See pages 210-213

LATE CENOZOIC GEOLOGY AND SOILS OF THE LOWER ANIMAS RIVER VALLEY, COLORADO AND NEW MEXICO

by

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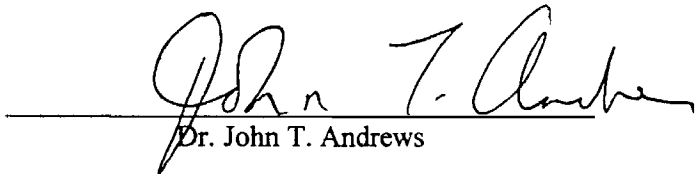

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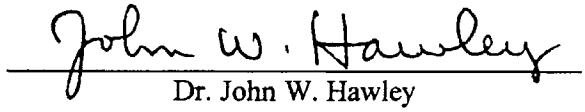

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Gillam, Mary Lee (Ph.D., Geological Sciences)

Late Cenozoic Geology and Soils of the Lower Animas River Valley, Colorado and New Mexico

Thesis directed by Professor John T. Andrews

The Animas valley displays end moraines of middle and late Pleistocene age at Durango and river terraces of Holocene to Miocene (?) age for 80 km downstream to Farmington. This study addresses the distribution, age, and origin of these landforms in relation to local bedrock, climatic cycles, and long-term incision. Soil development with age and climate was also examined for this semiarid region.

The Animas River flows from the San Juan Mountains to the San Juan Basin, crossing varied rock types before joining the San Juan River. During glaciations, the upper valley contained one of the largest glaciers in the U.S. Rocky Mountains. Laramide and late Cenozoic uplift is the major cause of long-term incision.

Three moraine groups (Animas City, Spring Creek, and Durango) are distinguished by increasing distances downvalley, heights above river level, and later modification. Ages from 15 to 360 ka are estimated from correlations to other areas and an amino-acid racemization date.

The terraces include 34 levels, of which 22 reflect stable or aggrading regional profiles and others indicate local adjustments. Only groups TG7 to TG5 are related to existing moraines, but TG4 to TG1 may also be fluvioglacial. The oldest terrace remnant, now on a drainage divide, is underlain by Bridgetimber Gravel of the La Plata River. Ages for TG7 and TG6 are estimated from moraines, but ages for older groups are based mainly on long-term incision rates calibrated with respect to Lava Creek B ash. The highest Animas terraces are late Pliocene and the Bridgetimber Gravel is Pliocene or late Miocene (?).

Terraces from single climatic cycles include fill and fill-cut surfaces near moraines, which merge downstream and become straths. Preserved moraines may have formed late in each glacial phase. Terrace ages and early river diversions suggest that incision accelerated toward the present.

Soils on moraines and terraces formed in glacial, fluvial, and other sediments. Amounts of pedogenic clay and carbonate and the strengths of many properties increase with age and vary with climate along a foothills-basin transect. However, most trends are weak because of multiple parent materials, complex profiles, and variable leaching.

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CHAPTER 1

INTRODUCTION

Studies of individual glacial and fluvioglacial sequences in alpine areas are important for defining both the chronology of glaciations and differing local responses to climatic and tectonic forcing. Soil chronosequences facilitate correlation between these areas and others with similar soil-forming factors, where more precise age control is poor. This study addresses both issues by describing glacial moraines, terraces, and soil development in the lower Animas River valley of southwestern Colorado and northwestern New Mexico.

The Animas valley is significant because it is the largest glaciated valley on the margin of the Colorado Plateau and is one of the largest in the western United States (Porter and others, 1983; Richmond, 1986b; Leonard and others, 1993). Its also descended to one of the lowest terminal elevations in the Rocky Mountains (Richmond, 1965a). Although its moraine sequence is average in complexity and age, the proglacial area is unusual for the large number and age range of its terraces, which record climatic cycles as old as late Pliocene. The oldest terrace in the river's present drainage, located on its western divide, was formed by the La Plata River and may be late Miocene in age.

The Animas River rises in the western San Juan Mountains and flows through the northern San Juan Basin before joining the San Juan River, a major tributary of the Colorado River, in Farmington (Figures 1.1 and 1.2). Among late-Pleistocene glaciers in the San Juan Mountains, the Animas was the largest at 600 km^2 (Leonard, 1984) and the longest with flow vectors up to 85 km (Atwood and Mather, 1932, Plate 3). It also

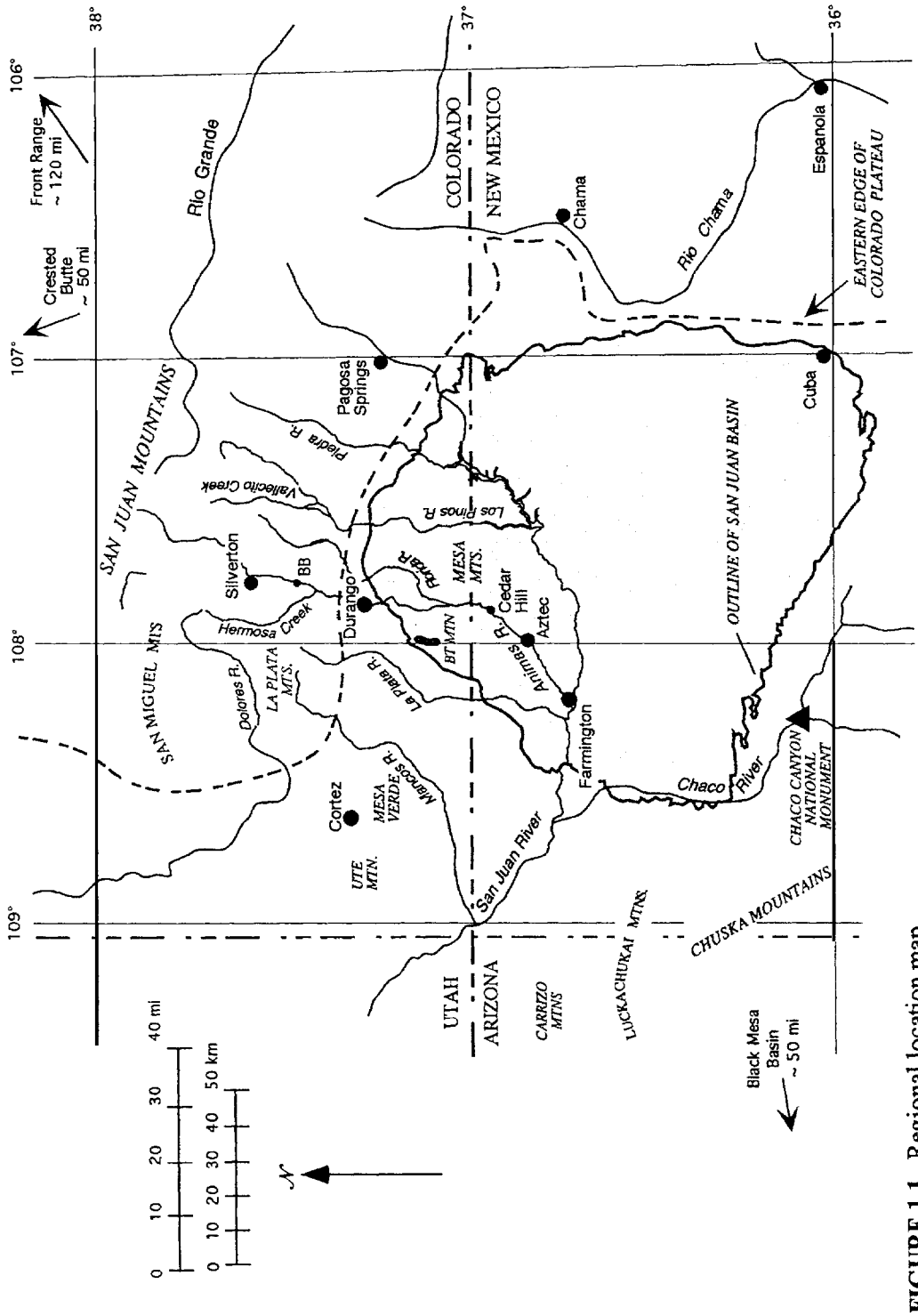


FIGURE 1.1 Regional location map.

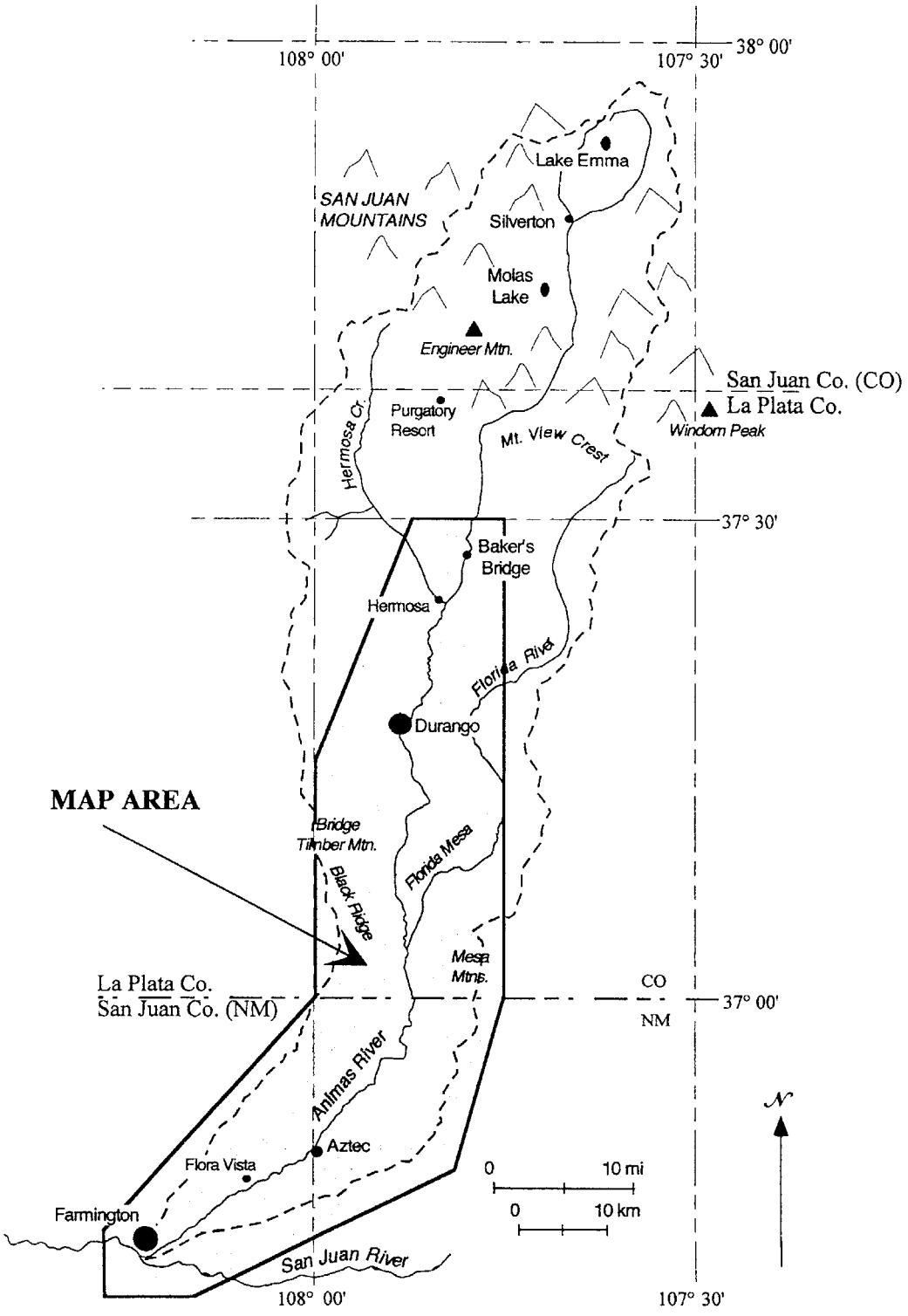


FIGURE 1.2 Location of map area in relation to Animas River basin and important features.

descended to the lowest terminal elevation, 2000 m (Leonard, 1984). With ice thicknesses up to 1000 m (Atwood and Mather, 1932), its location on the moist windward side of the range (Howe and Cross, 1906), and its southern aspect, mass flux and meltwater discharge were probably large for glaciers in the southern Rocky Mountains, but have not been reported. Ice of the Animas glacier and smaller Florida glacier covered about 20 % of basin area (3525 km^2) and 50 % of basin length (165 km). Possible depression of the permafrost limit (Péwé, 1983) and numerous landslides (Colton and others, 1975) suggest that permafrost and periglacial processes may have affected another 40 % of basin area. Therefore, the energy available for sediment transport was high.

Previous Work

When this project began in 1981, previous work on the moraines and terraces varied in scope and quality, but none had described soil development at present standards for chronosequences. Earlier studies of moraines at Durango were brief overviews (e.g. Howe and Cross, 1906; Atwood and Mather, 1932; Richmond, 1965b) and those for possibly comparable areas in the San Juan Mountains were restricted to a few locations or time periods (e.g. Carrara and Andrews, 1975; Sinnock, 1978; Leonard and others, 1993; Elias and others, 1991). Previous work had addressed most of the terrace sequence from Durango to Farmington, but varied in quality and was poorly integrated (e.g. Atwood and Mather, 1932; Richmond, 1965b; Pastuszak, 1968; Bandoian, 1969; Brown and Stone, 1979). Comparable information for other rivers in the region was very limited (e.g. Gonzales and Dethier, 1991). Although soil surveys were available or in progress (Keetch and others, 1980; Pannell and others, 1988), increasing soil development with time had been mentioned only for the moraines (Richmond, 1965b).

This study benefited from partly concurrent work on both the moraines and terraces (e.g. G.R. Scott and D.W. Moore, unpublished mapping; Gillam and others, 1984; Moore and Gillam, 1994; Ward, 1990; Johnson, 1990; Johnson and Gillam, 1995; Robson and Wright, 1995). Studies addressing environmental issues (e.g. Chafin, 1994) also demonstrated a need for better information about the surficial geology of the area.

Purpose and Scope

The initial objective was to study soil development with time for profiles formed in lithologically mixed materials under presently semiarid conditions. The project was designed to show how soils on moraines at Durango, and on terraces in the Durango and Farmington areas, varied with landform stability, increasing age, and local climate within a piedmont-basin transect. This research intended to rely on previous mapping and age estimates for the moraines and terraces. During initial field work, however, it became clear that previous studies had not established an adequate framework for determining either the relative or actual ages of soils at different sites. Therefore, other objectives included re-mapping the moraines and terraces and estimating their ages. To accomplish these tasks effectively, controls on moraine and terrace formation were evaluated. These controls include bedrock lithology and structure, stream diversions, climatic oscillations, tectonic uplift, and base-level fall.

Methods

These objectives were achieved by several methods that are summarized here and described more fully in the following chapters. The distributions of selected morphostratigraphic units were identified during field mapping and interpretation of aerial

photographs for most of the lower valley area (Figure 1.2). This information was recorded on parts of seventeen 7-1/2 minute topographic quadrangles at 1:24,000 scale and later compiled on reduced versions at 1:50,000 scale (Plate 1). A longitudinal profile showing moraine and terrace remnants was constructed at the same scale as the original maps for the 105-km reach from Bakers Bridge to Farmington, and later simplified for final drafting at 1:100,000 scale (Plate 2). Correlations among terrace remnants were interpreted partly from elevations and gradients portrayed on this profile, but also from related fluvial deposits and consideration of bedrock controls.

Age estimates for the moraines and terraces were based mainly on calibrated long-term incision rates, on the geomorphic position of the Lava Creek B ash, and on correlation to other areas with numeric ages. Supporting information included amino acid racemization in fossil snails (collected for this study, but analyzed by Alan R. Nelson from the U.S. Geological Survey) and paleomagnetic polarity of terrace sediments at two sites (John D. Strobell, U.S. Geological Survey, written communication, 1978). To confirm identification of the Lava Creek B ash, selected elemental concentrations were measured in several samples by XES. These analyses were performed by Fred Luizer and John Drexler (University of Colorado, Department of Geological Sciences).

Approximately 65 soil profiles were described, of which 58 are reported here. Laboratory data for 16 profiles include particle size distribution, carbonate content, and bulk density for the <2 mm fraction. In addition to weights of secondary clay and carbonate, profile development indices (Harden, 1982; Harden and Taylor, 1983) were calculated to compare development at different sites.

Organization of this Report

Chapter 2 summarizes background information on bedrock geology, glaciation, climate, and vegetation that affect Quaternary deposits and soils of the Animas valley. Chapters 3 and 4 describe the moraine and terrace sequences, including genetic relationships and evidence that supports correlations within the study area. Chapter 5 presents information about moraine, terrace, and other deposits which are important for distinguishing mapping units and as parent materials for soils. Soil development on moraines and terraces is discussed in Chapter 6, which also addresses limitations on the use of soils in this area. Chapter 7 presents age estimates for the moraines and terraces. Finally, Chapter 8 summarizes major points from earlier chapters and discusses climatic and tectonic controls on the moraine and terrace sequences. Basic data for sediment types, soil profiles, and volcanic ash sites are presented in Appendices A, B, and C, respectively.

Preliminary results from this study have also been reported in several articles or field-trip guides (Gillam and others, 1984; Moore and Gillam, 1984; Gillam and others, 1985; Love and Gillam in Patton and others, 1991; and Johnson and Gillam, 1995).

CHAPTER 2

PHYSICAL SETTING

Many interrelated characteristics of the Animas River basin have affected the formation of moraines and terraces and the nature of their deposits and soils. Constants or relative constants during the study period (mainly late Pliocene to present) are basin physiography, bedrock geology, and structure. Other characteristics, which varied significantly during glacial cycles, include glacial and periglacial features, climate, vegetation, river discharge, and soil-forming factors.

Physiography

Basin physiography, which reflects geology and affects local climate, also defines the scale of glacial and fluvial features. The Animas River heads at the crest of the western San Juan Mountains and flows generally south to southwest, joining the San Juan River at Farmington (Figures 1.1 and 1.2). The upper basin has rugged topography with many peaks above 4000 m and partly adjoins the Continental Divide. Local elevations are 2000 to 2700 m near Durango and 1600 to 1800 m near Farmington. Maximum relief between the highest point (Windom Peak, 4294 m) and the basin mouth (1597 m) is 2697 m. The basin's area is approximately 3525 km^2 (Denis and others, 1984) and its mid-line length is roughly 160 km.

Regional Geology and Geomorphology

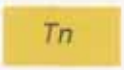
Bedrock geology and structure have influenced the distribution of moraines and terraces and the lithologic composition of their sediments. The Animas drainage basin and surrounding areas are underlain by a wide variety of rock types (Figure 2.1). The Laramide San Juan dome exposes Precambrian metamorphic and plutonic rocks including mainly granitic rocks, gneisses, and quartzites. Onlapping metamorphic and sedimentary rocks, of Cambrian to Cretaceous age, include mostly sandstones and siltstones with minor conglomerate and limestone. The San Juan volcanic field, of middle Tertiary age, includes mostly intermediate lava flows and volcaniclastic deposits, and silicic ash-flow tuffs with minor basalt. Before and during volcanic eruptions, or from latest Cretaceous to middle Tertiary time, small intrusions of varying compostion were emplaced in the La Plata Mountains and farther north. The Hogback Monocline, which forms the northern and western boundaries of the Laramide San Juan Basin, exposes interbedded sandstones, shales, and carbonaceous rocks of late Cretaceous to Paleocene age. The uppermost basin fill which consists of fluvial sandstones and shales of Paleocene and Eocene age, was deposited during Laramide uplift of the La Plata and San Juan domes. Surficial deposits of the Animas and other river valleys differ in lithology based on rock types in their source areas.

The study area extends from Precambrian granite on the edge of the San Juan Dome to the west-central San Juan Basin. Within this reach, near-surface bedrock structure and lithology have affected moraine and terrace formation. Maximum dips where the river crosses the monocline are 25° to 35° southeast (Zapp, 1949), whereas dips in the basin are generally less than 2° and vary from southeast near Durango to northeast near Farmington, except in minor folds (Reeside, 1924; Brown and Stone, 1979; Gillam, unpublished data). The basin axis crosses the river south of Cedar Hill (Kelley and Clinton, 1960). The

FIGURE 2.1 Bedrock geology of the Animas River valley and adjacent areas (simplified from Dane and Bachman, 1965, Tweto, 1979, and O'Sullivan and Beikman, 1963; basin axis from Kelly and Clinton, 1960). Key to units:

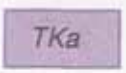
Tertiary volcanic rocks (Pliocene to Eocene) - Mostly intermediate lavas, pyroclastic rocks, and ash-flow tuffs. Minor mafic lavas.

San Jose Formation (Eocene) - Mostly light gray to brown sandstone with minor conglomerates and red, brown, and light gray claystones.



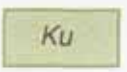
Nacimiento Formation (Paleocene) - Gray to olive gray shales and minor gray to yellow sandstone.

Ojo Alamo Sandstone (Paleocene and Upper Cretaceous) - Brown sandstones with basal conglomerates and abundant petrified wood.



Animas Formation (Paleocene and Upper Cretaceous) - Greenish gray and tan andesitic conglomerates, sandstones, and shales. Includes the McDermott Member - Reddish brown to purple volcaniclastic sandstones, breccia, conglomerates, and shale.

Intrusive rocks (Paleogene and Cretaceous) - Wide variety of hypabyssal igneous rocks, including gabbro, diorite, granodiorite, monzonite, quartz monzonite and granite.



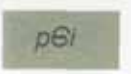
Kirkland, Fruitland, Pictured Cliffs, Lewis Shale, and Mesasverde Formations (Upper Cretaceous) - Alternating light gray sandstones, dark gray shales and minor carbonaceous shales and coals.

Mancos Shale (Upper Cretaceous) - Dark gray shale and minor argillaceous limestones and sandstones.

Dakota Sandstone, Burro Canyon, Morrison, Wanaka, and Entrada Sandstone Formations (Upper Cretaceous and Jurassic) - Light gray to brown sandstones, chert pebble conglomerates, varicolored claystones and mudstones, limy shales, and light gray crossbedded sandstones.

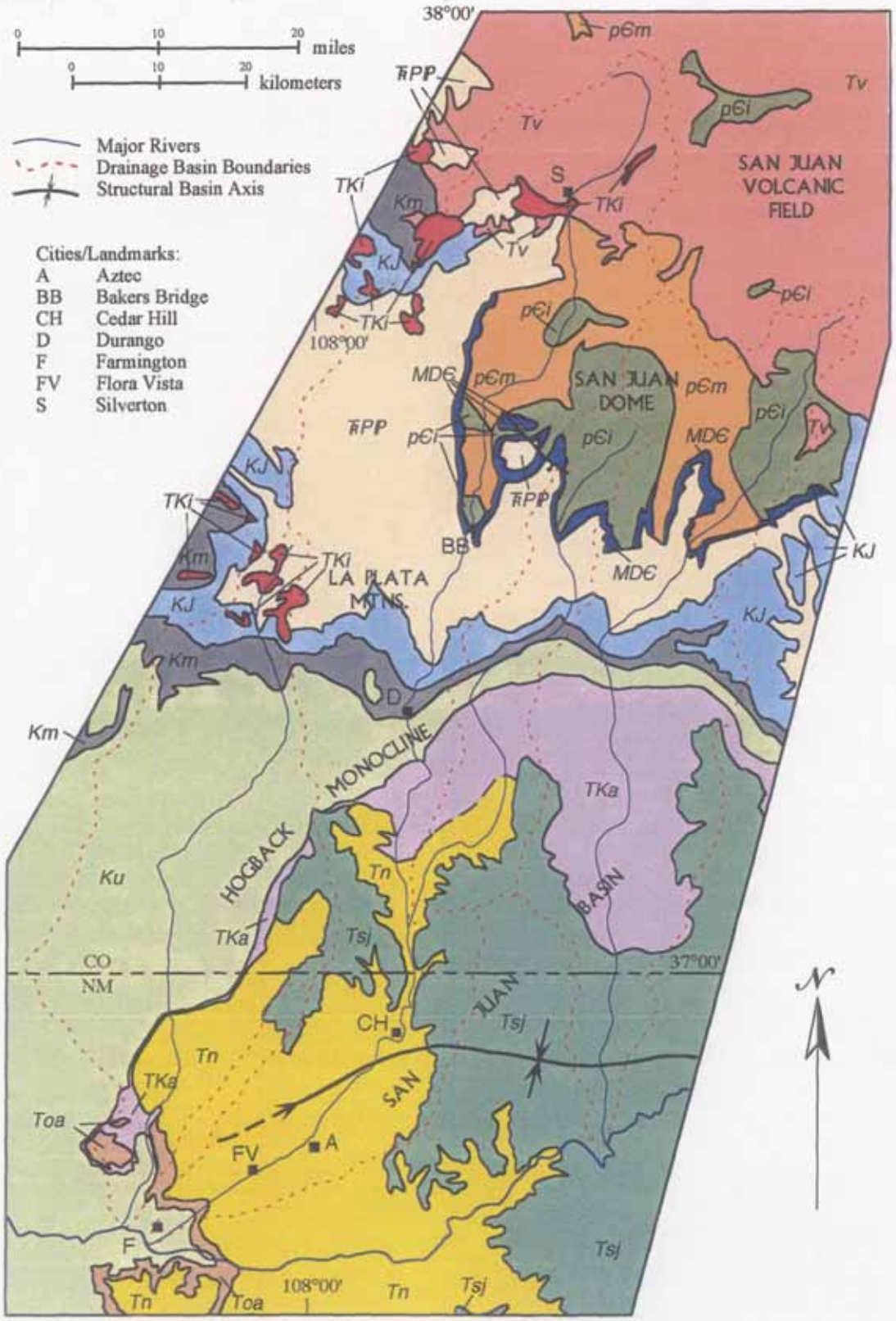
Dolores, Cutler, Rico, Hermosa, and Molas Formations (Triassic, Permian, and Pennsylvanian) - Primarily red siltstones, sandstones, and arkosic grits. Includes dark gray shales and limestones in the Hermosa Formation.

Leadville Limestone, Ouray Limestone, Elbert Formation, Ignacio Quartzite (Mississippian, Devonian, and Cambrian) - Gray limestones, quartzitic sandstones, and varicolored shales and siltstones.



Precambrian intrusive rocks (Proterozoic) - Pale red granites, brick red quartz monzonites, pink granodiorites, and minor gabbro and diorite. Includes the Bakers Bridge, Eolus, Tenmile, and Trimble granites, and the Electra Lake Gabbro.

Precambrian metasediments and metavolcanics (Proterozoic) - Includes varicolored metaconglomerates (Vallecito Conglomerate), light gray to blue quartzites and gray green, and black slates (Uncompahgre Formation), gneisses, amphibolites, quartzites, schists, and minor iron formations (Irving Formation and Twilight Gneiss).



0 10 20 miles
0 10 20 kilometers
Major Rivers
Drainage Basin Boundaries
Structural Basin Axis
Cities/Landmarks:
A Aztec
BB Bakers Bridge
CH Cedar Hill
D Durango
F Farmington
FV Flora Vista
S Silverton
38°00'
108°00'
37°00'
CO
NM
SAN JUAN VOLCANIC FIELD
SAN JUAN DOME
LA PLATA MTNS.
HOGBACK MONOCLINE
SAN JUAN BASIN
pЄm
pЄi
Tv
TRPP
TKi
Km
KJ
MDЄ
S
BB
D
TKa
Tn
Tsj
Ku
CH
FV
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former Animas glacier (described below) terminated at the north hinge of the monocline during the last several glaciations (Johnson and Gillam, 1995). The modern channel and older terraces trend down-dip and up-section from the terminal moraines to just north of the basin axis, where river and terrace gradients are locally parallel to dip. Conversely, the channel and terraces trend up-dip and down-section from there to the San Juan River.

Minor variations in rock hardness have affected terrace widths, gradients, and preservation. Terraces are relatively narrow where they cross more-resistant rocks, as in the monocline (which exposes several sandstone formations and sandy or conlomeratic members and beds), at the basin axis (where numerous sandstone beds in the Nacimiento and San Jose Formations have created a "narrows" in the valley's cross section), and at Farmington (where the Ojo Alamo Sandstone and basal sandstone beds of the Nacimiento Formations crop out). Resistant sections at the basin axis and at Farmington form local base levels that affect river and terrace gradients for many kilometers upstream and downstream. Smaller knickpoints are associated with resistant sections or beds in other areas. Terraces are wider on softer rocks, especially upstream from local base levels. As terrace age increases, rock hardness becomes more important in protecting terrace remnants from erosion. The oldest remnants are underlain by relatively hard rocks whose distribution reflects facies changes in the basin fill (Baltz and others, 1966; Baltz, 1967; Smith, 1992; Smith and Lucas, 1991).

Late-Tertiary geomorphic development must have influenced younger features, but its nature is uncertain because deposits and landforms of this age range are either rare or undated. Certain landforms of the San Juan Mountains and high-level gravels in surrounding areas have been interpreted as evidence for widespread peneplanation during this time (Atwood and Mather, 1911, 1932). More recent mapping has shown that a peneplain of the proposed scale and age could not have formed, but that some landforms are local erosion surfaces of Tertiary age (Steven, 1968).

Former Glacial and Periglacial Features

During the late Wisconsin glaciation, ice covered approximately 5,000 km^2 in the San Juan Mountains (Atwood and Mather, 1932; Leonard, 1984; Figure 2.2). This ice complex, which included several large icefield-outlet glacier systems and numerous valley glaciers, was one of the largest south of the Laurentide ice sheet, probably exceeded in area only by the Yellowstone-Absaroka complex (Leonard and others, 1993). The distribution of older moraines suggests that ice extent was similar during several earlier glaciations, except possibly in the Dallas Creek-Cerro Summit area (e.g. Dickinson, 1965; Sinnock, 1978, 1981). No glaciers exist in the San Juan Mountains today, but perennial snowfields occur in some north-facing cirques.

The Animas glacier was an outlet glacier fed by a large icefield with 75 contributing cirques (Atwood and Mather, 1932; Figure 2.3). In places, transection ice covered divides leading to adjacent icefields and valley glaciers. Among late Pleistocene glaciers in the San Juan Mountains, the Animas was the largest at roughly 600 km^2 (Leonard, 1984) and the longest with flow vectors up to 85 km. It also descended to the lowest terminal elevation (2000 m). Ice thicknesses reached at least 900 m at the head of east Hermosa Creek near Purgatory Resort (Atwood and Mather, 1932). Preliminary flow models (Pierce, in Porter and others, 1983; Leonard, 1984; and Small, 1995) have not been published in detail, but three factors suggest that mass flux was very high. These are relatively high precipitation on the windward side of the range (Howe and Cross, 1906; Leonard, 1984), possibly high water content of late Pleistocene snowpack (Porter and others, 1983; Leonard, 1989), and high ablation rates inferred from low latitude, low terminal elevation, and southern aspect (Johnson and Gillam, 1995; Bandoian, 1969).

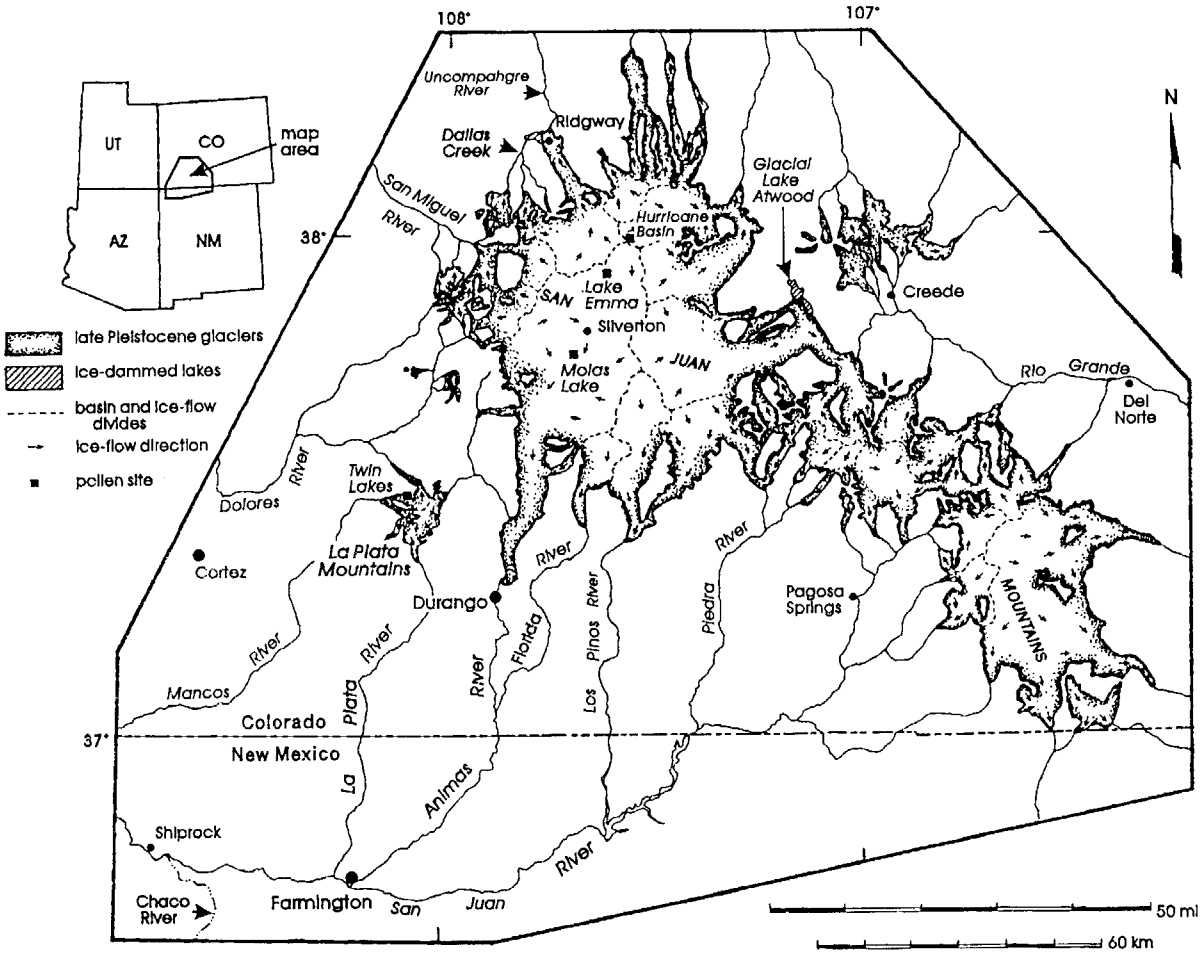


FIGURE 2.2 Distribution of late Pleistocene glaciers in the San Juan Mountains, in relation to major tibutaries of the San Juan River. For simplicity, numerous aretes and nunatacks narrower than 1-2 km in width are not shown. Ice extent is from Atwood and Mather (1932, Plate 3), modified slightly in the Durango area.

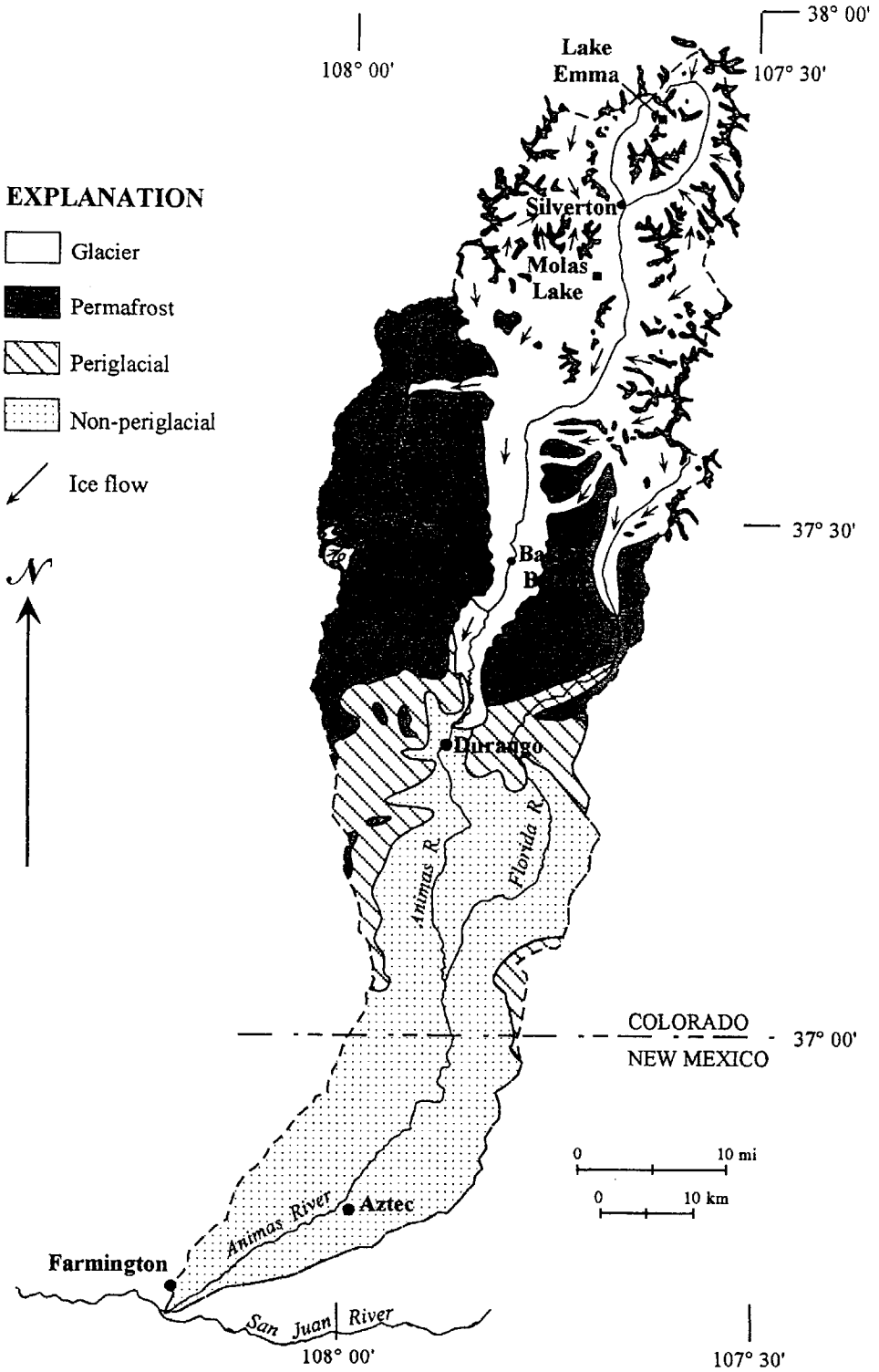


FIGURE 2.3 Approximate extent of glacial ice, permafrost, and periglacial areas in the Animas River drainage basin during the late Pleistocene. Ice limit from Atwood and Mather (1932, Plate 3, modified slightly in the Durango area); permafrost limit estimated from elevations in surrounding areas (Pewe, 1983; Giardino, 1983; Morris, 1987); lower periglacial limit estimated from landslide elevations (Colton and others, 1975).

Smaller glaciers also formed in the upper basins of two tributaries to the Animas River (Atwood and Mather, 1932; Figure 2.3). The Florida glacier, with an area of 100 km^2 (Leonard, unpublished data) developed in the upper Florida River valley. Tiny glaciers formed in the upper part of south Hermosa Creek, which drains the northeastern La Plata Mountains. Overflow from the Animas glacier also reached north Hermosa Creek.

Beyond the ice limit, periglacial processes may have increased sediment yields at elevations as low as 2100 m (Figure 2.3). No features requiring permafrost (such as patterned ground, ice or sand wedges, and rock glaciers) have been observed in the Durango area. However, other features may have formed in periglacial environments without permafrost, such as numerous landslides, nivation hollows, and possible solifluction features. Landslides, the best documented of these landforms (Colton and others, 1975), generally head above 2100 m, but some head as low as 2000 m at sites with favorable aspect, slope, or lithology. Therefore, 2100 m is considered the likely lower limit for widespread periglacial processes. In contrast, the distribution of modern and Wisconsinan permafrost features in the western cordillera (Péwé, 1983, Figure 9-14; Giardino, 1983; Morris, 1987) suggests that the lower permafrost limit was depressed by about 600 m at 37°N, to an average altitude of 2400 m. If so, undiscovered permafrost features may exist at favorable sites outside the former ice limit. Rock glaciers and other periglacial features within the ice limit (White, 1979; Fitzgerald, 1994) are postglacial in age.

In summary, late Pleistocene glaciers covered about 20 % of the Animas River basin and about half of the river's length. Periglacial processes may have affected another 40 % of basin area.

Modern Climate

Climate affects soil-forming and geomorphic processes through its effects on vegetation, weathering, runoff, and discharge.

Temperature and Precipitation

In the study area, mean annual air temperature (MAT) varies roughly from 5 to 11 °C and mean annual precipitation (MAP) from 200 to 540 mm. MAT decreases and MAP increases at higher elevations, as shown graphically for the Animas valley (Figure 2.4) and in regression equations for larger areas (Table 2.1). Correlation coefficients indicate that elevation explains approximately 84 % of variations in MAT and 55 % of those in MAP. Local variations in temperature reflect mainly latitude, slope aspect, and cold air drainage, whereas those in precipitation reflect mostly air-mass circulation and rain-shadow effects. Snow-accumulation patterns in the San Juan Mountains (Leonard, 1984) show that relatively warm, moist air tends to flow up the Animas valley from the southwest.

Historic means vary for specific periods, but MAT is roughly 10.7 °C at Farmington 4NE and decreases slightly to 8.0 °C at Durango; MAP is roughly 199 mm at Farmington 4NE, but increases to 481 mm at Durango (EarthInfo, 1995). MAT and MAP for Bridge Timber Mountain, the highest point in the study area, were estimated from regressions equations (Table 2.1) as 5.4 °C and 534 mm, consistent with local vegetation and soils (Pannell and others, 1988). Monthly temperature and precipitation were estimated by equal offset from corresponding values at Durango.

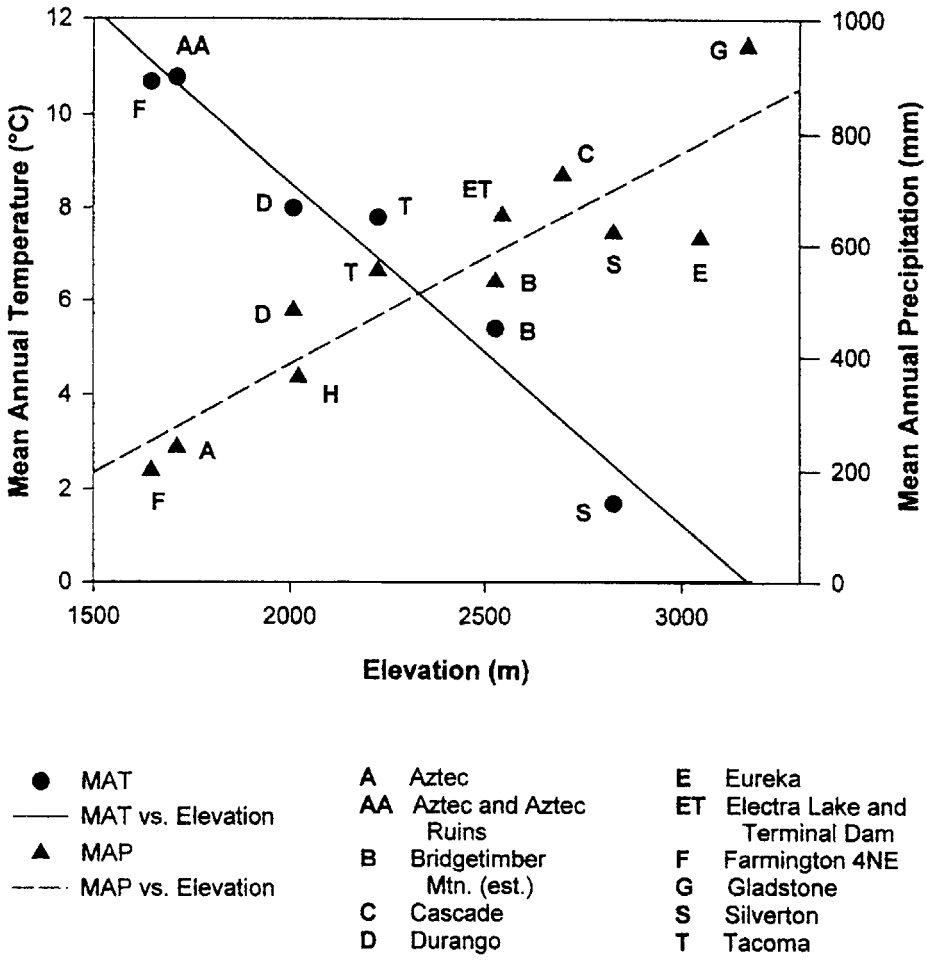


FIGURE 2.4 Modern temperature and precipitation versus elevation in the Animas River drainage basin. Data are for stations operated by the National Weather Service during various periods (Martin, 1933a,b; Colorado Climate Center, written communication, 1984; EarthInfo, 1995). Stations are located in Figure 2.5.

TABLE 2.1 TEMPERATURE AND PRECIPITATION VS. ELEVATION, FOUR CORNERS AREA

CLIMATE VARIABLE	REGRESSION EQUATION AND CORRELATION COEFFICIENT [1]	LAPSE RATE [1]	REGION	TIME PERIOD	SOURCE
MEAN ANNUAL TEMPER-ATURE	y = 20.39 - 5.92x (r = 0.917) where y = MAT in °C x = elevation in thousands of meters	5.9 °C per 1000 m	stations in and near San Juan National Forest (generally southwestern Colorado)	not stated	U.S. Forest Service, cited by Barry and Bradley (1976)
	not given	≈5 °C per 1000 m	northwestern New Mexico	not stated	Stute and others (1995)
MEAN ANNUAL PRECIPI-TATION	y = 25.67x - 11.76 (r = 0.74) where y = MAP in cm x = elevation in thousands of meters	25.7 cm per 1000 m	southwestern Colorado, including foothills and San Juan Mountains west of Continental Divide (except Wolf Creek)	1951-1960	Barry and Bradley (1976)
	not given	33.1 cm per 1000 m	"	1940-1960	"
	y = 39.2x - 46.6 (r not given) where y = MAP in cm x = elevation in thousands of meters	39.2 cm per 1000 m	San Juan basin (Colorado and New Mexico) and San Juan Mountains (Colorado only)	not stated; all prior years for each station?	Ireland (1983)
		27.0 sm per 1000 m	southeastern Utah and southwestern Colorado, foothills only	all prior years for each station	Whitfield and others (1983)

1. Converted here to metric units.
2. Computed here from slope of line drawn by authors to enclose drier stations.

Wind Direction and Strength

In the western United States, upper-level winds blow generally from the southwest, west, or northwest (Visher, 1966). Surface winds are affected by local topography and by occasional temperature inversions, which fill valleys and basins with stagnant air (Andersen and others, 1981). In the Four Corners region, the resultant direction of surface winds faster than 5.2 m/sec (10 knots) is southwesterly to westerly (Wells and others, 1990). Lighter surface winds often blow up and down valleys but stronger surface winds, affected by wider topography, range from northerly to southerly at specific sites.

To illustrate the directions of stronger surface winds, potential sand transport was calculated from selected wind records (Figures 2.5 and 2.6; Table 2.2). Potential sand transport or drift (Fryberger and Dean, 1979) is a relative measure of the wind energy that is available to move easily entrained particles (0.25 to 0.30 mm) under ideal conditions (loose grains on a smooth or rippled surface without vegetation). Stronger winds are weighted heavily because transport is proportional to the square of wind speed and to the first power of excess speed above a threshold value, for example 6.0 m/sec (11.6 knots) at an anemometer height of 10 m. Resultant magnitudes of potential sand transport at individual sites range from very low to high (Table 2.2), reflecting differences in site exposure and recording methods. Because instrumental methods strongly affect recorded velocities, transport directions are stressed in Figure 2.6 by scaling all wind roses equally.

Former Climates

Glacial climates were cooler and effectively moister than present in the southwestern United States, but specific changes are uncertain because of limited data and interpretive assumptions. Selected data for the late Pleistocene and early Holocene in the

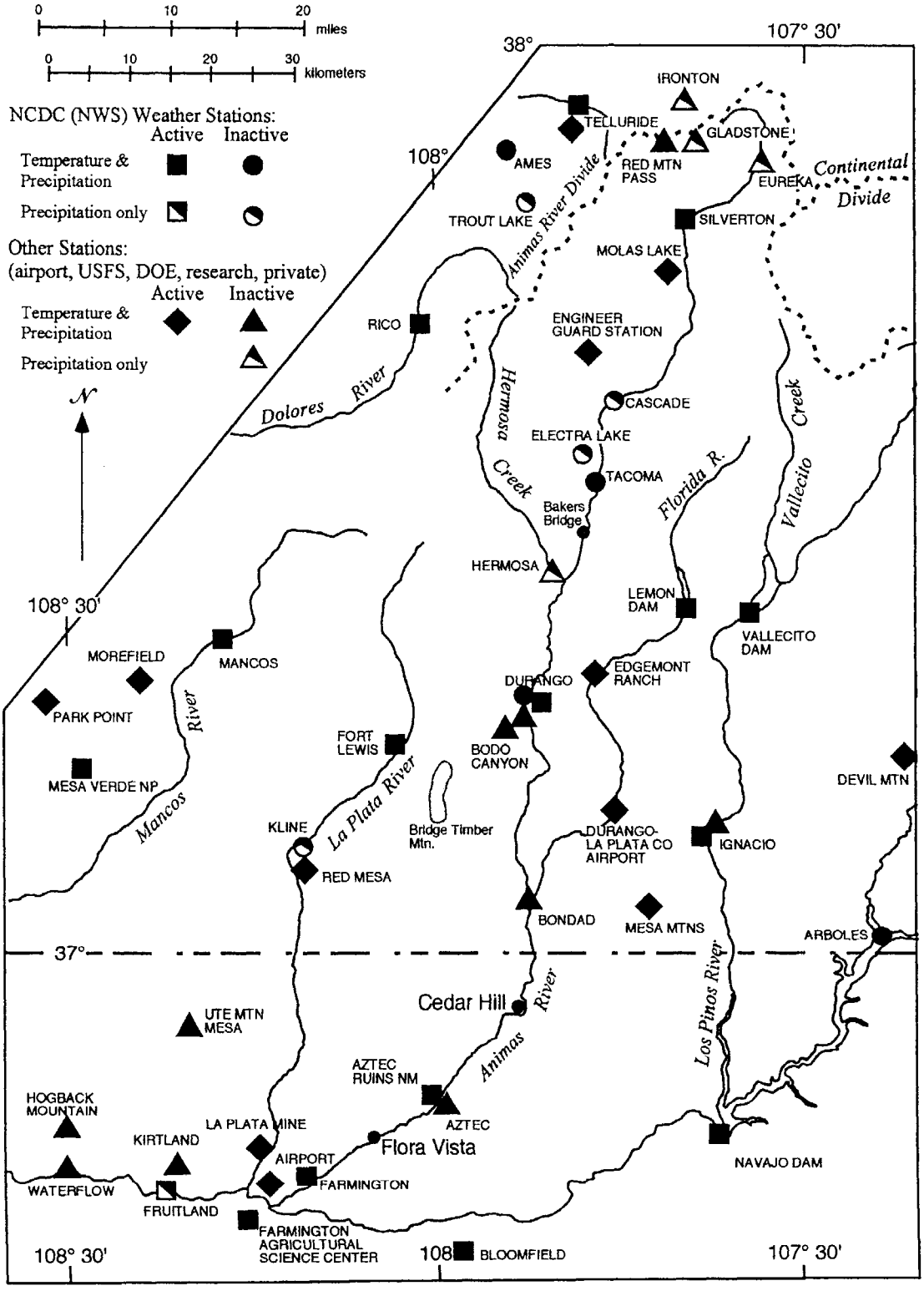


FIGURE 2.5 Weather stations in and near the study area.

