles; common moderately thick clay films in pores and on ped faces; thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; very strongly alkaline (pH 9.2); clear wavy boundary.

Ckqn - 36 to 53 cm; light gray (10YR 7/2) very gravelly sandy loam, grayish brown (10YR 5/2) moist; massive; hard, firm, non-sticky, non-plastic; few fine roots; 50 percent gravel and 5 percent cobbles; thin calcium carbonate and silica pendants on the undersides of coarse fragments; violently effervescent; very strongly alkaline (pH 9.6); clear smooth boundary.

Ck - 53 to 152 cm; light brownish gray (10YR 6/2); very gravelly sand, dark grayish brown (10YR 4/2) moist; massive; slightly hard friable, non-sticky, non-plastic; stratified coarse fragments range from 35 to 60 percent gravel and 5 to 10 percent cobbles; thin calcium carbonate pendants on undersides of coarse fragments; strongly effervescent; moderately alkaline (pH 8.2).

T2 Terrace - Quantified Soil Field Properties

Horizon	Av	Btn	Btkn	Ckqn	Ck
Texture	--	80	70	20	0
Dry Consistence	--	10	20	10	0
Moist Consistence	--	10	10	10	0
Structure	--	40	30	0	0
Rubification	--	20	40	0	0
Clay film	--	40	55	0	0

Normalized Data

Texture	--	.89	.78	.22	0
Dry Consistence	--	.10	.20	.10	0
Moist Consistence	--	.10	.10	.10	0
Structure	--	.67	.50	0	0
Rubification	--	.11	.21	0	0
Clay film	--	.15	.27	0	0

Index Results

Sum of normalized properties	--	2.02	2.06	.42	0
Divide by no. of properties	--	.34	.34	.07	0
Multiply by horizon thickness	--	3.40	4.42	1.19	0
Soil-development index	9.01 index-cm				

F2 Fan

Representative pedon: loamy-skeletal, mixed, mesic Typic Natrargid

Avn - 0 to 15 cm; light gray (10YR 7/2) very fine sandy loam, brown (10YR 5/3) moist; moderate medium platy breaking to moderate medium angular blocky structure; hard, firm, sticky, plastic; common coarse, medium and fine roots; 5 percent gravel; strongly effervescent; strongly alkaline (pH 8.8); clear smooth boundary.

Btkn - 15 to 46 cm; light yellowish brown (10YR 6/4) very gravelly sandy loam; yellowish brown (10YR 5/4) moist; weak medium prismatic breaking to moderate medium angular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common coarse, medium and fine roots; 45 percent gravel and 10 percent cobbles; common moderately thick clay films bridging sand grains; few thin (1-2 mm) calcium carbonate and silica coatings on coarse fragments; strongly effervescent; strongly alkaline (pH 8.6); clear wavy boundary.

Ckqn - 46 to 69 cm; pale brown (10YR 6/3) very gravelly sand, brown (10YR 4/3) moist; massive; loose, loose, non-sticky, non-plastic; common fine roots; 50 percent gravel and 5 percent cobbles; common thin (1-2 mm) calcium carbonate and silica pendants on coarse fragments; strongly effervescent; very strongly alkaline (pH 9.2); clear wavy boundary.

C - 69 to 150 cm; pale brown (10YR 6/2) very gravelly sand, brown (10YR 4/2) moist; massive; loose, loose, non-sticky, non-plastic; 45 percent gravel and 10 percent cobbles; few thin clay films on coarse fragments; slightly effervescent; moderately alkaline (pH 8.2).

F2 Fan - Quantified Soil Field Properties

Horizon	Avn	Btkn	Ckqn	C
Texture	--	40	0	0
Dry Consistence	--	20	0	0
Moist Consistence	--	20	0	0
Structure	--	45	0	0
Rubification	--	20	20	0
Clay film	--	50	0	0

Normalized Data

Texture	--	.44	0	0
Dry Consistence	--	.20	0	0
Moist Consistence	--	.20	0	0
Structure	--	.75	0	0
Rubification	--	.11	0	0
Clay film	--	.23	0	0

Index Results

Sum of normalized properties	--	2.01	0	0
Divide by no. of properties	--	.32	0	0
Multiply by horizon thickness	--	10.54	0	0
Soil-development index	9.97 index-cm			

T3 Terrace

Representative pedon: fine, montmorillonitic, mesic, Typic Paleargid

Av - 0 to 5 cm; light gray (10YR 7/2) fine sandy loam, brown (10YR 5/3) moist; moderate medium platy structure; hard, firm, sticky, plastic, many medium and fine vesicular pores; violently effervescent; strongly alkaline (pH 8.8); abrupt smooth boundary.

Btk1 - 5 to 15 cm; light brown (7.5YR 6/4) gray, brown (7.5YR 4/4) moist; moderately medium prismatic breaking to strong medium angular blocky structure; very hard, firm, sticky, plastic; common fine roots; 10 percent gravel; common moderately thick clay films in pores and on ped faces; common medium segregations of soft calcium carbonate with violent effervescence; matrix is strongly effervescent; moderately alkaline (pH 8.4); clear smooth boundary.