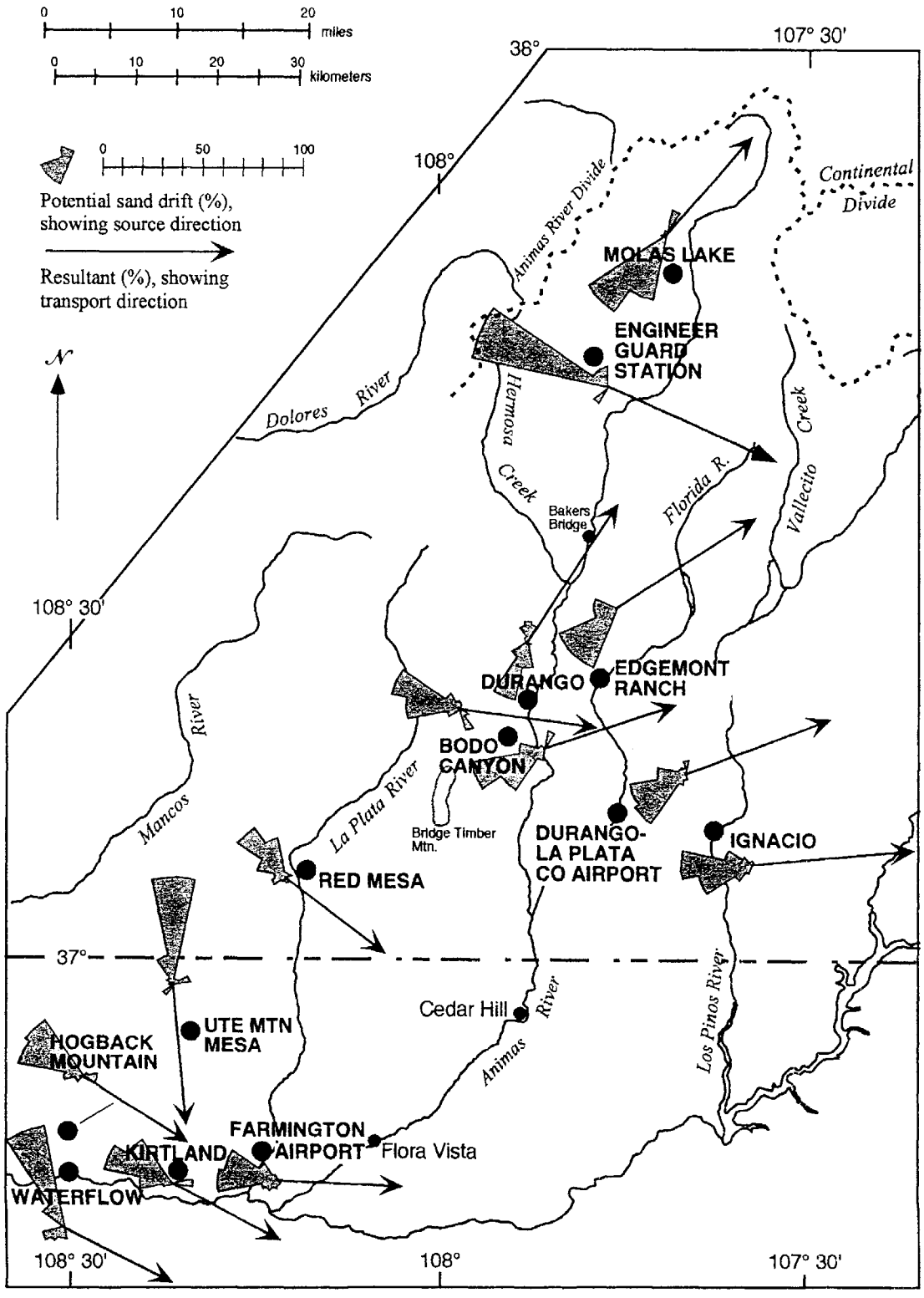


FIGURE 2.6 Potential sand transport directions.

TABLE 2.2 WIND DATA SITES AND POTENTIAL SAND DRIFT

SITE NAME, THIS STUDY [1]	ELEVATION AND LOCAL TOPOGRAPHY	LOCATION, NEW MEX. BASE LINE & PRINC. MERID.; TOPO. QUAD.	PERIOD [1]	WIND MEASUREMENT METHODS	POTENTIAL SAND DRIFT [2]		WIND DATA SOURCE AND RELATED INFORMATION
Molas Lake	3285 m (10,780 ft), 0.4 km NW of Molas Lake; on broad bench, at foot of long NNE-trending slope that rises toward Sultan Mountain; above inner valley of Animas River to E; downwind from SW-trending valley of Lime Creek	NE/4 SE/4 NE/4 Sec 12 T40N R8W Silverton (1955)	12/85-12/88 (2.6 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	9.6 NA NA	Air Resource Specialists, Inc. (1986, 1987a, 1987b, 1988a, 1988b, 1989); station operated for U.S. Forest Service
Engineer Guard Station	2760 m (9050 ft), at USFS guard station; on W edge of broad bench, at intersection between valley of Cascade Creek, locally trending SE, and long slope that rises toward Engineer Mountain, trending NE; above inner valley of Animas River to E	NE/4 SE/4 SE/4 Sec 12 T39N R9W Engineer Mountain (1960)	12/85-12/88 (2.3 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 114	Air Resource Specialists, Inc. (1986, 1987a, 1987b, 1988a, 1988b, 1989); station operated for U.S. Forest Service
Edgemont Ranch	2180 m (7160 ft); in valley bottom of Florida River, locally trending SW and flanked by ridges and cuestas with same trend	SW/4 NE/4 NE/4 Sec 18 T35N R8W Durango East (1963)	9/87-8/91 (4 yr)	1-hour avg., 24 obs./day, 8 directions (all others 16); 10 m ground mast	total: resultant length: resultant azimuth	NA NA NA	"Durango site;" University of Colorado, Joint Center for Energy Management, written comm. (1992)
Durango (NCDC)	1995 m (6550 ft), 1631 W Third Ave.; low terrace in valley floor locally trending SSW and flanked on both sides by ridges and low peaks	SE/4 NW/4 SW/4 Sec 20 T35N R9W Durango East (1963)	1/39-12/43 (5 yr)	1-2 minute visual estimate?, 4 obs./day; 11 m rooftop mast	total: resultant length: resultant azimuth	NA NA NA	WBAN #93004 (old #471); National Climatic Data Center, written comm. (1991)
Durango (DOE)	approx. 1980 m (6490 ft), between railroad yard and Highway 160 bridge; on floodplain or very low terrace of valley floor locally trending SSE and confined between ridges; opposite mouth of Lightner Creek, locally trending E	NW/4 NW/4 SW/4 Sec 29 T35N R9W Durango East (1963)	2/82-1/83 (1 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 97	U.S. Department of Energy (1984a,b)
Bodo Canyon	2150 m (7060 ft), near W end of tailings impoundment site; on north side of divide between broad valleys trending generally WSW and E	NE/4 NW/4 SE/4 Sec 36 T34-1/2N R10W Basin Mountain (1968)	1/82-12/82 (1 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA NA	U.S. Department of Energy (1984a,b)
Durango-La Plata County Airport	2030 m (6660 ft), at old terminal building; on mesa top SE of Florida River valley, locally trending SSW, and NW of Salt Creek valley, trending SE	SW/4 SE/4 SE/4 Sec 30 T34N R8W Loma Linda (1968)	2/86-12/86 (0.9 yr)	unknown, possibly 1-hour avg., 16 obs./day, daytime only; aprox. 6 m? rooftop mast	total: resultant length: resultant azimuth	NA NA NA	Colorado Division of Aviation, written comm. (1991)

TABLE 2.2 WIND DATA SITES AND POTENTIAL SAND DRIFT, continued

SITE NAME, THIS STUDY [1]	ELEVATION AND LOCAL TOPOGRAPHY	LOCATION, NEW MEX. BASE LINE & PRINC. MERID.; TOPO. QUAD.	PERIOD [1]	WIND MEASUREMENT METHODS	POTENTIAL SAND DRIFT [2]		WIND DATA SOURCE AND RELATED INFORMATION
Ignacio	1990 m (6530 ft), at N edge of tribal campus; on low terrace in valley bottom of Los Pinos River, locally trending NE; rolling piedmont west of site	NW/4 SW/4 NE/4 Sec 5 T33N R7W Gem Village (1968)	12/82-8/91 (8.8 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA NA	"Ute #1;" Southern Ute Indian Tribe, Air Quality Department, written comm. (1992)
Red Mesa	2005 m (6580 ft), 1.3 km W of Redmesa; on very broad terrace 0.8 km from La Plata River, locally trending SSE; site aligned with SE-trending streams W of river	SW/4 NE/4 NE/4 Sec 19 T33N R12W Redmesa (1968)	12/82-8/91 (8.8 yr)	1-hour avg., 24 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 127	"Ute #2;" Southern Ute Indian Tribe, Air Quality Department, written comm. (1992)
Farmington Airport	1675 m (5500 ft), near NE corner of E-W trending runway; on mesa top within broad valley of San Juan River, locally trending ESE; bordered by inner valleys of La Plata and Animas Rivers, locally trending SSW and SW	SE/4 SE/4 NE/4 Sec 8 T29N R13W Farmington South (1965)	3/53-12/78 (24.9 yr)	1-hour avg.; 2/53-12/64: 24 obs./day, 10.1 m rooftop mast; 10/65-12/78: 8 obs./day, 6.7 m ground mast	total: resultant length: resultant azimuth	NA NA 92	WBAN #23090, projects NM2309065.12 and NM2309065.13; National Climatic Data Center, written comm. (1991)
Ute Mountain Mesa	1895 m (6220 ft); on cuesta top S of S-trending section of Ute Canyon	NE/4 NE/4 SW/4 Sec 8 T31N R14W Purgatory Canyon (1979)	12/83-12/85 (1.1 yr)	0.5-hour avg., 48 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 175	San Juan Air Monitoring Program, #129; Public Service Co. of New Mexico, Inc., written comm. (1992)
Kirtland	1630 m (5350 ft), 2.6 km N of Kirtland; on crest of low ridge crest in rolling piedmont area that slopes generally SW	SW/4 SW/4 SE/4 Sec 31 T30N R14W Youngs Lake (1963)	5/83-11/83 (0.6 yr)	0.5-hour avg., 48 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 117	San Juan Air Monitoring Program, #126; Public Service Co. of New Mexico, Inc., written comm. (1992)
Hogback Mountain	1645 m (5400 ft); on lee side of continuous ridge, about 0.2 km from crest and 40 m lower	SW/4 SW/4 NW/4 Sec 23 T30N R16W Chimney Rock (1983)	5/83-3/86 (2.9 yr)	0.5-hour avg., 48 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 122	San Juan Air Monitoring Program, #125; Public Service Co. of New Mexico, Inc., written comm. (1992)
Waterflow	1535 m (5040 ft), 1.8 km WSW of Waterflow, on floodplain of San Juan River, locally trending ENE; downwind from water gap, but strongest winds flow over reentrant in continuous ridge roughly 3.4 km NW of site and 150 m higher	SE/4 SW/4 NW/4 Sec 2 T29N R16W Waterflow (1963)	5/83-3/86 (2.9 yr)	0.5-hour avg., 48 obs./day; 10 m ground mast	total: resultant length: resultant azimuth	NA NA 127	San Juan Air Monitoring Program, #124; Public Service Co. of New Mexico, Inc., written comm. (1992)

1. Table includes sites and periods for which joint frequency distributions, giving wind direction and speed, were available in 1992. Omitted are sites and periods with directional but not speed data (Silverton, Red Mountain Pass), untabulated data (Farmington Agricultural Science Center, Telluride), and later data for sites with continuing records.
2. Calculated by method of Fryberger and Dean (1979). Magnitudes in "vector units" (m^3/sec^3) that are proportional to mass transport per unit of time; azimuths in degrees.

southern Rocky Mountains and Colorado Plateau are summarized here to illustrate the potential range of past climates relative to the present. This comparison does not show the full range of late Quaternary climates because parts of the Holocene were warmer and/or drier than present.

Late Pleistocene

Temperature. Paleotemperature estimates for the study area are based mainly on the composition of groundwater in two basins, on depression of upper treeline or timberline in several mountain ranges, and on the absence of certain periglacial or permafrost features in the Durango area. For simplicity, this discussion emphasizes mean annual temperature, but changes in vegetation suggest that summer temperature decreased more than winter and mean annual temperatures (e.g. Van Devender and others, 1987; Betancourt, 1990).

Concentrations of noble gases or stable isotopes (^{18}O and D), measured in radiocarbon-dated groundwater, have yielded paleotemperature estimates for the San Juan Basin and for the Black Mesa Basin, which is located 100 km farther west in northeastern Arizona. In the San Juan Basin, noble gases indicate that mean annual soil temperature (MAST) was 5.5 ± 0.7 °C lower than present during the Late Pleistocene (Stute and others, 1995), whereas ^{18}O and D suggest marginally greater cooling of 5 to 7 °C (Phillips and others, 1986). Data for ^{18}O and D in the Black Mesa Basin (Zhu and others, 1988) are comparable.

At Molas Lake in the upper Animas River drainage (Figures 2.2 and 2.3), pollen data suggest that timberline was 670 m lower than present when ice withdrew. This depression indicates summers about 5 °C cooler than present (Maher, 1961). In support, pollen studies at other sites suggest comparable depressions of timberline or treeline and associated temperature changes. These sites include Alkali Basin near Crested Butte in

west-central Colorado (Markgraf and Scott, 1981; Fall, 1997); Devlin's Park in the Front Range of east-central Colorado (Legg and Baker, 1980); and Hay Lake in the White Mountains of east-central Arizona (Jacobs, 1983). Wright and others (1973) inferred a larger treeline depression (about 900 m) for Deadman Lake in the Chuska Mountains of northwestern New Mexico, but this estimate is poorly constrained.

Temperature-diagnostic permafrost and periglacial features, such as ice or sand wedges, involutions, and patterned ground, have not been observed in the Durango area in spite of suitable materials and excellent exposures. The MAT required to form involutions and patterned ground is uncertain, but may range from -1 to 0 °C, based on maximum MAT's for modern permafrost (Embleton and King, 1975). The MAT needed for wedges varies, but is about -5 °C (Washburn, 1980; Mears, 1987). The absence of such features, at elevations from Durango to Bridge Timber Mountain, indicates either that cooling was less than 8 to 10 °C, or that snow protected the ground from colder air temperatures.

In summary, groundwater data suggest that MAT was lowered by <5 to 7 °C in the Farmington area. This estimate is consistent with summer cooling of at least 6.3 °C in southeast Utah, based on depression of blue spruce (Betancourt, 1990). Annual cooling near Durango and higher in the San Juan Mountains may have been greater because of the tendencies for glacial ice to reduce summer air temperatures (e.g. Rannie, 1977; Kutzbach and others, 1993) and for cold-air drainage to cool valley floors. However, the absence of certain periglacial and permafrost features suggests that cooling at Durango may not have been much greater than at Farmington, perhaps 6 to 8 °C. Summer cooling of 5 °C at Molas Lake seems inconsistent with these estimates and may reflect either partial warming before ice withdrew from high elevations, or discrepancies in temperature estimates by different methods.

Precipitation. Changes in mean annual precipitation are more difficult to estimate than those in temperature because of increased runoff, reduced evapotranspiration, and

shortening of the season for snow melt. Increased groundwater recharge in basins, depression of vegetation zones, and joint temperature-precipitation requirements to sustain Colorado glaciers suggest a precipitation increase of uncertain size in the study area.

Aquifer models, calibrated with radiocarbon dates, have been used to estimate rates of groundwater recharge in the San Juan and Black Mesa basins. In the San Juan Basin (Phillips and others, 1986), average recharge was about 45 % greater from 25 to 15 ka than from 15 ka to the present (as computed from the authors' Figure 6; their recharge rates for shorter periods depend on fewer measurements, and thus appear more speculative). In the Black Mesa Basin, late Pleistocene recharge rates were two to three times greater than present (Zhu and others, 1998). Precipitation could have increased either more or less than recharge, depending on the effects of reduced evapotranspiration (from cooler temperatures) and increased runoff (from soil saturation).

In contrast to aquifer recharge, depression of the lower limits of plant species indicates that MAP increased at least 60 to 100 % in most areas of the southwestern United States (Van Devender and others, 1987). At the same time, summer precipitation decreased by at least 10 to 20 % on the Colorado Plateau (Betancourt, 1990). It is not clear if the authors adjusted these values for changes in evapotranspiration. For example, depression of lower subalpine forest by about 900 ± 100 m, to 2000 ± 100 m (Betancourt, 1990) corresponds to an apparent increase in precipitation of 50 to 70 %, based on the modern lapse rate for southeast Utah (Whitfield and others, 1983; Table 2.1). However, estimated cooling would have reduced evapotranspiration by 20 to 25 %, so precipitation may have increased by only 25 to 50 %.

Various combinations of summer cooling and winter precipitation can account for maintenance of late Pleistocene glaciers in Colorado (Leonard, 1989, Table 4). Summer cooling of 8.5 to 6.3 °C (comparable to possible cooling at Durango) would require precipitation increases of 100 to 200 %. However, Leonard's statewide averages do not

apply specifically either to the San Juan Mountains or to Durango. Moderately high moisture in the San Juan Mountains snowpack (Porter and others, 1983; Leonard, 1989) and greater exposure to southerly moisture sources suggest that smaller precipitation increases may have been needed to maintain glaciers here than elsewhere in the state. Also, Durango is roughly 1000 m below the equilibrium-line elevation (ELA) of the Animas glacier, estimated at 3109 ± 100 m (Leonard, 1984), and was probably warmer. If summer temperatures at the ELA decreased 8.5 to 10.4 °C (about 2 °C more than at Durango, assuming greater cooling from glacial ice), precipitation at the ELA may have increased only 50 to 100 % based on statewide averages (Leonard, 1989, Table 4).

In summary, MAP may have increased by 30 to 100 % during the last glaciation, but this range is poorly constrained. Similar patterns of late Pleistocene ELA's and modern snow accumulation in the San Juan Mountains indicate that winter circulation was similar in late Pleistocene to present time (Leonard, 1984). However, minor differences in the patterns suggest a small increase in southerly moisture sources, possibly associated with the southern branch of a split jet stream (e.g. Kutzbach and others, 1993).

Wind. Information on the strengths and directions of local winds during glaciations is extremely limited. However, dune orientations in the Chaco dune field suggest that the net direction of sand transport was more east-northeasterly than shown in Figure 2.6 (McFadden and others, 1983; Wells and others, 1990). Patterns of late-Pleistocene ELA's in San Juan Mountains (Leonard, 1984) show that air tended to flow up Animas valley as it does today.

Holocene

The largest postglacial temperature change is between the full glacial and the early to middle Holocene, when temperatures 1 to 2 °C warmer than present are indicated by

midden, pollen, and groundwater data from the southern Rocky Mountains and Colorado Plateau (e.g. Thompson and others, 1993, and references therein). Sites closest to the study area include Chaco Canyon (Betancourt and others, 1983; Betancourt, 1990), Molas Lake (Maher, 1961), Hurricane Basin (Andrews and others, 1975), Twin Lakes (Peterson and Mehringer, 1976) Lake Emma (Carrara and others, 1984; Friedman and others, 1988; Elias and others, 1991), Alkali Basin (Markgraf and Scott, 1981; Fall, 1997), and the San Juan basin (Stute and others, 1995).

In this region, the driest parts of the postglacial occurred in the middle and late Holocene (Betancourt, 1990; Thompson and others, 1993). The range given above for the difference between modern and full glacial precipitation probably includes the maximum for the postglacial period.

Vegetation

Modern Vegetation

Vegetation affects land-surface stability and soil-forming processes. In the Animas River basin, the pattern of vegetation communities is complex because of variations in elevation, local topography, microclimate, and soils (Soil Conservation Service, 1976; Camilli, 1983; Knight, 1992). Generally, an altitudinal zonation of climax communities ranges from alpine tundra to Great Basin shrub-steppe (Figure 2.6). Boundaries between communities are lowest on relatively moist sites like north-facing slopes, valley bottoms, and rocky soils.

In the lower basin near terminal moraines and terraces, the highest areas such as Bakers Bridge and Bridge Timber Mountain are covered with ponderosa pine-Gambel oak woodland (Douglas fir is restricted to small patches on north-facing slopes). Most of the study area is within the altitudinal range for pinyon-juniper woodland. However, local

factors suppress the growth of pine-oak and pinyon-juniper woodland in parts of their zones. For example, montane shrub communities are widespread at 1800 to 2700 m on moderate to steep slopes with shaley soils, possibly because of repeated disturbance by fire and snow (Floyd-Hanna and others, 1996). Sagebrush steppe covers deep, well-drained soils like those on loamy eolian and alluvial deposits, which blanket many moraines and terraces. Halophytic desertscrub occurs on saline soils derived from shale or mudstone, and riparian cottonwood-willow communities border perennial streams. Generally, pinyon-juniper woodland, mountain shrub, and sagebrush steppe dominate the northern part of the study area. In the southern part, sagebrush steppe (with inclusions of grama-galleta grassland) dominates widespread terraces, but pinyon-juniper woodland covers rocky soils on terrace scarps or valley sides.

Former Vegetation

General features of late Pleistocene and early Holocene vegetation have been inferred from packrat middens and pollen spectra in the southern Rocky Mountains and Colorado Plateau (as reviewed by Van Devender and others, 1987; Betancourt, 1990; and Thompson and others, 1993). During the late Pleistocene, upper timberline and vegetation zones were depressed by hundreds of meters (Figure 2.6) and their compositions also changed (for example, some tree species persisted, while others migrated into or out of the area). Communites adapted to specific soils, such as sagebrush steppe and halophytic desertscrub, changed less than others, so that mosaic patterns in many areas may have resembled those of the present (Betancourt, 1990). During the early to middle Holocene, an interval which was warm and moist, forests expanded both above and below modern levels (e.g Betancourt, 1990; Elias and others, 1991; Fall, 1997).

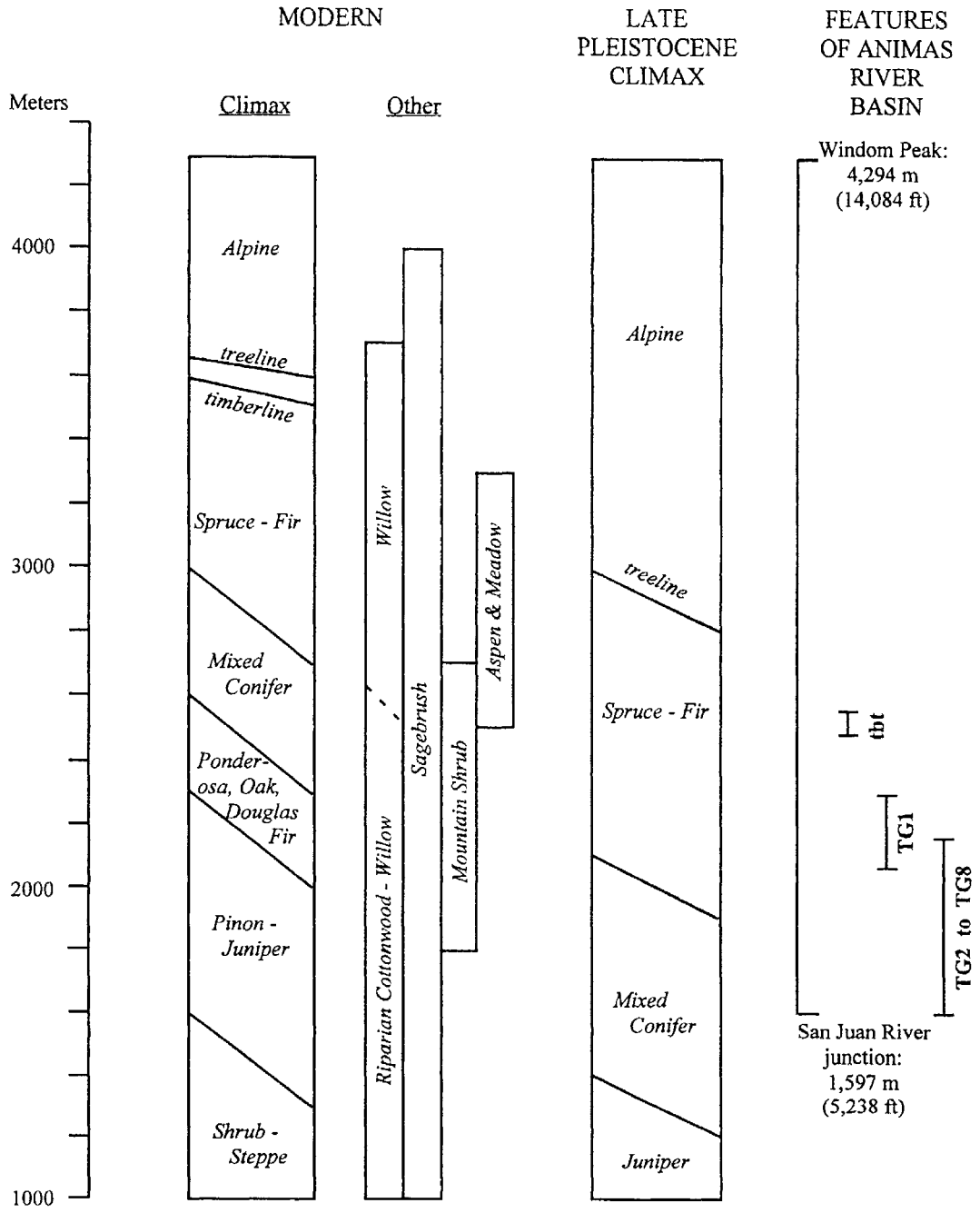


FIGURE 2.7 Altitudes of vegetation zones in the San Juan Mountains and Colorado Plateau during modern and late Pleistocene time. Modern ranges after Maher (1963), Carrara and others (1984), Betancourt (1990), Elias and others (1991), Spencer and Romme (1996), Floyd-Hanna and others (1996), and Jamieson and others (1996). Late Pleistocene ranges after Van Devender and others (1987) and Betancourt (1990).

The study area lies within estimated, late-Pleistocene altitudinal ranges for spruce-fir and mixed conifer forest (Figure 2.7). Possibly, sagebrush steppe retained its present distribution or expanded slightly. Mountain shrub may have contracted because of reduced fire frequency, and halophytic desertscrub may also have contracted because of greater leaching in presently saline soils. Different communities or denser understories probably reduced soil erosion below modern average rates, except in periglacial areas.

River Discharge

The average historic discharge of the Animas River at Farmington is 25.9 m^3/sec (Denis and others, 1984). During the largest known flood, on October 5, 1911, maximum discharges were approximately 2,300 m^3/sec at Durango (25,000 ft^3/sec; Duncan and others, 1984) and 2,800 m^3/sec at Farmington (30,000 ft^3/sec; Federal Insurance Administration, 1978). Flow data at Farmington, "Cedar Hill" (near Bondad), and Durango suggest that nearly all modern discharge originates in the mountains, with small amounts coming from the foothills and very little from the lower basin. Glacial discharge has not been estimated, but was probably greater and more variable, with much larger flood peaks.

Soil-Forming Factors

Climate and vegetation, as discussed above, imply varying conditions for soil development, depending on site location and soil age in relation to glacial cycles (Table 2.3). At present, MAT decreases slightly from Farmington to Bridge Timber Mountain, while MAP more than doubles. Annual potential evapotranspiration (PET; Thornthwaite, 1948), decreases from 340 % of MAP at Farmington to 95% of MAP at Bridge Timber Mountain. The leaching index (or total monthly excess of precipitation over

TABLE 2.3 SOIL TEMPERATURE AND MOISTURE REGIMES

SITE, CLIMATE PHASE	MEAN ANNUAL AIR TEMPERATURE (°C)	MEAN ANNUAL PRECIPITATION (mm)	POTENTIAL EVAPOTRANS. (mm) [1]	SOIL TEMPERATURE REGIME	SOIL MOISTURE REGIME	LEACHING INDEX (mm) [2]
FARMINGTON 4NE						
modern	10.7	199	683	mesic	aridic	42
full glacial [3]	≈4.7	≈298	≈500	frigid	ustic	<150
DURANGO						
modern	8.0	481	580	mesic to frigid	aridic-ustic to ustic	180
full glacial [4]	≈1	≈722	≈428	cryic	udic	<480
BRIDGETIMBER MTN.						
modern [5]	~5.4	~534	~503	frigid	ustic	~244
full glacial [6]	≈-1.6	≈804	≈367	cryic	udic	<580

1. Calculated by method of Thornthwaite (1948).
2. Sum of monthly excesses of precipitation over evapotranspiration (Arkley, 1967); values probably overestimate actual leaching during glaciations, when more precipitation would have fallen as snow and proportionally more spring runoff may have occurred than at present, leaving less moisture available for infiltration.
3. Estimated by applying the following factors: 6°C depression in mean annual temperature, distributed with maximum depression of 6.6°C in July and minimum depression of 5.4°C in January; 15% decrease in July-October precipitation; and 50% increase in mean annual precipitation.
4. Estimated by applying the following factors: 7°C depression in mean annual temperature, distributed with maximum depression of 7.6°C in July and minimum depression of 6.4°C in January; 15% decrease in July-October precipitation; and 50% increase in mean annual precipitation.
5. Mean annual temperature and precipitation estimated from regression equations (Barry and Bradley, 1976; Ireland, 1983). Monthy values determined by adding or subtracting 1/12 of difference in mean annual values for Bridge Timber Mountain and Durango to or from monthly values for Durango.
6. Estimated as in note 4. Estimated monthly air temperatures indicate a pergelic soil-temperature regime, but insulating effect of heavy snowfall and absence of permafrost features suggest that soil temperatures were warmer (i.e., cryic).

evapotranspiration; Arkley, 1967) increases roughly six times between these areas. Approximate soil-moisture balances (Soil Survey Staff, 1975) were calculated for 200 mm of available water-holding capacity, a value near the median for the top 1.5 m of soils on moraines and terraces (Pannell and others, 1988; Keetch and others, 1980). Typical soil-forming conditions range from mesic and aridic at Farmington to frigid and ustic at Bridge Timber Mountain (Figure 2.8; Table 2.3).

During glacial episodes, soils were colder and wetter than at present. Several assumptions, based on the preceding discussion of glacial climate, were used to illustrate possible soil-forming conditions: MAT decrease of 6 °C at Farmington and 7 °C at Durango and Bridge Timber Mountain, unevenly distributed to be 0.6 °C colder in January and 0.6 °C warmer in July; precipitation decrease averaging 15 % from July to October, distributed to remove modern peaks from monsoonal circulation; and MAP increase of 50%, distributed to give a smooth peak in midwinter. As shown (Table 2.3; Figure 2.9), conditions probably ranged from frigid and ustic at Farmington to cryic and udic at Bridge Timber Mountain (assuming that snow insulated the soil from pergelic air temperatures). PET may have decreased 20 to 30 % (averaging 26 % in the three simulations). Leaching increased greatly, but the leaching index probably overstates this increase (from 140 to 260 % in simulations) because water-balance calculations do not realistically address the processes of snow accumulation, melting and runoff.

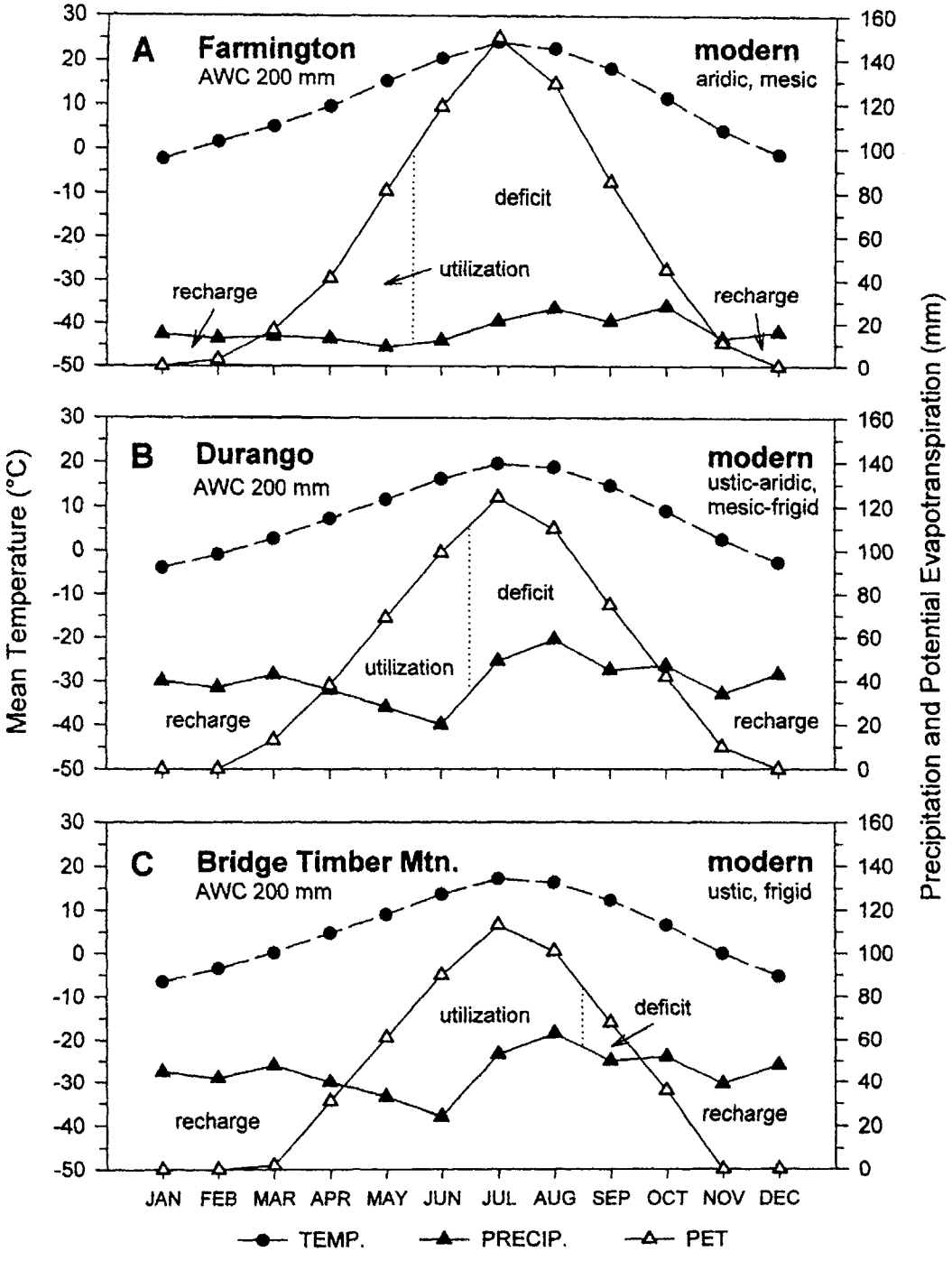


FIGURE 2.8 Approximate soil-moisture balances for Farmington, Durango, and Bridge Timber Mountain based on modern climatic records.

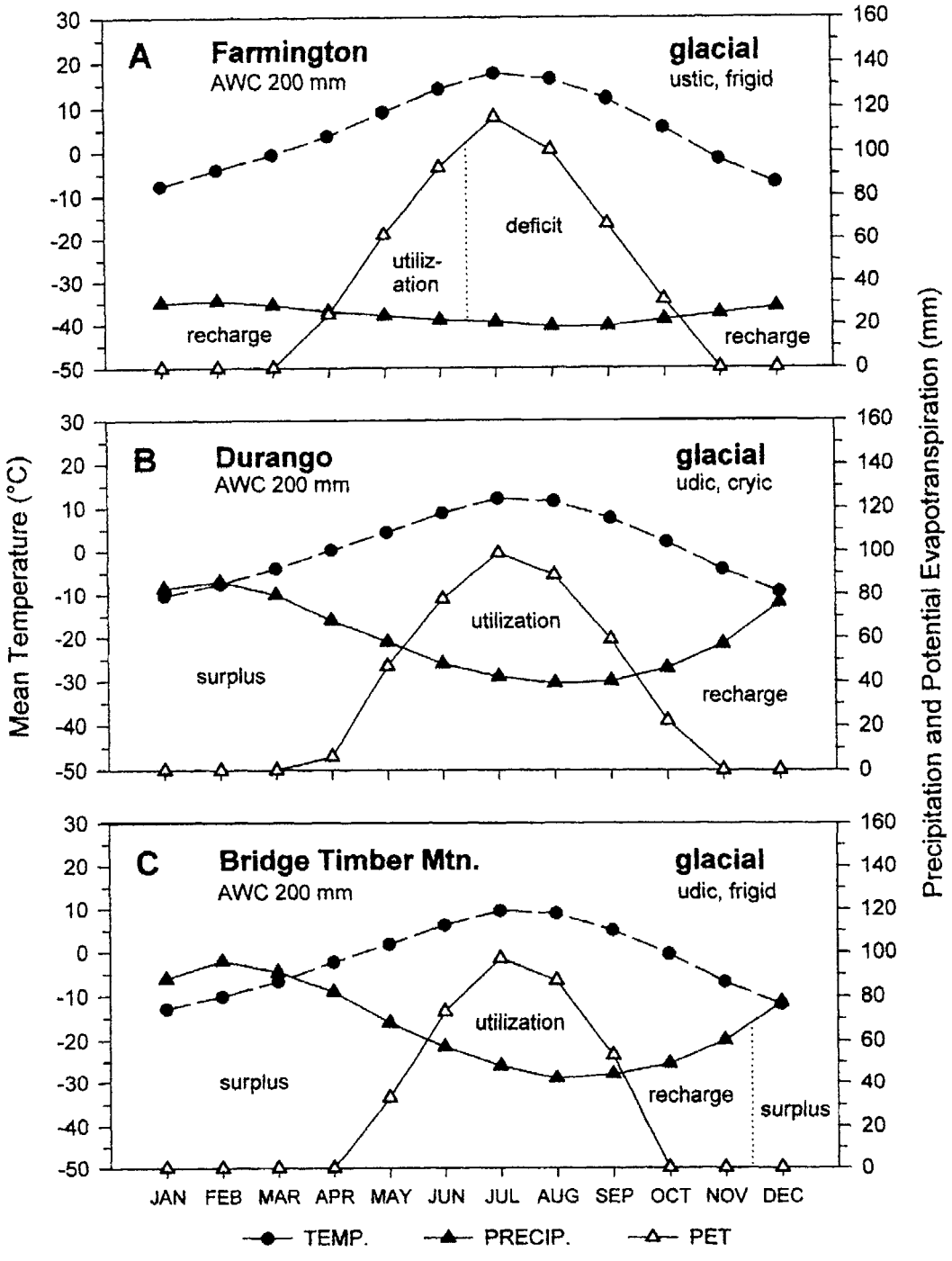


FIGURE 2.9 Approximate soil-moisture balances for Farmington, Durango, and Bridge Timber Mountain based on estimated late-Pleistocene temperature and precipitation.

CHAPTER 3

MORAINE SEQUENCE

Three groups of terminal moraines are preserved in the Durango area. From youngest to oldest, these are the Animas City, Spring Creek, and Durango moraines. Other features which are related to the youngest group, but appear farther upvalley, include moraine-like ridges in the Bakers Bridge area and lateral moraines in the Falls Creek area. This chapter synthesizes recent work on the moraine sequence.

Previous Work and Nomenclature

Knowledge about the glacial sequence in the San Juan Mountains has evolved through many studies. In the Animas River valley or surrounding region, these have addressed several main topics: first, moraine locations and ages (Table 3.1; Hills, 1884; Howe and Cross, 1906; Atwood and Mather, 1912; Atwood, 1915, 1918; Atwood and Mather, 1932; Richmond, 1954 and 1965b; Carrara and Andrews, 1975; Andrews and others, 1975; Sinnock, 1978, 1981; Scott, unpublished; Gillam and others, 1984, 1985; Richmond, 1986b; Johnson and Gillam, 1995); second, sedimentology of moraine deposits (Harrington, 1970; Johnson, 1990; Johnson and Gillam, 1995); and third, glacier or climate modeling (Porter and others, 1983; Leonard, 1984; Small, 1995). Howe and Cross (1906) noted that glaciers were confined to valleys and did not extend to broader piedmont areas, that rivers incised into bedrock between glaciations, and that terraces beyond ice limits could indicate earlier glaciations without preserved moraines. Atwood and Mather (1932)

TABLE 3.1 NAMES OF GLACIAL DEPOSITS IN DURANGO AREA AND SAN JUAN MOUNTAINS

Hills (1884) **San Juan Mountains**	**Howe and Cross (1906)** **San Juan Mountains**	**Atwood and Mather (1912)** **San Juan Mountains**	**Atwood (1915, 1918); Atwood and Mather (1932)** **San Juan Mountains**	**Richmond (1954)** **Dallas Creek (upper Uncompahgre River)**	**Johnson and Gillam (1995); Gillam, this study** **Durango area**
[not recognized]	*moraines of corrie and cliff glaciers*	[not recognized]	[not recognized]	*rock glaciers* *cirque moraines*	[absent]
two moraines in Bakers Park near Silverton [1]	[not recognized]			[absent]	
[not recognized]			Wisconsin Till above valley step at Bakers Bridge		"Baker's Bridge moraine" (below valley step)
two terminal moraines (unnamed) formed when piedmont ice had retreated into valleys	two terminal moraines (unnamed) and lateral moraines as far north as Tacoma (younger drift)	two terminal moraines of Uinta glacial epoch	Wisconsin Till [text mentions only two terminal moraines but mapped area includes Spring Creek moraine remnants]	*late Wisconsin till (two moraines)*	Animas City 3 Animas City 2
[not recognized]	[not recognized]	[not recognized]	[not recognized or included with Wisconsin Till]	*Durango till (two moraines)*	Animas City 1 Spring Creek 2 Spring Creek 1
	[recognized outwash gravel, but not moraines]	moraine of Bighorn glacial epoch on higher rock bench	Durango Till	[absent]	Durango 2 Durango 1
piedmont glaciation phase, forming bouldery deposits 5 mi east of Durango [colluvium or pediment deposits flanking La Plata Mountains]	*no piedmont moraines in Durango area; older drift in Horsefly Peak area, upper Uncompahgre River drainage*	*no valley moraines in Durango area; older drift in Horsefly Peak area (San Juan glacial epoch)*	*Cerro Till in Horsefly Peak area* (correlated with Florida Gravel in Durango area)	*Cerro till*	[absent]

Continued on next page.

TABLE 3.1 NAMES OF GLACIAL DEPOSITS IN DURANGO AREA AND SAN JUAN MOUNTAINS, continued

Richmond (1965b) Durango area	Carrara and Andrews (1975); Andrews and others (1975) northern San Juan Mountains	Sinnock (1978, 1981) Dallas Creek - Ridgeway area	Scott (unpubl.; ca. 1980) Durango area	Gillam and others (1984, 1985); Richmond (1986b); Johnson (1990) Durango area	Johnson and Gillam (1995); Gillam, this study Durango area
[absent]	*rock glaciers* *Yankee Boy* *Grenadier* [absent]	[absent]	[absent]	[absent]	[absent]
late Pinedale till (below valley step)				Bakers Bridge moraine (below valley step)	"Baker's Bridge moraine" (below valley step)
middle Pinedale till		younger Pinedale till	Qpt2 [younger Pinedale till]	Animas City inner moraine (III)	Animas City 3
early Pinedale till		older Pinedale till	Qpt1 [older Pinedale till]	Animas City middle moraine (II)	Animas City 2
late Bull Lake till [includes some probable terrace remnants]		younger Bull Lake till	Qbt2 [younger Bull Lake till]	Animas City outer moraine (I)	Animas City 1
				Spring Creek inner moraine	Spring Creek 2
early Bull Lake till [includes some probable terrace remnants]		older Bull Lake till	Qbt1 [older Bull Lake till]	Spring Creek outer moraine	Spring Creek 1
Sacagawea Ridge till		[absent]	Qit2 [younger Illinoian till]	Durango inner moraine	Durango 2
			Qit1 [older Illinoian till]	Durango outer moraines	Durango 1
[absent]		*Horsefly Peak Till*	[absent]	[absent]	[absent]

1. Standard typeface is for Durango area and italic typeface is for other parts of San Juan Mountains.

prepared a regional report that is still the most detailed for many areas in the San Juan Mountains, including parts of the upper Animas valley. More recent work has refined the moraine sequence and its origins. Richmond (1965b) first mapped the Spring Creek moraines (which he called Bull Lake). Other subdivisions of the moraine groups (G. R. Scott, U.S. Geological Survey, unpublished mapping) influenced later work.

Various names have been used for moraines or their deposits (Table 3.1), including informal names for glacial deposits in parts of the Rocky Mountains or Midwest. In the Animas valley, Atwood and Mather (1932) formally named the Durango Till. Gillam and others (1984) retained this name for the Durango moraines but proposed informal, local names for younger moraines pending better evidence for correlations with other areas. Within each moraine group, subdivisions are numbered from oldest to youngest (Johnson and Gillam, 1995).

Criteria for Recognizing and Subdividing Moraines

Studies in the Animas valley (Table 3.1) have distinguished moraines primarily from their constructional shapes and secondarily from their deposits. Constructional shape is diagnostic for well preserved moraines, but not for those which are very poorly preserved. Also, erosional remnants of other landforms, such as terraces, may have ridge-like shapes. Where landforms are inconclusive, interpretation of deposits is more important, but fluvial deposits occur in both moraines and terraces (Johnson and Gillam, 1995; Chapter 5). Till and landslide deposits may also appear similar (Harrington, 1970), but in this area, few landslides are located where they may be confused with moraines.

In the Durango area, both exposures and landforms have changed during progressive urban development. In a few places, landforms have been extensively and obviously modified, but in many others, modifications are not clearly detectable and must

be identified on early aerial photographs. Differing interpretations for some features (discussed below) may reflect the availability of outcrops and unrestricted views at various times.

Criteria used to identify moraine groups include downvalley sequence, crestal elevations, elevations of basal contacts between moraine deposits and underlying bedrock, preservation of constructional shape, thickness of overlying loess, and soil development. Additional criteria used to subdivide moraines within groups include the continuity and orientations of moraine crests.

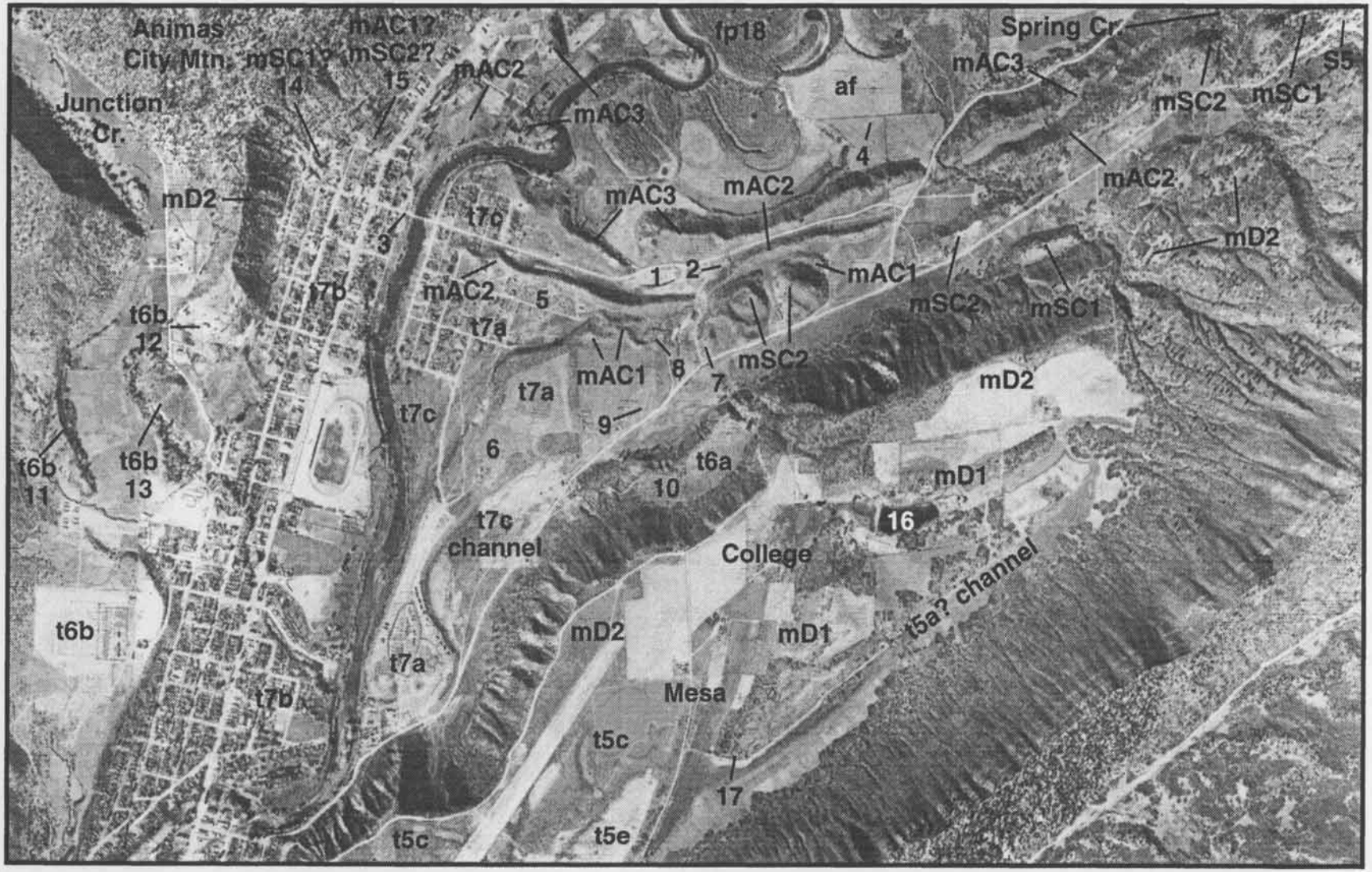
Moraines in the Durango Area

Terminal moraines of the Animas glacier are located in north Durango, where they form continuous or partial loops that are located within a horizontal distance of 1 km (Figures 3.1 and 3.2; Plate 1A). Crestal elevations are approximately 2000 to 2150 m (Figure 3.3). Table 3.2 summarizes moraine elevations and shapes. The Animas City moraines are discussed first as models for older moraines that are more poorly preserved and exposed.

Animas City Moraines

Remnants of three moraines mark the southern limit of the glaciated valley. These include two parallel, almost continuous loops (Animas City 3 and 2) and a third moraine (Animas City 1) that is represented by two small segments slightly farther downvalley. These moraines lie south and east of Animas City Mountain, which is named for an early settlement near the 32nd Street bridge. They are distinguished by upvalley position, crestal elevations that are below the bases of Spring Creek moraines, basal elevations that are

FIGURE 3.1 Aerial photograph showing moraines, terraces, and related features in northern Durango area. Labeled features, from youngest to oldest: fp – flood plain covering fill surface of former proglacial, moraine-dammed lake; mAC3, mAC2, mAC1 – Animas City 3, 2, and 1 moraines, associated respectively with outwash terraces t7c, t7b, and t7a; mSC2, mSC1 – Spring Creek 2 and 1 moraines; t6b, t6a, outwash terraces probably associated with Spring Creek 2 and 1 moraines; mD2, mD1 – Durango 2 moraine and Durango 1 moraine group; t5c, t5e – outwash terraces graded to Durango 2 moraine; numerals refer to sites discussed in text. Photographs from USDA, Soil Conservation Service, project DKR, frames 2-100 and 2-145, nominal scale 1;20,000. North is toward top of image. Area shown is 6 km wide from west to east.


Animas City Mtn.
mAC1?
mSC1?
mSC2?
Junction Cr.
14
15
mAC2
mAC3
fp18
af
Spring Cr.
mAC3
mSC2
mSC1
S5
4
mD2
mAC3
mAC2
t7c
3
mAC2
mAC2
mD2
1
2
mAC1
t7b
5
mSC2
mSC1
t6b
12
t7a
mAC1
8
7
mSC2
mD2
t7a
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t6b
11
t6b
13
t6a
10
mD1
16
t7c
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mD1
t7a
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Mesa
t5c
17
t5c
t5e

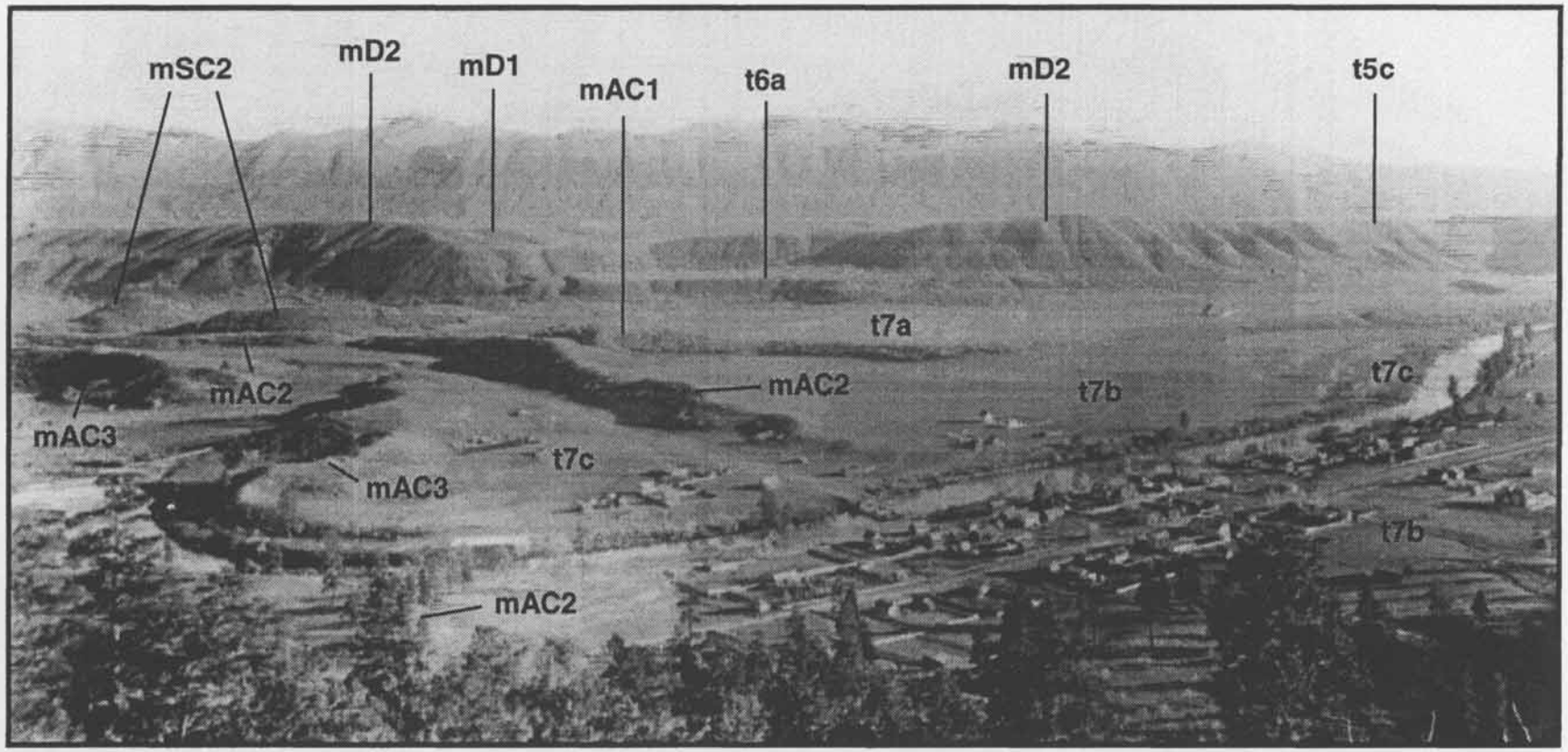
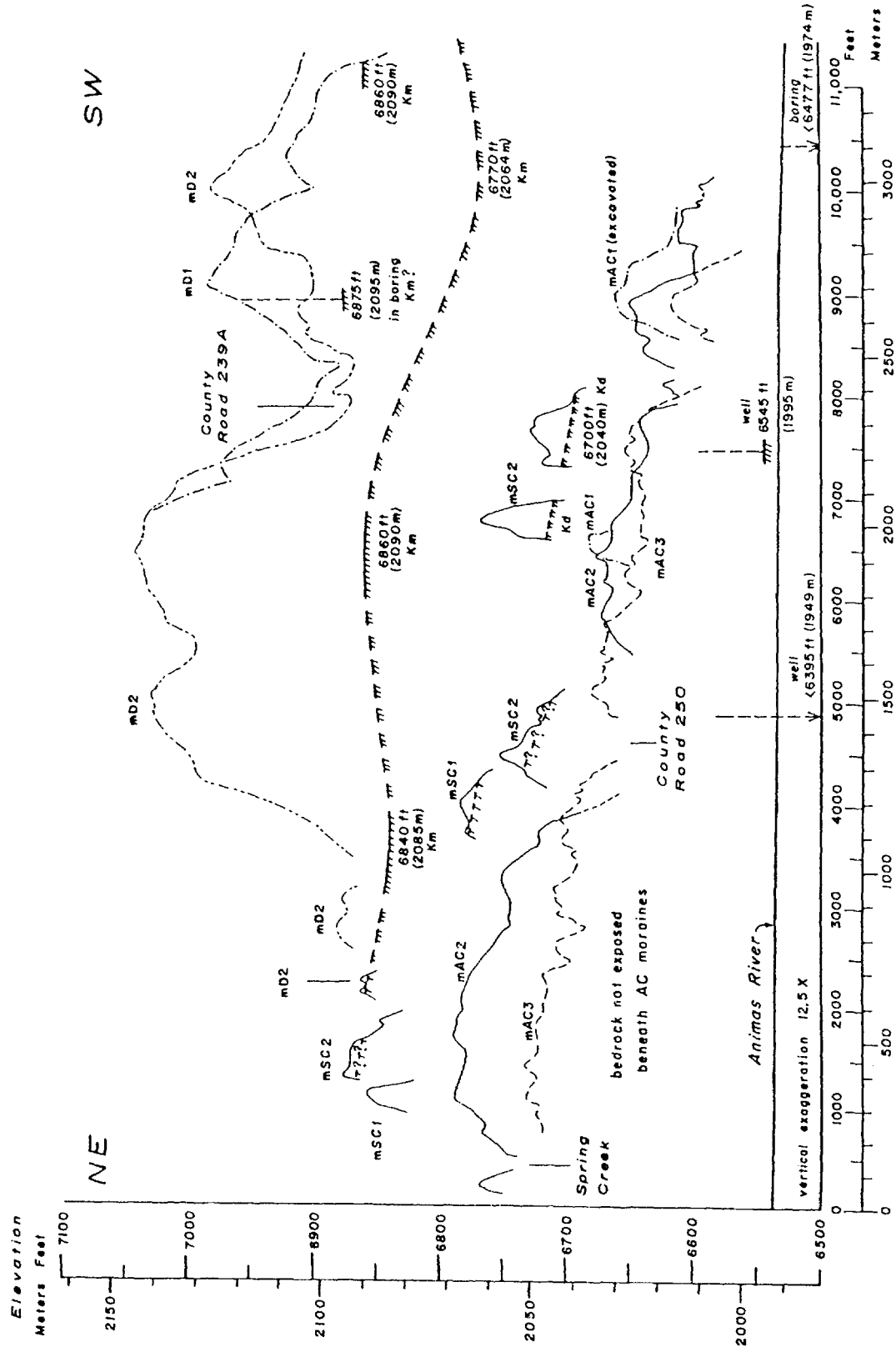


FIGURE 3.2 View southeast over former Animas City from southeast end of Animas City Mountain, showing moraines and outwash terraces now covered by Durango. Labeling as in Figure 3.1 and Plates 1 and 2. Photograph by Whitman Cross shortly before 1905 (modified from Howe and Cross, 1906, and Gillam and others, 1984).

FIGURE 3.3 Longitudinal profile of moraine crests along better-preserved, eastern part of moraine belt, projected to N45E (approximate axis of belt). Moraines labeled as in Figure 3.1. Hachured lines and elevations show points where depth to bedrock has been measured in outcrops, water wells, or test borings; Kd - Dakota Sandstone, Km - Mancos Shale; minimum elevations are given for bases of wells and borings that did not reach bedrock. Note decreasing crestal elevations from more lateral (NE) to more central (SW) positions, decreasing basal elevations of progressively younger moraines, relative thinness of Spring Creek deposits probably reflecting deep erosion, and varying irregularity of moraine crests. Modified from Gillam and others (1984).


NE
SW
Elevation
Meters Feet
7100
7000
6900
6800
6700
6600
6500
2150
2100
2050
2000
mD2
mD1
mSC2
mSC1
mAC2
mAC3
mAC1
mAC1 (excavated)
Kd
County Road 239A
County Road 250
Spring Creek
Animas River
6840 ft (2085 m) Km
6860 ft (2090 m) Km
6875 ft (2095 m) in boring Km?
6770 ft (2064 m) Km
6700 ft (2040 m) Kd
well 6545 ft (1995 m)
well (6395 ft (1949 m)
boring (6477 ft (1974 m)
bedrock not exposed beneath AC moraines
vertical exaggeration 12.5 X
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
Feet
0
500
1000
1500
2000
2500
3000
Meters
Distance Along Projection Line

probably below river level in most places, minor erosional modification (except for the Animas City 1 moraine), thin loess deposits, slight weathering, and weakly to moderately developed soils.

Animas City 3 and 2 moraines. These moraines were identifed by Hills (1884) and later mapped as Wisconsin till (Atwood and Mather, 1932) or as an early and middle Pinedale till (Richmond, 1965b). Both moraines are nearly continuous, but are narrowly breached at their apex by the Animas River and in several other places by small streams that flow upvalley toward the former ice-filled basin. Between gaps, the moraines have narrow, hummocky crests with a few undrained depressions. The moraines rise 25 to 60 m above the valley bottom north of the moraines and 15 to 27 m above adjacent outwash terraces. They are approximately 60 to 150 m wide at these levels. Near their eastern and western ends, where the moraines are closely spaced and confined against the valley sides, former meltwater troughs follow their distal sides and intervening depressions. Outwash in these troughs is mostly concealed by postglacial alluvium of local streams, but is reported in water wells. Near the apexes of the moraines, where they are farther apart and less confined, broader outwash terraces are graded to their distal sides.

Small streams that now flow upvalley though breaks in the moraines have probably exploited gaps created earlier by meltwater flows in the opposite direction. After ice retreat, local drainage was reversed by growth of alluvial fans from the valley sides and by stream capture along steeper gradients toward the ice-scoured, bedrock basin north of the moraines. However, several natural gaps have been enlarged by mechanical excavation. An obvious case is the large gap in the Animas City 3 moraine at the former Bacus gravel pit (site 1 in Figure 3.1). Now widely breached, the Animas City 2 moraine was nearly continuous at Holly Avenue (below the numeral 2 on Figure 3.1). A small remnant of this moraine was also removed from west bank of the river (directly north of site 3).

East of the Animas River, crestal elevations vary from 2015 to 2070 m (Table 3.2; Figure 3.3). Basal contacts are not exposed, but several water wells and test borings indicate that the contacts are near or below river level. For example, the base of the Animas City 2 moraine is probably below that of related outwash, which occurs at roughly 1995 m in a water well at 934 East 32nd Street (site 2 in Figure 3.1). At the west abutment of the 32nd Street bridge (site 3), a test boring bottomed in sediments of the Animas City 2 moraine at approximately 1974 m. Roughly 150 m north of the Animas City 3 moraine, a water well at 30 Moenkopi Drive (site 4) bottoms in glacial or postglacial sediments at approximately 1949 m.

Former ice-contact slopes of the two moraines have similar, relatively steep gradients (Table 3.2) which suggest either that they are close in age, or that both have been affected equally by later fluvial undercutting (the middle moraine by meltwater from the inner one, and the inner moraine by the Animas River and its larger tributaries). A sinuous meltwater stream has also undercut the distal slope of the Animas City 3 moraine between East Fifth and East Seventh Streets (site 5 in Figure 3.1). Other characteristics that suggest relatively young ages include bouldery surfaces, loess generally less than 20 cm thick, minimal clast weathering (most granitic clasts are fresh, and schistose clasts are beginning to split along foliations), and weak soils (on crestal sites, cambic or very weak argillic horizons 10 to 15 cm thick).

Animas City 1 moraine. Two segments east of the river indicate the outermost Animas City moraine (Figures 3.1 and 3.4; Plates 1A and 2). The larger, western segment was excavated in the 1970's, but it originally extended from Hilltop Drive eastward along 31st Street. The second segment lies farther east, below the base of a larger Spring Creek segment, and is separated from it by a narrow outwash trough.

Richmond (1965b) mapped the larger segment as late Bull Lake till, probably because it is aligned in map view with other segments that he included in that group (here

TABLE 3.2 MORAINE ELEVATIONS AND SHAPES

MORAINE	ELEVATION, ft (m) [1] CREST	BASAL CONTACT	HEIGHT OF BASAL CONTACT ABOVE (+) OR BELOW (-) ANIMAS RIVER, m (ft)	GRADIENT OF FORMER ICE-CONTACT SLOPE, in degrees [2]	CRESTAL IRREGULARITY, in direction changes per km (per mi) [3]
Animas City					
3	2015-2051 (6610-6730)	>1949, <1990 (>6395, <6530)	<-41 to +1 (>-135 to +5)	27.3 +/- 3.3 (n=10)	28 (45)
2	2027-2070 (6650-6790)	<1974-<1995 (<6477-<6545)	<-16 to <+5 (<-53 to <+15)	27.7 +/- 2.8 (n=10)	15 (24)
1	2027-2030 (6650-6660)	<1826 (<5990)		20 (n=1)	(16) approx 26
Spring Creek					
2	2051-2091 (6730-6860)	2042-2073 (6700-6800?)	+52 to +82? (+170 to +270?)	26-29 (n=3)	meaningless because of erosion
1	<2067-2097 (<6780-6880)	<2067-2091? (<6780-6860?)	<+76 to +101? (<+250 to +330?)	29-30 (n=2)	"
Durango					
2	2128-2146 (6980-7040)	2063-2091 (6770-6860)	73-101 (240-330)	22-24 (n=2)	5 (8)
1	2103-2128 (6900-6980)	2091-2096 (6860-6875)	101-105 (330-345)	18-22 (several)	5 (8)

1. Elevations are for remnants east of Animas River and may represent different positions along moraine loops. Crestal elevations are from topographic maps with 2-ft contour interval, prepared for City of Durango in 1974. Basal elevations are from exposures, water wells, and test borings.

2. Gradients for Durango 2 moraine were measured in the field. For other moraines, they were computed from city topographic maps. Average +/- one standard deviation given for 10 measurements. Approximate range given for fewer measurements.

3. Crestal irregularity was calculated from the longitudinal section showing moraine remnants east of the Animas River by counting changes in slope direction (up or down) along moraine crest and dividing by the total projected length of the moraine segments.

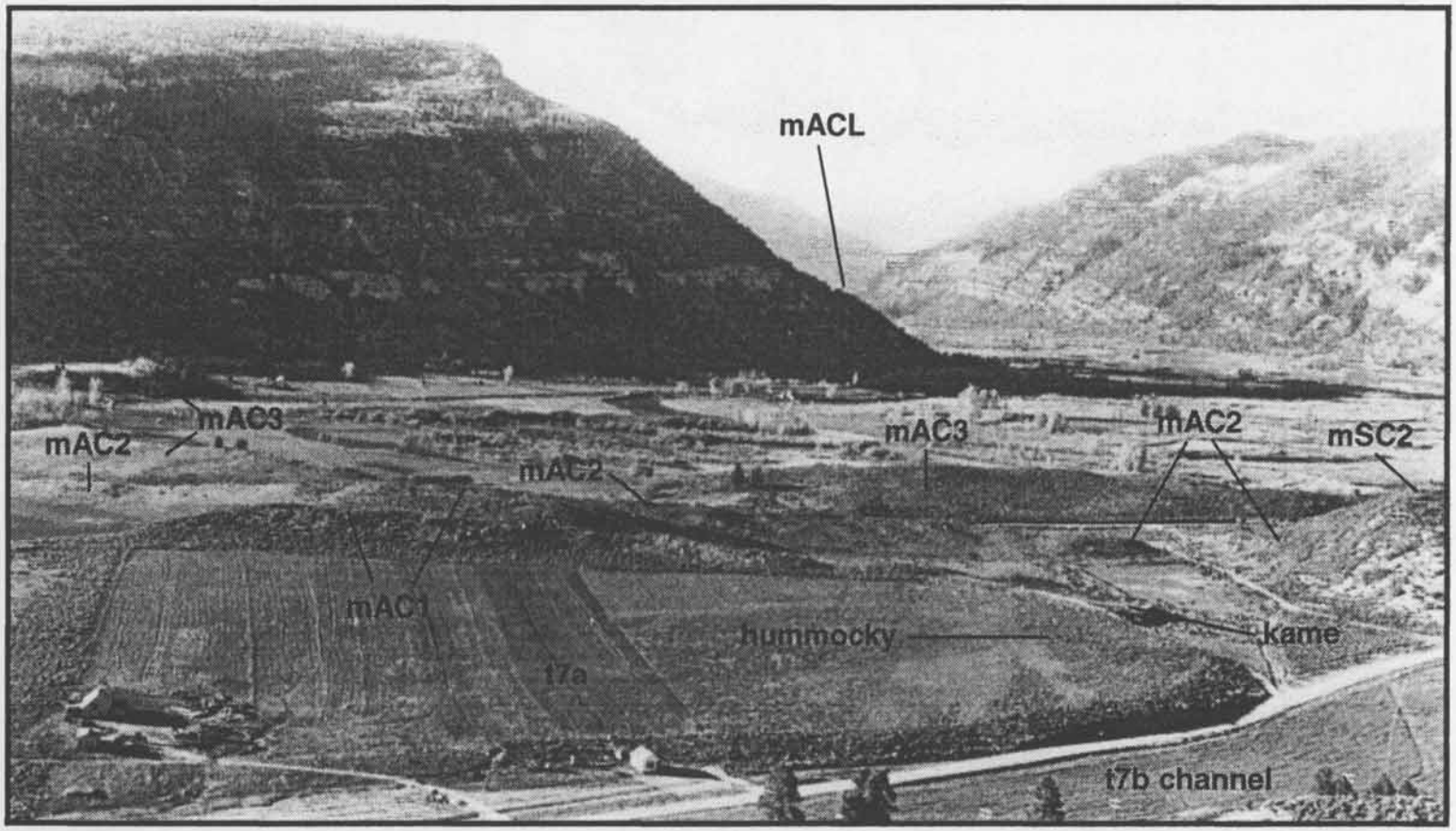


FIGURE 3.4 View north across Animas City moraines toward Animas City Mountain (on left) and U-shaped upper valley, from slope below Durango 2 moraine. Moraines and terraces labeled as in Figure 3.1. Channel – meltwater channel graded to Animas City 3 moraine; kame? – lobate extension from t7a into channel, possible kame terrace indicating former presence of stagnant ice in area between Animas City 3 and 2 moraines; hummocky – irregular area on part of t7a indicating possible outwash deposition over stagnant ice or erosional remnants of an older Animas City moraine. Animas City 3 moraine, possible kame terrace, and hummocky area were all excavated or regraded before construction of buildings that now cover the area. Photograph 1-7-57 from collection at Center for Southwest Studies, Fort Lewis College, date unknown.

called Spring Creek 2 and described below); however, he did not recognize the smaller one. Later workers accepted Richmond's age assignment (Harrington, 1970; Scott, unpublished), but three factors indicate that these segments record an earlier ice advance related to the Animas City moraine group. First, the crests of both segments are below the base of moraine sediments in nearby Spring Creek remnants (Figure 3.3). Also, the larger segment had well-preserved constructional forms that contrasted with more dissected forms of nearby Spring Creek remnants. The larger segment had several sharp, slightly sinuous crestal ridges (Figures 3.1 and 3.4), parts of which still existed when detailed topographic maps were made for the City of Durango in 1974. Finally, the adjacent outwash terrace is more like those of group TG7 (Chapter 4), which are graded to other Animas City moraines, than to those of TG6, which project to Spring Creek moraines.

Several other features may be related either to the Animas City 1 moraine or to an earlier, but now largely destroyed, moraine of the same group. These include a small spur ridge extending from a Spring Creek moraine segment (site 7 on Figure 3.1), a possible kame terrace (site 8), and a hummocky area on the terrace next to the western segment of Animas City 1 (site 9). The west slope of the spur ridge is smoother and steeper than other slopes of Spring Creek remnants, suggesting more recent abrasion during an ice advance. Diamicton at the southwest corner of this spur may have been deposited at this time. If so, fabric measurements at the "late Bull Lake" locality of Harrington (1970) may be in much younger Animas City deposits. Downvalley fining for surface sediments in this area also resembles trends for Animas City moraines (Harrington, 1970). The possible kame terrace is a relatively flat-topped, steep-sided lobe of sediment located where the east end of the larger Animas City 1 segment abuts its outwash terrace, in the regraded area near the intersection of Cedar Avenue and Holly Drive. Its position and shape suggest that it formed against stagnant ice which lay upvalley from the maximum advance which created the Animas City 1 moraine. Finally, a hummocky area on t6a (site 9 on Figure 3.1; Figure

3.4) may represent either lag remnants of moraine deposits from an earlier Animas City advance, or remnants of a kettled outwash surface.

Spring Creek Moraines

East of the Animas River, the Spring Creek moraines are located 50 to 250 m downvalley from the Animas City moraines. These moraines are segmented into isolated hills and broadly breached by the Animas River. Much of this erosion is due to meltwater and probably ice abrasion during construction of the Animas City moraines. These moraines were first recognized by Richmond (1965b), who correlated them with the Bull Lake Glaciation in the Wind River Range. Gillam and others (1984) renamed them for Spring Creek, which enters the Animas valley at the east end of the moraine loop, and reclassified one remnant as Animas City 1 moraine. Spring Creek moraines are distinguished by their position between Animas City and Durango moraines, crestal elevations that are below the bases of Durango moraine sediments, basal elevations that are above Animas City moraines, severe erosion, thin loess deposits, moderate weathering, and moderately developed soils.

Richmond (1965b) also identified several small ridges, benches and hills west of the river, 120 to 1500 m downvalley from the Animas City moraines, as Bull Lake moraines. Based on present forms and exposures, some of these features have been reinterpreted as terrace remnants and the origin of others is ambiguous.

Spring Creek 1 and 2 moraines east of river. Landforms widely accepted as moraine segments (e.g. Richmond, 1965b); Harrington, 1970; Scott, unpublished; Gillam and others, 1984; Johnson, 1990) include several isolated hills, most of which are elongated roughly parallel to more-continuous Animas City and Durango moraines (Figures 3.1, 3.2, and 3.3; Plate 1A). These hills are capped with moraine deposits 3 to 17 m thick. Their

lower slopes are underlain by Mancos Shale or Dakota Sandstone and are covered in places by thick colluvial or mass wasting deposits. Irregular distal slopes of the larger remnants are erosional features below the level of in-situ moraine sediments.

The number and locations of Spring Creek moraine crests are uncertain because of erosion, but the arrangement of segments suggests an outer moraine, designated Spring Creek 1, and an inner moraine, Spring Creek 2. Crestal elevations now range from 2051 to 2097 m (Figure 3.3). The thinness of moraine deposits, compared to those of the Animas City and Durango moraines, suggests that erosion has lowered the crests by tens of meters at least. Therefore, apparent crests may actually be erosional features carved from the middle and lower parts of the deposits, and may be offset laterally from the original crests. Basal elevations beneath the moraine deposits vary from 2051 m to approximately 2073 m.

Richmond (1965b) concluded that the Spring Creek 1 and 2 moraines represent two stades because they are related to different outwash terraces (t6a and t6b; Figure 3.1; Plates 1A and 2; Chapter 4). Detailed relations between the inferred moraine loops and terrace levels cannot be determined because erosional gaps between the closest remnants are 1.2 km for the older moraine-terrace pair and 2.0 km for the younger. However, different basal elevations for segments of Spring Creek 1 and 2 moraines indicate an interval of river incision, supporting Richmond's moraine-terrace correlations and an age difference between the two pairs.

Moraine features that suggest an intermediate age for the Spring Creek moraines, compared to Animas City and Durango moraines, include clast weathering (all schistose and some granitic clasts are grusified) and frequency of surface boulders (intermediate between those of Durango and Animas City moraines). The maximum gradients of former ice-contact slopes resemble those of Animas City moraines (Table 3.2), probably because of undercutting during formation of the Animas City moraines.

Spring Creek-Related Landforms of Uncertain or Nonglacial Origin

The following sections describe proposed Spring Creek segments that are recognized by some workers but not others. Several segments are reinterpreted here as terrace remnants, but the origins of others are now uncertain because of poor exposures.

Bench in College Mesa. Richmond (1965b) mapped a bench on the north side of College Mesa (Figure 3.1, site 10; Figure 3.2; Plate 1A) as early Bull Lake till, probably because it is roughly aligned with other deposits that he assigned to this unit. In contrast, Scott (unpublished; in Gillam and others, 1984) interpreted it as a block landslide because he observed a slip plane near its northeast end. Here, this feature is considered a terrace because 6 m of imbricated sandy gravel, interpreted as fluvial deposits, are exposed in a cut near its southwest end. The feature also has a relatively flat top that resembles a terrace tread and is roughly coplanar with several terrace remnants elsewhere in Durango (Plate 2). Scott's slip plane may be related to mass movements along the steep mesa scarp northeast of this feature.

Ridge between Arroyo Drive and Delwood Avenue. Near the west edge of the valley floor, a short, narrow ridge trends roughly north-south between Arroyo Drive and Delwood Avenue (Figure 3.1, site 11; Plate 1A). It is separated from the valley side by Dry Gulch arroyo and is bordered on the east by the floodplain of Junction Creek. Richmond (1965b) mapped this feature as an early Bull Lake moraine, probably because of its shape, height, and bouldery crest. However, the ridge's topography, deposits, and location suggest that it is a terrace remnant. Most of the ridge crest has been regraded for housing construction, but the undisturbed, wider part near the south end is flat-topped and roughly coplanar with several terrace remnants (Figure 3.1; Plate 2). The southern tip, which is lower and also flat-topped, resembles a fill-cut terrace. In limited exposures, deposits forming the ridge appear fluvial. For example, in soil profile CO23 (Table A.4), most of

the upper 1.8 m is composed of stratified sandy gravel that is clast-supported and contains 35 to 75 percent gravel. In a lower roadcut along Arroyo Drive, the deposits consist of unstratified sandy gravel with clast-supported cobbles and boulders. Finally, pebble fabrics at this site differ slightly from those at other moraine sites in the area (Harrington, 1970). The ridge's shape could reflect erosion by Dry Gulch arroyo and Junction Creek, rather than a constructional moraine form. The presence of shale at shallow depths beneath the ridge's western edge suggests that fluvial deposits aggraded against the valley side, and that the ridge's west slope was cut later by stream incision into shale.

Hills near Miller Junior High School. Extending south from the moraine-capped, bedrock spur at the south end of Animas City mountain is a hilly area that is bounded roughly by 28th Street, Pine Tree Way, Cottonwood Drive, and West Third Avenue (Figure 3.1; Plate 1A). From north to south, this area includes irregular slopes at the base of the spur (site 12 in Figure 3.1), a broad saddle under Miller Junior High School, and detached hills under and near St. Mark's Lutheran Church (site 13). The saddle probably marks a former course of Junction Creek. Several lower, narrow terraces that trend southward along the east flank of the area were cut by the Animas River, probably when it flowed along the base of the bedrock spur. Richmond (1965b) mapped sites 12 and 13 as late Bull Lake till, probably because of their bouldery surfaces and relative heights. Later workers accepted his interpretation (Harrington, 1970; Scott unpublished; Gillam and others, 1984), but the shapes of the hills and nature of underlying deposits suggest that they are actually terrace remnants. The hilltop at site 13 is broader and flatter than any part of the Animas City or Spring Creek moraine crests east of the river. Slopes along its northwest and east sides form a "V" that points toward the southeast corner of the bedrock spur and may have been cut by the Animas River as it followed different trends downstream from the spur. Deposits at and near site 13 are poorly exposed, but appear very gravelly. For example, in soil profile CO18 (Table A.4), most of the upper 2.5 m is stratified, sandy gravel that is

clast-supported and contains 50 to 85 percent clasts. Therefore, the detached, hilly area (site 13) appears to be underlain mainly by fluvial deposits with aggradational tops and undercut sides. Because this area is probably not a moraine segment, the origin of irregular topography at the base of the spur (site 12) is also questionable. Deposits in that area are poorly exposed and mostly disturbed, but they are tentatively interpreted as fluvial deposits of t6b because of their spatial relations to site 13.

Ridges near Valley View Drive. A small bench and ridge project from the southeast slope of Animas City Mountain in the area from Valley View Drive to 32nd Street (Figure 3.1, sites 14 and 15; Plate 1A). Richmond (1965b) mapped this area as early Bull Lake till and Harrington (1970) accepted this interpretation. Although Scott (unpublished) did not map moraines here, Moore (in Gillam and others, 1984) identified two moraine segments designated as Spring Creek 1 and 2. The origin of these landforms cannot be verified because both are now covered with homes, partly excavated, and very poorly exposed. On early aerial photographs, the ridge (site 15) has a distinct crest that descends gradually toward outwash terrace t7b from the Animas City 2 moraine. Its shape and old gravel pits in the north flank suggest that it could be part of an Animas City or Spring Creek moraine. Parts of the bench (site 14) are underlain by sandstone beds with a thin mantle of colluvial and alluvial deposits from Animas City Mountain. However, other parts may once have appeared moraine-like.

Durango Moraines

The Durango moraines are preserved mainly east of the Animas River on a large bedrock bench, locally known as College Mesa, that extends northeast from Fort Lewis College (Figures 3.1 and 3.2; Plate 1A). A small, eroded remnant also caps a spur west of river. In previous studies, Atwood and Mather (1932) designated deposits of these

moraines as the type Durango Till (Table 3.1). Richmond (1965b) correlated them with the Sacagawea Ridge Glaciation in the Wind River Mountains. Scott (unpublished; in Gillam and others, 1984) subdivided the moraines on College Mesa into an outer group and a single inner moraine on the basis of cross-cutting crestal relations. Comparable basal elevations suggest that the remnant west of the river correlates with the inner moraine.

The Durango moraines are distinguished from younger moraines by their position farthest downvalley, higher crestal elevations, basal elevations that are above the crests of younger moraines, rounded shapes, broad breaching by the Animas River, thick loess deposits, moderate weathering, and strongly developed soils.

Durango 1 moraines. On College Mesa, the outer moraines form a complex with three major ridge crests. The older two moraines are roughly parallel to the trend of the bench and the youngest truncates them obliquely. A small reservoir now occupies part of the intervening depression. Crestal elevations vary from 2100 to 2130 m, but were probably lowered during erosion that rounded and broadened the crests. Elevations of the basal bedrock contact are poorly known, but it is at 2095 m in a boring at the reservoir's water filtration plant (San Juan Testing Laboratory, Inc., 1978; Figure 3.1, site 16; Figure 3.2) and at about 2091 m near the south end of Hillcrest Drive (site 17).

Durango 2 moraine. The single inner moraine forms a prominent, slightly curving ridge along the north edge of College Mesa. Subsequent lateral erosion of the mesa's scarp has divided the ridge into two segments. Crestal elevations from 2128 to 2146 m broadly resemble those for the outer moraines. Basal elevations in exposures along the edge of the bench vary from 2063 to 2091 m. Although this range overlaps with basal elevations for the outer moraines, basal elevations beneath most of the inner moraine appear lower. These differences could suggest either relief on the subglacial bedrock surface, or an episode of bedrock incision between deposition of the inner and outer moraines. A

previously stated basal elevation of 6670 ft (~ 2033m, Gillam and others, 1984) for the Durango 2 moraine is incorrect.

Many features of the Durango moraines indicate that they are older than the Spring Creek and Animas City moraines (Table 3.2). Both the outer and inner moraines have relatively broad crests and smooth shapes that lack undrained depressions. Crestal widths are 20 to 40 m for the outer moraines and 10 to 30 m for the inner moraine. Maximum gradients of former ice-contact slopes have decreased to 18 to 24 degrees. Crestal rounding, topographic smoothing, and reduced slope gradients probably reflect a combination of processes including erosion of moraine deposits, loess deposition, and colluviation. Loess thicknesses vary greatly. On moraine crests, loess is a few centimeters to more than 2 m thick (Appendix A, soil profiles CO26, CO27, CO31, and CO32). Similar deposits are approximately 9 m thick in two borings and more than 16.5 m thick in a third boring at the city reservoir (San Juan Testing Laboratory, Inc., 1978; Figure 3.1, site 16). Thicknesses from 3 to 6 m are probably common, and larger thicknesses in depressions, like those at the reservoir, may reflect reworking of loess as slopewash. Soils have strongly developed argillic horizons that are 50 to 80 cm thick on moraine crests and 120 to 180 cm thick on backslopes. All schistose clasts and most granitic clasts are grusified.

Moraines and Related Features North of Durango

Glacial Lake Durango

A relatively flat "park," floored with postglacial alluvium, extends north from the Animas City 3 moraine for 21 km to a bedrock step in the valley floor above Bakers Bridge (Plates 1A and 2). As ice retreated from the moraine, a proglacial lake formed in the lower part of this reach and later filled with sediments (Atwood and Mather, 1932). Although

lacustrine sediments and shoreline features are buried by younger main-river and side-stream alluvium, several kinds of evidence indicate that the lake existed. These include the very low valley-floor gradient north of the moraine, approximately 0.7 m/km; increases in the river's gradient at the upper and lower edges of the Animas City moraine belt, showing that coarse sediment winnowed from the moraines has armored the lip of the ice-scoured bedrock basin; and thick, silty to sandy sediments in water wells. The north edge of the lake was probably near Hermosa (Johnson and Gillam, 1995), where the valley floor steepens and buried, resistant bedrock units (Lee and others, 1981) rise northward to near the lake's inferred outlet level at the Animas City 3 moraine.

The thickness of postglacial sediment in this reach apparently varies, but is locally great in the southern part, as defined by the depths of water wells and an exploratory gas well. The gas well, drilled about 5 km north of Durango in 1926, is poorly documented but may have penetrated more than 900 ft (275 m), 800 ft (245 m), 600 ft (180 m), or 440 ft (134 m) without reaching bedrock, as reported by various authors (Latch and Kilgore, 1971; Lauth, 1972; Blair and others, 1996, p. 256; and Maher, 1961, respectively). The last figure (based on oral communication from Walter Osterhaudt, a nearby resident) may be the most accurate. Several water wells in this area also penetrate to depths near 150 m (Butch Knowlton, La Plata County Building Department, oral communication, 1996).

The deepest sediments in the ice-scoured basin have not been reached, but could include lodgement till, melt-out till, and ice-rafted debris. Shallower sediments observed in water wells, generally less than about 75 m deep, become finer downvalley, varying from sandy cobble gravel near Bakers Bridge to silt and very fine sand with rare pebbles and many wood fragments near Durango. Upward coarsening in some wells records the downvalley progradation of fluvial deposits.

Recessional and Lateral Moraines

Recessional moraines, lateral moraines, eroded remnants of till, and ice-stagnation features are present in places from Durango to contributing cirques (Howe and Cross, 1906; Atwood and Mather, 1932; Carrara and Andrews, 1975; Leonard, 1989; Small, 1995), but few have been studied in detail. Most recessional moraines are in tributary valleys (Atwood and Mather, 1932). Lateral moraines occur intermittently along both sides of the Animas valley from the terminal moraines to Mountain View Crest on the east and Engineer Mountain on the west (Howe and Cross, 1906; Leonard, 1989). Some of the younger lateral moraines enclose lake or stream sediments that may have potential for pollen studies and radiocarbon dating.

Bakers Bridge area. Two moraine-like ridges of till are present at the north end of the alluviated reach, both above and below a 60 to 80 m bedrock step in the valley floor (Plate 1A). Atwood and Mather (1932) mapped "Wisconsin till" along a narrow ridge above the step at elevations of 2130 to 2260 m. This ridge is at the summit of a small cuesta formed by resistant limestone beds, so the ridge may be a hogback that is thinly covered by glacial deposits, or "palimpsest" moraine. The western deposit in this area is roughly aligned in map view with other ridge segments that are located below the bedrock step at about 2070 m. Richmond (1965b) interpreted the lower segments, which are underlain by till, as a recessional moraine of late Pinedale age and later (1986b) called it the Bakers Bridge moraine. From detailed studies of roadcuts along old U.S. Highway 550, near soil profile CO2 (Table A.4), Johnson (1990) found that sediment in part of the lower ridge is lodgement till that accumulated under active ice (Chapter 5). The term "Bakers Bridge moraine" is used here with quotation marks because the present ridge form could be either constructional and related to local ice flows, or erosional and shaped by adjacent streams (Mark D. Johnson, Gustavus Adolphus College, oral communication, 1998).

Falls Creek area. A small, unnamed valley parallels the west side of the Animas valley for several kilometers from Hermosa Creek to Animas City Mountain, where it turns west and joins Junction Creek (Plate 1A). The north end of this valley is a bench with rolling hills traversed by Falls Creek. Downstream, most of the valley has a broad, unchanneled floor that is confined between bedrock ridges and cuestas. Atwood and Mather (1932) mapped "Wisconsin till" in the form of extensive lateral moraines on the northern bench and as smaller terminal moraines in the confined valley both upstream and downstream from Chapman Lake, a small reservoir. They concluded that a lobe of the Animas glacier flowed down the valley to the present reservoir area. Later, Richmond (1965b) designated the "terminal moraines" as early and middle Pinedale till. However, Moore and Gillam (1984) reinterpreted the ridges near Chapman Lake as remnants of landslide debris because the deposits contain only local rock types and large landslides cover adjacent slopes. Irregular spurs along the west side of the valley, between the lateral and supposed "terminal" moraines, indicate that ice did not extend as far as Atwood and Mather thought. Conversely, the valley's breadth and the meandering planform of its west-trending reach indicate large water flows. Discharge was probably great because the valley carried not only ice-marginal meltwater, but also the diverted flow of Hermosa Creek, the largest tributary of the Animas River north of Durango (Moore and Gillam, 1984). Undercutting along the outsides of valley bends probably initiated landslide activity during glaciation. Recent valley-floor alluvium probably buries outwash and deposits that accumulated in a landslide-dammed lake. Comparison with the Animas City moraines suggests that any terminal moraines in this valley were either eroded by meltwater, or small enough to be buried by younger deposits.

Moraines in Other Parts of the San Juan Mountains

In addition to the three moraine groups in Durango, two younger groups and possibly one older group have been recognized elsewhere in the San Juan Mountains (Table 3.1). No Neoglacial moraines are present, but Grenadier or Yankee Boy moraines occur in some cirques at distances of 0.4 to 2 km from the headwalls (Carrara and Andrews, 1975). Diamictons older than the Durango moraines have been called the Cerro Till (Atwood and Mather, 1932; Richmond, 1954) or the Horsefly Peak Till (Sinnock, 1978, 1981). However, the type Cerro Till consists of landslide deposits (Dickinson, 1965) and the glacial origin of other diamictons is unproved (Richmond, 1986b). As in many mountain ranges, the absence of older moraines is due to erosion in topographically confined or steep areas. In the San Juan Mountains, large areas at high elevations promote ice accumulation, so extensive glaciers should have formed whenever the ELA declined to levels like those of recent glaciations (Leonard, 1989).

CHAPTER 4

TERRACE SEQUENCE

Terraces extend along the Animas River from the glacial moraines in northern Durango to the San Juan River at Farmington, for a distance of about 80 km. Although most terraces are near the river's present course, isolated remnants occur on or near modern drainage divides. Small terraces also exist near Bakers Bridge, 20 km north of Durango. While this study focuses on terraces of the Animas River, some terraces of the La Plata, Florida, and San Juan rivers are included where they merge with or are near Animas River terraces. This chapter describes terrace remnants and their correlations within the study area. By establishing approximate time lines, correlations show progressive changes in the longitudinal profile and course of the river. Their patterns also record controls on river behavior, such as climatic cycles and tectonic uplift.

During the period reflected in the terrace sequence, the Animas River has incised episodically into bedrock. This long-term channel incision was interrupted by intervals of stability or aggradation, when fluvial deposits accumulated on the valley floor in larger volumes. Renewed incision and topographic reversal have left remnants of these deposits as terraces along valley sides, on hilltops, or on major divides.

Thirty-four existing terraces have been identified, but their original extent and significance vary (Table 4.1). Twenty-two levels represent periods when stable or aggrading river profiles existed throughout the area. Twelve levels reflect local profile adjustments of two types. The first involves local incision below a part of a stable or aggrading profile, without change along the rest of the profile. After later incision, this

TABLE 4.1 SUMMARY OF TERRACE FEATURES AND DISTRIBUTION

TERRACE	HOGBACK MONOCLINE - NORTH FLORIDA MESA					BONDAD - CEDAR HILL AREA					FLORA VISTA - N. FARMINGTON AREA				
	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)
t1u	?	?	0	≥488	--	strath or thin fill	4 - 7	4	348 - 418	--					
t2a						strath	2 - <8	2	360	--					
t2b						strath	1.5 - 5	3	344	6.9					
t2c						strath	4 - 5	3	320	7.3					
t2d						strath	3	3	305	7.8					
t2e						strath	3	1	299 - 302	5.5					
t2f						strath	8	1	262 - 265	5.3					
t2g						fill	22 - 27	2	252 - 256	5.8					
t2h											strath	2 - 3	2	183	--
t2i											strath	5	2	177	--
t3a											strath	3 - 4	3	119 - 122	4.7
t3b											strath	3 - 6?	2	107 - 110	4.7
t4a	fill	6 - 33	8	174 - 186	9.4	fill	6 - 46	3	119 - 122	<5.1* - 7.3					
t4b	fill and fill-cut	2 - 34	8	162 - 165	7.7	thin fill, fill-cut & strath	4 - 12?	2	107 - 116	<5.7* - 6.6	strath	4 - 8	3	85 - 91	4.9
t4bx						fill-cut	1.5 - 5	2	110 - 113	~6.6					
t4c	fill	>9 - ≥35	4	152 - 159	7.7										
t4d	fill and fill-cut	2 - 31	16	140 - 143	7.7	thin fill	4 - 12	5	91 - 98	<4.7* - 5.3	strath	3 - 7	3	73	4.2
t4e						strath	4 - 7	3	76	<5.6* - 5.3	strath	2	1	55 - 61	3.7
t4ex											strath	≤2	1	49	3.6

TABLE 4.1 SUMMARY OF TERRACE FEATURES AND DISTRIBUTION, continued.

TERRACE	HOGBACK MONOCLINE - NORTH FLORIDA MESA					BONDAD - CEDAR HILL AREA					FLORA VISTA - N. FARMINGTON AREA				
	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)	TYPE	GRAVEL THICKNESS (m)	no. of obs.	HEIGHT, GRAVEL TOP (m)	AVE. GRAD-IENT (m/km)
t5a	fill	6 - >38	13	125 - 131	8.6	strath	?	0	abs. - 67	–	strath	2 - 6	2	43 - 46	4.7
t5b	fill	2 - ≥43	9	116 - 119	8.1										
t5c	fill or fill-cut	2 - >46	5	116	7.5										
t5d	fill or fill-cut	16 - 24	23	107 - 110	6.7										
t5e	fill or fill-cut	23 - 39	10	104 - 110	6.1	fill and strath	2 - 12	19	32 - 79	6.4					
t6a	fill & fill-cut	2 - 18	14	35 - 47	6.9	strath	2 - 3	2	35 - 43	–	strath, fill-cut	1.5 - 8	6	27 - 34	4.2
t6b	fill & fill-cut	1 - 14	12	26 - 36	6.9	strath	1 - 4	1	26 - 30	4.9	strath	2 - 3	4	18 - 30	4.5
t7a	fill & fill-cut	1.5 - 24	5	18 - 21	7.5	t7ab strath, fill, fill-cut	1 - 15	11	9 - 27	4.2	t7u strath	not exposed	0	<3 - 15	3.5
t7b	fill & fill-cut	1 - 9	18	12 - 15	6.2										
t7c	fill-cut & strath	1 - 3	2	6 - 9	6.9	strath	2 - 4	2	6 - 12	–					
flood plain	strath	2 - 5	2	–	7.0	strath	2 - 4	2	–	3.9	strath, thin fill?	3 - 9	3	–	4.5

Notes:
* Gradient estimated by connecting widely spaced remnants.
Shading or "abs." indicates terrace absent from area.

process leaves two terraces in the adjusted reach, which merge in adjacent reaches. The second type of adjustment involves pauses in incision from one widespread terrace level to the next. This process creates terraces of very limited extent that are often located upstream from resistant rock units.

Although flights of terraces are prominent in most areas and some levels are well preserved locally, no level appears continuous throughout the study area because of merging, partial erosion, or poor exposures. Based on patterns of terrace preservation, maximum heights above the modern river (regardless of specific level) are 107 m at Durango, 195 m in the upper Hogback area, possibly 482 m at the northern Mesa Mountains, 372 m near Aztec, and 189 m in Farmington. Minimum heights are usually about 6 m but range from 15 m to near flood-plain level.

Terrace types include fill, fill-cut and strath surfaces. Generally, fill and fill-cut terraces merge near Durango, fills thin downstream, and straths dominate the lower reaches. The age of most remnants is late or middle Pleistocene, but a few remnants are Holocene, early Pleistocene, Pliocene, and possibly late Miocene (Chapter 7).

Previous Work and Nomenclature

Early workers located most terrace remnants, briefly desribed some deposits, and estimated relative ages (Tables 4.2 and 4.3), but miscorrelations and scale differences limit the usefulness of their work. Errors arose from varying detail, failure to recognize all terrace levels, poorly known terrace heights, and misidentification of some reworked deposits as primary terrace gravels. Therefore, these studies overlooked or de-emphasized important regional patterns such as terrace convergences, divergences, and intersections, and preservation of specific levels in some reaches but not others. Because of differing correlations, some terraces identified in this study include remnants that other workers

TABLE 4.2 COMPARISON OF COLORADO TERRACE STUDIES

Howe and Cross (1906) Durango to state line	**Atwood and Mather (1932)** San Juan Mountains to state line	**Richmond (1965b)** Durango to state line	**This Study** Durango to central Farmington
not studied, but predicted	Bridgetimber Gravel [as mapped, it includes fluvial gravels of Animas, La Plata and Los Pinos rivers, many redeposited gravels, and a few areas of bedrock- derived residuum]	Bridgetimber Gravel (restricted to La Plata River gravels) and some deposits of Bayfield Gravel; Washakie Point outwash	Bridgetimber Gravel
		gravel on the Mesa Mountains; Cedar Ridge outwash [includes many redeposited gravels]	t1u
[absent]	[absent]	[absent]	t2a
[absent]	[absent]	[absent]	t2b
[absent]	[absent]	[absent]	t2c
[absent]	[absent]	[absent]	t2d
not studied, but predicted	[not recognized]	[not recognized]	t2e
[absent]	[absent]	[absent]	t2f
not studied, but predicted	[not recognized]	[not recognized]	t2g
[absent]	[absent]	[absent]	t2h
[absent]	[absent]	[absent]	t2i
[absent]	[absent]	[absent]	t3a
[absent]	[absent]	[absent]	t3b
high terraces	Florida Gravel; outwash of Cerro glaciation [older than Durango moraines]	Florida Gravel; early Sacajawea Ridge outwash [unclear if he projects to or above Durango moraines]	t4a t4b [older than Durango moraines]
	outwash of Durango glaciation [Durango moraines]	Florida Gravel; late Sacagawea Ridge outwash [Durango moraines; map incorrectly shows most as Bull Lake outwash]	t4bx t4c t4d t4e
[absent]	[absent]	[absent]	t4ex
high and intermediate terraces [Durango moraines not recognized]	outwash of Durango glaciation	Florida Gravel; late Sacagawea Ridge outwash [Durango moraines; map incorrectly shows most as Bull Lake outwash]	t5a t5b t5c t5d [outwash of Durango moraines]
[absent]	[absent]	[absent]	t5u
high and intermediate terraces [as above]	outwash of Durango glaciation	Florida Gravel [as for t5a-t5e]	t5e
	interglacial terrace or not recognized? [as below]	not recognized?	t5ex
intermediate and low terraces [Spring Creek moraines not recognized]	text describes as interglacial, but map includes with Wisconsin outwash [Spring Creek moraines not recognized]	Bull Lake outwash (2 levels) [map shows most incorrectly as Pinedale and Neoglacial outwash]	t6a t6b [outwash of Spring Creek moraines]
low terraces [Animas City moraines]	outwash of Wisconsin glaciation [Animas City moraines]		t7a
		Pinedale and Neoglacial outwash [part related to Animas City moraines]	t7b t7c [outwash of Animas city moraines]
absent	Qal (modern alluvium) [not divided from flood plain]	absent	t8a t8b t8c t8d

( ) encloses information from author [ ] encloses clarification based on this study

TABLE 4.2 COMPARISON OF COLORADO TERRACE STUDIES, continued

Moore and Scott (1981) Basin Mountain 7-1/2' quadrangle	**Scott (unpubl., ca. 1978)** Durango to northern Florida Mesa	**Gillam and others (1984)** Durango to northern Florida Mesa	**Gillam and others (1985)** Durango to northern Florida Mesa	**This Study** Durango to central Farmington
Bridgetimber Gravel	[absent]	[absent]	[absent]	Bridgetimber Gravel
[absent or not recognized]	[absent] Nebraskan (?) outwash	[absent]	[absent]	t1u
[absent]	[absent]	[absent]	[absent]	t2a
[absent]	[absent]	[absent]	[absent]	t2b
[absent]	[absent]	[absent]	[absent]	t2c
[absent]	[absent]	[absent]	[absent]	t2d
[absent]	[absent]	[absent]	[absent]	t2e
[absent]	[absent]	[absent]	[absent]	t2f
[absent]	[absent]	[absent]	[absent]	t2g
[absent]	[absent]	[absent]	[absent]	t2h
[absent]	[absent]	[absent]	[absent]	t2i
[absent]	[absent]	[absent]	[absent]	t3a
[absent]	[absent]	[absent]	[absent]	t3b
[absent]	Florida Gravel; Kansan outwash	tK	3a1	t4a [older than
[absent]		tJ	3a2	t4b Durango moraines]
[absent]	[absent]	[absent]	[absent]	t4bx
[absent]	most Florida Gravel; some not recognized	tI	3b	t4c
Illinoian (?) outwash		tH	3c1	t4d
[absent]	[absent]	[absent]	[absent]	t4e
				t4ex
Illinoian (?) outwash	Illinoian outwash (2 levels)	tG	3c2, some 3b1?	t5a [outwash of
		tF, some tE	3d1 and 3d2	t5b Durango
		tE, some tF	3d2, some 3d1	t5c moraines]
[absent]		tE, some tD [D1 moraine]	3d2 and 3d3	t5d
[absent]	[absent]	[absent]	[absent]	t5u
Illinoian (?) outwash	Illinoian outwash (lower level than above)	tD [D2 moraine]	3d3	t5e
[absent]	[absent]	[absent]	t4a2 (labelled t4b2 in Fig. 3.2A]	t5ex
Bull Lake (?) outwash (undivided)	Bull Lake outwash (2 levels)	tC1 [SC2 moraine]	4a1	t6a [outwash of Spring Creek
		tC2 [SC1 moraine]	4a2, 4a3	t6b moraines]
		TB1 [AC1 moraine]	4b1	t7a [outwash of Animas
Pinedale (?) outwash (undivided)	Pinedale outwash (2 levels)	tB2 [AC2 moraine]	4b2	t7b city
		tB3 [AC3 moraine]	4b3	t7c moraines]
absent	absent	absent	absent	t8a
				t8b
				t8c
				t8d

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TABLE 4.3 COMPARISON OF NEW MEXICO TERRACE STUDIES

Pastuszak (1968) central Farmingon	**Bandolan (1968, 1969)** all except central Farmington	**Brown (1976); Brown and Stone (1979)** state line to Aztec (Aztec 15' quadrangle)	**Scott (unpubl., ca. 1978)** state line to Aztec (Aztec 15' quadrangle)	**This Study** Durango to central Farmington
[absent]	[absent]	[absent]	[absent]	Bridgetimber Gravel
[absent]	[absent or not recognized]	Qtp [some not recognized; includes some reworked gravels]	Bridgetimber Gravel [some not recognized]	t1u
[absent]	Mesa Mountain surface [includes some reworked gravel] (Ditch Canyon surface includes some reworked gravel)	Qtp; Mesa Mountain surface (Ditch Canyon not a single geomorphic surface; all gravel reworked)		t2a
[absent]				t2b
[absent]				t2c
[absent]				t2d
[absent]			Nebraskan outwash [unclear]	t2e
[absent]			Nebraskan outwash	t2f
[absent]	[absent]	[absent]	[absent]	t2g
Hood Mesa	[absent]	[absent]	[absent]	t2h
Twin Mounds	[absent]	[absent]	[absent]	t2i
	Aztec (type), some Arch Rock	[absent]	[absent]	t3a
Martin Mesa	Arch Rock (type)	[absent]	[absent]	t3b
[absent]	Arch Rock	Qtp (terrace and pediment deposits) [some not recognized or shown where buried; most levels re-recognized undivided on map.	Illinoian outwash [Kansan outwash consists of reworked gravels]	t4a [older
Martin Mesa	Arch Rock and [Aztec] Airport (type)			t4b than Durango moraines]
[absent]				t4bx
	[absent]	[absent]	[absent]	t4c
Farmington Airport	[Aztec] Airport	Qtp [as above]	Illinoian outwash, Illinoian outwash (?)	t4d
[absent]	Cedar Hill (type) and [Aztec] Airport		Illinoian outwash (?)	t4e
	Cedar Hill		[absent]	t4ex
Farmington Airport	Bald Mesa (type) and Cedar Hill [one not recognized]		Illinoian outwash (?) Bull Lake outwash (?)	t5a [outwash
[absent]	[absent]	[absent]	[absent]	t5b of Durango
[absent]	[absent]	[absent]	[absent]	t5c moraines]
[absent]	[absent]	[absent]	[absent]	t5d
[absent]	Bald Mesa and Cedar Hill	Qtp [as above]	Bull Lake outwash (?) some not recognized	t5u
[absent]				t5e
[absent]	Cedar Hill or not recognized		Bull Lake outwash (?) or not recognized	t5ex
Jackson Lake	Terrell Ditch (type) and Bald Mesa [some not recognized]		Bull Lake outwash; some not recognized	t6a [outwash of Spring
				t6b Creek moraines]
"recent" [not divided from flood plain]; some Jackson Lake	"present valley alluvium" [not divided from flood plain]	"valley fill alluvium" [not divided from flood plain]	Pinedale outwash	t7a [outwash
				t7b of Animas
				t7c City moraines]
	absent	absent	absent	t8a
				t8b
				t8c
				t8d

( ) encloses information from author [ ] encloses clarification based on this study

TABLE 4.3 COMPARISON OF NEW MEXICO TERRACE STUDIES, continued

Manley and others (1978, 1987) state line to Aztec (Aztec 1x2 degree quadrangle)	**Gillam and others (1985)** state line to Cedar Hill; Flora Vista to NE Farm	**Ward (1990)** S of Aztec to Farm. (Farm. 30x60' quad.)	**Love and Gillam in Patton and others (1991)** Durango to central Farmington	**This Study** Durango to central Farmington
[absent]	[absent]	[absent]	Bridgetimber Gravel	Bridgetimber Gravel
Bridgetimber Gravel [some not recognized]	t1a	[absent]	t1u [at least 2 levels, undivided]	t1u
	t1b	[absent]	t2u [at least 6 levels, undivided; 7 levels on Plate 3]	t2a
		[absent]		t2b
	t1c	[absent]		t2c
	t1d	[absent]		t2d
[not shown]	t1e	[absent]		t2e
[not shown]	t1f	[absent]		t2f
[absent]	[absent]	[absent]		t2g
[absent]		Q1		t2h
[absent]				t2i
[absent]	t2a	Q3a and Q3b	t3u [2 levels, undivided]	t3a
[absent]	t2b	Q3b, some Q3c		t3b
Qg (outwash and pediment gravel) [undivided]	[absent]	[absent]	t4u [6 levels, undivided; 9 levels including those below]	t4a [older
	t3a and t3a1	Q3c, some Q3b and Q4a		t4b than Durango moraines]
	t3a2	[absent]		t4bx
	[absent]			t4c
	t3b and t3c	Q4a, some Q3b and Q3c		t4d
	t3c	Q4c, some Q3c and Q4d		t4e
[absent]	t3d1	Q4c and Q4e		t4ex
Qg [undivided]	t3d2	Q4d, Q4e, Q4f		t5a [outwash
[absent]	[absent]	[absent]	t5u [3 levels, undivided; text includes in group 4]	of
[absent]	[absent]	[absent]		t5b Durango
[absent]	[absent]	[absent]		t5c moraines]
Qg [undivided]	[absent]	[absent]		t5d
	t3d, t3d1	[absent]		t5u
				t5e
	t3d, t3d2	[absent]		t5ex
	t4a1, one 4a2	Q5b, some Q6a or not recognized	t6u [4 levels, undivided; text describes as group 5]	t6a [outwash of Spring
	t4a2, one t4a3			Spring
				t6b moraines]
Qal (alluvium on valley floor and lowest terraces) [not divided from flood plain]	t4b; some undivided from younger alluvial fans	Q6a, Q6b, Qnt (Naja and Tsegi Alluviums), Qcf (channel and flood-plain alluvium)	t7u [4 levels, undivided; text describes as group 6]	t7a [outwash of Animas
				t7b City
absent	absent			t7c moraines]
				t8a
				t8b
				t8c
				t8d

( ) encloses information from author [ ] encloses clarification based on this study

assigned to two or more levels. The correlations given here also vary slightly from those in preliminary reports (Gillam and others, 1984; Moore and Gillam, 1984; Gillam and others, 1985; Love and Gillam in Patton and others, 1991).