Btk2 - 15 to 25 cm; light brown (7.5YR 6/4) clay loam, brown (7.5YR 4/4) moist; moderate medium angular blocky structure; hard, friable, sticky, plastic; common fine roots; 10 percent gravel; common thin clay films in pores and on ped faces; common medium segregations of soft calcium carbonate with violent effervescence; matrix is strongly effervescent; moderately alkaline (pH 8.0); clear smooth boundary.

Btk3 - 25 to 38 cm; yellow (10YR 7/6) gravelly clay loam, yellowish-brown (10YR 5/6) moist; weak medium and fine subangular blocky structure; hard, friable, sticky, plastic; few fine roots; 20 percent gravel and 5 percent cobbles; common thin clay films on ped faces; common medium segregations of soft calcium carbonate and common thin (2-10 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.8); clear wavy boundary.

Ck1 - 38 to 76 cm; very pale brown (10YR 7/3) very gravelly sandy loam; brown (10YR 5/3) moist; massive; slightly hard, friable, non-sticky, slightly plastic; 25 percent gravel and 10 percent cobbles; thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.8) clear wavy boundary.

Ck2 - 76 to 117 cm; light gray (10YR 7/2) very gravelly sandy loam, brown (10YR 5/3) moist; massive; hard, firm, non-stricky, non-plastic; 40 percent gravel and 10 percent cobbles; common thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.8).

T3 Terrace - Quantified Soil Field Properties

Horizon	Av	Btk1	Btk2	Btk3	Ck1	Ck2
Texture	--	90	80	80	30	20
Dry Consistence	--	20	20	10	0	10
Moist Consistence	--	10	0	0	0	10
Structure	--	60	30	20	0	0
Rubification	--	60	60	80	20	10
Clay film	--	55	45	40	0	0

Normalized Data

Texture	--	1.0	.89	.89	.33	.22
Dry Consistence	--	.20	.20	.10	0	.10
Moist Consistence	--	.10	0	0	0	.10
Structure	--	1.0	.50	.33	0	0
Rubification	--	.32	.32	.42	.11	.05
Clay film	--	.27	.19	.15	0	0

Index Results

Sum of normalized properties	--	2.89	2.1	1.89	.44	.47
Divide by no. of properties	--	.48	.35	.32	.07	.08
Multiply by horizon thickness	--	4.80	3.50	4.16	2.66	3.28
Soil-development index	18.4 index-cm					

T4 Terrace

Representative pedon, partially eroded: coarse-loamy, mixed, mesic Typic Haplargid

Av - 0 to 8 cm; light gray (10YR 7/2) silty clay loam, brown (10YR 5/3) moist; moderate medium platy structure; hard, firm, sticky, plastic; violently effervescent; moderately alkaline (pH 8.2); clear smooth boundary.

Btk1 - 8 to 20 cm; light yellowish brown (10YR 6/4) gravelly sandy clay loam, dark yellowish brown (10YR 4/4) moist; moderate fine angular blocky structure; slightly hard, friable, sticky, plastic; common medium and fine roots; 20 percent gravel; few thin clay films coating sand grains; common thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.8); gradual smooth boundary.

Btk2 - 20 to 53 cm; light yellowish brown (10YR 6/4) gravelly sandy loam, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky structure; soft, friable, slightly sticky, slightly plastic; few fine roots; 20 percent gravel and 5 percent cobbles; few thin clay films coating sand grains; common thin (1-2 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.4); clear smooth boundary.

Ck1 - 53 to 86 cm; very pale brown (10YR 7/3) very gravelly sandy loam, brown roots; 35 percent gravel and 5 percent cobbles; common moderately thick (2-10 mm) calcium carbonate coatings on coarse fragments; violently effervescent; mildly alkaline (pH 7.4); clear smooth boundary.

Ck2 - 86 to 102 cm; light brownish gray (10YR 6/2) very gravelly sand, dark grayish brown (10YR 4/2) moist; single grain; loose, loose, non-sticky, non-plastic; 40 percent gravel; few thin (1-2 mm) calcium carbonate coatings on coarse fragments; strongly effervescent; mildly alkaline (pH 7.6); clear smooth boundary.

Ck3 - 102 to 114 cm; pale brown (10YR 6/3) very gravelly loamy sand; brown (10YR 4/3) moist; single grain; loose, loose, non-sticky, non-plastic; 50 percent gravel and 5 percent cobbles; few thin (1-2 mm) calcium carbonate coatings on coarse fragments; strongly effervescent; mildly alkaline (pH 7.6).

T4 Terrace - Quantified Soil Field Properties

Horizon	Av	Btk1	Btk2	Ck1	Ck2	Ck3
Texture	--	70	40	20	0	10
Dry Consistence	--	10	0	0	0	0
Moist Consistence	--	0	0	0	0	0
Structure	--	30	20	0	0	0
Rubification	--	40	40	20	0	20
Clay film	--	30	30	0	0	0

Normalized Data

Texture	--	.78	.44	.22	0	.11
Dry Consistence	--	.10	0	0	0	0
Moist Consistence	--	0	0	0	0	0
Structure	--	.50	.33	0	0	0
Rubification	--	.21	.21	.11	0	.11
Clay film	--	.08	.08	0	0	0

Index Results

Sum of normalized properties	--	1.67	.106	.33	0	.22
Divide by no. of properties	--	.28	.18	.06	0	.04
Multiple by horizon thickness	--	3.36	5.94	1.98	0	.48
Soil-development index	11.28 index-cm					