In earlier systems of nomenclature, some workers named terrace deposits while others named landforms (Tables 4.2 and 4.3). These schemes include formal lithostratigraphic names for fluvial gravels, taken from local features (e.g. Florida Gravel; Atwood and Mather, 1932); lithostratigraphic names for glacial deposits in the Wind River Mountains, applied informally to fluvial gravels (e.g. Pinedale outwash; Richmond, 1965b); formal morphostratigraphic names for terraces, taken from local features (e.g. Airport terrace; Bandoian, 1969); chronostratigraphic names for glaciations in the Midwest, applied informally to fluvial gravels (e.g. Illinoian outwash; G.R. Scott, U.S. Geological Survey, unpublished mapping); and informal morphostratigraphic names adapted from earlier versions of the system used here (e.g. t4a; Ward, 1990).

Rather than redefining earlier names, this report introduces informal morphostratigraphic names based on number-letter combinations. Numbers indicate relative-age groups of terraces, whereas letters indicate single levels within each group. Reasons for this two-tiered system are that grouping simplifies discussions of common features, and that group assignments may be more certain than level assignments. Groups are defined on the basis of regional height relationships, present distribution, associated moraines (Chapter 3), and soil development (Chapter 6). Levels are defined by relative height within the group, gradient, continuity, and relation to underlying gravel bodies.

In this system, the oldest group has the number "1" (based on conventions of the U.S. Geological Survey) and the oldest level in each group has the letter "a." The suffix "u" usually indicates undivided remnants of multiple levels that are either too poorly preserved or exposed for subdivision, or too small to be shown separately on Plates 1 and 2. However, it is also used for levels that cannot be correlated reliably to one of several levels

in another reach. The suffix "x" indicates remnants with limited distributions that probably formed during pauses in incision.

Where two terraces merge, the name of the lower terrace is used downstream from the intersection because of relative surface ages. In this case, the higher terrace upstream and the single terrace downstream begin to form at the same time, but when the lower terrace forms upstream, the downstream terrace is sill being reworked. After further incision and abandonment of all segments, the lower terrace upstream and the single terrace downstream are closer in age although all surfaces are diachronous. If the initial profile represents a fill terrace, names for terraces that represent the maximum fill level will change among reaches upstream and downstream from intersection points.

Mapping and Correlation Issues

What is a Terrace?

The term "terrace" is used here for the relatively flat top of a fluvial deposit, regardless of any overlying, non-fluvial deposits and their surface forms, if present. The top of fluvial deposit, usually consisting of sandy gravel (Chapter 5), fits the definition of a terrace because it is a surface or buried landform.

By definition, a river terrace is an abandoned flood plain (the term refers to the landform, not to fluvial deposits that are implied to be present). Young terraces are relatively planar surfaces that slope downstream at gradients reflecting former river processes. Older terraces are progressively modified in varying ways that usually include erosional dissection and burial by non-fluvial deposits. Where overlying deposits are thin in relation to vertical separations between terraces, the deposits do not interfere with terrace mapping and correlation. Therefore, many workers have used the terms "terrace"

and "terrace deposits" informally to indicate composite landforms and sediment sections, while emphasizing the fluvial phases of their origin.

In the Animas valley, however, overlying sediments (mainly side-stream alluvium, but also colluvial, eolian, and other deposits) can be so thick that they must be treated consistently for accurate terrace mapping and correlation. Their total thickness often exceeds 10 m and locally reaches 45 m. Related landforms, including alluvial fans, colluvial slopes, and eolian ramps or dunes, are influenced by buried terraces but generally slope toward modern streams and have dissimilar surface relief. Where non-fluvial deposits hide the scarps between buried terraces, the number of terrace levels and their heights cannot be determined easily from present landforms on topographic maps and aerial photographs. Even where an alluvial fan covers a single terrace remnant, the important height for correlation is that of the gravel top. If correlations are based on modern surface heights, which include varying thicknesses of non-fluvial deposits, errors will result. These two issues – mapping buried terraces from modern landforms and using inconsistent datums to estimate terrace heights – explain many differences in terrace mapping and correlation between this and earlier studies.

Terrace levels are subdivided if they can be distinguished consistently in part of the study area. For example, the tops of fluvial deposits exhibit local relief at varying scales. On younger and better-exposed deposits, local relief of 2 to 5 m is due to small-scale, constructional and erosional features such as bars, scours, and channels. Areas with slightly different average elevations can be traced for short distances but not across erosional gaps. Therefore, areas with local relief equaling about 6 m or less are treated here as complexes of constructional and erosional surfaces that form a single terrace level. Where younger deposits bury fluvial gravels, such small-scale relief is visible only in very good exposures, and the gravel top usually appears in scarps as a break in slope that is rounded by erosion and exposed discontinuously. In these areas, average heights for gravel

tops can be traced reliably and separate terraces can be identified if their heights differ by more than about 6 m.

Terraces are classified by the thickness of fluvial deposits, shape of the sub-alluvial contact, and implied processes of fluvial aggradation, lateral cutting, and incision (e.g. Howard, 1959; Bull, 1991). The basic terms used here are fill, full-cut, and strath (Leopold and Miller, 1954). Overslag terraces are fill terraces with strath-like extensions at their tops (Zonnefeld, 1975). In practice, accurate classification depends on the length, location and orientation of exposures and may be impossible for some remnants (e.g Ritter and others, 1995). For example, the eroded edge of a fill or overslag terrace could look like a strath. In this study, classification is based either on cross sections of gravel bodies or on random measurements of gravel thickness. Highly variable thicknesses probably indicate fill terraces. Typical scour depths for the Animas River are unknown, but relatively consistent measurements of about 5 m or less probably indicate straths.

Idealized terrace types reflect simple sequences of vertical incision to the sub-alluvial contact, followed by either stability with strath cutting or aggradation to a fill surface, and finally abandonment by further incision that isolates the surface from fluvial action. However, many terrace deposits may contain internal unconformities that record more complex sequences of events (e.g. Leopold and Miller, 1954). In the Animas valley, for example, composite gravel bodies may extend continuously beneath several adjacent terraces. The basal contacts and upper surfaces of these bodies have irregular shapes that may record larger aggradational and incision events, but internal unconformities that could identify smaller events are rarely visible because of poor exposures and the relative uniformity of most deposits.

Informal terms are also defined here for clarity. Gravel bodies with shapes and relative positions that suggest they formed independently are called "distinct." "Height" means the difference in elevation between a terrace and the modern channel, as measured

along a projection line that is roughly perpendicular to the river's local trend. The verbs "converge" and "diverge" indicate that vertical separations between terraces either increase or decrease downstream. "Merge" and "emerge" indicate that terraces intersect or separate downstream.

Mapping and Profile Construction

Terraces were mapped and analyzed at 1:24,000 scale during intensive field work and interpretation of aerial photographs. Nominal photographic scales were mostly between 1:15,000 and 1:24,000, and older photos, such as 1950 series for the Soil Conservation Service, were emphasized because they predate some urban development. Data from seventeen quadrangles were combined, reduced, and simplified in places for the compilation in Plate 1 at 1:50,000 scale. This is a geomorphic map because contacts of terrace remnants are placed at the tops of fluvial gravels, and thus emphasize data used in correlations. In contrast, contacts on geologic maps are placed at the bases of surficial units.

Field mapping addressed issues such as the distribution and heights of terrace remnants, subdivision of terrace levels, thickness and cross-sectional shape of associated gravel bodies, and distinction between primary fluvial gravels and reworked gravels that can superficially resemble them (Chapter 5). Deposits containing reworked fluvial clasts usually have lower gravel concentrations and differing matrix compositions from primary fluvial gravels, reflecting mixtures of reworked materials (originally from distal sources) and local materials. These differences are usually clear in outcrop but may not be apparent from the surface. On many older slopes and knobs that are covered by gravelly deposits, erosion and colluviation have gradually destroyed outcrops and created dense, gravelly pavements. Without exposures showing matrix composition and sedimentary structures,

fluvial and reworked deposits can sometimes be distinguished from their locations, planform shapes, or directions and angles of depositional slopes. Because misinterpretation of reworked gravels would bias terrace distributions and correlations, the tops of gravelly deposits were mapped as terrace remnants only if the origins of related deposits could be confirmed. Possible remnants are queried.

A longitudinal profile showing terrace elevations versus valley length was constructed at 1:24,000 scale and simplified as necessary for the version in Plate 2 at 1:100,000 scale. Three main projection lines were used, including a middle line ("Y") for the modern channel and most terraces and other lines for terraces on or near drainage divides (Plates 1 and 2). The middle line bends to roughly follow the valley axis, but bifurcates at Florida Mesa and in central Farmington into branches that are aligned more closely with different terrace groups. Because valley trends during formation of the oldest terraces cannot be determined, the western ("X") and eastern ("Z") lines link the few existing remnants and are registered to the middle line at the state border. This approach best portrays relations among the highest remnants, but shifts their locations slightly with respect to most terrace remnants and the modern channel.

Correlation Criteria

Correlations among terrace remnants are based mainly on the elevations and gradients of gravel tops in relation to longitudinal profiles of the modern channel and of larger or more continuous remnants. Some workers have used gravel bottoms to correlate remnants of strath terraces, but gravel tops are better exposed and more useful for fill terraces with irregular basal contacts. Where available, heights of sub-alluvial bedrock contacts are considered.

Other correlation criteria, which are useful in specific cases, include the following: alignment of terrace remnants and scarps in plan view, stratigraphic relations between deposits of fill and cut terraces, lenses of volcanic ash that appear restricted to certain levels, effects of local base levels and knickpoints, relative preservation, and soil development. Many of these criteria have limitations. For example, soil development is useful only for distinguishing terraces in broad developmental groups, each of which includes many levels (Chapter 6).

Descriptions Of Terrace Groups

Terrace groups (abbreviated "TG") are described from youngest to oldest in descending numerical order so that better-preserved terraces may serve as models for others. Photographs show typical terrace development in five reaches, including the very wide Florida Mesa-Bondad reach (Figure 4.1), narrows in resistant rocks at the state line (Figure 4.2), wide reaches south of Cedar Hill (Figure 4.3) and east of Farmington (Figure 4.4), and an area of resistant rocks in Farmington (Figure 4.5). Relations between some terraces and bedrock erodibility are discussed where critical to terrace development.

Terrace Group 8

TG8 includes selected postglacial adjustment terraces that are next to the modern channel (Plates 1A and 2). Four terraces (t8a to t8d) are present near Bakers Bridge and one (t8u) is present in Farmington.

After deglaciation in the Bakers Bridge area, the river cut or deepened a slot canyon through a 60- to 80-m bedrock step that crosses the valley floor 1 km north of the bridge. Alluvium now extends downstream from the mouth of this canyon, locally beveling

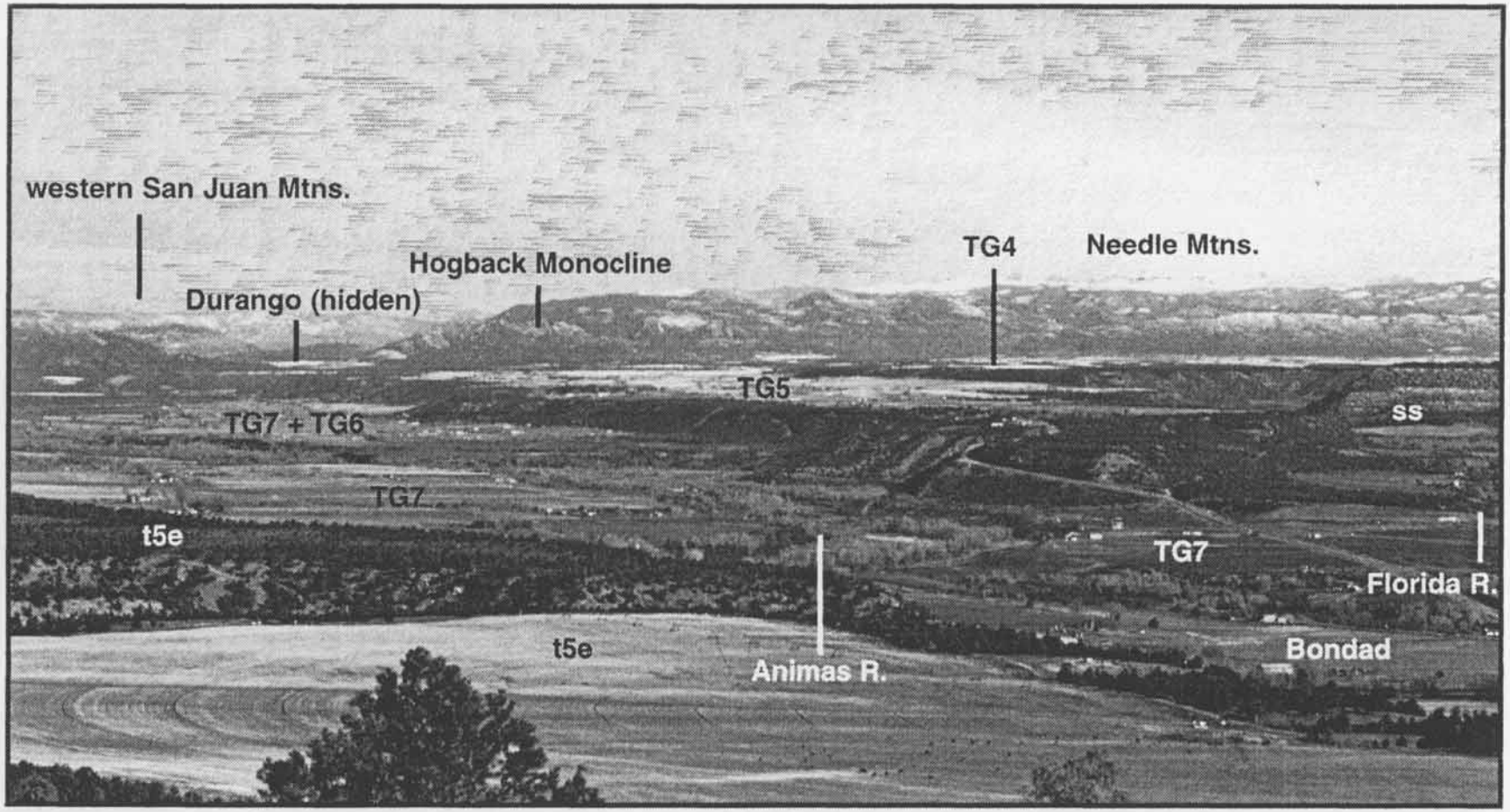


FIGURE 4.1 View north-northeast from Bondad area, showing relatively broad terraces between Hogback Monocline and narrows in state line area. Lava Creek B ash is present at several sites on upper Florida Mesa (labeled TG4). Terraces are on relatively soft rocks of upper-Animas, Nacimiento, and San Jose Formations; ss – approximate northern edge of relatively sandy sequence near base of San Jose Formation, which forms knickpoints in narrows.

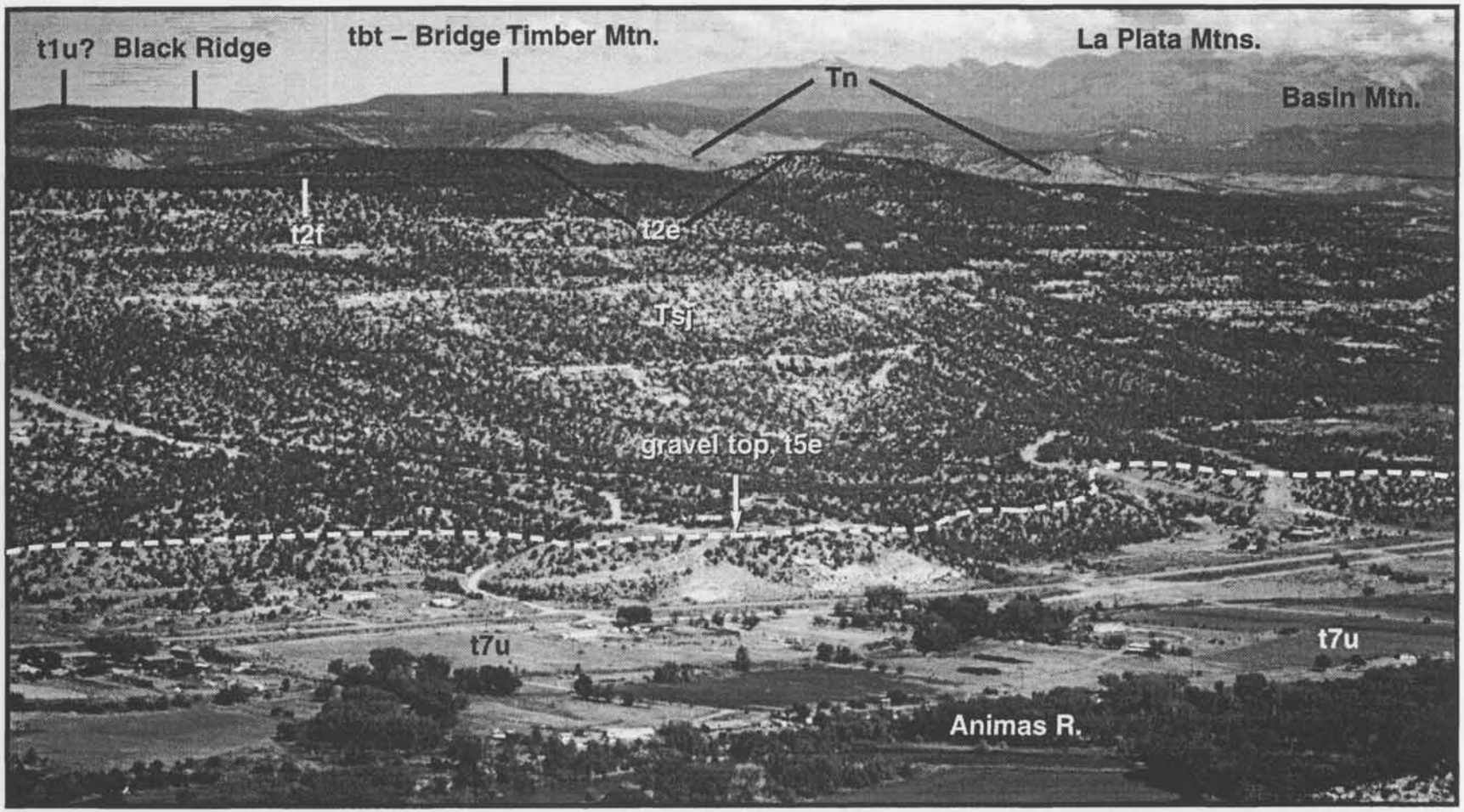


FIGURE 4.2 View north-northwest cross the narrows, showing relations of terraces to bedrock facies and older terraces along western drainage divide. Terraces t2e and t2f are near top of relatively sandstone-rich section of San Jose Formation (Tsj) near basin axis, whereas t5e is cut into less-sandy Nacimiento Formation. Softer facies of Nacimiento Formation (Tn) in background.

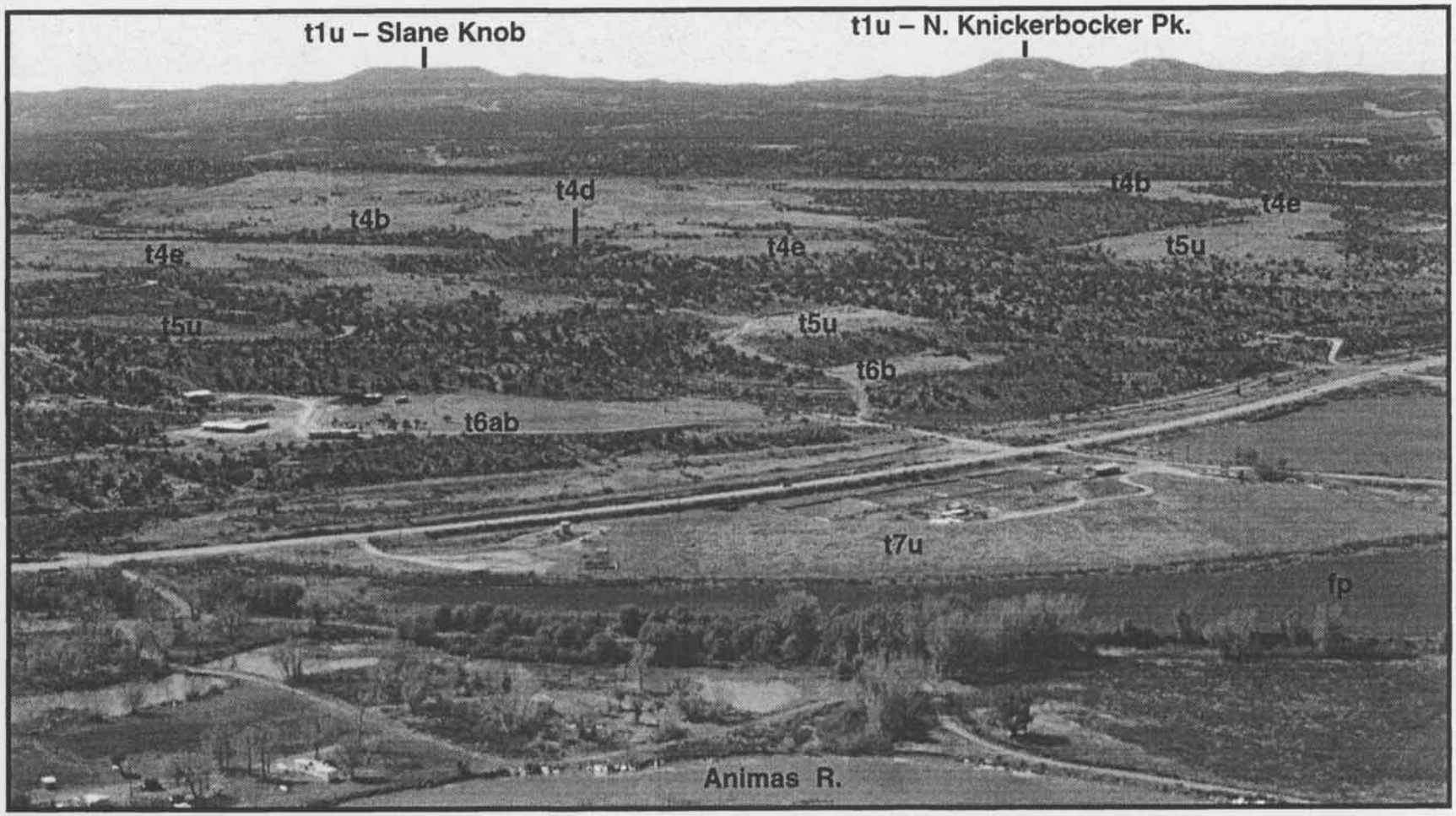


FIGURE 4.3 View southeast from 6 km south of Cedar Hill, showing relatively broad terraces downstream from the narrows and oldest terraces on eastern drainage divide. Bedrock is mainly Nacimiento Formation with locally resistant sandstone beds; however, sandstone beds of San Jose Formation form slopes of mesas beneath fluvial gravels of tlu.

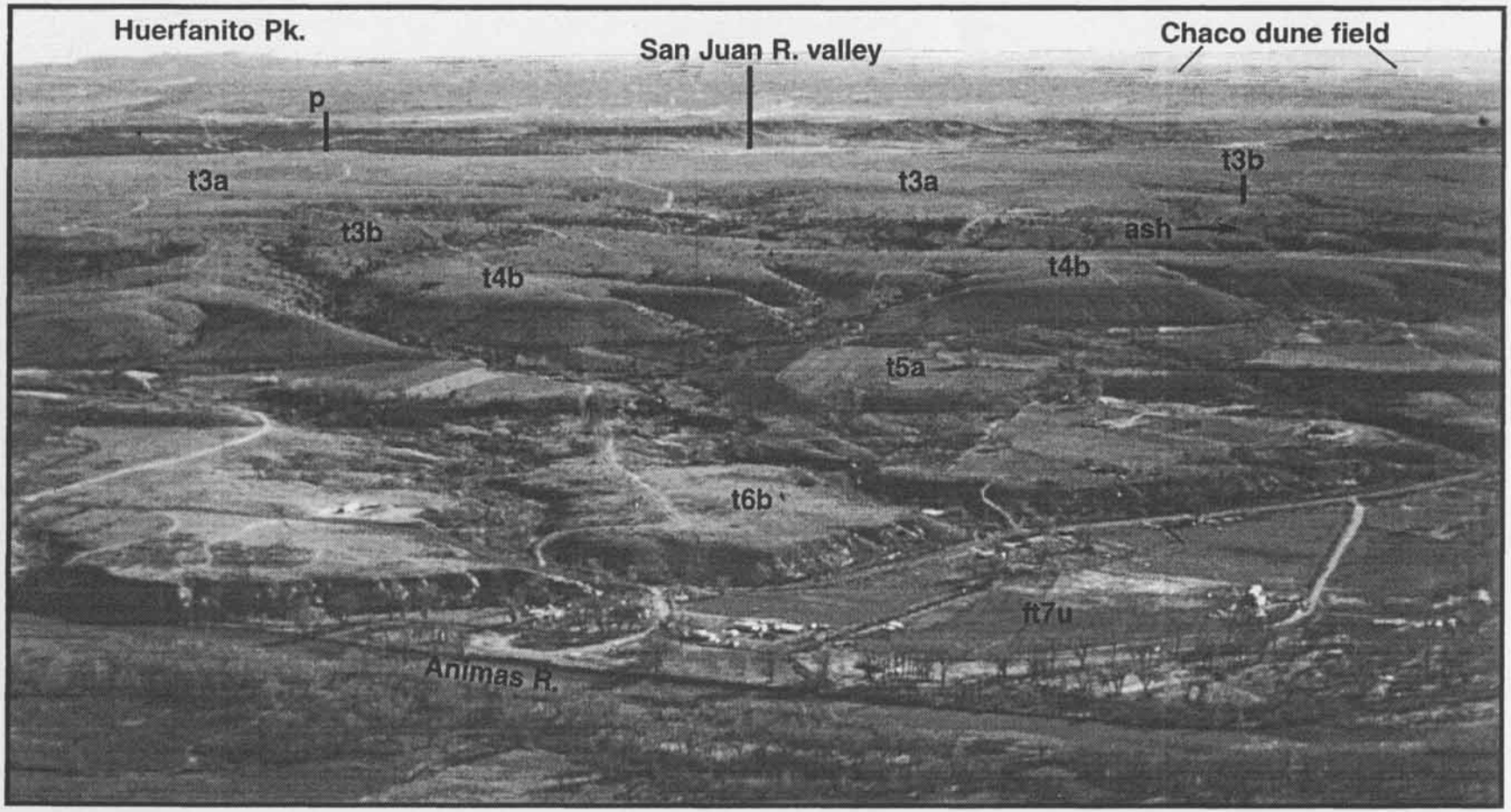


FIGURE 4.4 View south from Flora Vista area, showing relatively broad terraces on north part of Crouch Mesa. Ash – Lava Creek B ash at site A17. Area is upstream from terrace intersections with top of resistant Ojo Alamo Sandstone. Terrace t6b overlies upper Ojo Alamo Sandstone and higher terraces overlie Nacimiento Formation. Photograph by William D. Page for Woodward-Clyde Consultants, Inc. and Public Service Company of New Mexico.

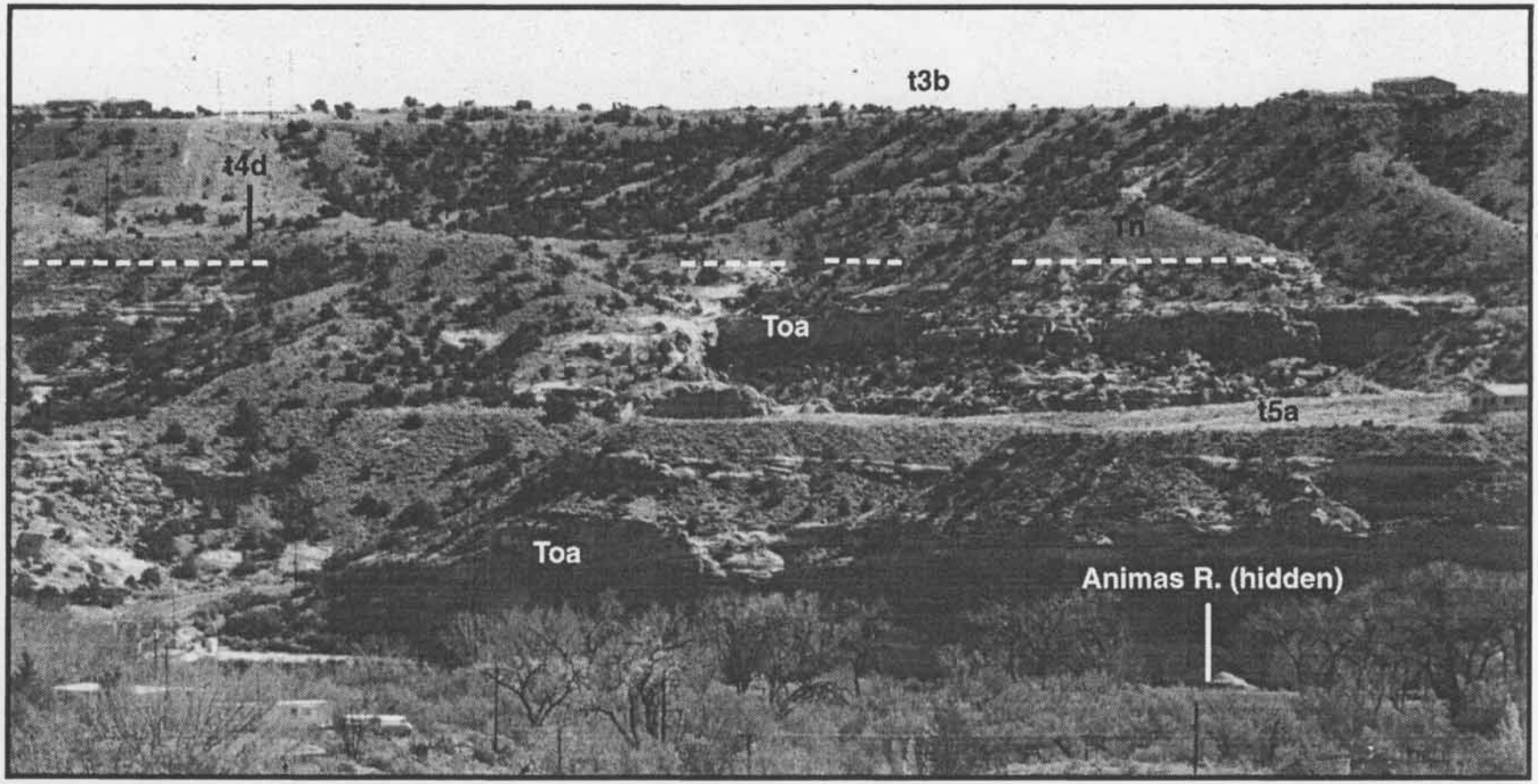


FIGURE 4.5 View southeast of terraces at southwest end of Crouch Mesa, east of Farmington. Relatively resistant Ojo Alamo Sandstone (Toa) formed large knickpoints in gradients of terraces and modern channel in this area. Sandstone beds in overlying Nacimiento Formation (Tn) probably formed smaller knickpoints.

till of the "Bakers Bridge moraine." The highest terrace in this area, t8a, is a composite surface that includes a stranded cutoff channel in the lower canyon, segments along Elbert Creek, and broader remnants where sediment from both sources coalesced. The upper surface of the cutoff-channel deposits, 21 to 24 m above present river level, is probably a strath. Broader terrace remnants decrease in height from 18 m at the canyon mouth to 2 m where the largest (t8a) projects beneath the Coon Creek alluvial fan, 2.7 km downstream. A low scarp now separates the fan toe from the flood plain, but relative gradients indicate that t8a formerly merged with the flood plain in this area. Gravel thicknesses in water wells, as much as 37 m, show that the broad part of t8a is a fill terrace. Inset terraces (t8b to t8d) form a narrow belt from the canyon mouth to Bakers Bridge, where they are roughly parallel to t8a at heights of 12 to 15 m, 9 to 11 m, and 3 to 6 m. These terraces may merge downstream with the steeper part of t8a (Plate 2), but intersection points have not been located. The tops of t8a and t8b project toward low-gradient reaches of the canyon channel that are separated by knickpoints, so their formation may be related in part to knickpoint retreat.

Terraces t8a to t8d reflect profile adjustments during and after deglaciation in a fan-like setting. Aggradation occurred at the mouths of confined channels, partly filling the profile concavity below the step and burying several roches moutonées. Stagnant ice may have been present when this process began, but t8a is not kettled, so any ice must have melted before the surface was abandoned. When sediment delivery slowed or the t8a surface became too steep for aggradation to continue, the fan head was incised and deposition shifted downstream. Terraces t8b to t8d are probably cut terraces that formed during pauses in incision, so this fill-and-cut sequence records a complex response cycle.

Another remnant designated t8u lies between the Animas and San Juan rivers at Farmington (Plates 1B and 2). This remnant, roughly 5 m high, formed during a pause in

incision below TG7, but differs from TG7 in having amino-acid evidence for overbank sedimentation in Holocene time (Chapters 5 and 7).

G.R. Scott and D.W. Moore (U.S. Geological Survey, unpublished) first mapped the terraces near Bakers Bridge. The remnant at Farmington was formerly included with flood plain or alluvial fan deposits (Pastuszak, 1968; Bandoian, 1969), or with older terraces (Ward, 1990).

Terrace Group 7

Group 7 includes three principal levels (t7a to t7c) that are graded to the Animas City 1, 2, and 3 moraines (Plates 1 and 2; Figures 3.1 and 3.2; Table 4.1). Some levels are present in most places between Durango and Farmington, but t7a and t7b cannot be clearly distinguished and may merge north of Bondad. The remaining surfaces are undivided south of Cedar Hill because of poor exposures. Unlike older terraces, these exhibit primary bar-and-swale topography in places.

Terrace heights are 30 to 6 m in Durango, 18 to 12 m at Florida Mesa, 24 to 12 m in the Bondad-state line area, and 12 to 6 m at Cedar Hill (Plate 2; Table 4.1). The lowest surface may be less than 3 m above the channel from Aztec to north Farmington. Farther downstream, the channel steepens, terraces diverge, and their heights increase to 12 to 5 m at the San Juan River junction. Each principal level includes multiple surfaces that are associated with a single gravel body. From Durango to Bondad, overlying deposits are thin or absent in many places, permitting detailed study. Farther south, where the terraces are covered by thick alluvial fans, field work was limited to target areas and the terraces are portrayed schematically (Plates 1 and 2).

Terrace t7a. The highest terrace, t7a, can be traced from the Animas City 1 moraine to the Wilson Gulch area (Plate 2). Downstream from there, it could either merge

with t7b or continue as the upper part of a complex of closely spaced surfaces shown on Plate 2 as t7ab.

Its most important remnant for establishing relative age, located beneath Riverview Drive in north Durango (Figure 3.1, feature 6; Figure 3.4), is 29 to 27 m high. This remnant was graded to the western segment of the Animas City 1 moraine, which was excavated in the 1970's. Richmond (1965b) considered the moraine and terrace equivalent to Bull Lake till and outwash in the Wind River Mountains, but this remnant is included in TG7 for two reasons. The former moraine segment was more similar in shape and height to Animas City than to Spring Creek moraines (Chapter 3). Also, the base of the gravel is closer in elevation to those of other TG7 terraces than to TG6 terraces. Although the gravel is poorly exposed, its base is near river level in at least two places. Springs issuing from the gravel have formed travertine mounds 3 to 6 m above the river at the south end of the Riverview Drive remnant. Also, a sewer tunnel beneath the narrowest part of this remnant, west of Folsom Place (Figure 3.1, southwest of area labeled "t7c channel"), penetrated gravel near river level (City of Durango, written communication, 1997). In comparison, the lowest gravel exposures beneath younger terraces of TG7 are roughly 3 to 6 m above the river, versus 21 m for TG6. Therefore, paleovalley axes beneath Riverview Drive and other TG7 remnants are comparable in height, but much lower than those beneath TG6 remnants. The greater height of Riverview Drive, compared to other TG7 remnants, must be due to aggradation of thicker deposits, possibly more than 24 m thick where described above.

The highest terrace remnant in downtown Durango appears to project slightly below the Riverview Drive remnant, but is interpreted as a fill-cut or lower fill terrace of t7a because it is clearly higher than t7b (Plate 2). Scott (unpublished) interpreted this remant as Pinedale outwash (equivalent to TG7). From here to Wilson Gulch, t7a remnants roughly parallel the modem channel at heights of 18 to 21 m.

Terrace t7b. Terrace t7b, graded to the Animas City 2 moraine, is more continuous than t7a in and near Durango. From the moraine to Wilson Gulch, its height varies between 12 and 15 m. The base of the gravel is not exposed near the moraine, but thicknesses from 1 to 6 m farther downstream suggest that t7b includes both fill and cut surfaces (Figure 4.6).

As noted earlier, t7a and t7b converge near Koshak Mesa and may merge between Koshak Mesa and Sunnyside Mesa (Plates 1A and 2). Several cross sections (not included as figures) show that many, closely spaced fill and cut surfaces in this area associated with a single gravel body. If part of the fill accumulated during aggradation to the t7a surface in and near Durango, some of the highest surfaces could correlate with t7a. However, t7a and t7b probably merge in this reach for the following reasons. Near the moraines, paleovalley axes under both terraces are at similar levels, and the greater height of t7a is due to thicker aggradation. If t7a deposits became thinner downstream, as demonstrated for older terraces with better-exposed deposits, t7a and t7b would have become closer in height. At some location, most or all t7a surfaces would probably have been reworked during formation of t7b surfaces.

The height range of surfaces in this complex, designated t7ab, varies slightly. It is 12 to 18 m at Koshak Mesa, 15 to 21 m at Weaselskin Bridge, 12 to 21 m near Bondad, and 9 to 14 m at Cedar Hill. Gravel thicknesses up to 12 m indicate that most surfaces are probably fill and fill-cut terraces. However, straths are prominent where the surfaces cross sandstone beds at low angles, for example at Bondad.

Terrace t7c. Terrace t7c is graded to the Animas City 3 moraine. In Durango, it is 8 to 11 m above the river and well preserved but narrower than t7b. Farther downstream, it includes a few small remnants at fluctuating heights between 6 and 11 m. These remnants are associated with a lower and narrower gravel body than that beneath the t7ab complex (Figure 4.6). The base of the gravel is not exposed near the moraines. Elsewhere, the

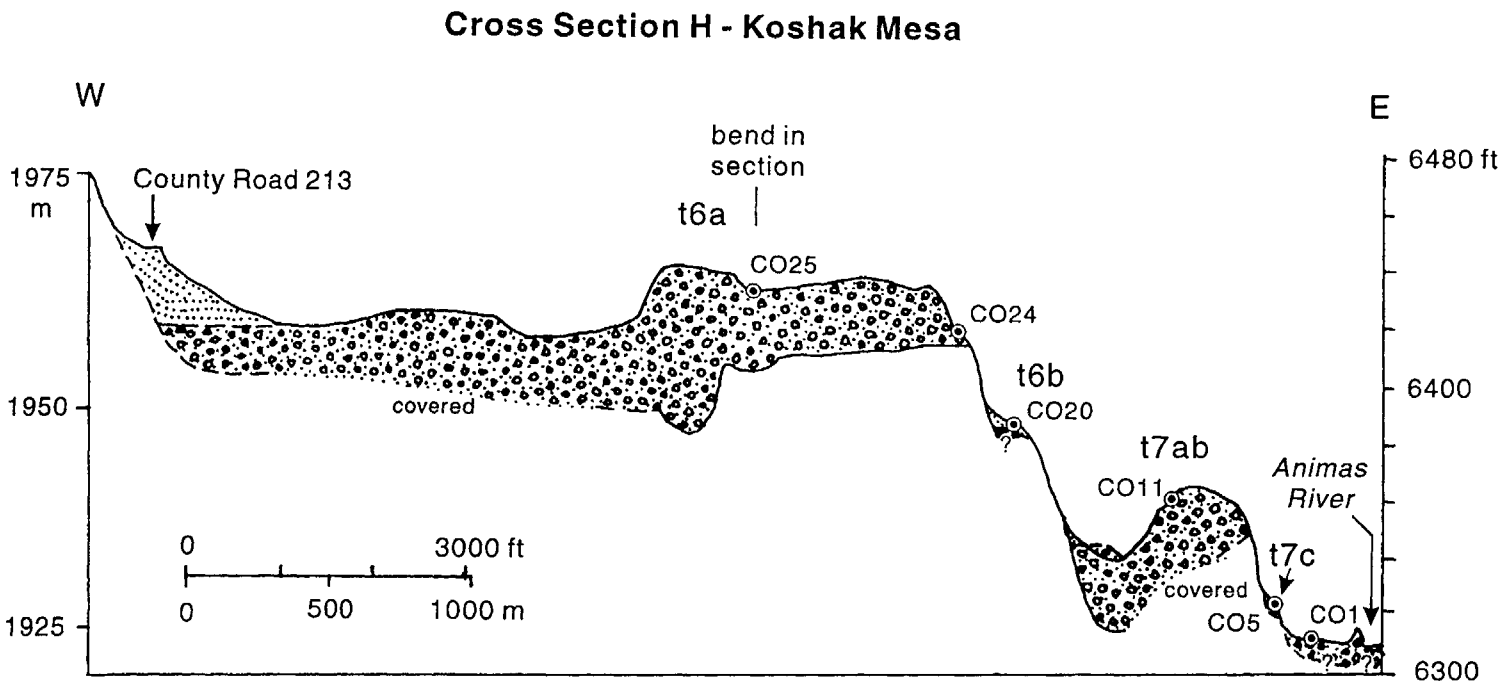


FIGURE 4.6 Cross section H through TG6 and TG7 at Koshak Mesa. The land surface represents topography along the line of section, whereas the basal contacts reflect exposures mainly along the south sides of the terraces. The horizontal scale is 1:24,000 and the location of this cross section is shown on Plate 1A.

deposits are 0.6 to 3 m thick in most places, but are up to 9 m thick at one site that could correlate instead with t7ab. The limited extent of t7c suggests that the river occupied this surface for a shorter period than t7a or t7b.

Undivided terraces (t7u and ft7u). From south of Cedar Hill to central Farmington, younger alluvial fans cover nearly all terraces of TG7. Multiple surfaces may be present but have not been identified, so the estimated average height of undivided remnants is shown on Plate 2 as a single line. These remnants converge gradually with the modern channel and may merge with the flood plain near Flora Vista area. The southernmost known exposures of terrace gravel are 2 to 3 km south of Aztec, where their surface is only 4 m above the channel at low flow. Because of recent alluvial-fan deposition along many river cutbanks, evidence that TG7 terraces merge with the flood plain is inconclusive. However, this evidence includes converging gradients for the undivided terrace remnants and modern channel, and the absence of terrace gravels in cutbanks at several places.

Where undivided terraces of TG7 are definitely above the flood plain, but overlain by alluvial fans, they are designated as t7u (Plates 1B and 2). However, where these terraces could merge with the flood plain, and associated gravels may extend below flood-plain level, the symbol ft7u shows that buried terraces may be present in some places and that side-stream alluvium may overlie flood-plain deposits in others.

In most of the study area, the depth of incision below TG7 is large enough that terrace and flood-plain gravels are separated vertically by bedrock (Figure 4.6). Because of convergence, however, the lowest terrace gravels and younger flood-plain gravels may overlap in places from Cedar Hill to north Farmington, depending on terrace height and gravel thickness. Such overlap has been observed 2 km south of Cedar Hill.

Farmington area. Several terrace surfaces diverge from the modern channel in central Farmington (Plate 2). These surfaces are mapped as t7u (undivided) because they

cannot be traced to specific levels near Durango, and because incision below these surfaces may be related to base-level fall along the San Juan River, rather than upstream changes in sediment load and discharge. Gravel thicknesses have not been recorded, but these terraces may be mostly straths with thin fill and fill-cut surfaces..

The pattern of upper (t7uu) and lower (t7ul) surfaces on the interfluve between the Animas and San Juan rivers suggests slight aggradation, followed by development of lower cut surfaces including a southward-trending channel belt that was abandoned before incision at the Animas River's present course. This pattern (resembling complex response in a distributary channel system), broadening of the San Juan valley floor in the confluence area, incision by the modern San Juan River along the south side of its valley, and a large recess in its southern valley slope, all suggest that deposits from the Animas River pushed the San Juan River toward the opposite side of its valley, and in doing so, enhanced aggradation along the San Juan River upstream from the confluence.

Regional patterns in the height of TG7 (gradual convergence downstream from Durango, possible intersection with the flood plain north of Flora Vista, and divergence in central Farmington) indicate that some factors have delayed incision in the Flora Vista-north Farmington area. The main factor is apparently erosional resistance of the Ojo Alamo Sandstone, which crosses the San Juan River in north Farmington. The sandstone is not exposed in or next to the channel, but structural projections indicate that the divergence point is located where the modem channel cuts through the base of the sandstone (Ward, 1990, and bedrock mapping for this study). Thus the sandstone acts as a local base level. Other factor that may reduce incision in the Flora Vista-north Farmington are relatively large volumes of sediment supplied by tributary streams, as indicated by their large alluvial fans, and sediment from river incision in upstream reaches.

In Colorado, terraces of TG7 were first recognized by Howe and Cross (1906) and mapped by Atwood and Mather (1932). Richmond (1965b) described Pinedale terraces

(equivalent to TG7) as 25 ft (approximately 8 m) high in Durango, but a larger range is given here, partly due to inclusion of some remants that Richmond considered Bull Lake (equivalent to TG6). Scott and Moore (unpublished) first mapped these terraces in detail and identified fill and cut surfaces. In New Mexico, early workers did not divide these terraces from flood plain or alluvial fan deposits (Pastuszak, 1968; Bandoian, 1969), but later workers identified some remnants (Scott, unpublished; Ward, 1990).

Terrace Group 6

TG6 projects to the Spring Creek moraines across short erosional gaps (Plates 1A and 2). Detailed relations between the terraces and moraines cannot be determined because of extensive erosion in the terminus area (Figures 3.1 and 3.2), but both occupy similar, intermediate elevations between other moraines and terraces.

TG6 includes two principal levels (t6a and t6b) that are poorly to moderately preserved from Durango to south Florida Mesa, virtually absent from there to Hart Canyon north of Aztec, and moderately to well preserved downstream to Farmington. Where extensive and not covered by younger deposits, each terrace has numerous, closely spaced fill and cut surfaces. Heights ranges are 58 to 34 m in Durango, 150 to 80 ft near Bondad, 120-80 ft near Cedar Hill, 70-100 ft at Flora Vista and 60-110 ft in Farmington (Table 4.1). Despite overall convergence with the modern channel, locally the terrraces are parallel to or diverge from the channel. Gravel thicknesses range from 1 to 18 m between Durango and Florida Mesa, where most surfaces are probably fill and fill-cut terraces. Gravel thicknesses generally decrease to 1.5 to 7 m in the Bondad-state line area and to 1 to 5 m farther downstream, where most surfaces are probably straths.

Because of variations in terrace distribution and exposure, different mapping and correlation methods were used in four areas. From Durango to south Florida Mesa, closely

spaced surfaces at slightly varying gradients cannot be traced individually for long distances. In this area, spot measurements of gravel thickness and cross sections along some exposures show that the surfaces are associated with two composite fills (for example, see Figure 4.6). Each principal level includes the surfaces associated with one fill. From south Florida Mesa to Hart Canyon, north of Aztec, possible correlations are based on the assumption that relatively constant gradients connect the larger remnants. Other remnants are thought to indicate multiple surfaces associated with the principal levels. From Hart Canyon to Farmington, two terraces are moderately to well preserved, but covered by younger deposits, so each may include multiple surfaces. In Farmington, exposures are poor, but detailed city maps were used to identify multiple surfaces where possible.

Terrace t6a. In Durango, t6a includes three remnants that converge rapidly from 58 to 49 m above the river. Richmond (1965b) interpreted the northern remnant, a bench on the side of College Mesa (Figure 3.1, site 10), as early Bull Lake till, whereas Scott (unpublished; Gillam and others, 1984) considered it a landslide. However, its relatively flat top and an exposure of cobble gravel suggest that it is a terrace remnant (Chapter 3). Richmond (1965b) also interpreted the middle remnant (Figure 3.1, site 11) as early Bull Lake till, but it is considered a terrace because its top is coplanar with other t6a remnants, its ridge-like form could result from later erosion, and underlying deposits appear stratified (Chapter 3). The southern remnant, which forms the upper surface at Greenmount Cemetery, is underlain by two lithofacies, a lower unit with sandstone and volcanic clasts deposited by Lightner Creek, and an upper unit with varied rock types from the Animas River watershed (Mark Johnson, oral communication, 1985). Slightly lower surfaces are also visible in several areas. The base of t6a deposits is poorly exposed, but gravel thicknesses from about 1.5 to >12 m indicate that the highest surface is a fill terrace, and that lower surfaces may be mostly fill-cut terraces.

South of Durango, t6a includes multiple surfaces developed on the upper of two gravel bodies related to TG6 (Figure 4.6). The height range of these surfaces decreases slightly from 34 to 41 m at Koshak Mesa, to 30 to 34 m at Sunnyside Mesa (Plate 2). Irregular sub-alluvial contacts and gravel thicknesses up to 18 m indicate the presence of fill and fill-cut surfaces. Small, isolated remnants underlain by thin deposits could be either straths or edges of fill terraces.

From Sunnyside Mesa to Hart Canyon, the upper of two more extensive levels and one slightly higher remnant are assumed to correlate with t6a (Plate 2). While rare, these remnants show that the height of t6a varies through the reach, but is about 30 m at Hart Canyon. Gravel thicknesses from 0.3 to 2 m suggest that both surfaces included in t6a are straths.

Converging gradients show that t6a merges with t5e between Hart Canyon and Aztec, as discussed below for t5e. Downstream from the likely intersection area, soil development is typical of TG6 (Table A.5, soil profile NM8) and the terrace is nearly continuous to north Farmington. Multiple surfaces may be present, but the terrace is shown on Plate 2 as a single surface that decreases in height from about 30 m at Aztec to 24 m in north Farmington. In central Farmington, several surfaces appear in places. Those tentatively correlated with t6a diverge slightly in central Farmington and are 30 to 34 m in height where nearest to the San Juan River . Gravel thicknesses from 2 to 8 m suggest that t6a is mainly a strath from Hart Canyon to Farmington, but it may include fill and fill-cut surfaces locally.

Terrace t6b. In Durango, t6b includes two remnants that converge rapidly from 43 to 34 m above the river. Richmond (1965b) interpreted the northern remnant (Figure 3.1, site 13) as early Bull Lake till, but its relatively flat top, similar height to the southern remnant, and stratified gravelly deposits (Table A.4, soil profile CO18) suggest a terrace origin (Chapter 3). Gravel thicknesses from 2 to 15 m indicate that t6b is a fill terrace in

most places, but fill-cut and possible strath surfaces are visible locally. For example, a fill-cut terrace bevels the north remnant, and at Greenmount Cemetery, part of the south remnant is a strath or a fill edge that overlaps the distinctive basal unit beneath t6a.

South of Durango, t6b includes multiple surfaces developed on the lower of two gravel bodies (Figure 4.6). Their height range decreases slightly from 37 to 21 m at Koshak Mesa to 31 to 26 m at Sunnyside Mesa. As for t6a, irregular sub-alluvial contacts and gravel thicknesses up to 8 m indicate the presence of fill, cut, and possibly strath surfaces.

From Sunnyside Mesa to Hart Canyon, the lower of two more extensive levels and one slightly lower remnant are assumed to correlate with t6b. Gravel thicknesses from 1 to 3 m indicate that t6b surfaces in this area are straths. The height of t6b is about 27 m at the former settlement of Inca.

Terrace t6b is absent near the intersection between t6a and t5e. However, it is preserved discontinuously from south of Aztec to north Farmington, where it is roughly 6 m lower than t6a and decreases in height from 24 to 18 m. In central Farmington, several closely spaced surfaces are visible in places, but cannot be traced beneath overlying deposits. The long scarp near Vine Avenue seems to expose a single surface that converges with the modern channel (Plate 2), but this surface may consist of shorter, down-stepping segments that cannot be distinguished because of poor exposures, recent excavations, and former gravel pits. Near the San Juan River, the principal level shown is 21 to 24 m high.

In Colorado, early workers identified these terraces, but considered them interglacial because they did not recognize the Spring Creek moraines (Howe and Cross, 1906; Atwood and Mather, 1932). Atwood and Mather mapped the terraces with younger Wisconsin (Animas City) outwash terraces. Richmond (1965b) probably recognized most terrace remnants, but estimated heights and correlated some differently than here. For example, he stated the heights of Bull Lake outwash terraces in Durango as 170 and 100 ft

(52 and 30 m). These correspond roughly to the heights of t6a and t6b at Greenmount Cemetery, but his lower height is probably for the Riverside Drive remnant that is assigned here to t7a. Terrace heights 11 km south of Durango, given as 150 and 80 ft (46 and 24 m), are slightly different values for the highest t6a surfaces and lowest t6b surfaces at Koshak Mesa. On Richmond's regional map, most outwash at these heights is included erroneously with Pinedale and Neoglacial deposits; except in Durango, the areas mapped as Bull Lake outwash actually are covered by deposits of TG4, TG5, and side-stream alluvium. Scott and Moore (unpublished; 1981) first mapped Bull Lake terraces in detail and identified fill and cut surfaces. Divisions between their Bull Lake and Pinedale terraces, and between TG6 and TG7 of this report, are similar in most places. In New Mexico, earlier workers recognized most remnants of TG7, but did not identify multiple levels. Because of differences in correlation, t6a and t6b both include remnants that other workers have assigned to several levels (Bandoian, 1969; Gillam and others, 1985; Ward, 1990).

Terrace Group 5

TG5 includes at least 5 levels (t5a to t5e) that are related genetically to the Durango moraines, the oldest preserved moraine complex (Plates 1 and 2). The highest terrace, t5a, projects at least 9 m above the moraine crests, but is included in TG5 for several reasons: gravel thicknesses up to 37 m suggest that its sub-alluvial contact projects well below the moraine crests; t5a is similar in preservation to other terraces of this group; and the small difference in heights can be explained in two ways. For example, t5a could have been graded to a higher moraine of roughly the same age, which was destroyed by ice fluctuations and meltwater erosion in the confined area north of the Hogback ridge (Plate 1A). Alternatively, later erosion of existing moraine crests could have exceeded the height difference. In contrast to t5a, terraces t5b to t5d project below the moraine crests, and

remnants of two levels (t5c and t5e) are graded to the distal slope of the youngest moraine (Figures 3.1 and 3.2).

As a group, these terraces are moderately preserved from Durango to Farmington and some levels are among the most continuous in the study area. Individual terraces converge with the modern river channel and locally with other terraces, so that several probably merge from the Hogback to middle Florida Mesa. Two terraces of TG5 are present below the narrows, but only one is present in Farmington. A series of cross sections (Figures 4.7 to 4.10) shows the relationships among terraces and gravel bodies of TG5 and TG4 between the Hogback Monocline and Cedar Hill. Individual terraces of these groups are moderately preserved, but better exposed than younger terraces, and therefore provide better models for downstream changes in terrace features.

Terrace t5a. This is a fill terrace in the Hogback-Florida Mesa area, absent in a long reach that includes the narrows, and a strath or thinner fill terrace farther downstream (Plates 1 and 2). Its upstream and downstream sections are correlated by their relative height above t5e, which is nearly continuous. Terrace t5a is well preserved at the Hogback and on northern Florida Mesa, where it is underlain by 6 to >37 m of gravel. Its extent on southern Florida Mesa is uncertain because the lower bordering scarp cannot be traced beneath overlying deposits. One water well in this area, definitely located on t5a, penetrated about 16 m of gravel. Downstream from the narrows, t5a is moderately preserved from Aztec to Farmington, where it is underlain by 3 to 6 m of gravel. The terrace could be more extensive in north-central Farmington than mapped because of human disturbance or burial by overlying deposits.

The relationship of t5a to lower terraces in the Hogback area is uncertain. In places, the fills associated with t5a and t5b appear distinct (Figure 4.7, sections A and C). In others, the scarp between the terraces and the rise in the sub-alluvial contact seem to be offset laterally (Figure 4.8, section D). While the second case could show that t5a and t5b

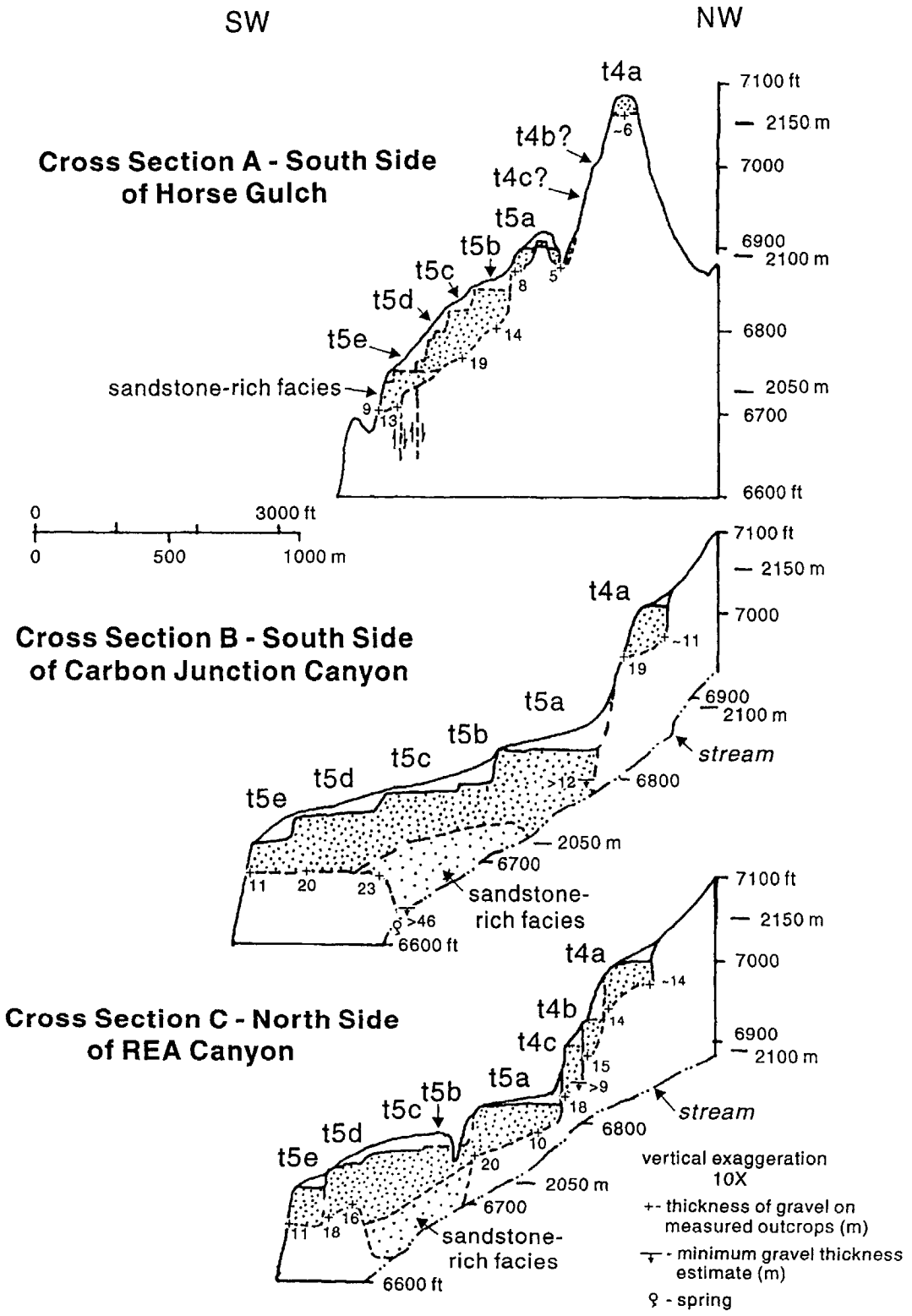


FIGURE 4.7 Cross sections through TG4 and TG5 on the east side of the Animas River, between Horse Gulch and REA Canyon. The horizontal scale is 1:24,000 and the locations of the cross sections are shown on Plate 1A.

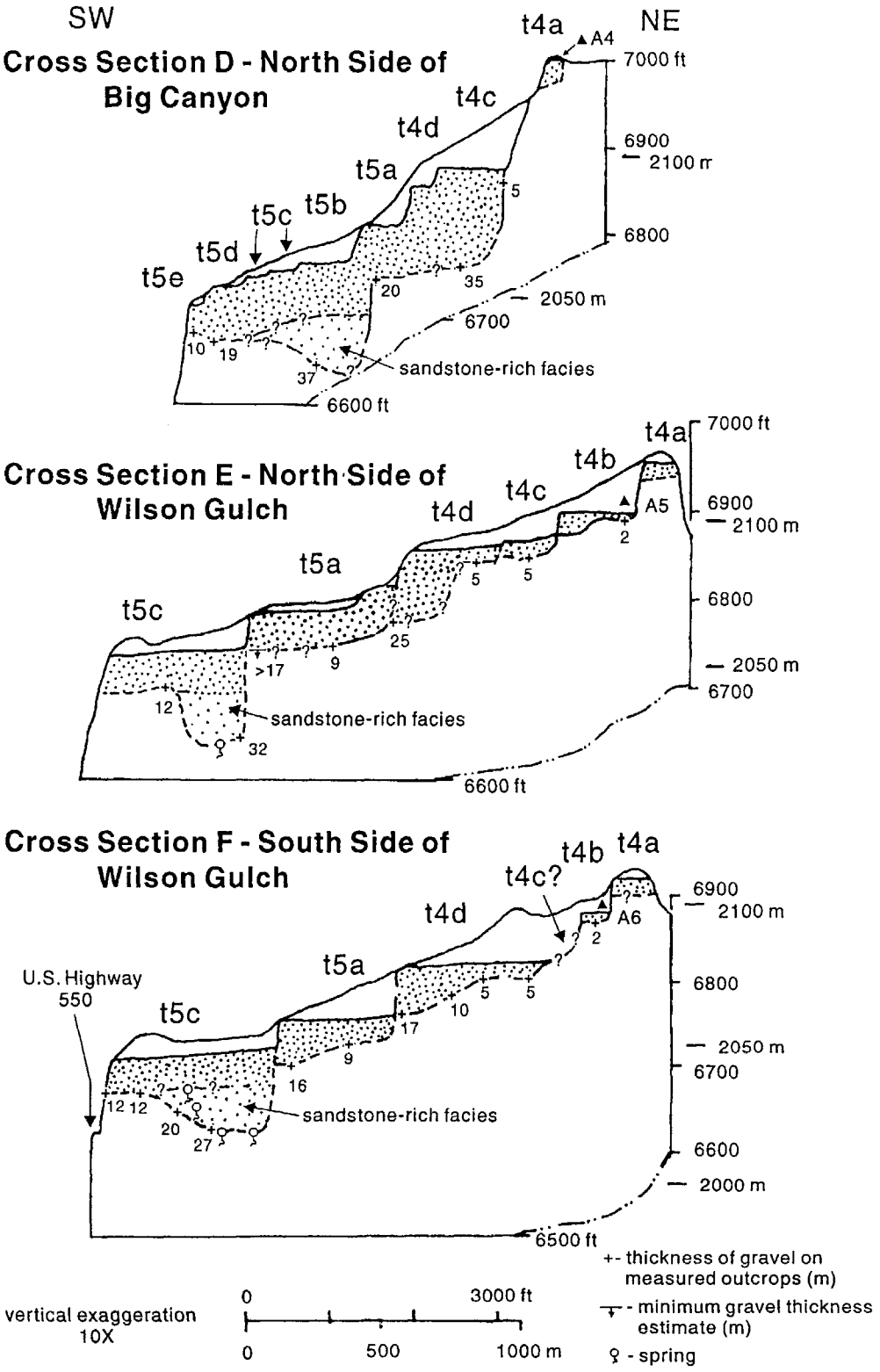


FIGURE 4.8 Cross sections through TG4 and TG5 on the east side of the Animas River, between Big Canyon and the northwest end of Florida Mesa. The horizontal scale is 1:24,000 and the locations of the cross sections are shown on Plate 1A.

are related to a single, composite gravel body, the offset could also be an artifact of curvature in the upper and lower contacts of the gravel and of the locations of outcrops projected to the plane of section. If the lateral offset is an artifact, these terraces could be related to distinct gravel bodies that overlap in height.

Terraces t5b to t5e. At least four terraces (t5b to t5e) appear to merge between the Hogback and middle Florida Mesa, based on converging gradients (the intersections are concealed by overlying deposits or eroded; Plates 1 and 2). From there, t5e continues downstream to the Hart Canyon area north of Aztec, where it appears to merge with t6a.

In the Hogback area, the four named terraces are thought to illustrate typical relationships among a larger number of existing terraces, which cannot be traced individually because of poor exposures and low scarp heights. Cross sections (e.g., Figure 4.7, sections A and C; Figure 4.8, section D) show composite gravel bodies with many terrace treads separated by scarps as low as 1.5 m. Such low scarps are visible in good exposures but cannot be traced beneath overlying deposits, so terrace treads that appear to slope toward the valley axis may actually consist of many smaller, indistinguishable steps. Because small features cannot be traced with reasonable confidence, only larger composite features have been named and mapped. Generally, these features are bounded by relatively high scarps with enough relief to be traced beneath overlying deposits in some places.

Terrace gradients suggest that t5b merges with t5c between REA Canyon (Figure 4.7, section C) and Sale Barn Canyon (Plates 1 and 2). Terrace t5d probably merges farther downstream with either t5c or t5e (Figure 4.8, sections D and E), but this intersection cannot be identified because of erosion. The remaining two terraces, t5c and t5e, merge near the middle of Florida Mesa (Figure 4.9, sections I and J). These intersections show that the long profile of the river was adjusted episodically in the Hogback Monocline-northern Florida Mesa area, while remaining more stable downstream from middle Florida Mesa.

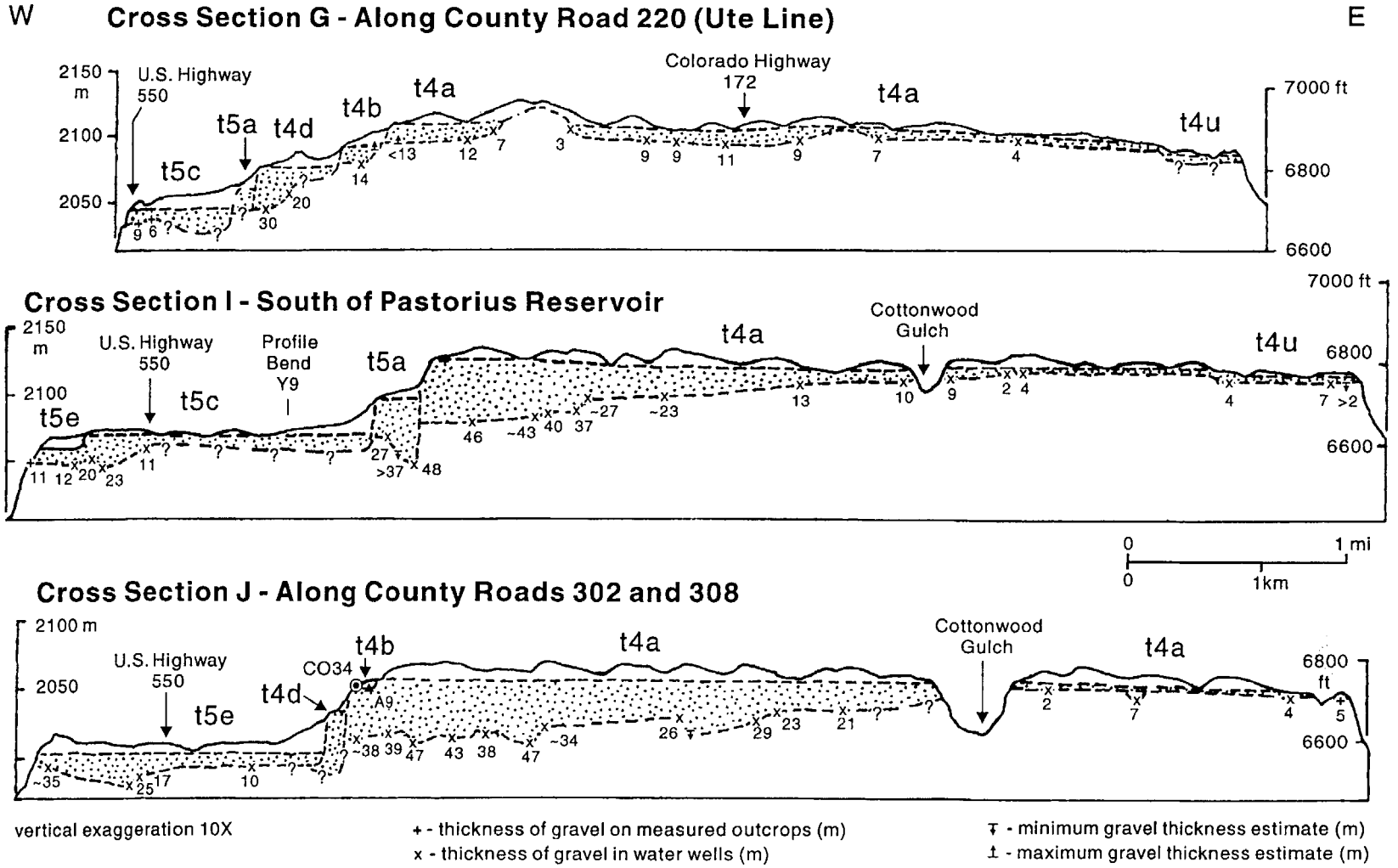


FIGURE 4.9 Cross sections through TG4 and TG5 on Florida Mesa. The horizontal scale is 1:48,000 and the locations of the cross sections are shown on Plate 1A.

The composite gravel bodies beneath these terraces have complex shapes that vary locally (Figures 4.7 to 4.9). Variations exist not only in the number, width, and relative heights of terraces, but also in the shape of the sub-alluvial contact. In some sections where paleovalley thalwegs are preserved, the lowest deposits lie beneath different terraces (t5e in Horse Canyon, Figure 4.7, section A; t5c or t5b at REA Canyon, Figure 4.7, section D; and t5b at Big Canyon, Figure 4.8, section D). Because the shape of each gravel body could result from different sequences of incision and aggradation events, it is impossible to determine the depths of incision and subsequent aggradation that formed each terrace. However, comparisons among the cross sections provide some constraints, as shown in the following examples. In these comparisons, the long profiles that formed during incision events are assumed to be relatively smooth through the Hogback Monocline area, so that differences in gravel thickness between sections are not related to local knickpoints.

For example, the largest observed thickness of gravel directly beneath t5b, roughly 40 m at Big Canyon (Figure 4.8, section D), indicates that it is a fill terrace that formed after 40 m of net aggradation at this area. Where the gravel directly beneath t5b is thinner, such as roughly 12 m at Horse Gulch (Figure 4.7, section A), it is clear that this thickness does not reflect the full amount of aggradation known to have occurred nearby, and that incision at Horse Gulch must have extended well below the contact directly beneath t5b. In this area, the lower part of the t5b gravel could either extend laterally beneath lower terraces, or it could have been eroded during formation of those terraces. The lowest gravel at Horse Gulch and several other sections consists of distinctive deposits with a high proportion of locally derived, sandstone clasts (Chapter 5). The position of this gravel at Horse Gulch suggests that both the lowest and highest gravel deposits accumulated during aggradation to the t5b surface, and that younger terraces are thinner fill or cut surfaces.

A second example concerns the thickness of gravel beneath t5c. At Big Canyon (Figure 4.8, sction D), the gravel directly beneath t5c is probably between 20 and 27 m

thick. Thus, the maximum possible aggradation preceding formation of the t5c surface is about 27 m. Less aggradation could have occurred if any of the basal gravel is part of the t5b fill. At Carbon Junction Canyon (Figure 4.7, section B), where gravel directly beneath t5c is more than 45 m thick, gravel deeper than about 27 m must be part of the t5b fill.

By such comparisons, it appears that maximum possible aggradations are more than 50 m to the t5b surface is; less than about 21 m to t5c; about 19 m to t5d, and less than about 18 m to t5e. The thickest deposits accumulated during aggradation to the t5b surface. Gravel deposited during aggradation to each of the lower terraces could be thinner than the maxima given above, if part of the gravel beneath them was deposited during earlier aggradation events. Therefore, these terraces could be either fill terraces underlain by thinner deposits than t5b, or fill-cut terraces.

The vertical interval between the highest and lowest gravels beneath t5b to t5e is greatest at the north end of the Hogback area and generally decreases downstream to Florida Mesa. Generally, this interval is more than 49 m at Carbon Junction Canyon (Figure 4.7, section B), 32 m at north Wilson Gulch (Figure 4.8, section E), and 23 m at Pastorius Reservoir (Figure 4.9, section I). Below its intersection with t5b, terrace t5e is a fill terrace with maximum gravel thicknesses that decrease downstream from about 27 m to 12 m near the south tip of the mesa. However, some wells near the tip could be located in buried remnants of t5a. The uppermost gravel must be associated with t5e, but deeper deposits could have accumulated during earlier aggradations that created t5b in other areas.

Downstream from Florida Mesa, t5e has a relatively smooth profile because it passes below a resistant sandstone sequence in the San Jose Formation that forms a local base level for terraces of TG4 (as described below). From Bondad to Cedar Hill, gravel thickness varies from 2.4 to 12 m, but generally decreases downstream. Some local variations are related to small knickpoints in the suballuvial profile that formed where the river cut through sandstone beds.

South of the narrows, a short terrace above t5e probably reflects local regrading of the profile through a larger knickpoint (Plate 2). This terrace emerges from the t5e surface near Cedar Hill, then parallels it at a level roughly 8 m higher, and appears to merge with it north of Hart Canyon. This terrace is designated t5u because its age relationship to t5b, t5c, and t5e is unknown. The convexity in the upper terrace is probably caused by a knickpoint that formed where the river cut through at least one of several prominent sandstone beds in the area. This hypothesis is supported by larger gravel thicknesses downstream from the convexity, where a concavity should occur. In this reach, the smoother profile of t5e was probably established by knickpoint retreat.

Projected gradients indicate that t5e probably merges with t6a downstream from Hart Canyon, but their intersection is concealed by overlying deposits. No evidence of t5e as a distinct terrace has been found downstream from this area, so the two terraces evidently do not diverge again. The absence of t5e at Farmington suggests that only one terrace related to the Durango moraines, t5a, is present near the junction of the Animas and San Juan rivers. Thus, ages for nearby terraces along the San Juan River (Cooley and others, 1969; Weide and others, 1979; Strobell and others, 1980) should be reassessed.

The intersection of t5e and t6a near Hart Canyon is the only case in which terraces of much different ages merge. The following hypothesis explains the convergence, as discussed in Chapter 7. Due to interaction with the Ojo Alamo Sandstone, a relatively resistant formation in north Farmington, the junction of the Animas and San Juan Rivers has shifted generally southeast since at least TG2 time. Until at least t4d or t5a time, these rivers very likely joined farther north than now, possibly over central Farmington. If the San Juan River incised near the south edge of its floodplain after t5e time, this would have lengthened the lower Animas River by about 3 km. Given the average gradient of terraces near Farmington, about 7.6 m/km, shifting the river's profile laterally by 3 km would have the same effect as raising its base level by 15 m. This effect may have offset the normal

tendency for incision below t5e to occur the confluence, so that this reach remained stable until and during formation of t6a, while upstream reaches incised. Significantly, the estimated base-level effect of a shift in the confluence is comparable to vertical spacings between individual terraces of TG4 and TG5 in the Aztec-Farmington area, or 12 to 18 m. The location of the intersection between t5e and t6a may have been controlled by sandstone beds in the Nacimiento Formation between Hart Canyon and Aztec. A slight increase in the gradient of t6a near Knowlton Canyon is probably downstream from a knickpoint (Plate 2, approximately 27 km from San Juan River) that locally reduced incision from t5e to t6a.

Terrace t5ex. Several remnants are interpreted as local features that formed during incision below t5e. These include three very small straths from north of Bondad to the lower narrows and possibly a cut terrace that bevels t5e deposits near Cedar Hill (Plates 1 and 2). Gravel thicknesses range from 1.5 to 3 m and heights decrease downstream very slightly from 52 m to 49 m. Because t5e slopes more steeply in this reach than t5ex, the two terraces may have intersected near Cedar Hill.

Although remnants of t5ex near Bondad are similar in height to t6a at Koshak Mesa in the Hogback Monocline area, they were not correlated for several reasons. Soil data are not available for t5ex, but a soil on t5e downstream from the likely intersection of t5e and t5ex (profile NM9, Table A.5) is much stronger and apparently older than a soil on t6a (profile NM8). Also, if t6a remnants at Durango and Koshak Mesa were correlated with the remnants called t5ex, the reconstructed river profile would parallel the modern channel from Durango to Cedar Hill, whereas t5e converges markedly and younger terraces converge slightly in the same reach. Because the remnants in question are very small, and are underlain by sandstone beds that protected them from erosion, it seems more likely that they are local features which formed during incision below t5e, than that they are related to t6a.

Previous workers recognized most remnants of TG5, but did not distinguish all levels and correlated some of them differently than in this study (Tables 4.2 and 4.3). Atwood and Mather (1932) first interpreted gravel beneath these terraces as outwash from the Durango moraines. Richmond (1965b) accepted this correlation and extended the name "Florida Gravel" to include these deposits, but his map shows them incorrectly as Bull Lake outwash. Scott and Moore (unpublished) first recognized multiple levels in the Hogback area and noted that some merge downstream (oral communication, 1980). Because of differences in correlation, each level defined here often includes remnants previously assigned to several levels (Bandoian, 1969; Scott, unpublished; Gillam and others, 1984, 1985; Ward, 1990).

Terrace Group 4

TG4 includes 5 levels of which the four highest (t4a to t4b) project above the Durango moraines (Plates 1 and 2). The lowest level (t4e) is not present near Durango, so its relation to the moraines cannot be determined. These terraces are moderately preserved from Durango to Farmington and are the highest terraces near the river in most places, but the continuity of each level varies greatly. They converge with the modern channel from Durango to the south end of Florida Mesa, then diverge slightly to the downstream end of the narrows, and converge again toward Farmington. Overall heights for TG4 decrease from 195 to 150 m in the Hogback Monocline area to 95 to 55 m in north Farmington. Gravel thicknesses vary from 2 to 35 m at the north end of this reach, are as great as 49 m in places on Florida Mesa, and decrease to 4 to 8 m at the south end of the reach.

As discussed below, t4a is a fill terrace that converges downstream with t4b. Near Durango, t4b is a fill terrace, but it may be a cut terrace in the Florida Mesa-Cedar Hill area. Likewise, t4c is a fill terrace that converges downstream with t4d, a fill or cut terrace.

Both of these fills thin downstream to straths. Terrace t4e is a strath that has been preserved mainly from Cedar Hill to Farmington, but cut out by river migration or buried by younger gravels near Durango.

Several kinds of evidence are critical to correlations among TG4 remnants. As shown in Plate 2, the heights and gradients of these remnants vary greatly from Durango to Cedar Hill when compared to those of the most continuous terrace (t5e). Long erosional gaps separate some remnants, especially through the narrows, so other data are used in correlations, including the distribution of volcanic ash deposits on t4a and t4b, local base levels and knickpoints associated with resistant bedrock at the narrows, gravel thicknesses, and shapes of gravel bodies in cross sections. Terraces t4a and t4b, the best preserved of TG4, are first described in detail to illustrate the pattern of development for TG4. This pattern is then applied to t4c, t4d, and t4e.

Terraces t4a and t4b. The key to correlating t4a and t4b through the narrows is the distribution of volcanic ash deposits identified as the Lava Creek B (Plates 1 and 2; Appendix C). Ash occurs at several sites on both t4a and t4b upstream from the narrows, but immediately downstream it occurs on the lower of two terraces which is assumed to be t4b.

Reliance on the ash as a basis for correlation is justified for several reasons. First, no ash has been found on any other terraces during this or earlier studies. Second, the relative purity of basal deposits at most ash sites suggests that the ash was reworked almost immediately from fresh airfall deposits, not from older, undiscovered ash beds on higher terraces. Finally, the apparent lack of ash on higher terraces, compared to its frequency on t4a and t4b, suggests that conditions on the latter terraces were uniquely suited to trap and preserve the ash. This situation could occur if alluvial fans were prograding across t4a and t4b when the ash fell, but were stable or being dissected on older terraces.

Proposed correlations of t4a and t4b through the narrows, based on ash sites, imply that these terraces had lower gradients in the upper narrows, where they have not been preserved, than in adjacent areas (Plate 2). If so, a convexity in their long profiles, indicating a local base level, must have extended upstream from the narrows. As described in Chapter 2, valley width decreases at the narrows because of a local increase in the proportion, thickness, and hardness of sandstone beds in Tertiary bedrock. This relatively resistant, sandy sequence is folded into a broad, northeast-plunging syncline. Small knickpoints, corresponding to individual sandstone sheets, may have existed in this area. On a larger scale, relatively gentle gradients in the upper narrows and steeper gradients in the lower narrows suggest that the entire sandy sequence acted as a local base level. Steeper gradients in the lower narrows, through the downstream limb of the syncline, indicate that the sandy sequence is effectively more resistant to incision where bedding dips upstream. This interpretation is confirmed by a computer model that shows sequential river profiles through sandstone beds with varying dips (Thomas W. Perry, consulting geologist, written communication, 1994). Conversely, terrace preservation through the downstream limb of the syncline, but not the upstream limb, suggests that terraces were initially wider in the latter area. This situation indicates that less lateral cutting occurred though the upstream limb, possibly because the river maintained a straighter channel there to maximize its gradient and to promote incision. Based on the influence of bedrock dip, it seems likely that the convexity was located near the axis of the syncline, close to the upstream end of t4b remnants in the lower narrows.

Other information about t4a and t4b is consistent with correlations based on ash sites and with the proposed base level and knickpoints at the narrows. This includes the long profile of the sub-alluvial contact (Figure 4.11), the shapes and thicknesses of gravel bodies in cross section (Figures 4.7 to 4.10), and terrace gradients (Table 4.1; Plate 2).

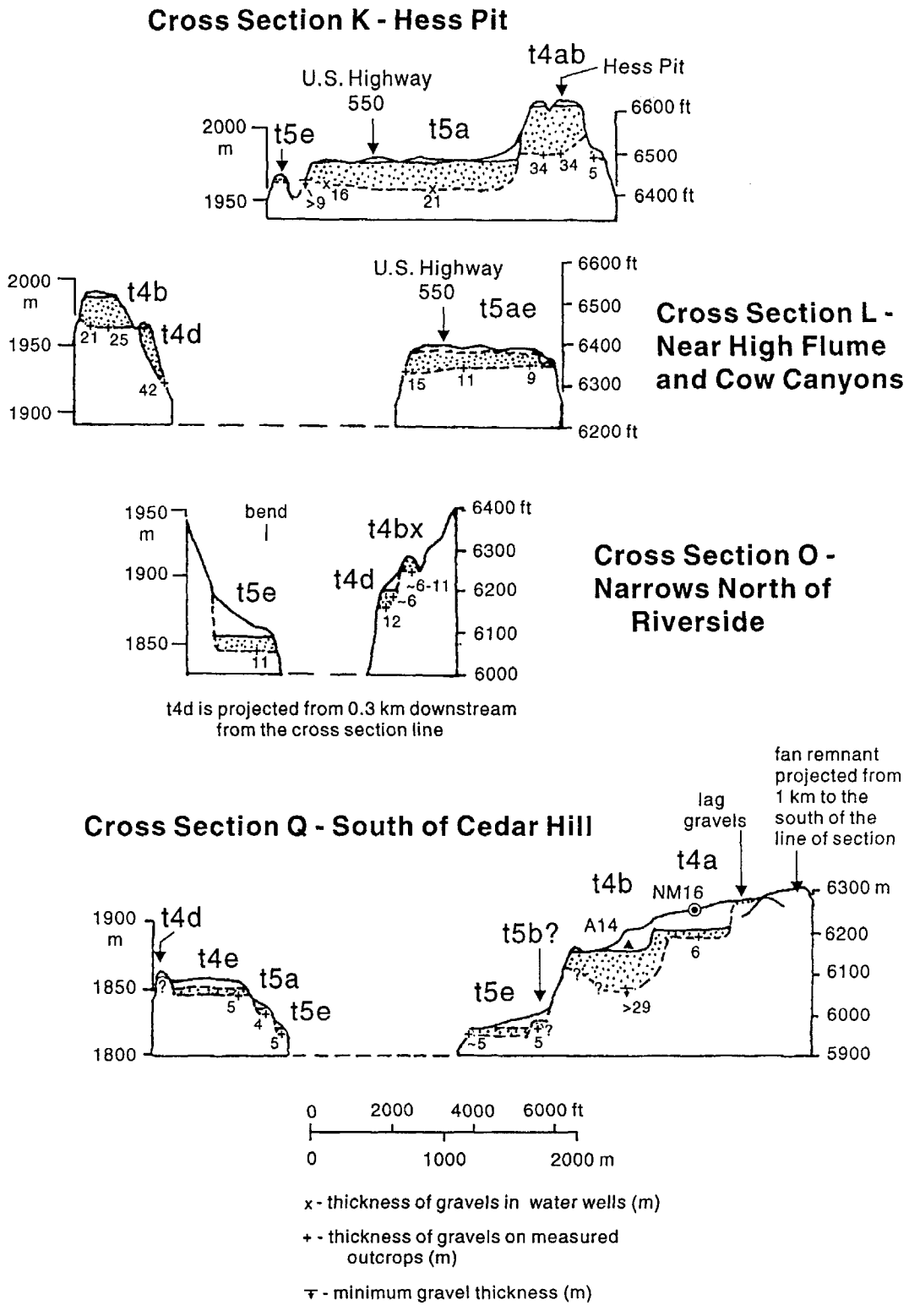


FIGURE 4.10 Cross sections through TG4 and TG5 from the south end of Florida Mesa through to Cedar Hill. Horizontal scale is 1:48,000 and the cross section locations are shown on Plates 1A and 1B.

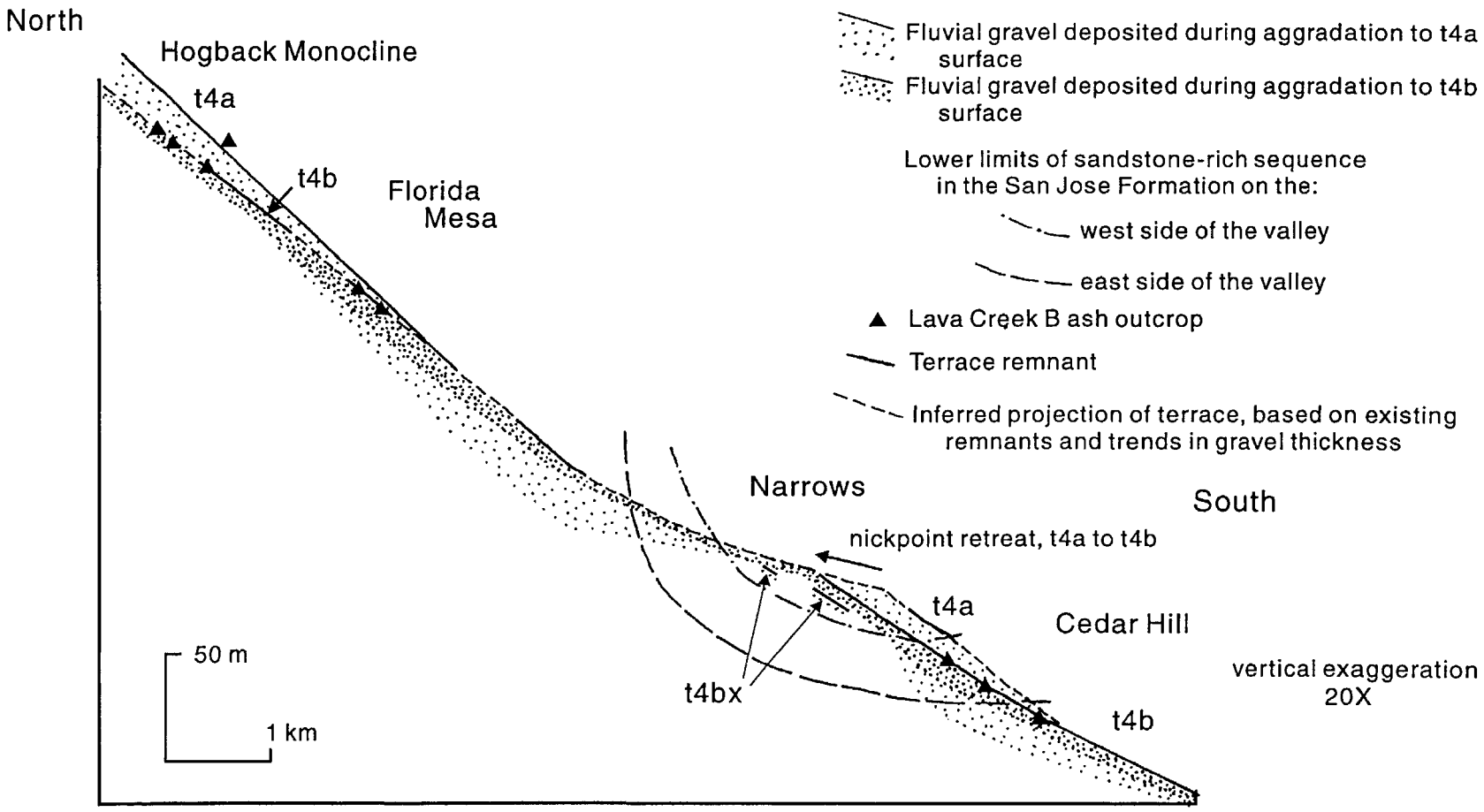


FIGURE 4.11 Schematic longitudinal section showing relation between t4a, t4b, and related gravel deposits. Gravel thicknesses are based on water well control and field mapping.

The sub-alluvial profile of t4a is more concave directly upstream and downstream from the narrows, consistent with the inferred base level (Figure 4.11), and gravel thicknesses along the paleovalley axis are greatest at these concavities. For example, the largest preserved thickness at the Hogback Monocline, 19 m (Figure 4.7, section A) is a minimum but still much less than maximum thicknesses of 46 to 49 m in water wells on Florida Mesa (Figure 4.9, sections I and J; Figure 4.10, section K). Former gravel thicknesses at or near the convexity are unknown, but gravel near the downstream end of the narrows is 3 m thick. The eroded segment in the narrows was probably a strath or thin fill like t4b remnants in the area. Downstream from the narrows, the maximum thickness of a composite fill, about 45 m (Figure 4.10, section Q, from top of t4a gravel to base of t4b gravel), marks the paleovalley axis in the lower concavity. This fill probably lies below a knickpoint that formed where the river cut though the base of the resistant bedrock sequence (Figure 4.11). Shallower concavities in the t4a surface show that the volume of sediment deposited by the river was insufficient to establish a more uniform gradient from Florida Mesa to Cedar Hill.

The nature of t4b and its relations to t4a vary downstream. At the Hogback monocline and on northern Florida Mesa, t4b apparently forms the top of a lower fill (Figure 4.7, section C; Figure 4.8, sections E and F; Figure 4.9, section G). Farther south on Florida Mesa, the terraces are closer in height and the basal contact of the gravel body passes beneath them at similar levels (Figure 4.9, section J). In this area, t4b is either a fill-cut terrace that bevels the t4a fill, or a fill terrace underlain by thinner deposits than those of t4a. The scarp between t4a and t4b becomes lower and disappears beneath overlying alluvial and eolian deposits near the south end of Florida Mesa (Plates 1 and 2; Figure 4.10, section K). Converging gradients suggest that the terraces merge in this area, but their intersection is concealed.

Continuing downstream, terraces t4a and t4b probably diverge again in the lower narrows and then merge downstream from Miller Canyon (Figure 4.11). Neither terrace is preserved in the upper narrows, but in the lower narrows t4b is a strath or thin fill with 3 to 6 m of gravel. It projects below t4a and its gravel at the downstream end of the narrows, so the terraces were probably separate in the lower narrows. At Miller Canyon, where a composite gravel body apparently extends beneath both terraces (Figure 4.10, section Q), t4b could be either a cut terrace that bevels the t4a fill, or a fill terrace underlain by thinner deposits. Because a knickpoint probably existed upstream from this section, as stated above, t4b is more likely a fill terrace here. South of Miller Canyon, t4a disappears beneath overlying deposits and is absent farther downstream, whereas t4b continues to Farmington with minor gaps (Plates 1 and 2). The absence of any terrace higher than t4b in this area suggests that t4a merges with t4b near Miller Canyon. Downstream from Miller canyon, maximum gravel thicknesses beneath t4b are 11 m as far south as Aztec and 8 m in Farmington. Therefore, this part of t4b is a fill or strath terrace underlain by deposits that become thinner with distance from the concavity below the narrows.

Several factors indicate that where both terraces are present, t4b formed during a local adjustment of the river profile associated with t4a. These include the lower gradient of t4b in the Hogback Monocline-Florida Mesa area where t4a is steepest, the smaller thickness of gravels beneath t4b, the narrower width of t4b on Florida Mesa (Plate 1; Figure 4.9, sections G and J), and terraces intersections above and below the narrows. Downstream from Miller Canyon, the river maintained approximately the same profile before and after upstream adjustments. Some basal gravel in this area may have accumulated during aggradation to the t4a surface farther upstream, whereas the upper gravel in this area must be roughly coeval with t4b gravel farther upstream.

Terrace t4bx. Four small terrace remnants, located directly upstream from the narrows and in the lower narrows, are at elevations slightly below t4b (Plate 2 and Figure

4.11). Their lower heights and limited distribution suggest that they formed during a later profile adjustment that did not create a regional terrace, so they are designated t4bx. The northern remnants have lower gradients than t4b, and thus continue the trend of decreasing gradients from t4a to t4b. The southern remnants are probably strath and cut terraces, because underlying gravel is a few meters thick (Figure 4.10, section O). In contrast, thicknesses up to 27 m suggest that the northern remnants are cut terraces that bevel fills associated with t4a or t4b.

Terraces t4c and t4d. The model for development of t4a and t4b may now be applied to t4c and t4d, which are similar in many ways but are not as well preserved and merge farther upstream. At Big Canyon in the Hogback Monocline area, both are associated with a composite fill up to 35 m thick. Terrace t4c is a fill terrace, but t4d could be either an inset fill terrace or a cut terrace that bevels the t4c fill. Continuing downstream, t4d may merge with t4c between Wilson Gulch (Figure 4.8, sections E and F) and central Florida Mesa (Figure 4.9, section I), where t4d is a fill terrace underlain by gravel up to 48 m thick. Although the upper gravel must be associated with the t4d surface, the lower part could have accumulated while the older t4c surface formed farther upstream. Correlation of t4d through the narrows is based on the assumption that its gradient decreases here, and is supported by lower gradients for t4d remnants directly upstream from the narrows. Gravel thicknesses in the upper narrows, up to 12 m (Figure 4.10, section O), are associated with a knickpoint in the sandstone sequence. Downstream from the narrows, thicknesses from 3 to 8 m indicate that t4d is a strath terrace or a fill terrace underlain by thinner depoists (Figure 4.10, section Q).

Terrace t4e. Terrace t4e is preserved mainly downstream from the narrows, where it resembles t4b and t4d but is now less continuous (Plates 1 and 2). Also, a small remnant between Florida Mesa and the upper narrows is correlated tentatively to t4e on the basis of vertical spacing in relation to nearby terraces. Because t4e is well preserved and relatively

wide in some areas, it is interpreted as a regional terrace that has been mostly eroded upstream from the narrows. Gravel thicknesses from 3 to 8 m (for example, in Figure 4.10, section Q) indicate that all t4e remnants are straths.

Terrace t4ex. This terrace is represented by a short series of narrow remnants near Lake Farmington (formerly Beeline Reservoir) in the Flora Vista-north Farmington area (Plates 1 and 2). Its limited extent suggests that it formed during a pause in incision below t4e. Such a pause could have resulted from slower incision through underlying sandstone beds. Gravel thicknesses up to 2 m indicate that t4ex is a strath.

Previous workers recognized most remnants of TG4 terraces, but did not divide multiple levels in some areas and correlated many remnants differently than in this study (Tables 4.2 and 4.3). In Colorado, Atwood and Mather (1932) named the Florida Gravel for deposits on Florida Mesa that are associated mainly with t4a. Scott and Moore (unpublished) first identified multiple levels in this area and realized that some levels merge downstream (oral communication, 1980). Because of differences in correlation, each level defined here often includes remnants that other workers have assigned to several levels (Scott, unpublished; Bandoian, 1969; Gillam and others, 1985; Ward, 1990). Some reworked gravels in the Cedar Hill area have been mapped incorrectly as terrace remnants (Bandoian, 1969; Scott, unpublished).

Terrace Group 3

TG3 includes two levels (t3a and t3b) that are well preserved from Flora Vista to Farmington but absent in most of the study area, though a possible remnant occurs on northeastern Florida Mesa (Plates 1 and 2). Except for their limited distribution, terraces of TG3 resemble those of TG4.

Remnants cap an unnamed mesa west of Flora Vista, form the crest of Crouch Mesa between the Animas and San Juan Rivers, and top a row of hills in north Farmington. Changes in overall trend from Crouch Mesa to north Farmington suggest that remnants in the latter area were deposited by the San Juan River directly downstream from its confluence with the Animas River. The present valley south of Crouch Mesa is along the former bedrock divide between the two rivers, but has been lowered by topographic reversal.

The heights of t3a and t3b are roughly 110 to 113 m and 119 to 122 m, respectively. Both terraces are generally parallel to the modern channel, but minor changes in gradient (Plate 2) probably reflect three factors: knickpoints associated with the Ojo Alamo Sandstone and sandstone sheets in the Nacimiento Formation, steeper gradients along the Animas River than along the San Juan River, and distortion from changes in relative trends of the terraces and profile projection line (Plate 1B). Gravel thicknesses of 3 to 5 m and possibly 6 m indicate that both terraces are mainly straths.

Other gravel deposits were evaluated as possible remnants of TG3 terraces, but no remnants have been confirmed. A large area where remnants could be preserved, but concealed by thick alluvial and eolian deposits, is on Florida Mesa. Because exposures are limited mainly to the mesa edges, this possibility was evaluated by examining drillers' logs for approximately 400 water wells from records of the Colorado Division of Water Resources. Elevations of the gravel top were estimated from depths on the logs, approximate well locations, and surface elevations interpolated from topographic maps. These elevations vary but generally correspond to those of younger terraces which are exposed along the mesa edges. However, gravel tops are consistently higher in one area on the northeast part of the mesa, where they could indicate a terrace of TG3 deposited by the Florida River (Plate 1A).

Gravelly deposits also cap small hills and ridges between the Florida River and the Mesa Mountains (Plate 1), but exposures show that most are side-stream channel deposits that combine locally derived sediments with upstream-derived gravel reworked from former terraces in the Mesa Mountains. Some unexposed deposits could be terrace remnants, but it is unlikely that terraces of TG3 would be preserved here because slopes below the north crest of the Mesa Mountains probably retreated during formation of of younger terraces. Therefore, deposits of indeterminate origin are tentatively assumed to be local alluvium resulting from dissection and retreat of the Mesa Mountains escarpment.

Other potential TG3 remants include two small hills west of the river, approximately 6 km south of Cedar Hill. Underlying deposits are poorly exposed, but appear to be side-stream alluvium with a cobbly pavement consisting of reworked clasts from other terraces.

Pastuszak (1968) first mapped t3a and t3b in Farmington as his Twin Mounds and Martin Mesa terraces, respectively. Farther north, Bandoian (1969) first mapped them as his Aztec and Arch Rock terraces, but correlated some remnants differently than in this study. Several deposits that Bandoian (1969) interpreted as Arch Rock remnants are actually side-stream, alluvial-channel deposits that contain upstream-derived clasts reworked from older terraces.

Terrace Group 2

TG2 includes small terrace remnants that are preserved in two areas where they cap hills and mesas near lower terraces (Plates 1 and 2; Figure 4.12). Seven levels (t2a to t2g) exist only near the state line. Two levels (t2h and t2i), present only in north Farmington, were probably formed by the San Juan River downstream from its confluence with the

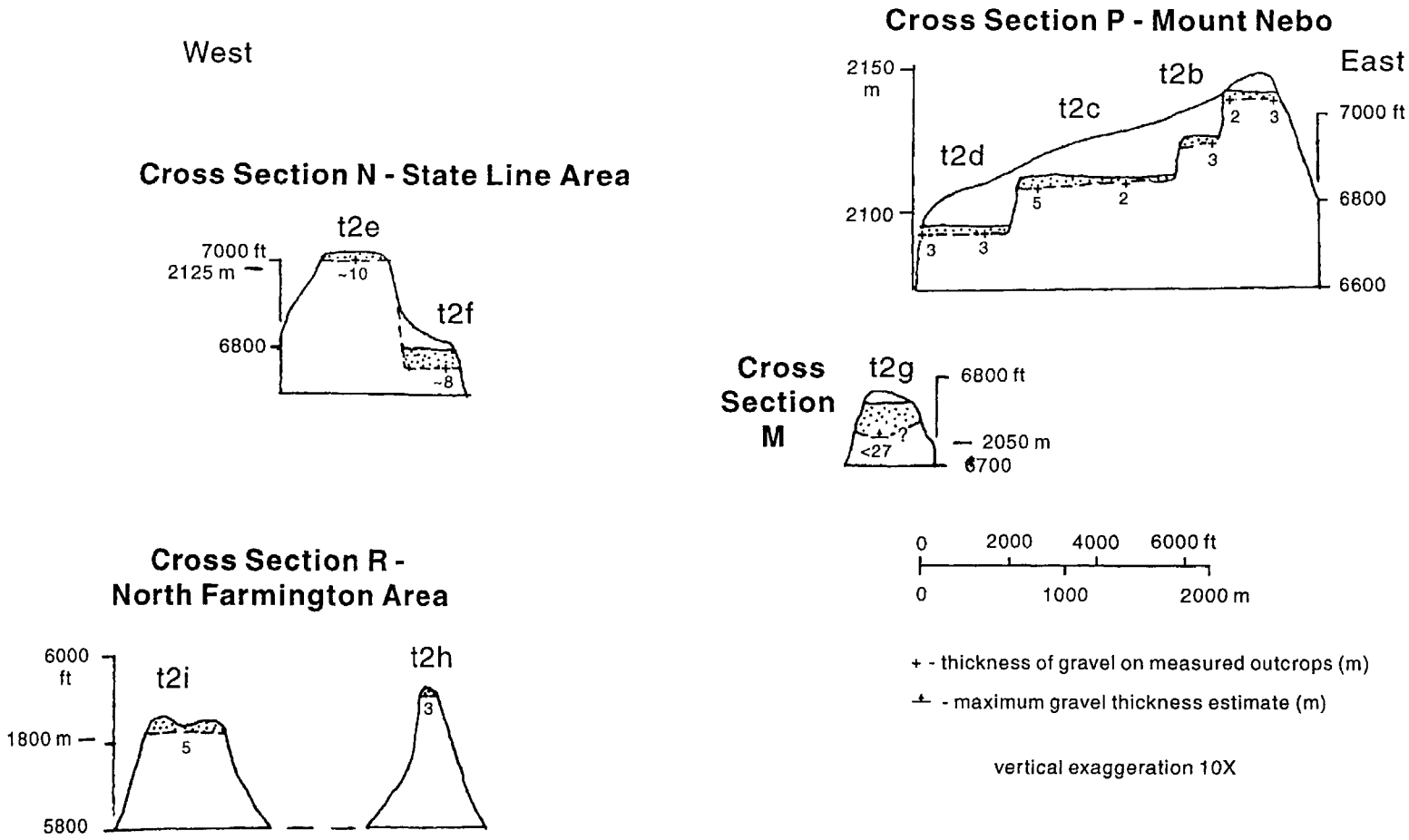


FIGURE 4.12 Cross sections through TG2 from the state line to north Farmington. Cross sections M and N are positioned vertically to show their relation to cross section P, if terraces are projected approximately along gradient. The horizontal scale is 1:48,000 and the cross section locations are shown on Plate 1B.

Animas River. Most of these terraces are straths or thin fills and that converge downstream with the modern channel, although gradients for shorter remants may be approximate.

In the state line area, heights for t2a to t2g range from 250 to 345 m. Gravel thicknesses typically vary from 1.5 to 5 m, but locally reach 8 m, indicating that most of the terraces are straths or thin fills. However, t2g is a fill terrace underlain by as much as 27 m of gravel. In north Farmington, single remnants of two levels, underlain by 2 to 5 m of gravel cap, two small mesas 180 and 175 m above the Animas River. Imbrication directions for these deposits indicate generally westward flows and deposition by the San Juan River below the confluence.

Possible correlations between these remnants and those near the state line were evaluated by comparing gradients of remnants near the state line with hypothetical gradients calculated between the two areas, and by comparing relative terrace heights within each area. Gradients from t2g to the Farmington remnants were calculated along the profile projection line, which approximates the original valley length between them. These gradients, 6.1 m/km to the higher remnant and 6.2 m/km to the lower one, are within the range for terraces near the state line (Table 4.1). Three long-term, incision-rate models were used to estimate terrace ages from relative heights in each area (Chapter 7, Figures 7.3 to 7.5). These models, which account very roughly for bedrock stratigraphy and other influences on local incision rates, confirm that the two Farmington remnants are comparable in relative height and age to TG2. Application of the most appropriate model to each area suggests that the Farmington remants are probably younger than those farther north, so the two are tentatively called t2h and t2i. If this age relationship is correct, then correlative remnants have not been preserved along the Animas River. However, complete destruction of an Animas River terrace seems possible because all terraces of TG2 are very poorly preserved.

Bandoian (1969) and Scott (unpublished) first recognized terraces of this group near the state line but did not distinguish all levels. Bandoian (1969) assigned the terraces to his Mesa Mountain surface, which he correlated with the gravels on the Mesa Mountains (Richmond, 1965b). Manley and others (1987) mapped the larger remnants as Bridgetimber Gravel, although that deposit and TG2 gravels differ in composition, and the gradients of TG2 remnants project well below Bridge Timber Mountain (Plate 2). Pastuszak (1968) first mapped t2h and t2i in Farmington as his Twin Mounds and Hood Mesa terraces. Previous workers also mapped some gravel deposits, that here are considered reworked, as terraces or named fluvial units (Atwood and Mather, 1932; Bandoian, 1969; Brown and Stone, 1979; Ward, 1990).

Terrace Group 1 and Bridgetimber Gravel

TG1 includes the highest remnants of Animas River terraces, which are located along the eastern drainage divide near the middle of the proglacial reach (Plates 1 and 2). Other, unidentified remnants may also exist along both divides. However, the highest part of the western divide, Bridge Timber Mountain, is a terrace of the La Plata River and is designated tbt.

Gravel deposits are common on hilltops and slopes along the higher parts of both divides. Along the western divide, these include Bridge Timber Mountain and its southward extension, Black Ridge. Along the eastern divide, they include the Mesa Mountains, a dissected cuesta, and its narrower southern extension. Atwood and Mather (1932) named these deposits the Bridgetimber Gravel (Table 4.2). Later, Richmond (1965b) showed that the type deposits on Bridge Timber Mountain are higher and lithologically distinct from those on Black Ridge and in the Mesa Mountains. He restricted the term "Bridgetimber Gravel" to those on Bridge Timber Mountain, which were

deposited by the La Plata River, and used the informal name, "gravels of the Mesa Mountains," for the lower gravels, which were deposited by the Animas River.

The maps of Atwood and Mather (1932) and Richmond (1965b) show gravel covering Black Ridge and the Mesa Mountains as if it forms a single homogeneous unit. Both interpreted the gravel as a fluvial deposit which Richmond (1965b) described as 6 to 12 m thick. However, the deposits actually vary in texture, bedding, topographic position, and origin. Most appear to be reworked from main-river gravel deposits and are less than 1 m thick. Therefore, several maps omit gravel on Black Ridge and show only thicker deposits in the Mesa Mountains (Barnes and others, 1954; Steven and others, 1974; Scott, unpublished; Condon, 1990).

Only four terrace remnants have been confirmed from exposures of fluvial gravels, although more may exist. These remnants cap the highest points east of Cedar Hill and Aztec (Plates 1B and 2). Tank Mountain, Slane Knob, and north Knickerbocker Peak are roughly collinear, but Hart Mountain lies 18 m below an imaginary line connecting Tank Mountain to Slane Knob. Because younger terraces and the modern channel have nearly flat profiles in this area, the relatively low height of Hart Mountain suggests that the remnants are from at least two terrace levels. Gravel thicknesses of 4 to 7 m indicate that the terraces are straths or thin fills. Lower gravels in the area are mostly thin and appear to be colluvial and alluvial deposits reworked from fluvial gravels.

In the northern Mesa Mountains, no terrace remnants have been identified and most gravel deposits are probably reworked. The highest gravels cap small, rounded hills along the north rim at elevations of 2305 and roughly 2325 m. Although these deposits occupy similar landscape position as terrace gravels farther south, their origin is uncertain because they are not exposed. Lower gravels cover most of the surrounding upland. Some of these deposits have nearly planar surfaces that are elongated along to present streams and have steeper gradients than Animas River terraces (10.0 to 20.8 m/km). Such features suggest

that they consist of side-stream alluvium reworked from upstream-derived, fluvial gravels, as verified from bedding and matrix composition at one site. Scattered exposures show that many deposits consist of colluvium and that some contain shear planes suggesting mass movement on gentle slopes, possibly by former solifluction processes.

Similar gravels are present, but less extensive, on Black Ridge and the narrower divide farther south. In this area, several of the higher hills have dense gravel pavements and relatively planar tops, but the origin of the deposits cannot be determined without exposures. Richmond (1965b) mapped Animas River gravel along the southeast side of Bridge Timber Mountain, but this area is an apron of colluvial and landslide deposits derived from the Bridgetimber Gravel (Scott and Moore, 1981).

The highest gravels along both divides are at roughly similar elevations and define an envelope with heights of 460 to 470 m at the north end of the Mesa Mountains, 355 to 395 m where projected across the state line, and 385 m at north Knickerbocker Peak. In comparison, tbt (at the top of the Bridgetimber Gravel) is 625 to 660 m above the Animas River.

The distribution of reworked gravels indicates that more extensive terraces once existed on or near both drainage divides. The large distance between the divides, 15 to 20 km, has led to interpretations of gravel origins that differ from those for younger and narrower terrace belts. Atwood and Mather (1932) interpreted the Bridgetimber Gravel (as restricted by Richmond, 1965b) and the gravel on the Mesa Mountains as alluvial deposits that accumulated on a Tertiary peneplain surrounding the San Juan Mountains, whereas Richmond (1965b) interpreted the gravel on the Mesa Mountains as remnants of an early Pleistocene outwash plain that predated Animas-valley incision. However, a long period of stable base levels along the Animas and nearby rivers would be required to form any broad surface with low relief. Steven (1968) has shown that the proposed Tertiary peneplain did not exist, and there is no evidence elsewhere in the region for a younger piedmont surface.

Because reworked gravels are not present everywhere along the present drainage divides, it is more likely that they indicate the locations of former river courses, than that they were derived from erosion of an extensive piedmont surface. If the gravels do indicate different river courses, were they formed by one or two rivers? The distance between the eastern and western divides is roughly comparable to the spacing between rivers draining the San Juan Mountains. Present information about gravel compositions on these divides and in adjacent river valleys is limited, but supports deposition of gravels along both divides (except for the Bridgetimber Gravel) by the Animas River (Richmond, 1965b). Gravels near the eastern divide (in the western Mesa Mountains) are distinct from those on younger terraces of the Florida and Los Pinos rivers, whereas gravels on the western divide are distinct from those of the La Plata River, but could indicate a combination of sediments from Animas and La Plata sources. These interpretations are tentative because preliminary work in the region shows that gravel lithologies vary not only between rivers, but also with time and with location along a single river (Chapter 5; Gillam, unpublished data; I. Luchitta, U.S. Geological Survey, and S. Davis, consulting geologist, oral communication, 1996). In addition, some rock types which are diagnostic for specific source areas may be depleted by weathering in deposits of this age.

Diversions of the River's Course

The distribution of terrace remnants shows that the lower course of the Animas River was diverted at least three and possibly four times between TG1 and TG3 time. Information used to constrain former courses (Figure 4.13) includes not only terrace distributions, but also sources and imbrication directions of fluvial gravels, and distributions of clasts that were reworked from terrace gravels. The river crosses the Hogback Monocline in an area where fracturing associated with many small faults (Zapp,

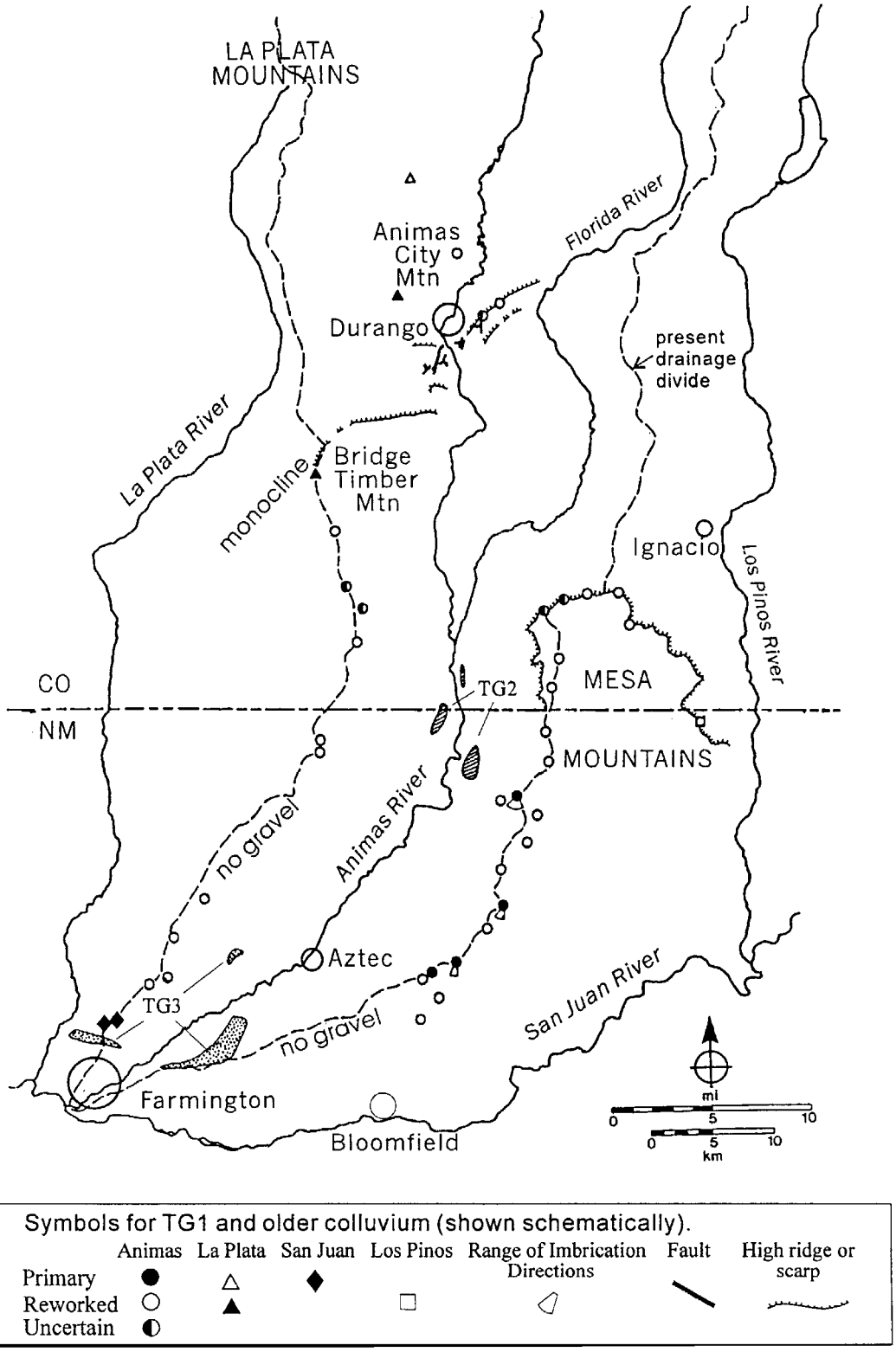


FIGURE 4.13 Features that constrain the locations of former river courses in the study area, including remnants of TG3 and older terraces, colluvial lag gravels deposited by different rivers, and selected faults (Zapp, 1949) in the rim of the San Juan Basin.

1949) has facilitated erosion. Upstream from there, the river is confined in a deep valley and has remained relatively stationary during the period represented by existing terraces. Diversions occurred at several places in the northern San Juan Basin, which cannot be pinpointed, partly in response to varying erodibility and structure of Tertiary sediments. However, cyclic aggradation and incision may also have facilitated diversions, depending on the mechanisms (such as spillover or capture) that were involved.

As described above, primary Animas River gravels related to TG1 are present along the eastern drainage divide, whereas reworked and possibly undiscovered primary gravels are widespread along parts of both divides at similar or higher elevations. If the distribution of primary and reworked gravels from the upper Animas River drainage indicates two courses in the TG1 age range, the eastern one may be older. A course from Durango toward the Mesa Mountains (Figure 4.14) would trend roughly down-dip across sandstones and shales of varying erosional resistance, but the river could later have spilled into, or been captured by, another stream cutting headward along a strike valley in softer rock. The presence of Bridgetimber Gravel, a deposit of the La Plata River, on the western divide supports this relative-age interpretation for early Animas River courses. Bridgetimber Gravel is probably older than TG1 (Chapter 7), and its greater height suggests that relatively high elevations existed in its vicinity during early TG1 time. The structural position of the Bridgetimber Gravel, on the edge of the San Juan Basin, could indicate that the La Plata River entered the basin and flowed into an early Animas River when the unit accumulated. However, this possibility seems unreasonable because it would require a mechanism for diverting or capturing the La Plata River back to its present valley outside of the basin, an unlikely event if the La Plata River were ever linked to a lower local base level along the Animas River.

Large volumes of reworked gravel indicate that the older TG1 course may have skirted the present northwestern rim of the Mesa Mountains in a strike valley and then

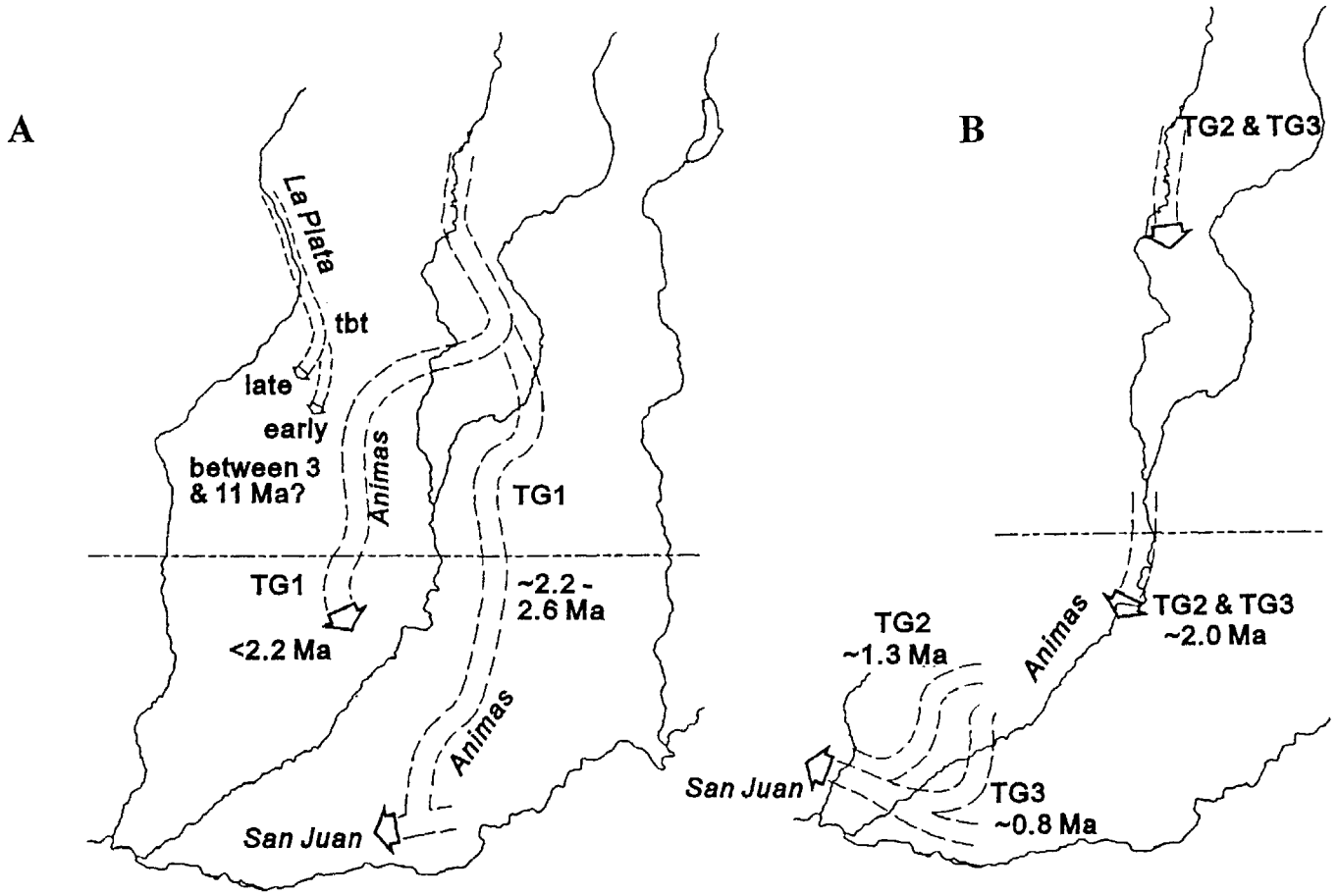


FIGURE 4.14 Inferred courses of the Animas, La Plata, and San Juan Rivers at successive times, based on the constraints in Figure 4.13. A, during tbt and TG1 time; B, during TG2 and TG3 time. Estimated ages show when various reaches became established.

continued more directly south than at present. Southward imbrication at Slane Knob and the absence of reworked gravels along the modern drainage divide, from east of Aztec to TG3 on Crouch Mesa, support this interpretation. Smaller volumes of reworked gravel on Black Ridge suggest that the younger course may have farther east, before turning more eastward west of Cedar Hill.

By early TG2 time, the Animas River had been diverted again to its present vicinity near the state line, and by late TG2 time, the lowest reach was near reworked gravels along the present western divide, but upstream from t2h and t2i, which are deposits of the San Juan River in north Farmington. In the same area by TG3 time, the junction of the Animas and San Juan rivers had apparently shifted farther east. More recently, the river has shifted by lateral cutting, rather than diversion, so its latest courses are marked by inset or laterally stepping terraces of TG3 and younger age.

CHAPTER 5

MORAINE AND TERRACE DEPOSITS

Several types of deposits are associated with moraines and terraces. Moraines are composed of till, diamicton, fluvial, and lacustrine sediments, whereas terraces are underlain by fluvial channel and overbank deposits from mostly main-river sources. Side-stream alluvium, eolian deposits, sheetwash, and colluvium are widespread but mainly of interest where they overlie moraines and terraces. Surficial deposits lie unconformably on, and are derived mostly from, older rocks in the Animas River drainage. However, much eolian silt may be transported from other parts of the Colorado Plateau that are upwind (generally southwest) of the study area.

The principal types of deposits are distinguished by texture, composition, color, bedding, sedimentary structures, and stratigraphic position with respect to landforms. For relatively fresh sediments, color varies mainly with composition. Among gravelly to sandy deposits, mineralogy and lithology distinguish sediments with sources upstream and downstream from the terminal moraines. Upstream sources include various rock types in the upper drainage basin, whereas local sources include mainly sedimentary rocks in the Hogback Monocline and northwestern San Juan Basin (Figure 2.1).

Fossil snails, identified by Emmett Evanoff (University of Colorado Museum, written communication, 1992-1997), provide information about local moisture and rarely temperature at a few sites. Unless redeposited, snails are found in habitats on former surfaces or at shallow depths within pre-existing sediment. Thus, environmentally

diagnostic species usually indicate conditions during pauses between deposition of underlying (or enclosing) and overlying materials.

In this chapter, descriptions of terrace and other widespread sediments are based on work for this study, but descriptions of moraine sediments are summarized from work by Johnson (1990) and in Johnson and Gillam (1995). Textural data from both studies are comparable but not identical because of differing analytical methods. In this study, grain-size distributions were determined according to the USDA-SCS system, but only for the fine fraction (<2 mm) of samples pretreated to remove carbonate and organic matter (see Appendices A and B for methods and data). Johnson measured grain-size distributions for both the fine and gravel fractions (up to 64 mm) of untreated samples, using the modified Wentworth system. Duplicate data for one sample suggest that analytical variations may be plus or minus one percent in total sand but up to several percent in total silt and total clay. These variations reflect not only grain-size systems, but also the size distribution of primary carbonate grains (unknown, but probably dominated by silt because calcite is more easily abraded than many minerals). Till and diamicton contain 12 to 18 % primary carbonate (as discussed below), so Johnson's textural data may be more accurate for moraine sediments from deep exposures with little pedogenic carbonate. Textural data from this study may be slightly biased for moraine sediments, but are considered accurate for other sediments with up to 2 % primary carbonate. In grain-size histograms, bar widths vary according to the class boundaries determined in each study. Bar heights indicate average weight percentages per ϕ unit of bar width.

As used here, "fluvial" indicates main-river deposits and "alluvial" indicates side-stream deposits, but Johnson (1990) also used "fluvial" for moraine sediments of small meltwater streams. "Upstream" and "local" refer to the original sources of sediments. However, upstream-derived clasts in fluvial deposits are often reworked by local processes

and redeposited with material from local sources as components of side-stream alluvium and colluvium.

Moraine Sediments

After general observations of moraine deposits in the Durango area (Harrington, 1970 and unpublished; Richmond, 1965b; Gillam and others, 1984), Johnson identified specific types of diamicton and sorted sediment from unusually good exposures of the Animas City 2 and 3 moraines and the "Bakers Bridge moraine" (Table 5.1; Figures 5.1 and 5.2). Similar types occur in other moraines. Diamictons include lodgement till in the "Bakers Bridge moraine" (facies BBM); matrix-rich diamicton with abundant silt (MDS), interpreted as debris-flow sediment; matrix-rich diamicton with color bands (MDB), interpreted as melt-out till; clast-rich diamicton (CD), interpreted mostly as coarse, debris-flow sediment but possibly containing stream sediment that is very poorly sorted. Better-sorted sediment includes stream (F) and lacustrine (L) deposits (eolian deposits that cover various landforms are described later).

Lodgement Till (BBM)

Lodgement till (Table 5.1, Figures 5.1 and 5.2A) is composed of sandy loam with moderate pebble to boulder content, diffuse lenses of slightly varying texture, many striated clasts, bullet boulders, a few broken pebbles with displaced fragments, and uniform striation directions with depth (Johnson, 1990). Pebble fabrics are weak and polymodal with a dominant trend that is parallel to striations.

TABLE 5.1 SEDIMENT TYPES IN ANIMAS CITY AND 'BAKERS BRIDGE' MORAINES

TYPE	Matrix-rich diamicton with abundant silt (MDS) [1]	Matrix-rich diamicton with color bands (MDB) [1]	Clast-rich diamicton (CD) [1]	Stream sediment (F) [1,2]	Lacustrine sediment (L) [1,2]	Matrix-rich, massive diamicton (BBM) [1,2]
COLOR (Munsell dry, moist)	7.5-5YR 4/4 (m) 7.5-10YR 6/3 (d)	5-10YR 4/4 (m) ND	7.5YR 4/4 (m) ND	ND ND	10YR 4/3 (m) 10YR 6-7/3 (d)	10-7.5YR 4/3-2 (m) 10-7.5YR 6/2-3 (d)
TEXTURE	Slightly gravelly to gravelly silt loam to loam	Slightly pebbly loam, silt loam, clay loam, or silty clay loam	Gravelly to very gravelly sandy loam	Nongravelly to very gravelly loamy sand, sand, sandy loam, and silt	Silt to clay	Gravelly sandy loam
SAND:SILT:CLAY [3]	40±11 : 48±8 : 12±12	35±11 : 48±6 : 17±8	66 ± 4 : 27 ± 3 : 7± 2	76±19 : 20±19 : 4±1	4±5 : 70±17 : 26±20	58±4 : 26±3 : 16±3
GRAVEL VOL. [4] (%)	27±16, range 5-59 (mostly pebbles, few cobbles, boulders rare but abundant near valley margins)	2±1, range 1-3 (mostly pebbles <1 cm, rare cobbles)	67±8, range 58-75 (mostly pebbles, few cobbles, boulders rare)	64±7, range 56-76 (mostly pebbles, few cobbles)	0; <1 very rare (pebbles)	42±8, range 30-50 (pebbles to boulders)
PRIMARY CARB. [5]	ca. 12-18 (sediment types undifferentiated)			ND	ND	ND
BEDDING AND SEDIMENTARY STRUCTURES	Beds separated by sandy partings; not graded; broken, displaced pebble fragments; beds dip downvalley	Beds have internal layers of differing color and texture, some draping over clasts; unlithified clay and sand clasts; beds dip upvalley	Beds massive, poorly sorted, matrix to clast supported; no imbrication or grading; beds dip downvalley	Beds moderately sorted, clast supported, imbricated; may have openwork; horizontally or cross bedded; minor cut and fill structures	Laminations conformable, very continuous; some draping	Diffuse zones with sandier texture; few broken, displaced pebble fragments; bullet boulders; many striated clasts

TABLE 5.1 SEDIMENT TYPES IN ANIMAS CITY AND 'BAKERS BRIDGE' MORAINES, continued

TYPE	Matrix-rich diamicton with abundant silt (MDS) [1]	Matrix-rich diamicton with color bands (MDB) [1]	Clast-rich diamicton (CD) [1]	Stream sediment (F) [1,2]	Lacustrine sediment (L) [1,2]	Matrix-rich, massive diamicton (BBM) [1,2]
PEBBLE FABRIC	Multimodal; dominant mode is perpendicular to moraine crest and dips downvalley	Unimodal, strong; mode is perpendicular to moraine crest and dips upvalley	Polymodal, weakest; no relation to moraine trend	ND	NA	Polymodal, weak; dominant mode is parallel to striations and constant with depth
RELATIONS TO ADJACENT UNITS	Interlayered with fluvial sediments along sharp, intertonguing contacts	Only on proximal side of moraine; inter-fingers with laterally adjacent MDS	Interlayered with fluvial sediments along sharp, intertonguing contacts	Interlayered with MDS and MDB	Interlayered with fine fluvial sediment and MDS in coarsening-upward sequence	Overlies striated granite
ORIGIN	Debris-flow of moderate viscosity with shearing throughout; derived from supraglacial debris and deposited proglacially (not on stagnant ice or overridden by active ice)	Meltout till, derived from melting of stagnant ice with high debris content	Mostly debris-flow sedi-ment, but part very poorly sorted fluvial sediment (?); derived from supra-glacial debris and de-posited pro- glacially (not on stagnant ice or over-ridden by active ice)	Fluvial sediment of small streams	Lacustrine sediment, deposited in ice-marginal lake	Lodgement till; sediment released by melting at base of actively sliding glacier
ABUNDANCE IN END MORAINES STUDIED	Abundant, especially in lateral positions	Rare	Common, especially in medial positions	Common, especially in medial positions	Rare	Observed only in Bakers Bridge "moraine"

1. Information paraphrased from Johnson (1990) and Johnson and Gillam (1995); NA – not applicable; ND – no data.
2. Johnson (unpublished data).
3. Weight percent, gravel free, formatted as mean ± 1 standard deviation; modified Wentworth scale; sediment contains primary carbonate.
4. Volume percent, formatted as mean(standard deviation).
5. This study, Tables A.1 and B.7.

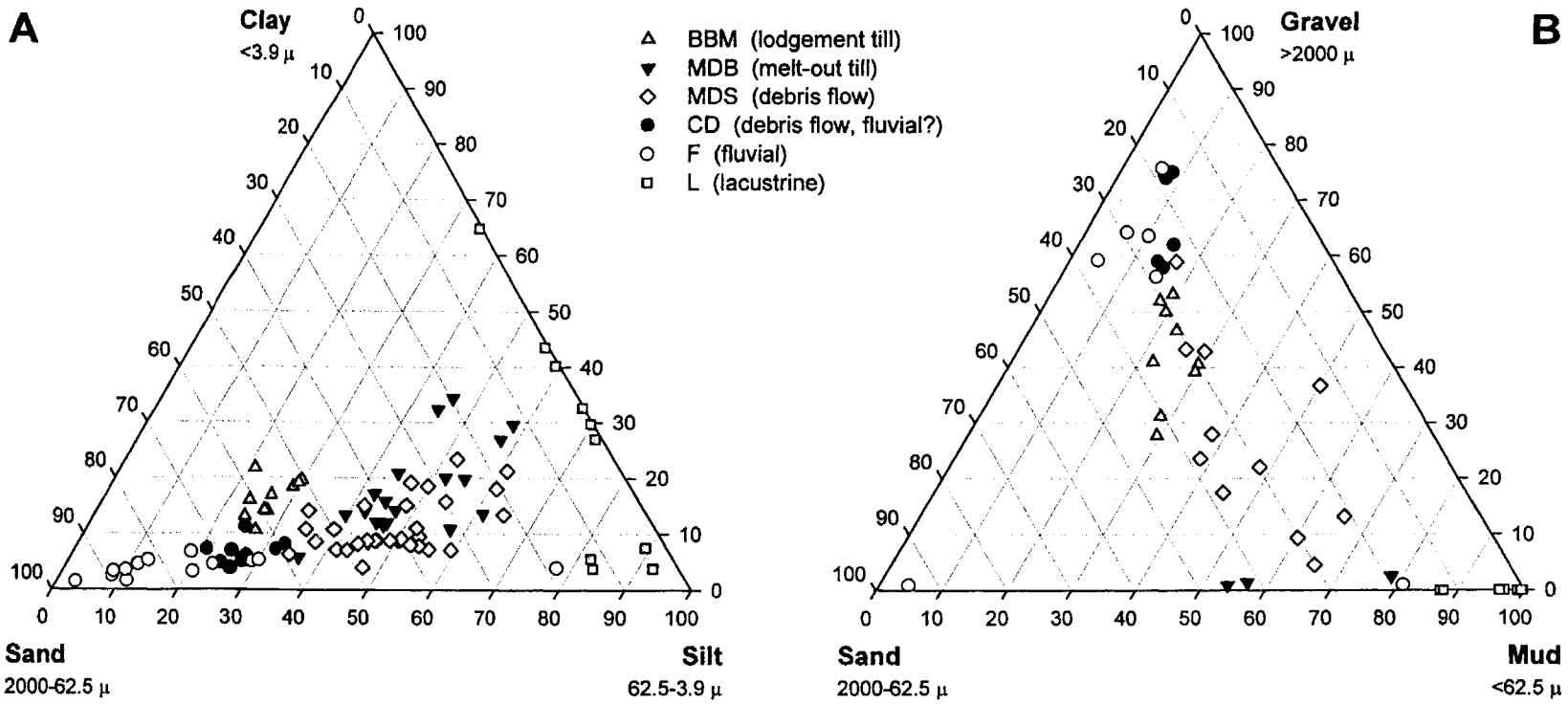


FIGURE 5.1 Ternary diagrams showing textures of moraine sediments (data from Johnson, 1990 and unpublished, and Johnson and Gillam, 1995).

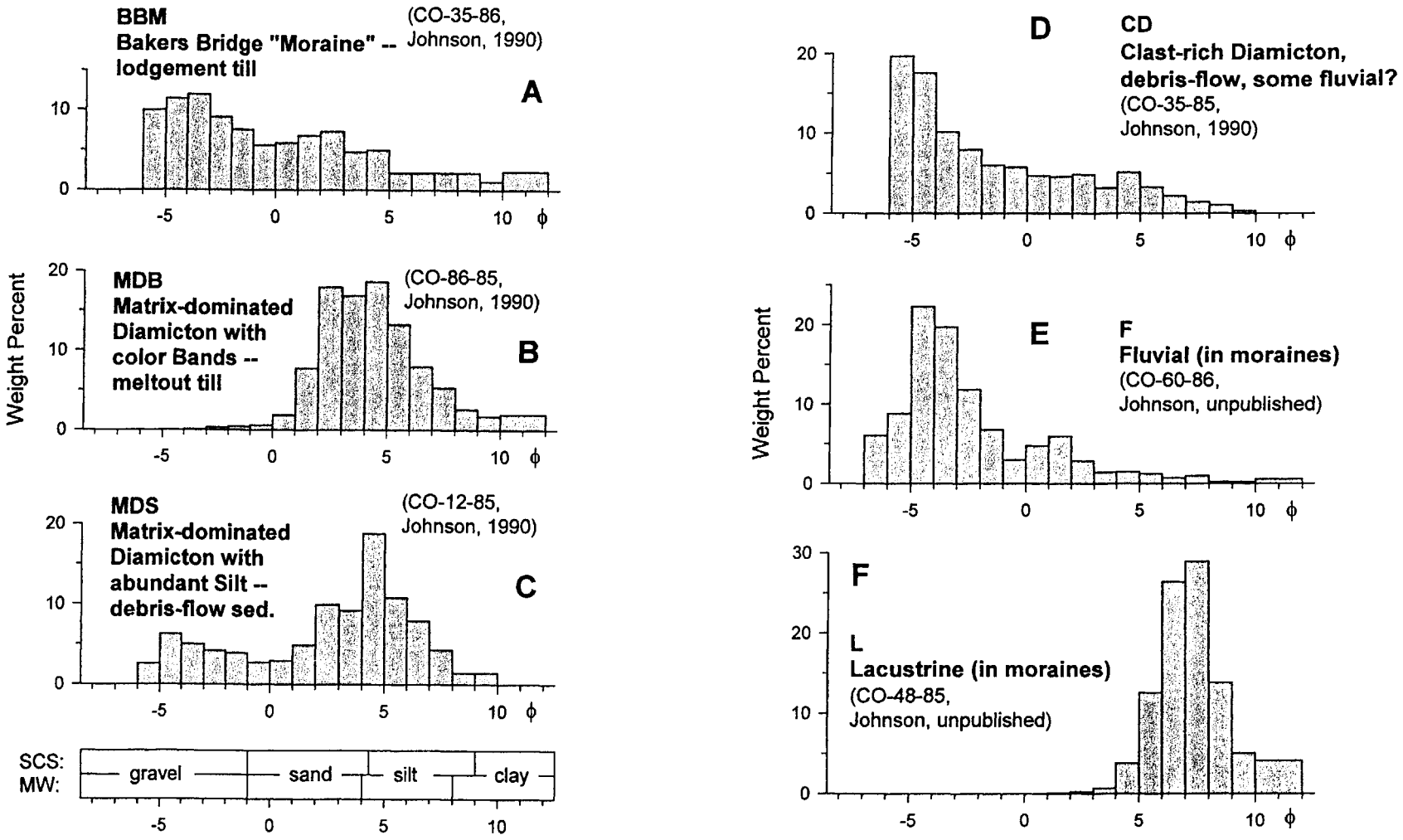


FIGURE 5.2 Histograms showing textures for typical samples of moraine sediments (data from Johnson, 1990 and unpublished).

Melt-Out Till (MDB)

Melt-out till (Table 5.1, Figures 5.1 and 5.2B) has silty to loamy textures, low pebble content, diffuse textural and color bands, rare clasts of unlithified sand and clay that were probably incorporated while frozen, strong pebble fabrics with a single mode that is perpendicular to the moraine crest and dips upvalley, and bedding that dips upvalley (Johnson, 1990; Johnson and Gillam, 1995). Normal faults indicate either melting of buried ice or loss of lateral support. Melt-out till was observed in only one exposure on proximal side of the Animas City 3 moraine, where it interfingers with clast-rich debris-flow deposits.

Silty Debris-Flow Deposits (MDS), Clast-Rich Debris-Flow Deposits (CD), and Fluvial Deposits (F)

Most parts of the Animas City 2 and 3 moraines are composed of silty debris-flow, clast-rich debris-flow, and fluvial (stream) sediments (Johnson, 1990; Johnson and Gillam, 1995). Silty debris-flow deposits (Table 5.1, Figures 5.1 and 5.2C) have silty to loamy textures, moderate pebble and varying boulder contents, generally massive beds, and multimodal pebble fabrics with a dominant mode that is perpendicular to moraine crests and dips downvalley. Clast-rich debris-flow deposits (Figure 5.2D) have sandy matrix, high pebble content, and massive beds that are matrix- or clast-supported. Pebble fabrics lack imbrication and are polymodal with no relation to moraine trend. Fluvial sediment from small meltwater streams (Figure 5.2E) has highly variable textures ranging from gravel-free, laminated silt and fine sand to very gravelly sand or granules. Gravelly stream sediments are distinguished from clast-rich diamicton by clast-supported fabrics, imbrication, better sorting, and internally stratified beds. At most sites, interbedded

diamicton and stream sediments strike parallel to the moraine crests and dip downvalley in complex foreset patterns.

Lacustrine Sediment (L)

Lacustrine sediment (Figure 5.2F) has silty to clayey textures, lacks gravel, and forms laminae that are upward-fining, conformable, and relatively wide. Johnson (1990) interpreted fine-grained, folded sediments on the proximal side of the Animas City 3 moraine as those of a proglacial, moraine-dammed lake. When ice readvanced, this small lake filled with upward-coarsening sediments that were folded and attached to the moraine. Comparatively undisturbed lake sediments also occur in the Animas City 2 moraine.

Discussion

The moraines are composed mostly of silty to sandy sediments with low to high pebble contents, few cobbles, and rare boulders. Variations in texture and composition are related not only to local stratigraphy, but also to position along the moraine loops (Johnson, 1990; Johnson and Gillam, 1995; Johnson, unpublished data). For example, sand and pebbles are more common at central sites and boulders are abundant at some lateral sites. Reddish-brown sandstone and siltstone clasts from Paleozoic formations near the terminal area (Figure 2.1) are more common in lateral positions, where they give reddish colors to sediments and soils, but clasts from distal sources are more common in medial positions.

Moraine sediments are generally finer and less stratified than outwash gravels (described below). In several exposures, distal moraine sediments either interfinger with or prograde across outwash of adjacent terraces (Richmond, 1965b; Gillam and others, 1984; Johnson, unpublished data), in relationships that indicate locally concurrent deposition

during overall ice advance. In the Bakers Bridge area, fluvial gravels of TG8 locally bury eroded glacial deposits. Similar relations may exist in northern Durango, but have not been observed.

Initial clay and carbonate contents of moraine sediments vary, but can be moderately high (Tables 5.1 and A.1). Initial clay in samples of till and debris-flow deposits (BBM, MDB, and MDS) ranges from 4 to 34 % and averages 14 % on the modified Wentworth scale (Johnson, 1990 and unpublished data). On the USDA-SCS scale, initial clay in pretreated samples of till and diamicton, undifferentiated but probably consisting mostly of MDS, is 6 to 9 %. Initial carbonate contents of undifferentiated till and diamicton in deep cuts are 15 to 18 %, whereas the lowest values in basal soil horizons are 12 to 13 % (profile CO26, Table B.7). These values probably reflect crushed, calcareous rocks, since gravels of t7ab contain roughly 27 % limestone and limy sandstone at site P1 (see later discussion of pebble counts). Despite differing grain-size scales, initial clay in clast-rich diamicton and fluvial moraine sediment (Table 5.1) appear comparable to amounts in fluvial terrace gravels (discussed below). Lacustrine sediment, generally highest in clay, is not a parent material for soils in this study.

Terrace Sediments

Terrace sediments include mainly gravelly, fluvial channel deposits and fine-grained overbank deposits. Interfingering between moraine and fluvial sediments indicates that some fluvial sediments are outwash that formed under fluvioglacial conditions. However, other fluvial sediments may have been deposited or reworked during interglacial periods, as discussed in Chapter 7. Although earlier studies (cited in Chapter 4) have addressed parts of the terrace sequence, previous descriptions of related deposits were very limited.

Fluvial channel deposits (FCP, FC)

Fluvial channel deposits are distinguished by their positions beneath terrace surfaces, moderate to high gravel contents, mostly clast-supported fabrics, and similarity to modern river deposits. Most consist of very gravelly sand to sandy loam, but a few deposits are slightly gravelly or gravel-free (Figures 5.3 and 5.4). Near the moraines, textures and compositions vary greatly, but most sequences coarsen upward and contain more proximally derived clasts in their upper parts. With increasing distance downstream, upward coarsening gradually disappears and the deposits become more uniform. Clast and matrix sizes decrease, while clast sorting, roundness, and lithologic maturity increase. The amount of locally-derived sediment also decreases, but increases again in some deposits near Farmington.

Several subtypes are important as parent materials for soils or as indicators of depositional processes. More poorly-sorted deposits (FCP) generally cap upward-coarsening sequences from the moraines to northern Florida Mesa. Better sorted deposits (FC) are minor components of upward-coarsening sections near the moraines, also form the basal sections of upward-coarsening sequences from the Hogback Monocline to Florida Mesa, and dominate more uniform sequences in the Bondad-Farmington area. Numerous locally-derived clasts distinguish deposits located at the mouths of tributary streams or formed after valley-wall collapse. Finally, boulder bars indicate catastrophic floods.

Near the moraines, channel deposits include such diverse types as pebbly sand from various sources, sandy pebble to cobble gravel with mostly well-rounded, far-travelled clasts, and sandy pebble to boulder gravel with mostly subrounded, proximal clasts. Boulders may be isolated or concentrated in beds or clusters. Except in rare sands and pebbly sands, the matrix is dominated by very coarse sand and fine pebbles of sedimentary

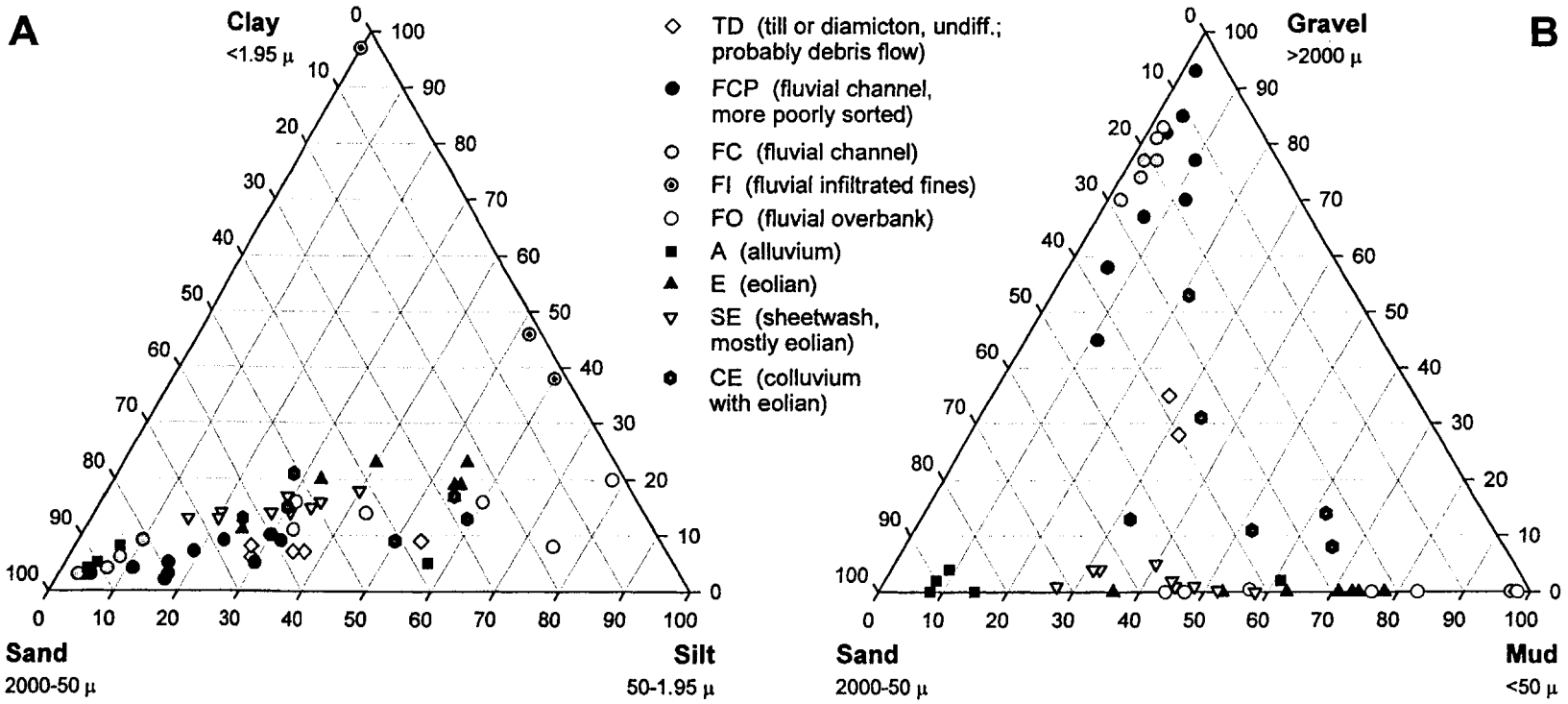


FIGURE 5.3 Ternary diagrams showing textures of fluvial, alluvial, eolian, sheetwash, and colluvial sediments (data from Table A.1).

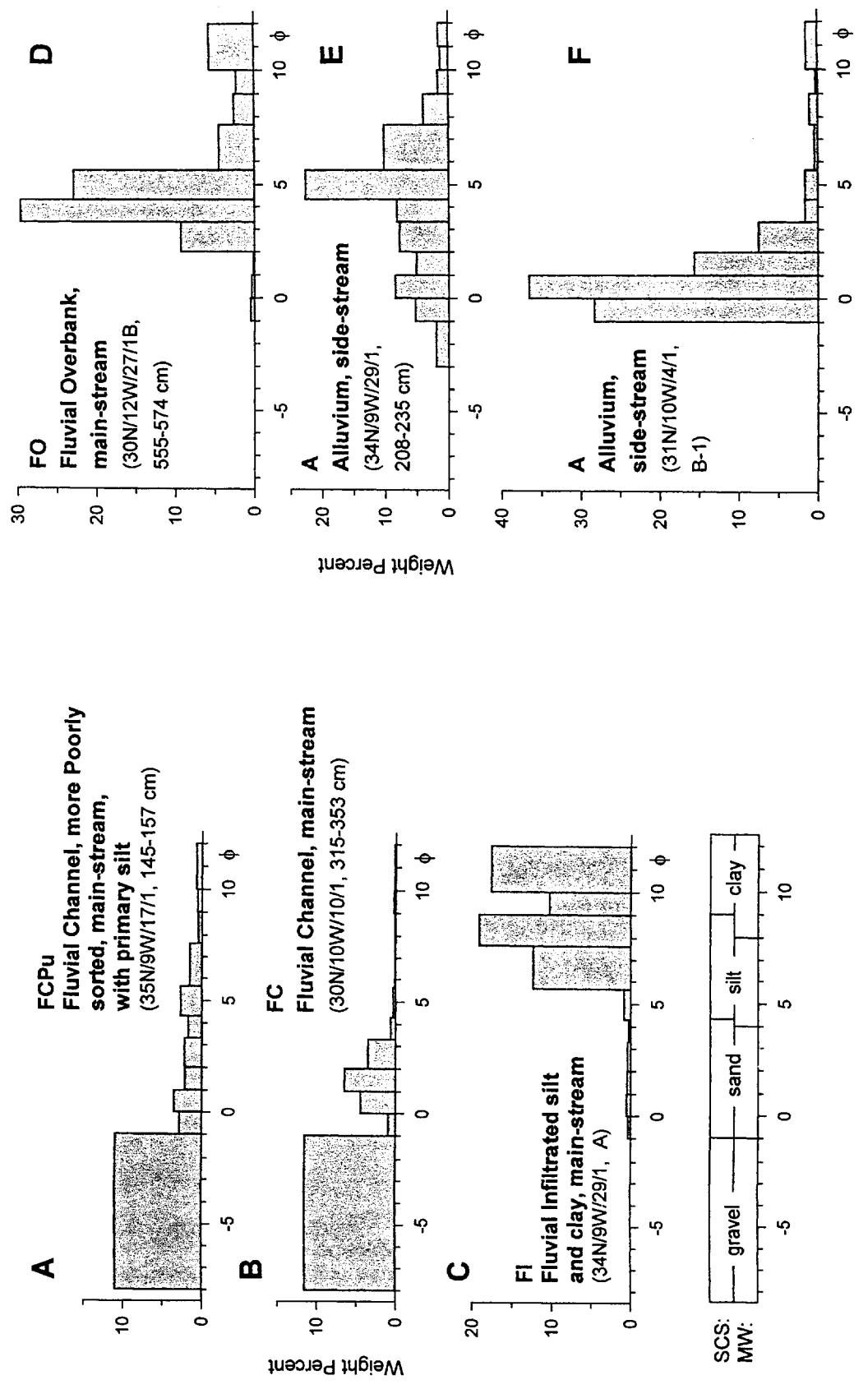


FIGURE 5.4 Histograms showing textures for typical samples of fluvial and alluvial sediments.

rocks from sources in and near the terminal area. Unit thickness ranges from a few centimeters to several meters. Coarser units appear structureless or display crude, subhorizontal bedding, but finer units have well-defined, subhorizontal bedding or planar-tabular crossbed sets. Imbrication is generally absent or very weak in coarser deposits with mostly equant clasts, but well-developed in pebbly beds with tabular fragments of sedimentary rocks. A few beds are normally or inversely graded. Large contrasts among adjacent beds and between exposures suggest varying discharges and depositional patterns.

Less-sorted deposits (FCP). Facies FCP, representing only the uppermost deposits in soil profiles near moraines, is composed of very gravelly, sandy loam or loamy sand that is very poorly sorted (Figures 5.3, 5.4A, and 5.5A; Tables 5.2 and A.1). Because granules and fine pebbles form much of the matrix, gravel contents are very high at 70 to 90 %. Clasts are subangular to subrounded and range up to large boulders. In the fraction finer than 2 mm, primary modes are in very coarse or coarse sand and secondary modes are typically in coarse silt. Initial porosity is very high, reflecting coarse textures and rare openwork lenses.

Better-sorted deposits (FC). Facies FC consists mostly of very gravelly, medium to coarse-grained, loamy sand or sand that is very poorly sorted (Figures 5.3, 5.4C, and 5.5B; Tables 5.2 and A.1). Gravel content is 50 to 70 % and includes mainly pebbles and cobbles, but also small boulders and rarely large boulders that are subrounded to well rounded. In the fine fraction, primary modes are typically in coarse or medium sand, while secondary modes are minor and variable.

Clast sizes. Intermediate diameters of the largest far-travelled clasts are generally 2 to 4 m in Durango, 50 to 100 cm in the state line area, and 25 to 40 cm at Farmington. However, proximally or locally derived boulders are slightly larger than far-travelled boulders in Durango and may be two or three times as large in other areas. Downstream-trending concentrations of boulders, as long as 1.2 km, are visible on shallowly buried

TABLE 5.2 SEDIMENT TYPES BENEATH TERRACES

TYPE	Fluvial channel deposits, more poorly sorted (FCP)	Fluvial channel deposits, typical (FC)	Fluvial overbank deposits (FO)
TYPICAL COLOR (Munsell dry, moist)	5YR 5-6/3 (d) 5YR 4-5/3-4 (m)	7.5-5YR 5-6/3 (d) 7.5-5YR 4-5/3-4 (m)	7.5YR 6/3.5 (d) 7.5YR 4.5-5/3-4 (m)
TYPICAL TEXTURE	very gravelly, very coarse loamy sand or sandy loam	very gravelly, coarse sand or loamy sand	fine-sandy loam to silt loam
SAND:SILT:CLAY [1]	71±12 : 21±8 : 7±5	89±5 : 6±3 : 5±2	33±21 : 53±21 : 14±2
GRAVEL VOLUME (%)	80±10 (approx.) (pebbles to large boulders)	60±10 (approx.) (pebbles to small boulders)	0 or trace
"coSi-vfS ratio" [1,2]	17±7	7±3	47±17
"m-vcoS ratio" [1,3]	57±14	70±8	3±2
DISTINCTIVE FEATURES	Clast-supported, poorly or not imbricated; clasts include many sed. rocks; openwork lenses	Clast-supported, well imbricated; lenticular bedding	Upward-fining and laminated units; rare fossil snails; small burrows; rare mottling or gleying
PRIMARY CARBONATE (wt % whole soil)	≈ 0.5 % (matrix) plus 1 to >17 % (clasts) (used 0.5)	≈ 0.5 % (matrix) plus 1 to 3 % (clasts) (used 0.5)	1.5-2.8, higher (used 2)
MAXIMUM THICKNESS (m)	4?	40 (approx.)	3.5

1. Formatted as average ±1 standard deviation; number of observations varies from 3 to 9. Some data summarized from table A.1.
2. Ratio of total coarse silt plus very fine sand to total silt plus sand.
3. Ratio of total medium, coarse, and very coarse sand to total silt plus sand.

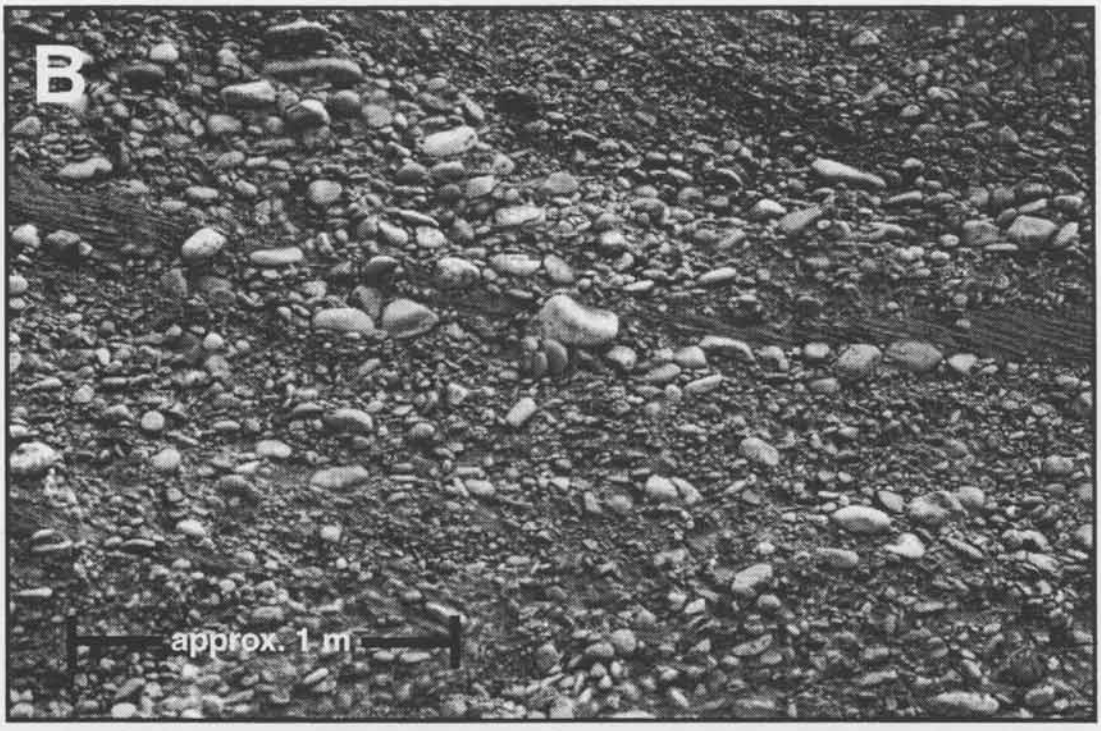


FIGURE 5.5 Typical fluvial-channel deposits. A, muddy sandy gravel (facies FCP) with matrix consisting of granules and very coarse sand, mostly structureless but very weakly bedded in places; reddish-brown color results from clasts of Pennsylvanian and Permian sedimentary rocks. B, mostly muddy sandy gravel with beds of sandy gravel and sand (facies FC); black coatings (probably iron-manganese compounds) on openwork beds.

terraces from Durango to Cedar Hill. Large intermediate diameters (generally less than 2 m but locally up to 6.5 m), boulder imbrication, and long-axis orientations transverse to flow indicate that these are very coarse bars which formed during catastrophic floods (Moore and Scott, 1981; Gillam and others, 1985).

Infiltrated silt and clay. Primary silt and clay, totaling 3 to 12 % of most samples including gravel (Tables 5.2 and A.1) is unevenly distributed in ways that could influence or be confused with soil development. Relatively large intergranular pores, up to several millimeters wide in the coarsest deposits, allowed syndepositional infiltration of fines to depths of several meters. Primary silt and clay may decrease downward from the top of the deposit from sandy interbeds in trends resembling pedogenic infiltration. Conversely, silt and clay may vary randomly among lenses. In a few beds near Durango, silt and clay form laminated, meniscate fills up to 2 cm thick in voids between clasts (Figure 5.6B). Smaller amounts of silt and clay form grain coats, caps, and bridges. Larger amounts, although rare, could accelerate soil formation by retaining moisture and reducing permeability.

Composition. Clast and matrix composition vary with source, transport distance, and terrace age, though differences among many deposits are modest or small. Most sediment was derived from formations that are exposed upstream from the moraines, but larger amounts of local rock types are present at some sites in the Durango-Hogback and Flora Vista-Farmington areas.

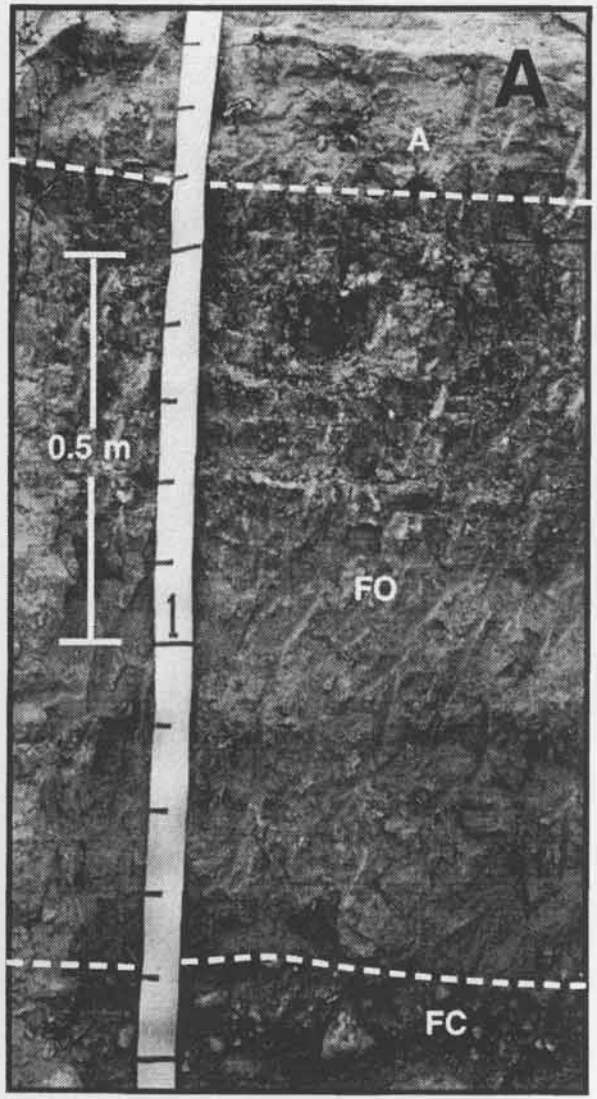
Rough counts of clast types at five sites (Table 5.3) illustrate general changes with transport distance and terrace age. The counts include deposits of TG7 (t7ab or t7u) and of t4b at sites 17 to 18 km and 72 to 74 km downstream from the Animas City 3 moraine, as well as deposits of t1u about 56 km from this moraine (Table 5.4; Plate 1). Trends with increasing distance vary for TG7 and t4b. At the northern sites, sedimentary rocks form roughly 60 % of gravel from t7ab but only 10 % of gravel from t4b, which is lithologically more mature. Gravels from both terraces show large downstream increases in

TABLE 5.3 LITHOLOGY OF CLASTS IN ANIMAS RIVER GRAVELS

TERRACE AND AGE (APPROXIMATE) SITE GENERAL LOCATION	t7ab, 10-15 ka P1 N	 P2 S	 avg.	t4b, 615 ka P3 N	 P4 S	 avg.	t1, 2.2-2.6 Ma P5 central
INTRUSIVE IGNEOUS ROCKS							
Granitic	5	8	7	2	12	7	7
Mafic	–	1	1	–	–	–	1
Finely crystalline, porphyritic	2	5	4	6	6	6	7
VOLCANIC AND METAVOLCANIC ROCKS							
Volcanic, porphyritic (mostly andesite and rhyolite, rare basalt)	2	7	5	34	20	27	30
Metavolcanic, porphyritic, dark gray-green	5	14	10	15	8	12	9
METAMORPHIC ROCKS (NON-VOLCANIC)							
Metaquartzite, light blue-gray banded or conglomeratic, pink, light blue, white	2	32	17	12	30	21	38
Orthoquartzite	9	6	8	1	3	2	2
Biotite gneiss and schist	5	7	6	7	2	5	1
Amphibolite and amphibolite gneiss	3	3	3	9	1	5	2
Metasediment, fine, bluish-green	–	–	–	1	–	–	2
SEDIMENTARY ROCKS							
Medium-grained sandstone, white with rusty flecks, strong calcareous cement	8	–	4	3	1	2	–
Medium-grained sandstone, muddy fine-grained sandstone, and sandy mudstone, dark red, ochre, and purple	14	4	9	7	3	5	–
Muddy fine-grained sandstone to sandy mudstone, olive	6	–	3	–	–	–	–
Shale and mudstone, black	4	–	2	–	–	–	–
Muddy fine-grained sandstone with irregular limey lenses, pitted-weathering, gray, olive, tan	10	3	7	–	6	3	–
Limestone, hard, gray, some fossiliferous	17	2	10	–	3	2	1
OTHER (not classified)	8	8	8	3	5	4	–
SUBTOTALS FOR GROUPS							
Intrusive igneous rocks	7	14	11	8	18	13	15
Volcanic and metavolcanic rocks	7	21	14	49	28	39	39
Quartzite	11	38	25	13	33	23	40
Other metamorphic rocks	8	10	9	17	3	10	5
Clastic sedimentary rocks (some calcareous)	42	7	25	10	10	10	–
Limestone	17	2	10	–	3	2	1
TOTAL	100	100	100	100	100	100	100

TABLE 5.4 SITE DATA FOR PEBBLE COUNTS

TERRACE AND AGE (APPROX.)	t7ab, 10-15 ka		t4b, 615 ka		t1, 2.2-2.6 ka
	P1 north	P2 south	P3 north	P4 south	P5 central
LOCATION	Weaselskin Bridge (at CO9)	Farmington	Florida Mesa (at CO34)	Crouch Mesa	Slane Knob (near NM21)
Site number (T/R/sec/number)	34N/10W/36/3	29N/13W/1/1	34N/9W/29/1	29N/12W/5/1	30N/10W/10/1
Location within section	SW/4 NW/4 SW/4 NE/4	NW/4 SE/4 SE/4 SW/4	NE/4 SE/4 SW/4 SE/4	SE/4 NW/4 SW/4 SW/4	NE/E NE/4 SW/4 SE/4
7 1/2' quadrangle	Basin Mountain (1968)	Farmington South (1965)	Loma Linda (1968)	Farmington North (1963)	Aztec (1985)
Profile distance (km)					
from San Juan River	62.9	6.8	64.0	9.2	24.5
from Animas City 3 moraine	17.8	73.9	16.7	71.5	56.1
CLAST SIZE (cm)					
Range (most clasts)	2-500	1-20	2-50	1-20	1-15
Size counted	5-15 (below median)	5-10 (median and above)	5-15 (median and below)	5-10 (near median)	5-10 (near median)
NUMBER OF CLASTS COUNTED	100	100	100	100	100



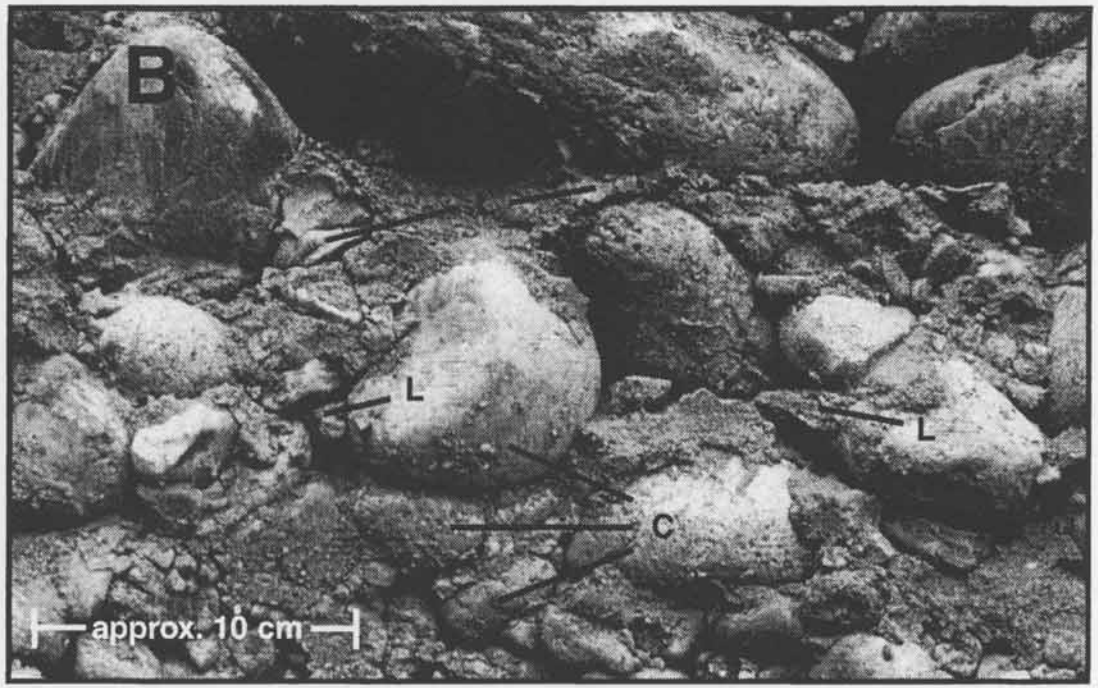


FIGURE 5.6 A, typical fluvial-overbank deposits (facies FO) including pinkish-brown, sandy, upward-fining units overlain by grayish-brown, laminated mud; other symbols: A – sidestream alluvium, FC – fluvial channel gravel with infiltrated fines from above. B, primary infiltrated silt and clay in muddy sandy gravel (FCP) that is weakly cemented with groundwater carbonate; L – silty to clayey laminae in voids, C – silt-clay coatings on clasts.

metaquartzite and granitic rocks, but the proportions of other types change less consistently (small differences are not statistically reliable). For example on t4b, the downstream decrease in volcanic and some metamorphic rocks suggests that they are more readily abraded than metaquartzite and granitic rocks. However on t7ab and t7u, downstream increases in volcanic and some metamorphic rocks reflect the larger reduction in sedimentary rocks. Changes with time from t1u to TG7 appear to include decreases in volcanic rocks, metavolcanic rocks, and quartzite and an increase in sedimentary rocks.

Rock types that enter the river below the moraines, and form most of the gravel and matrix near some tributary mouths and bedrock slopes in the Durango-Hogback Monocline area, include shallow intrusive rocks from the La Plata Mountains and Cretaceous sandstones and shales. Most locally-enriched deposits are very small. However, an unusually extensive unit underlies t5c west of the Durango 2 moraine (Glenn R. Scott, U.S. Geological Survey, unpublished mapping) and continues beneath terraces t5b to t5e for at least 7 km to the north side of Wilson Gulch (Figures 4.7 and 4.8). Near the moraine, this unit consists of chaotically sorted, apparently structureless, fine to bouldery material derived from local Cretaceous rocks and from older, more distal sedimentary rocks (Moore and Gillam, 1984). From there to Wilson Gulch, maximum clast size decreases from 5 m to the cobble range, while igneous and metamorphic clasts increase to several percent, and fluvial features such as clast support, imbrication and bedding become well developed. The unit rests on bedrock along a paleovalley axis, is more than 26 m thick at Carbon Junction Canyon in the Hogback area, and is overlain by typical channel gravels. Some deposits near the moraine lie roughly on the downslope projection of a broad, debris-mantled surface west of the river, resemble its deposits, and may have been emplaced by debris flows from that source. However, the unit's volume and distribution suggest that most originated as landslide debris from the western valley slope and was partly reworked by fluvial processes.

In contrast to locally-enriched fluvial deposits in the Durango-Hogback area, clasts of Tertiary sandstone are very rare in channel deposits within the San Juan Basin. This rarity reflects the low abundance of sandstone in some areas, relatively weak cementation in Tertiary sandstones, and more frequent reworking of sediments along channel reaches with little or no net aggradation.

Trends in matrix composition differ slightly from those in clast composition. As noted above, pebbly matrices in the Durango-Hogback Monocline area are composed almost entirely of sedimentary-rock fragments. However, the matrices of most deposits consist of upstream-derived, medium to coarse, arkosic sands with common lithic fragments and many pinkish, iron-stained grains from Pennsylvanian and Permian sedimentary rocks. In contrast, sand from Tertiary sediments is mostly coarse to very coarse, arkosic, and yellowish-brown. Because of its coarser texture and distinct color, additions of locally derived to upstream-derived sand should be readily apparent if not significantly diluted by upstream-derived sand. Locally-derived sand is usually insignificant, but forms much of the matrix at some sites in the Flora Vista-Farmington area.

Fluvial overbank deposits (FO)

Fluvial overbank deposits are distinguished by their position above fluvial gravels, fine textures, dominant upward-fining units, and mostly reddish-brown colors indicating a main-river source (Figures 5.3, 5.4D, and 5.6A; Tables 5.2 and A.1). Textures range from loamy fine sand to clay, but most deposits are fine-sandy loam to silt loam with primary modes in either fine sand or silt and secondary modes in medium and fine clay. Clay content is 11 to 20 percent in several samples from deep cuts with little or no pedogenesis.

Gravel is typically absent, but buried clasts may protrude into basal deposits and two sections have interbeds of pebbly sand.

Most sections are dominated by upward-fining units 10 to 30 cm thick, in which the coarser parts may display weak horizontal partings or small-scale cross bedding and the upper parts are structureless. These units may be interbedded with laminae of sand, silt, or rarely clay. Beds are commonly lenticular or vary in texture over tens of meters horizontally. At one site, beds with gleyed colors are capped with 0.2 m of organic-rich clay that suggests a marsh environment. Burrows of insects and small animals are abundant in places.

Fossil snails are present locally in the tops of upward-fining units (Tables 5.5 and 5.6, sites S3, S4, S8, and S10). Their species include mainly land snails but also freshwater snails indicating either dry environments or wet environments with standing water nearby. *Vertigo binneyana* at site S8 suggests cooler temperatures than present (E. Evanoff, written communication, 1997).

Brown to reddish brown hues and locally high mica contents indicate a main-river source for most sediments. Rarely, yellowish hues indicate either main-river deposits from local sources (as in profile CO15, Table B.4) or interbeds of side-stream alluvium near valley sides. Mottling and gleying are rare. The primary carbonate content of three modern samples, from 1.5 to 2.0 %, suggests that higher values for older samples include some secondary carbonate (Table A.1).

Because of their fine textures, overbank deposits may be eroded or poorly exposed, so trends in thickness and distribution are uncertain. Thicknesses of 1.5 to 3.5 m have been observed at one site south of Durango and at several sites from Cedar Hill to Farmington. In the Colorado area, typical thicknesses are 0.3 to 0.5 m but the deposits are absent or undetectable in many places. In the New Mexico area, typical thicknesses range up to 1 m

TABLE 5.5 QUATERNARY SNAIL TAXONOMY

Phylum MOLLUSCA
Class Gastropoda
Subclass Pulmonata

Order Geophilia (all land snails)*
- Family Valloniidae
  - Genus *Vallonia* Risso 1826
    - *Vallonia albula* Sterki 1893
    - *Vallonia cyclophorella* Sterki 1892
    - *Vallonia gracilicosta* Reinhardt 1883
- Family Pupillidae
  - Genus *Vertigo* Müller 1774
    - *Vertigo binneyana* Sterki 1890
    - *Vertigo ovata* (Say) 1822
  - Genus *Pupilla* Leach (in Fleming) 1828
    - *Pupilla blandi* Morse 1865
    - *Pupilla muscorum* (Linneaus) 1758
  - Genus *Pupoides* Pfeiffer 1854
    - *Pupoides albilabris* (C.B. Adams) 1841
    - *Pupoides hordaceous* (Gabb) 1866
    - *Pupoides inornatus* Vanatta 1915
- Family Succineidae
  - Genus *Catinella* Pease 1870
    - *Catinella* spp.
  - Genus *Succinea* Draparnaud 1801
    - *Succinea* spp.
- Family Discidae
  - Genus *Discus* Fitzinger 1833
    - *Discus cronkhitei* (Newcomb) 1865
    - *Discus shimeki* (Pilsbry) 1890
- Family Vitrinidae Fitzinger 1833
  - Genus *Hawaiia* Gude 1911
    - *Hawaiia minuscula* (Binney) 1840
- Family Thysanophoridae
  - Genus *Oreohelix* Pilsbry 1904
    - *Oreohelix cf. O. strigosa* (Gould) 1846
  - Genus *Microphysula* Cockerell and Pilsbry 1926
    - *Microphysula ingersolli* (Bland) 1874

Order Lymnophila (all freshwater snails)**
- Family Lymnaeidae
  - Genus *Fossaria* Westerlund 1885
    - *Fossaria parva* (Lea) 1841
  - Genus *Stagnicola* Leach (in Jeffreys) 1830
    - *Stagnicola caperata* (Say) 1829
- Family Physidae
  - Genus *Physella* Haldeman 1843
    - *Physella gyrina* (Say) 1821
- Family Planorbidae
  - Genus *Gyraulus* "Agassiz" in Charpentier 1837
    - *Gyraulus* (Torquis) *parvus* (Say) 1817
    - *Gyraulus* spp.

Systematics by Emmett Evanoff (University of Colorado Museum, written communication, 1997)

* Taxonomy from Burch and Pearce (1990)
** Taxonomy from Burch (1989)

TABLE 5.6 QUATERNARY SNAIL ASSEMBLAGES

SITE NUMBER	S1 34N/10W/36/1	S2 32N/10W/28/1	S3 29N/13W/17/2	S4 [1,4] 29N/13/W/21/1A
LANDFORM	Holocene alluvial fan	Holocene alluvial fan	Holocene flood plain	t8u
LOCATION, NEW MEX. BASE LINE & PRINCIPAL MERID.	SE SW NW SW Sec 36 T34N R10W	NE SE SW NW Sec 28 T32N R10W	NW SE SE Sec 17 T29N R13W	NE NW SE NE Sec 21 T29N R13W
TOPOGRAPHIC QUADRANGLE	Basin Mountain (1968)	Cedar Hill (1985)	Farmington South (1965)	Farmington South (1965)
SITE DESCRIPTION	riverbank near Weaselskin Bridge	dry wash on Bushelberger Mesa	San Juan River at Bisti Highway	San Juan Concrete Co. gravel pit
SEDIMENT	silty alluvium (side-stream fan)	sandy alluvium (side-stream fan)	fluvial overbank deposits (San Juan River); soil profile NM1, 21-82 cm	fluvial overbank deposits (Animas River); soil profile NM2, 27-62 cm
GASTROPOD COUNTS [2]				
LAND SNAILS				
Vertigo ovata				
Vertigo binneyana				
Pupilla blandi				2
Pupilla muscorum				
Pupilla spp.				x
Pupoides albilabris				1
Pupoides hordaceous		2		
Pupoides inornatus				
Vallonia albula				
Vallonia cyclophorella				36
Vallonia gracilicosta				
Vallonia spp.				x
Catinella spp.				61
Succinea spp.			3	
Discus cronkhitei				
Discus shimeki				
Discus spp.				
Hawaiia minuscula	1?			9
Microphysula ingersolli				
Oreohelix cf. O. strigosa				
FRESHWATER SNAILS				
Physella gyrina				5
Fossaria parva				
Stagnicola caperata				
Gyraulus parvus				
Gyraulus spp.				
PALEOENVIRONMENT [3]	Moist? (species is moisture-loving, but sample too small for certainty)	Dry, due to absence of moisture-loving species	Uncertain (taxon is wide-ranging)	Wet with standing water (intermittent or perennial) nearby

TABLE 5.6 QUATERNARY SNAIL ASSEMBLAGES, continued

SITE NUMBER	S5 [1,4] 35N/9W/14/1	S6 [4] 29N/13W/9/2	S7 [4] 33N/9W/8/1	S8 31N/11W/25/1
LANDFORM	SC1	t6a	t5e	t5e
LOCATION, NEW MEX. BASE LINE & PRINCIPAL MERID.	SW SW NW NW Sec 14 T35N R9W	SW SE NW NE Sec 9 T29N R13W	SE SW SW NE Sec 8 T33N R9W	SW NW SW NE Sec 25 T31N R11W
TOPOGRAPHIC QUADRANGLE	Durango East (1963)	Farmington South (1965)	Bondad Hill (1968)	Aztec (1985)
SITE DESCRIPTION	driveway at 2318 County Rd. 240	Brookside Drive, Farmington	gravel pit, south Florida Mesa	mouth of Hart Canyon
SEDIMENT	fine fluvial deposits in base of Spring Creek 1 moraine	fine lenses (slopewash?) in gravel at valley side	fine (overbank?) sequence within fluvial gravel	organic-rich (marsh) sediment at top of fluvial overbank deposits
GASTROPOD COUNTS [2]				
LAND SNAILS				
Vertigo ovata				4
Vertigo binneyana				2
Pupilla blandi	1			
Pupilla muscorum			x	21
Pupilla spp.	x			15
Pupoides albilabris				
Pupoides hordaceous				
Pupoides inornatus				
Vallonia albula	4			
Vallonia cyclophorella	5		x	10
Vallonia gracilicosta				1
Vallonia spp.	x			14
Catinella spp.		x	x	49
Succinea spp.				1
Discus cronkhitei	2			
Discus shimeki				
Discus spp.				1
Hawaiia minuscula				
Microphysula ingersolli				
Oreohelix cf. O. strigosa	30			
FRESHWATER SNAILS				
Physella gyrina				
Fossaria parva				22
Stagnicola caperata				1
Gyraulus parvus				6
Gyraulus spp.				
PALEOENVIRONMENT [3]	Moist with no standing water nearby	Dry, due to absence of moisture-loving species. Assemblage occurs in Pleistocene slopewash near Meeker, Colorado (Evanoff, 1983)	Dry, due to absence of moisture-loving species. Assemblage occurs in Pleistocene slopewash near Meeker, Colorado (Evanoff, 1983)	Wet, with perennial water nearby. All species live in southern Rocky Mountains today, except for Vertigo binneyana, which is unknown south of Montana

TABLE 5.6 QUATERNARY SNAIL ASSEMBLAGES, continued

SITE NUMBER	S9 [1] 29N/12W/6/2	S10 [1,4] 29N/12W/5/3	S11 35N/9W/5/1
LANDFORM	t5a	t4d	cuesta overlain by surficial deposits
LOCATION, NEW MEX. BASE LINE & PRINCIPAL MERID.	SE NW NW SE Sec 6 T29N R12W	SE NE NE NW Sec 5 T29N R12W	N/2 NE/4 Sec 5 T35N R9W
TOPOGRAPHIC QUADRANGLE	Farmington North (1963)	Flora Vista (1963)	Durango East (1963)
SITE DESCRIPTION	trench in terrace tread	terrace scarp	north of Animas City Mountain
SEDIMENT	sandy alluvium (side-stream fan)	fluvial overbank deposits (Animas River); below soil profile NM13	within lacustrine deposit of Lava Creek B ash (site A1)
GASTROPOD COUNTS [2]			
LAND SNAILS			
Vertigo ovata			
Vertigo binneyana			
Pupilla blandi			
Pupilla muscorum			
Pupilla spp.		x	
Pupoides albilabris			
Pupoides hordaceous			
Pupoides inornatus		120	
Vallonia albula			
Vallonia cyclophorella			
Vallonia gracilicosta			
Vallonia spp.			
Catinella spp.	?	216	
Succinea spp.		x	
Discus cronkhitei			
Discus shimeki			
Discus spp.			
Hawaiia minuscula			
Microphysula ingersolli			
Oreohelix cf. O. strigosa			
FRESHWATER SNAILS			
Physella gyrina			
Fossaria parva			
Stagnicola caperata			
Gyraulus parvus			
Gyraulus spp.			1
PALEOENVIRONMENT [3]	Uncertain because of small sample size	Dry, due to absence of moisture-loving species. Assemblage occurs in Pleistocene slopewash near Meeker, Colorado (Evanoff, 1983)	Uncertain because of small sample size, but probably wet with perennial water nearby

1. Amino acid racemization data given in Table 6.3.
2. Identified by Emmett Evanoff (University of Colorado Museum, written communication, 1983, 1992, 1996, and 1997) or Alan R. Nelson (University of Colorado, written communication, 1984).
3. Interpreted by Emmett Evanoff (written communication, cited above).
4. x – species present but not counted.

and many deposits can be traced for distances of 1 km or more. Thus, overbank deposits appear thicker and more extensive in downstream than in upstream reaches.

Discussion

Although these sediments were not compared in detail to facies models, several factors suggest deposition mainly in a bedload-dominant fluvial system with low sinuosities from Durango through the Hogback Monocline and in a higher-sinuosity, more mixed-load fluvial system from Cedar Hill to Farmington, with transitions probably fluctuating in the Florida Mesa-Cedar Hill area. Evidence for a bedload-dominant system in and near Durango includes heterogeneous textures, very poor sorting, and fill-like geometries of deposits in cross and longitudinal sections. Rapid sedimentation, typical in bedload-dominant systems, is apparent from very poor sorting, relatively high silt, weak imbrication, and rare openwork fabrics. However, several cross sections with strath-like wings extending laterally from the tops of fills ("overslag terraces" of Zonnefeld, 1975; Figures 4.8 to 4.10) suggest that some low-sinuosity channels developed higher sinuosity for periods before incision. Evidence for higher sinuosity, mixed-load fluvial systems includes more uniform textures, better sorting, apparently extensive overbank deposits, and uniform thicknesses of gravel bodies in cross- and longitudinal sections. Features of increased sediment reworking during channel migration are the typical absence of openwork fabrics and lower silt contents in channel deposits. Flood bars composed of large boulders, which are restricted to the Durango-Cedar Hill reach, suggest large flood peaks resulting from drainage of moraine-dammed lakes.

Associated Deposits

Other deposits that overlie or interfinger with moraine and terrace sediments are important for establishing patterns of deposition, for concealing buried terraces, and as parent materials for soils. Figures 5.7 to 5.9 illustrate typical morphostratigraphic relations among the main types of deposits that form and cover terraces. In addition, landslide and debris-flow deposits overlie terraces in a few areas. Lenses of redeposited Lava Creek B ash, which usually occur beneath or within alluvial and eolian deposits, are discussed in Chapter 7 and Appendix C.

Side-Stream Alluvium (A)

Alluvium of tributary streams is distinguished by fine-grained sediment from local sources, variable gravel content from mixed sources, and sedimentary structures indicating deposition in small channels. The deposits resemble those of modern streams and younger deposits have diagnostic alluvial-fan or valley-fill shapes.

The texture, composition, and color of side-stream alluvium vary with source area and depositional setting. Most deposits consist of loam to very coarse sand that is grayer or yellower than Animas River deposits of similar texture (Figures 5.3, 5.4E, 5.4F, and 5.10A; Tables 5.7 and A.1). Pebbles and cobbles typically form up to several percent of most sequences, but up to 70 % in large or steep channels. From Durango to Bondad, fines (less than 2 mm) are mainly loams and sandy loams derived from Cretaceous and Tertiary sedimentary rocks that contain little material coarser than medium sand. Clast types include both local rocks and upstream-derived rocks that have been recycled from older terrace gravels. From Bondad to Farmington, fines are mainly coarse to very coarse sands derived from Tertiary sandstone beds (most finer sediment from Tertiary rocks has been

TABLE 5.7 OTHER SEDIMENTS ON MORAINES OR TERRACES

TYPE	Alluvium, side-stream (A)	Eolian deposits (E) and sheetwash with mostly eolian material (SE)	Colluvium with eolian material (CE)
TYPICAL COLOR (Munsell dry, moist)	9-7.5YR 6/4 (d) 10-9YR 5.5/4 (m)	7.5YR 5-5.5/4 (d) 7.5YR 4/4 (m)	7.5YR 5-5.5/4 (d) 7.5YR 4/4 (m)
TYPICAL TEXTURE	slightly gravelly, loam to very coarse sand	silt loam to sandy loam	slightly to very gravelly, sandy loam, silt loam, or sandy clay loam
SAND:SILT:CLAY [1]	90±4 : 5±2 : 5±2 *(sandy)* 38 : 57 : 5 *(silty; 1 sample)*	26±3 : 54±1 : 20±3 *(sandy loess)* 49±14 : 32±7 : 18±2 *(silty cover sand)* 57±10 : 26±8 : 15±2 *(facies SE)*	45±14 : 41±15 : 14±4
GRAVEL VOLUME (%)	1-70 (pebbles and cobbles)	0 *(facies E)* 1-3 *(facies SE)* (pebbles)	5-40 (pebbles and cobbles)
"coSl-vfS ratio" [1,2]	5±3 *(sandy)* 20 *(silty, 1 sample)*	66±9 *(sandy loess)* 52±6 *(silty cover sand)* 53±13 *(facies SE)*	47±11
"m-vcoS ratio" [1,3]	82±11 *(sandy)* 41 *(silty, 1 sample)*	3±4 *(sandy loess)* 15±9 *(silty cover sand)* 11±9 *(facies SE)*	22±10
DISTINCTIVE FEATURES	thin subhorizontal bedding or cross-bedding; upstream-derived clasts reworked from facies FCP or FC; rare fossil snails	appears to lack sedimentary structures; insect burows; rare fossil snails	matrix- or clast-supported; structureless or weakly bedded; upstream-derived clasts reworked from facies FCP or FC
PRIMARY CARBONATE (wt % whole soil)	0.3-1 *(matrix)* plus 0-1 *(clasts)* (used 0.5)	0.1-4.1? *(matrix)* (used 2)	0.2-1.6 *(matrix)* plus 0-1 *(clasts)* (used 1)
MAXIMUM THICKNESS (m)	45 (approx.)	3.5 (approx.)	3?

1. Formatted as average ±1 standard deviation; number of observations varies from 3 to 9. Some data summarized from table A.1.
2. Ratio of total coarse silt plus very fine sand to total silt plus sand.
3. Ratio of total medium, coarse, and very coarse sand to total silt plus sand.

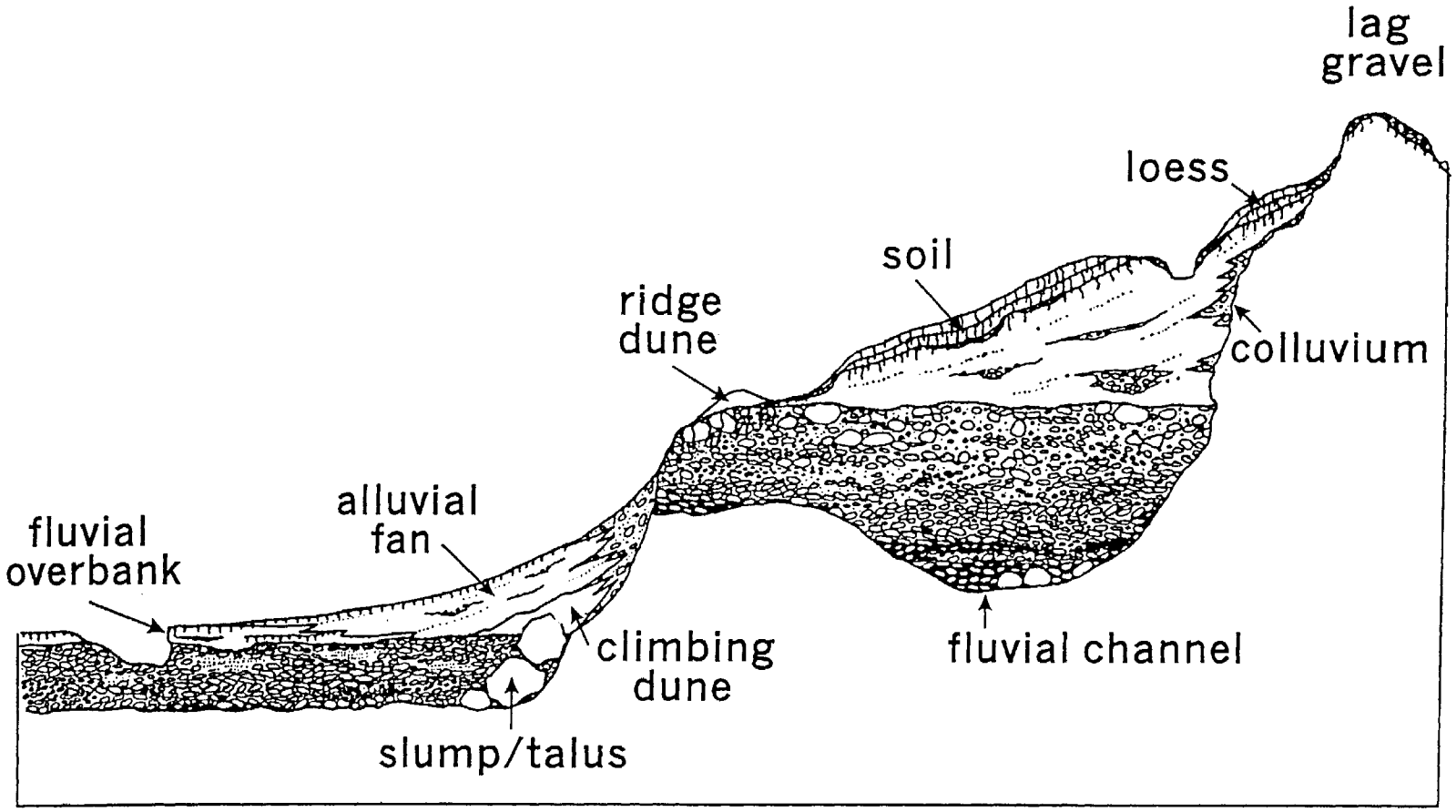


FIGURE 5.7 Schematic cross section showing typical relations of deposits and soils beneath several terrace benches. With time, constructional landforms become more dissected, fine-grained deposits are stripped, and topographic reversal creates gravel-capped hills.

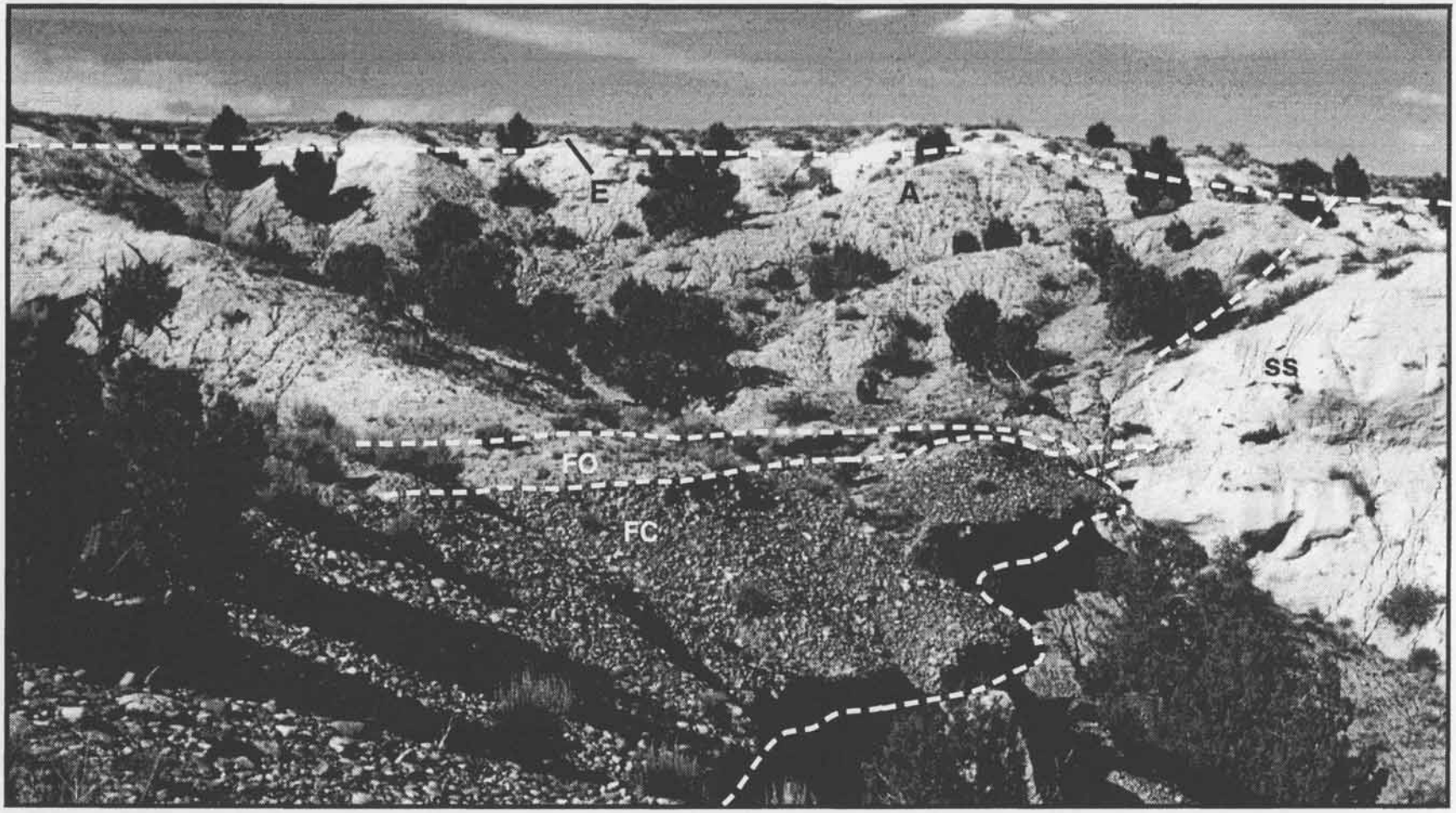


FIGURE 5.8 View of typical stratigraphic relations at rear edge of t3a on Crouch Mesa, near Farmington. FC – fluvial channel gravel, cemented at base with ground water carbonate (ca. 3.5 m); FO – fluvial overbank deposits (ca. 0.5 m); A – sidestream alluvium (ca. 15 m); E – eolian deposits containing a strong calcic soil (ca. 1.5 m); ss – sandstone.

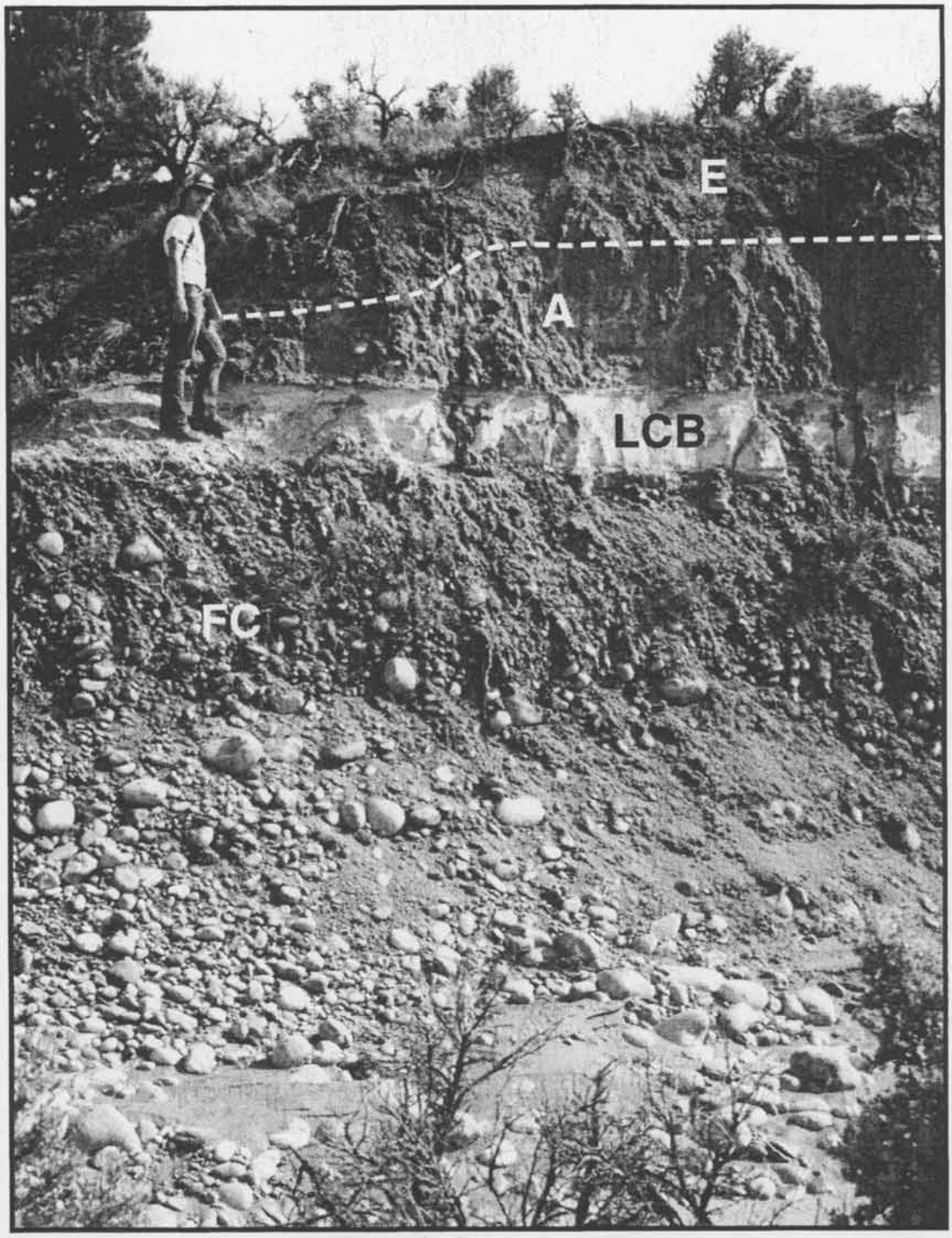


FIGURE 5.9 Stratigraphic relations at ash site A16 (Table C.1, Plates 1 and 2). E – eolian deposits; A – sidestream alluvium; LCB – tephra assumed to be Lava Creek B ash from Yellowstone caldera (up to 1.1 m thick); FC – fluvial channel gravel. Modern stream is transporting reworked surficial deposits.

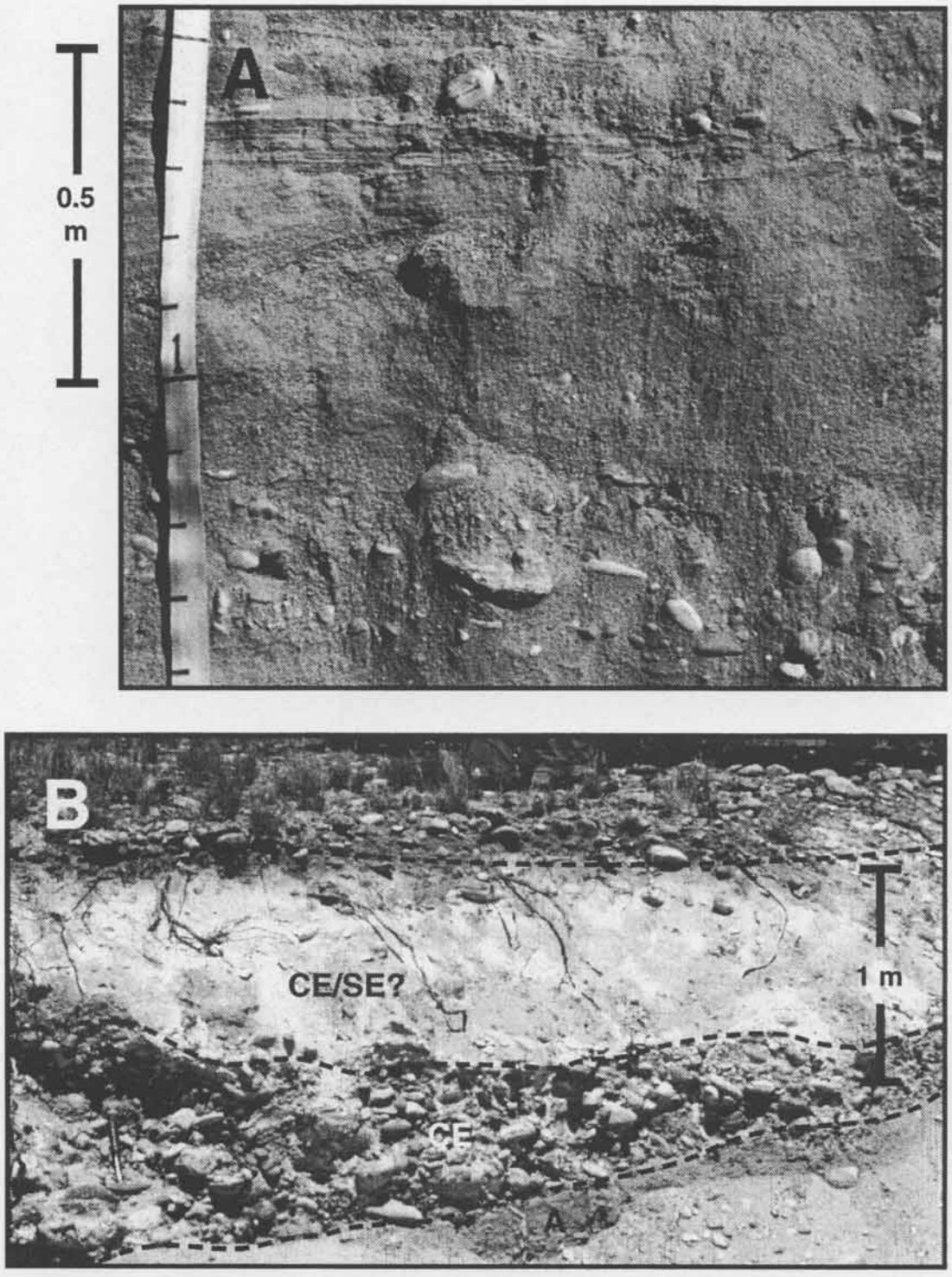


FIGURE 5.10 A, typical sidestream alluvium (facies A) derived mainly from Tertiary sandstones but containing reworked pebbles and cobbles from Animas River gravels. B, composite colluvial-eolian section overlying alluvium; CE – lag pavements consisting of cobbles (concentrated from alluvium but originally from Animas River gravel) and an eolian matrix; CE/SE -- interbed of finer colluvium, or possibly cumulic eolian sediments; A – alluvium.

removed as suspended load). However, in some small basins that head on terrace scarps, fines consist mostly of pinkish loam or fine sandy loam from older eolian and terrace deposits. Tertiary sandstones disintegrate readily, so clasts are reworked from older terrace deposits.

Fossil snails are rare but were located within alluvium at sites S1, S2, and S9 (Table 5.6). These small collections (consisting of one or two shells) are not climatically distinctive (Evanoff, written communication, 1997).

Typical structures include thin, subhorizontal beds that crosscut at low angles; planar-tabular, trough, and ripple crossbedding; and minor scours or small channel cuts with depths from several centimeters to decimeters. Pebbles and cobbles are isolated and matrix-supported, or form lenses with clast-supported and well-imbricated fabrics.

Side-stream alluvium is commonly 1 to 20 m thick, but is up to 45 m thick in some upper-fan settings. Alluvial deposits occur in several settings that affect terrace mapping. Due to reversal of topography, remnants of older channel fills may cap small hills, resembling some terrace remnants in outcrop form; however, alluvium and fluvial channel deposits generally differ in matrix composition and imbrication trend. Alluvial fans cover most terrace remnants, locally concealing inter-terrace scarps. Terraces of large streams may be inset below, and must be distinguished from, adjacent main-river terraces. Finally, recycled main-river clasts can indicate the former distribution of terraces which are no longer preserved.

Eolian (E) and Reworked Eolian Deposits (SE)

Eolian deposits (facies E) are distinguished by coarse-silty to fine-sandy textures, a lack of sedimentary structures, and presence on relatively stable surfaces. Finer deposits are sandy loess (as defined by Pye, 1987) and coarser ones resemble silty cover sands.

Sheetwash composed mostly of reworked eolian deposits (facies SE) also contains pebbles and reworked fragments of petrocalcic soil from up-slope sources.

These sediments consist of silt loam, loam, or sandy loam (Figures 5.3, 5.9, 5.10, 5.11A, and 5.11B; Tables 5.7 and A.1). Eolian sediments are gravel-free, but sheetwash contains up to 3 % very small pebbles or reworked fragments of petrocalcic soil. In the fine fraction, the modal class ranges from coarse silt to fine sand. Estimates of primary texture and composition are complicated by weak to moderate soil development in most exposures. However, primary clay appears to range from 13 to 15 % in sandy deposits and from 17 to 23 % in silty deposits that include some BCtk horizons with small amounts of pedogenic clay. All of the deposits are finer than eolian sands in the Chaco dune field, which typically have modes in fine sand and textures of fine sand to loamy fine sand (Schultz, 1980; Wells and others, 1983; Figure 5.11C). Present carbonate ranges from 0.1 to 4.1 % and averages about 2 % in modern samples and in soil horizons that may be slightly depleted or enriched in carbonate.

Typical colors of most unaltered deposits are brown to dark brown like loess in the Colorado Plateau and Animas River deposits. Yellower hues for coarser deposits resemble those of alluvium derived from late Cretaceous and Tertiary sandstones.

Eolian units from 0.2 to 1.2 m thick are separated by buried soils, stone lines, or rarely by grayish, organic-rich layers that indicate former marshes (D.W. Moore, U.S. Geological Survey, oral communication, 1981). The units are internally massive, possibly because soil formation has destroyed weak sedimentary structures. These deposits usually occur at the ground surface, where they form either sheets or bluff-edge dunes along windward scarps. The maximum observed thickness is 3.5 m.

Eolian material was probably transported from upstream, local, and distal sources including floodplains of the Animas and San Juan rivers, channels of tributary streams, and sandstone outcrops. Bandoian (1969) first recognized northward fining from south of

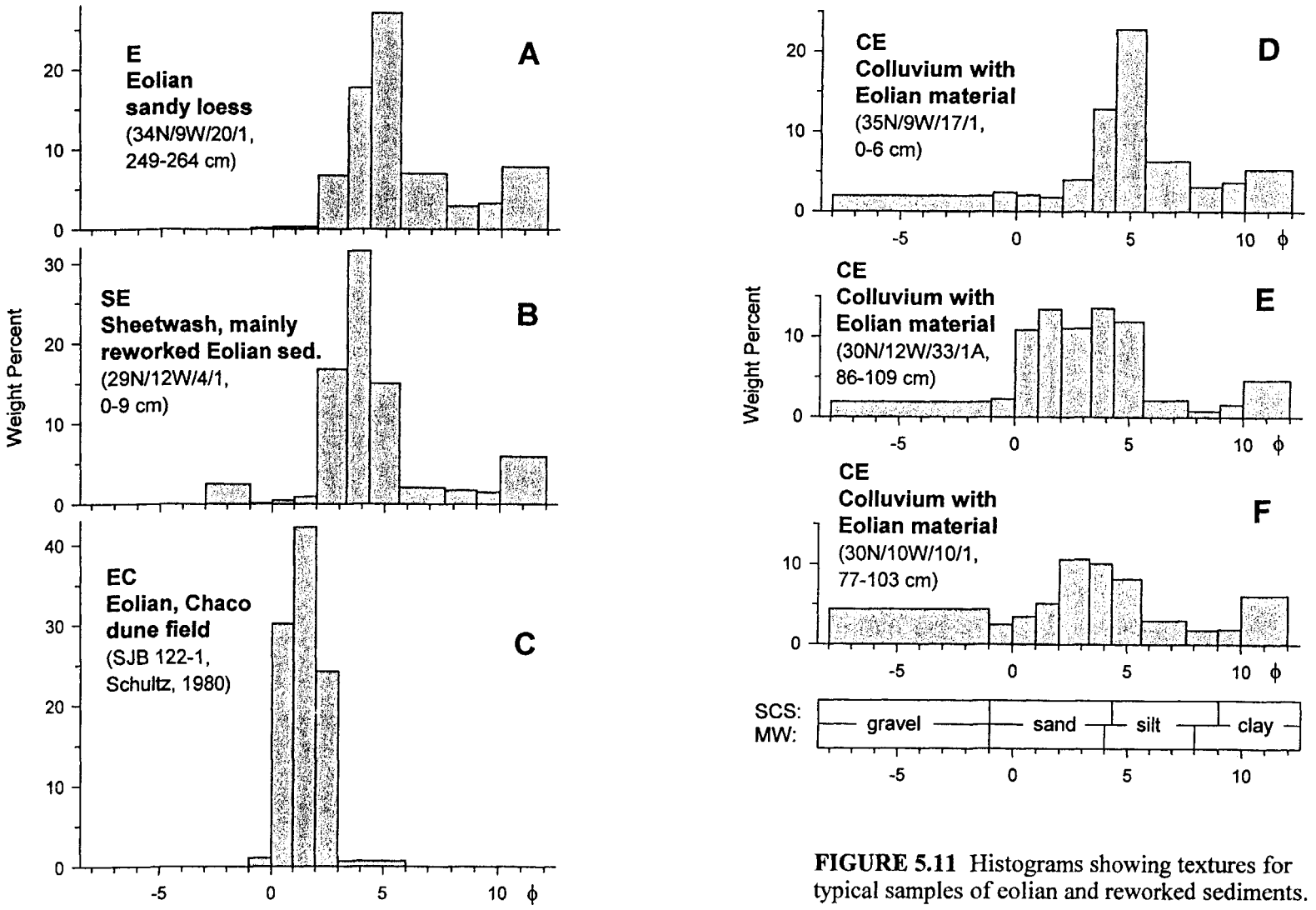


FIGURE 5.11 Histograms showing textures for typical samples of eolian and reworked sediments.

Aztec to Florida Mesa. Broader, north-northeasterly fining from the Chaco dune field to Durango is consistent with northeasterly fining in loess near Cortez (Price and others, 1988). Fining near Cortez was attributed to downwind sorting, but fining from the Chaco dune field to Durango more likely reflects a combination of eolian processes, sediment sources, and terrace heights.

In the study area, wind directions suggest mainly easterly to northerly transport with significant spatial variations (Chapter 2; Figure 2.6). The major source for eolian material was probably fluvial sediments in the Animas valley, but more material may have been entrained from lower reaches, where fine-grained deposits were relatively abundant and less sheltered by smaller clasts, than in upper reaches. Weakly cemented sandstones and sandy streambeds, resembling sources of sand for the Chaco dune field (Schultz, 1980; Wells and others, 1983), are also more common in the south part of the study area, where lower terrace heights would have facilitated the movement of sand onto terraces in the southern area. Loess in the northern and central areas may combine material from Animas valley and distal sources. Widespread loess on high plateaus such as Mesa Verde (Arrhenius and Bonatti, 1965) confirms that distal areas are important sources for reddish-brown silt and clay. However, similar material could have come from the Animas River flood plain. Yellowish-brown moraine sediments and silty alluvium may have been minor sources in the northern area.

Local dust-influx rates were not measured, but a 1-year influx of 3.60 mg/cm^2 has been reported at Mesa Verde National Park (Arrhenius and Bonatti, 1965). With an average bulk density of 1.6 g/cm^3 for Animas valley loess, this rate would yield accumulations of 2.3 cm/ka or 2.3 m/100 ka. Loess thicknesses suggest that long-term, net accumulation rates were generally lower in the Animas valley, as is typical for comparisons of historic and longer periods (e.g. Pye, 1987).

Colluvium with Eolian Material (CE)

Colluvium is distinguished by its location on modern or former slopes, variable texture and composition that are related to uphill or underlying deposits, and matrix- or clast-supported fabrics in which flat clasts are roughly parallel to slopes. Textures and colors vary greatly, but most deposits seem to include eolian material because they contain more coarse silt or fine sand than local sources (Figures 5.3, 5.11D, 5.11E, and 5.11F; Tables 5.7 and A.1). Since colluvium is widespread, this discussion is limited to deposits that affect terrace mapping and soil development. In addition to typical aprons on moderate slopes, two kinds of deposits are important: residual lag gravels on slopes and mixed layers in soil profiles.

Residual lag gravels range from continuous pavements to widely scattered clasts. Field relations show that the pavements formed by selective erosion of sandy matrix from underlying alluvial or colluvial deposits with lower gravel contents. Eventually, this process created dense, clast-supported layers up to 1 m thick on gentle and moderate slopes. After the pavements developed enough to prevent erosion, eolian material filled interstices and came to dominate the matrix. At a few sites, continuing eolian deposition has lifted the upper layer of pavement above a cumulic eolian zone as described by McFadden and others (1987). Because most alluvial and colluvial deposits contain reworked main-river clasts, similar pavements have formed on these deposits and main-stream fluvial gravels. Thus, pavements on benches do not necessarily indicate either the presence or height of main-stream gravels and terraces.

Scattered clasts that rest on many bedrock benches and knobs near drainage divides, particularly in the New Mexico area, have probably been reworked during several cycles of stream incision and slope regrading. Most clasts are well-rounded cobbles of weathering-resistant rock types from upstream sources, which have been reworked from

main-stream fluvial gravels. In areas where scattered cobbles occur, their concentrations vary greatly; but regional distributions are important evidence of early river courses. Other residual gravels, formed from conglomerate beds in the Ojo Alamo Sandstone, are distinguished by their proximity to conglomerate outcrops, pebble-sized clasts, and slightly differing lithologies.

Mixed layers in soil profiles probably combine materials from two or more facies, but the facies can no longer be identified from textural data because of pedogenic mixing and alteration. Typical examples are surface horizons, in which upper moraine or fluvial sediments have been slightly reworked and probably mixed with eolian deposits, and texturally transitional horizons between less-gravelly, near-surface materials and more gravelly, basal materials.

CHAPTER 6

SOIL DEVELOPMENT ON MORAINES AND TERRACES

Soils on the moraines and terraces were studied to show how soils vary with age and climate, to assess the stratigraphy of typical sites, and to support local correlations of moraine and terrace remnants. This chapter emphasizes soil-related issues and results, while detailed procedures and profile data are given in Appendix B.

The site-selection plan was to develop three soil chronosequences on moraines at Durango, on terraces near Durango, and on terraces near Farmington. Before field work, it was assumed that the first two chronosequences would differ mainly in parent materials and topographic setting, whereas the second two would form a climosequence that maximized variations along a foothills-basin transect. In practice, this approach was limited by landform preservation, parent-material variations, accessibility, and concurrent mapping status. Therefore, the profiles do not meet the definitions of chronosequences and climosequences. Nevertheless, the three profile groups do exhibit broad variations with age and climate, and small numbers of profiles fit the definitions more closely.

At least one profile was described on most major moraines and terraces, but several landforms were omitted because of late recognition or reinterpretation. For example, intended Spring-Creek moraine sites were reclassified as terrace sites. TG1 and TG2 sites are located near the middle of the transect because of poor preservation. Extra sites were described in some areas to distinguish closely spaced terraces of TG6 and TG7, or to take advantage of temporary exposures.

Site data and descriptions are given for 58 profiles (Tables B.1 to B.6). Particle size, carbonate content, and bulk density were determined for the fine (<2 mm) fraction of 16 profiles (Table B.7). Developmental indices based on field descriptions were calculated for all profiles and weights of secondary clay and carbonate were calculated for profiles with laboratory data (Tables B.8 and B.9). Trends in soil development with relative age and climate were evaluated by comparing individual profiles and by plotting data for profile groups composed of moraines, Colorado terraces, and New Mexico terraces.

In plots, the approximate height of terraces in the state line area is used as a proxy for relative age. Height was shown on the x axis, instead of estimated age (see Chapter 7) because age estimates will change as more information becomes available, whereas height reflects the permanent issues of terrace subdivision and correlation. Heights near the state line were used because the oldest terraces are preserved there. Heights for missing terraces are estimated from their spacing elsewhere and heights for moraines are those of correlated terraces.

Trend lines show patterns in the scatter plots, but their equations are not considered important for several reasons. First, the curve fits assume that statistical uncertainty exists only in the y-axis data, which is not true because of potential errors in height estimates and terrace correlation. Second, few data points are available to constrain the upper parts of the curves and many correlation coefficients are very low. Third, the trends are not chronofunctions that merit analysis in detail; rather, they reflect many factors including site-selection criteria, variations in soil parent materials, and estimates of parent-material properties in complex soils in addition to more usual analytical errors in soil descriptions and laboratory data.

In this chapter, summaries of soil-forming factors and profile features precede a discussion of dominant, soil-forming processes. Several profiles as then described as examples of soil development in relation to parent materials. Finally, groups of profiles are

compared to show trends in development with landform (reflecting topography and parent-material combinations), time, and climate.

Factors of Soil Formation

Site factors have determined the basic features of regional soils, including the profiles studied. Climate and vegetation varied with time as described in Chapter 2. Modern soil-forming conditions range from mesic and aridic at Farmington to frigid and ustic at Bridge Timber Mountain, whereas glacial conditions possibly varied from frigid and ustic to cryic and udic, and brought greater leaching (Table 2.3; Figures 2.7 and 2.8). During glaciations, many vegetation zones descended to lower elevations, changed in composition, or probably increased in density. Except in periglacial and stream-side areas, general landscape stability may have increased in relation to the present.

Most profiles are located on moraine crests or terrace treads with nearly flat slopes, but a few are on moraine slopes and terrace shoulders. These landforms have heights up to 620 m above modern river level (550 m relative height near the state line) and ages from Holocene to early Pliocene and possibly Miocene (Chapter 7). Due to unavoidable stratigraphic complexity, parent-material types include varied moraine, fluvial, alluvial, colluvial, and eolian deposits (Chapter 5).

General Features of Soil Profiles

Variations in profile depth and complexity have influenced trends in soil development (discussed below). The depth of most profiles is between about 1.5 and 3 m, but ranges to more than 6 m (Figure 6.1A). Most profiles on surfaces with relative heights less than 10 m (including the Spring Creek moraines, TG6, and younger surfaces) are

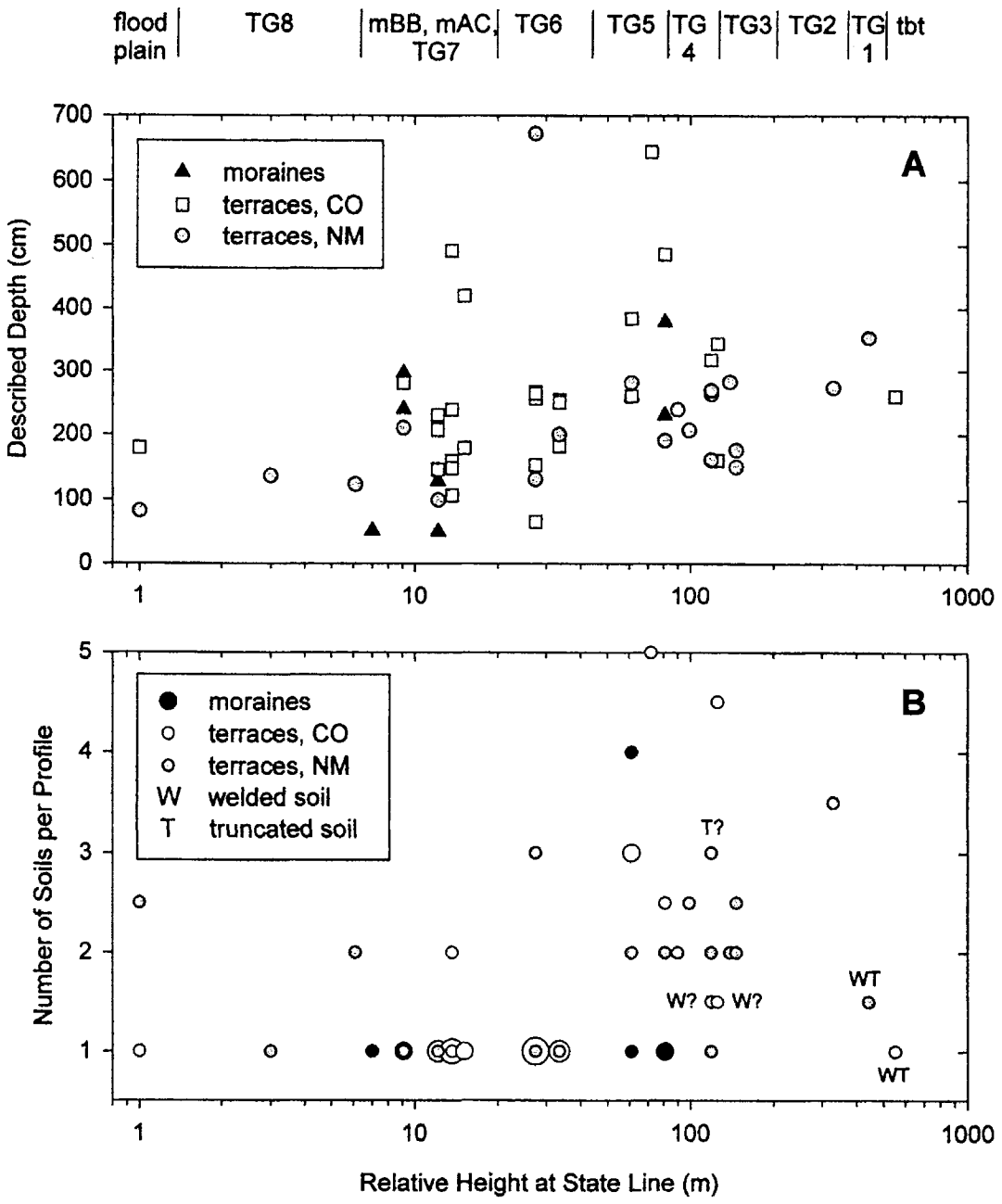


FIGURE 6.1 Described depth of profiles (A) and number of soils per profile (B) versus relative height of moraines and terraces (as a proxy for relative age). In diagram B, smallest circles indicate one profile and largest indicate five profiles.

single-story (Figure 6.1B), including both simple types (i.e., deposition ended before pedogenesis began) and cumulative types (deposition continued during pedogenesis). In contrast, most older soils have multistory profiles which are usually compound (individual soils overlap vertically), but may be composite (individual soils do not overlap), welded (individual soils overlap and are indistinguishable), or truncated (former surface horizons have been eroded). The number of parent materials per profile is usually two or three, but ranges from one to six (Figure 6.2A). All profiles are located at sites where moraine or fluvial deposits are present at varying depths, but the thickness of overlying deposits (colluvial, alluvial, and eolian) varies from a thin cap to much or all of the profile depth, depending on profile age and setting (Figure 6.2B).

Soil-Forming Processes

In this area, the main soil-forming processes are accumulation and redistribution of clay and carbonate. Other processes include weathering, rubification, and formation or redistribution of minor constituents such as organic matter, amorphous silica, gypsum, and soluble salts. In addition, relative rates of pedogenesis, continuing sediment deposition, and erosion affect soil thickness and horizon properties. Resulting soils are mainly Aridisols, Alfisols, and Mollisols. Due to the number and variability of parent materials, estimation of their properties affects all interpretations of pedogenic change.

Sedimentation and Erosion

After moraines and terraces formed, many parts of these surfaces were stable enough to retain their overall constructional shapes, but slower deposition or erosion occurred with soil development in most places. Initial modifications at most sites probably

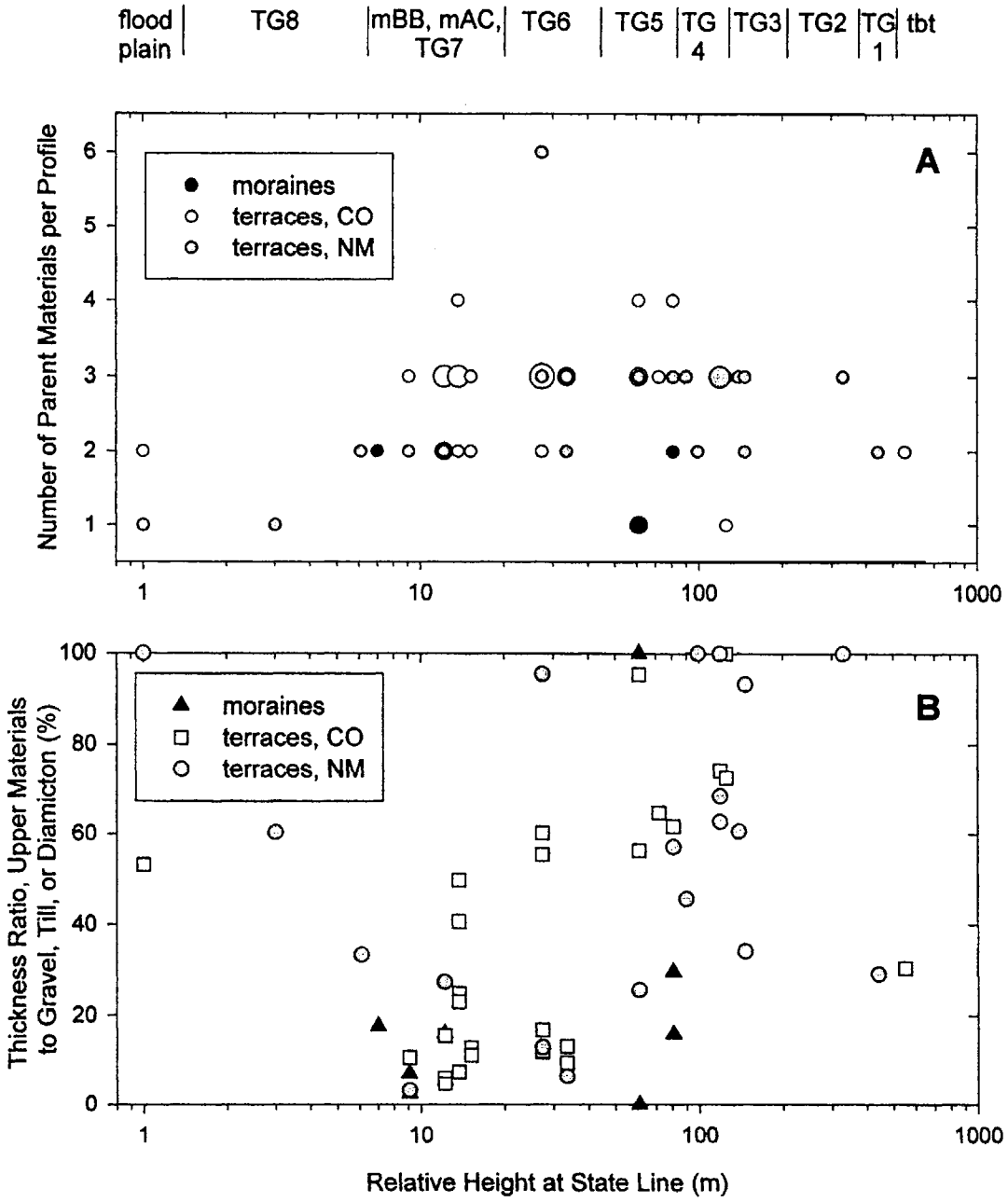


FIGURE 6.2 A, number of parent materials per profile versus relative height of moraines and terraces. B, relative thickness of different parent materials in profiles, as shown by the ratio of total thickness of colluvial, alluvial, eolian, and sheetwash deposits to the total thickness of fluvial gravel, till, and glacial diamicton, versus relative height of moraines and terraces. In B, smallest circles indicate one profile and largest indicate four profiles; profiles plotted at 100 % don't reach gravel, till, or diamicton.

involved reduction of local relief by colluvial and eolian processes. Among profile sites in this study, only moraine crests have experienced relatively continuous, net erosion, although eolian deposition has raised crestal elevations locally by at least 2.6 m (profile CO28, Table B.4). On terrace treads, younger alluvium (Chapter 5) has attained thicknesses up to 25 m on t7u in less than 15,000 yr and up to 45 m on t3a in roughly 800,000 yr. Depositional rates were lower in most areas, but the only sites without distinct alluvial caps are on parts of TG7 and TG6. Eolian deposits have probably been added to the epipedons of most soils. Distinct eolian caps are thin and patchy on mAC/TG7 and mSC/TG6, but widespread and up to several meters thick on mD/TG5 to TG2.

While terrace treads generally aggraded, terrace scarps either retreated or declined because of stream incision and slope erosion. As terrace edges treads shifted toward the centers of the terrace treads, existing alluvial and eolian sediments were truncated by erosion along shoulder slopes. The relative thinness of alluvial and eolian deposits on small remnants of TG1 and tbt, compared to greater thicknesses on larger terrace remnants of middle and early Pleistocene age, suggests that former fine-grained caps have been partly stripped (Figures 5.7 and 6.2A).

Clay Accumulation and Related Processes

Visible clay accumulation and translocation have occurred in all soils except some of the youngest, which are probably middle to late Holocene in age. Clay sources include primary clay, eolian influx, and weathering. Primary clay varies between and within different parent materials (Chapter 5). In fluvial materials, depositional features that affect initial clay content, but which may be difficult to identify after pedogenesis, include overbank deposits, upward fining in the matrix of gravelly deposits, and varying amounts of primary, infiltrated clay.

Eolian influx is an important source of clay in many soils (e.g. Reheis and others, 1995; Simonson, 1995). Its potential effect on gravelly soils is illustrated by this simple calculation based on average properties of sandy loess (gravel, 0 vol. %; clay, 15 wt. % of fine fraction; bulk density 1.6 g/cm^3 for fine fraction) and sandy gravel (gravel, 60 %; clay, 2 %; bulk density, 1.7 g/cm^3). Given these values, 100-cm columns of sandy loess and sandy gravel contain roughly 24 and 2 grams of clay per square centimeter, respectively. If 8 cm of sandy loess accumulated, and half of its clay were translocated into the top 25 cm of an underlying, sandy gravel, the average clay content of the 25 cm would quadruple.

Visible evidence of weathering includes rubification of all textures and weakening and disaggregation of clasts. The extent of disaggregation depends on clast lithology, soil moisture (reflecting texture and climate), and time. Granules and pebbles of shale and muddy sandstone, which are common in some moraine deposits (facies CD, F, and MDS) and form the matrix of relatively poorly sorted, fluvial channel gravels (FCP), are completely dispersed in some Bt horizons on TG6. Larger clasts of the same rocks and of micaceous, igneous and metamorphic rocks are weakened in the same soils. Clasts of similar, sedimentary and micaceous rocks are saprolized and dispersed in some horizons on the Durango moraines and on TG5. In contrast, many clasts on tbt are saprolized above 128 cm and a few are saprolized below 260 cm. Weathering is most intense in clayey horizons with high water-holding capacities and at textural boundaries that inhibit water movement, such as contacts between fine-grained and gravelly materials. Disaggregation of shales and muddy sedimentary rocks, including reddish brown clasts from Pennsylvanian and Permian formations north of Durango (Figure 2.1), rapidly increases the clay content and redness of some horizons.

Carbonate Accumulation

Most soils are calcareous in most horizons, except for very recent soils and leached epipedons in moister areas. However, enough leaching occurs on Bridge Timber Mountain, the highest and moistest part of the study area, that the soil on tbt is noncalcareous. Some soils at intermediate elevations have patchy carbonate accumulations that suggest partial leaching during glaciations.

The main sources of carbonate are probably eolian influx (e.g. Machette, 1985; Reheis and others, 1995) and weathering of other sediments in place. The initial carbonate content of eolian and fluvial overbank sediments is uncertain because most deposits have been affected by soil-water or groundwater movement, but it appears to be about 2 % based on lower measured values (Table A.1), if higher measured values are assumed to include some secondary carbonate. In most fluvial gravels (facies FC), similar reasoning suggests that initial carbonate in the fine fraction is about 0.5 % (Table A.1), whereas the clasts include an average of 2 % limestone (Table 5.3). However, more poorly sorted gravels (FCP) may contain as much as 17 % limestone with other calcareous clasts (Table 5.3, site P1). The initial carbonate content of side-stream alluvium (Table A.1) is probably comparable to that in the matrix of fluvial channel deposits (0.5 %), because total gravel content, including limestone, is generally low. In contrast, samples of morainal diamicton from deep cuts and basal soil horizons have relatively high carbonate contents from 12 to 18 % in the fine fraction (Chapter 5; Tables A.1 and B.7).

Several sources of error affect the calculated weights of pedogenic carbonate, as follows: due to large leaching depths or profile thicknesses, most profiles do not reach the base of carbonate accumulation; in middle Pleistocene and older soils, some carbonate may have been removed during periods of greater leaching; fragments of carbonate rinds, transported in sheetwash deposits that form parts of some profiles in New Mexico, were not

removed from bulk samples before processing and thus are included in pedogenic carbonate; carbonate coats on gravels were not included in measurements of total carbonate; and estimates of initial carbonate content may be incorrect. In calculations (Table B.8) the initial carbonate content of fluvial gravels was underestimated at 0.5 %, because this value does not account for partial solution or desintegration of limestone and other calcareous clasts. This factor would increase the calculated weights of secondary carbonate in fluvial gravels. However, other factors such as profile depth and omission of carbonate coats on clasts suggest that total weights of secondary carbonate are probably minimum values for most profiles. The net effect of these factors is unknown.

Examples of Pedogenic Changes in Various Parent Materials

The following examples illustrate major factors in the development of individual profiles, including complexity, parent materials, landform type, relative age, and climate. In depth plots of textural data, gravel content and two ratios for the fine fraction are useful as indicators of parent-material uniformity and origin. The ratio of coarse silt plus very fine sand to total silt and sand (called the "coSi-vfS ratio") is relatively high in till, diamicton, and eolian deposits. Conversely, the ratio of medium, coarse, and very coarse sand to total silt and sand ("m-vcoS ratio") is relatively high in side-stream alluvial and fluvial channel deposits. Vertical changes in single subclasses of sand and silt were also used to interpret parent-material stratification. The ratio of fine and medium clay to total clay can indicate pedogenic alteration, but it also varies among parent materials.

Profile CO26 on Durango 2 Moraine

This is a simple profile (Figure 6.3) with relatively uniform parent material, a rare combination for this region. The profile is located on a moraine crest that may have been lowered tens of meters by erosion, but the average rate of soil development has exceeded that of erosion. Relative uniformity of the parent material (probably debris-flow deposits, or facies MDS of Johnson, 1990) is shown by low variability in gravel content and textural ratios. A single clay bulge lies mostly above a single carbonate bulge, both of which show typical, rapid downward increases and more gradual downward decreases in clay and carbonate. Initial clay and carbonate contents are relatively high, reflecting their ranges in till and diamicton (Tables 5.1 and A.1).

Profile CO1 on Flood Plain

This simple profile with two main parent materials (Figure 6.4) illustrates the problem of distinguishing primary and pedogenic clay in upward-fining fluvial deposits. The profile is located on a flood-plain terrace that was last inundated in 1911. Mostly loamy, nearly gravel-free sediments in the upper part of the profile (parent materials 1 and 2) overlie very gravelly sandy loam (fluvial channel gravel, parent material 3). Though the upward decrease in gravel is abrupt, continuous upward fining of sand and silt fractions from within the gravelly unit to at least the 51-cm level suggest that the loamy unit consists of overbank deposits (the site has been plowed and possibly graded, so near-surface textures may reflect either a different overbank unit or mechanical mixing). Since the profile's location indicates a late Holocene age, at least for the upper deposits, the maximum clay content is higher than expected from soil development alone. Based on evidence for upward fining, clay below 51 cm was assumed to be primary, from upward

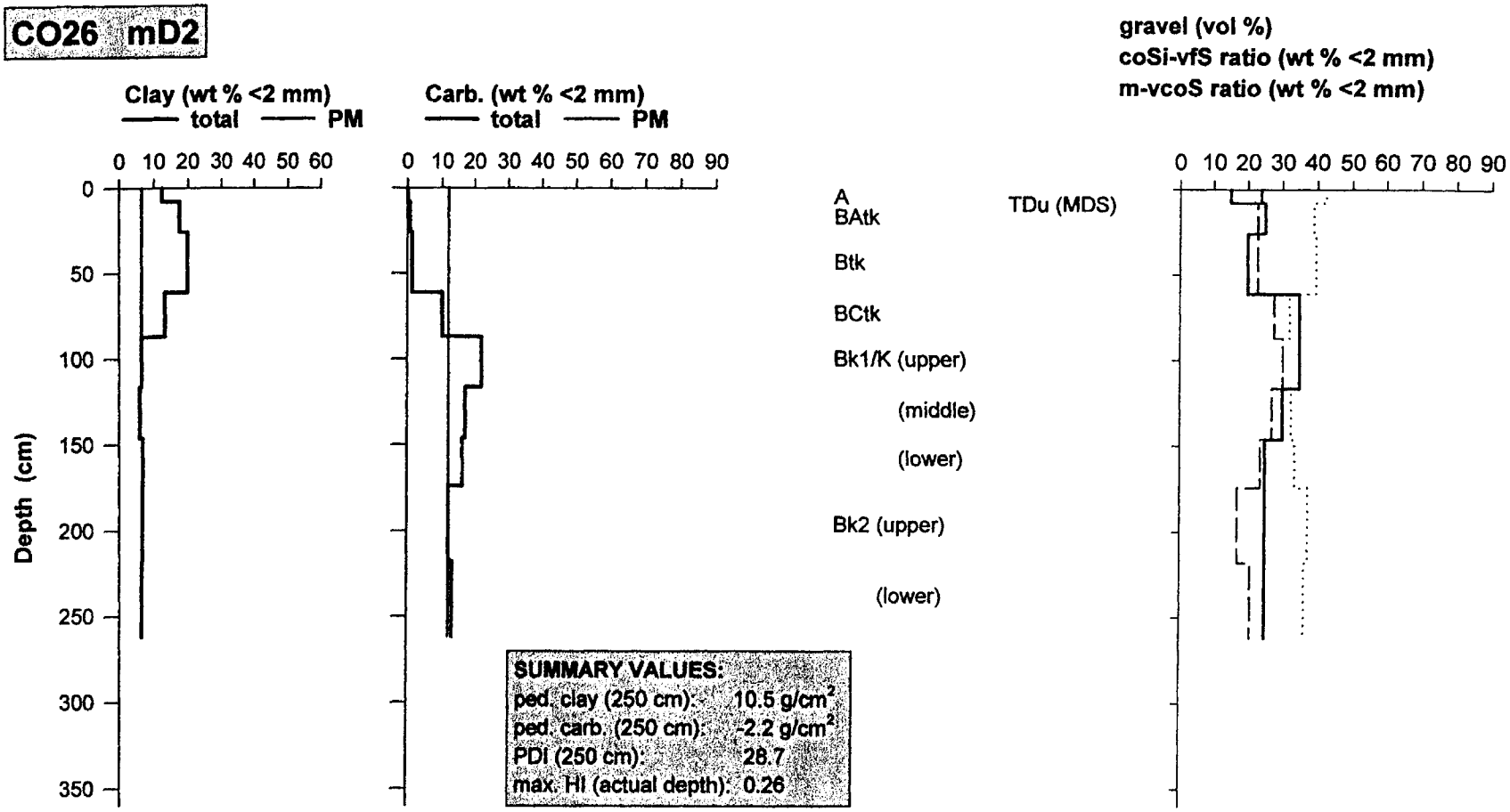


FIGURE 6.3 Depth plots for profile CO26 on the Durango 2 moraine crest, illustrating a simple profile in relatively uniform diamicton (probably composed of debris-slow deposits, or facies MDS of Johnson, 1990); coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

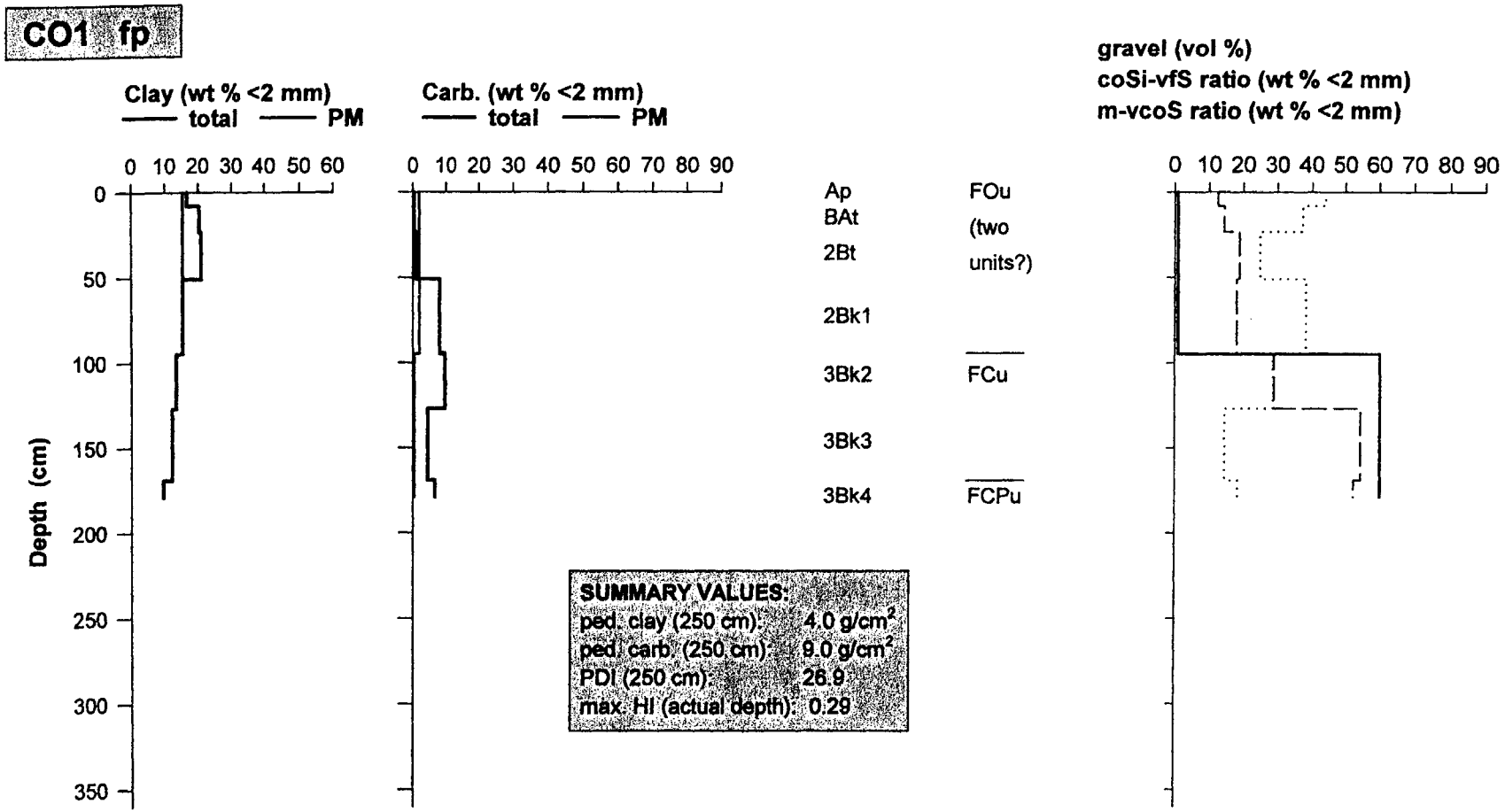


FIGURE 6.4 Depth plots for profile CO1 on a flood-plain terrace, illustrating a simple profile in upward-fining overbank and channel gravel deposits with primary infiltrated silt and clay; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

fining and possibly fluvial infiltration in very porous sediment; this assumption limits the extent of pedogenic change to a more reasonable value for the profile's age.

Profile CO25 on t6a

This profile (Figure 6.5) is typical for sites on TG6 and TG7 with relatively low sedimentation rates after river incision and terrace abandonment. It resembles the preceding profile in some ways but illustrates colluvial or pedogenic mixing in the upper part of the profile and textural controls on the depth of clay and carbonate distributions. Trends in gravel and textural ratios above 77 cm suggest primary, upward fining, but the upper horizons contain more gravel and silt than in CO1. Since alluvial fans do not reach this site, the parent material for the upper horizons could be a colluvial or pedogenic mixture of eolian, overbank, and channel deposits. Maximum and total pedogenic clay and carbonate are greater than in CO1. However, pedogenic carbonate continues below the exposure, and carbonate contents in the gravelly unit are minima because carbonate on clasts is not included. The depth and thickness of the clay bulge partly reflect parent-material stratification.

Profile NM7 on t6b

This profile (Figure 6.6) formed on younger materials than CO25, but at a site with relatively rapid alluvial and eolian deposition after terrace abandonment. Concurrent soil formation and deposition, at varying rates, have created a multistory profile with composite and compound soils that are weaker individually than the simple soil at CO25. Laboratory data were obtained for the upper depositional units, in which most soil development has occurred, and for a clayey zone at the top of the fluvial gravel.

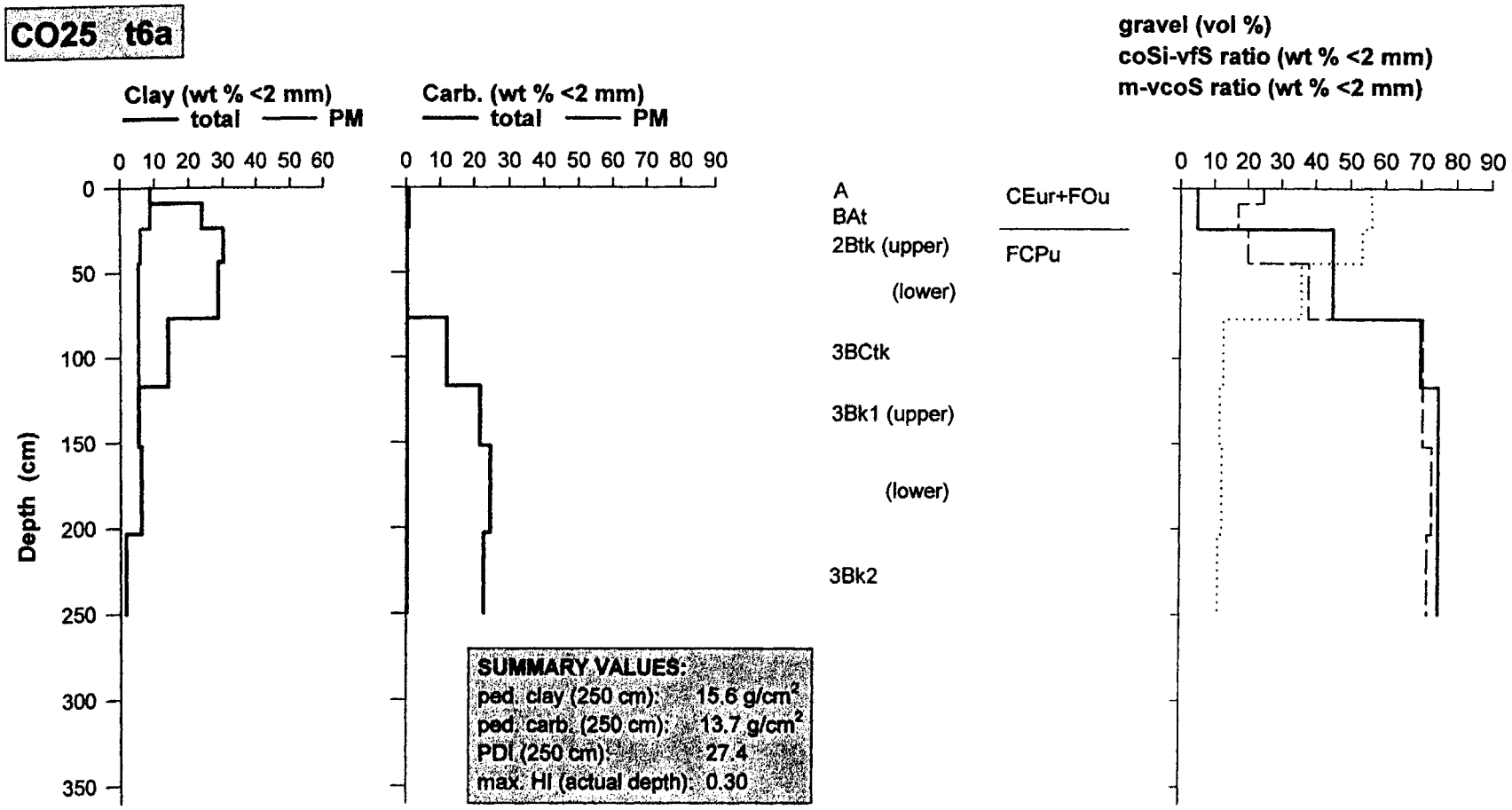


FIGURE 6.5 Depth plots for profile CO25 on t6a, illustrating a simple profile in mixed colluvial and overbank deposits and in fluvial channel gravel, with textural controls on horizon depths; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

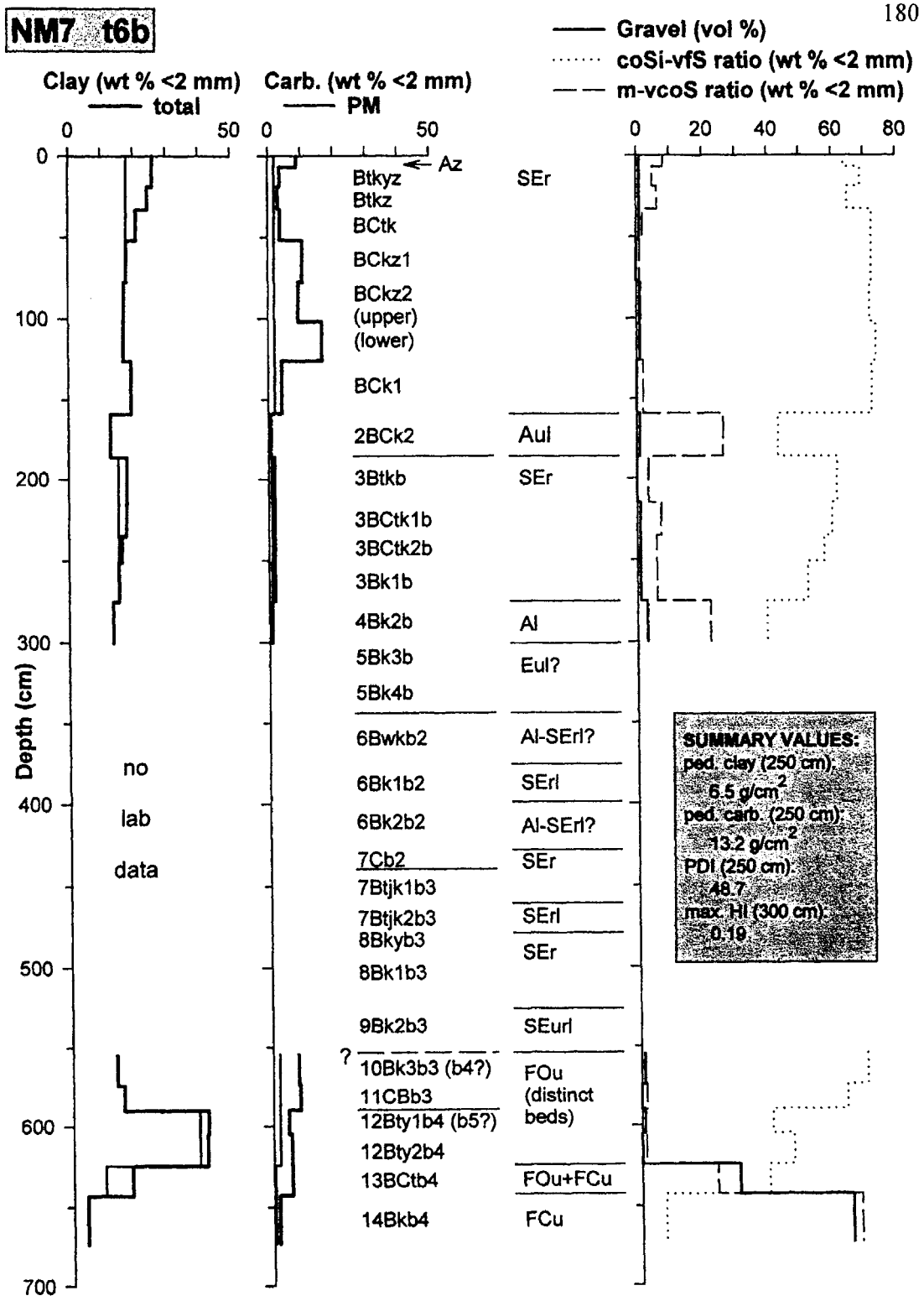


FIGURE 6.6 Depth plots for profile NM7 on t6b, illustrating clayey overbank deposits and a composite/compound profile in overlying alluvium and sheetwash-eolian sediments; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

The upper section includes two depositional cycles in which relatively coarse-sandy sediments, some with small-scale fluvial structures, are overlain by relatively fine-sandy sediments that lack sedimentary structures. These cycles appear to begin with relatively rapid alluvial-fan deposition and to continue with slower eolian or sheetwash deposition. In the surface soil, which has developed in the upper unit, several small carbonate maxima indicate a progressive decrease in leaching depths, probably due mainly to Holocene drying. Although cumulic soil development is also likely in an eolian setting, assumed values for parent-material clay restrict pedogenic increases to the zone with clay films. In the next-older depositional cycle, textural data and the lack of a carbonate bulge suggest that the upward increase in total clay reflects mainly upward fining in a non-fluvial environment, with minimal pedogenesis. In this alluvial-fan setting, upward fining could result from cyclic vegetation or runoff changes in the surrounding area.

Clay contents as high as 42 % at the top of the fluvial gravel resemble a buried Bt; however, the lack of a lower carbonate bulge and lateral stratigraphic relations indicate that the parent material from 555 to 624 cm consists of overbank deposits with high but variable primary clay. Nevertheless, estimated primary clay values allow for small increases in some horizons. In the clayiest zone, an arbitrary 3 % pedogenic increase was allowed because continuous clay films suggest translocation, and because the sediment's high water-holding capacity suggests that some weathering has probably occurred. Similarly, an arbitrary 8 % increase in the next lower horizon allows for clay translocation into the top of the gravel.

Profile CO30 on t5c

This profile (Figure 6.7) is on an outwash terrace graded to the Durango 2 moraine. Unlike CO26, on the moraine crest, CO30 illustrates soil development at a site where

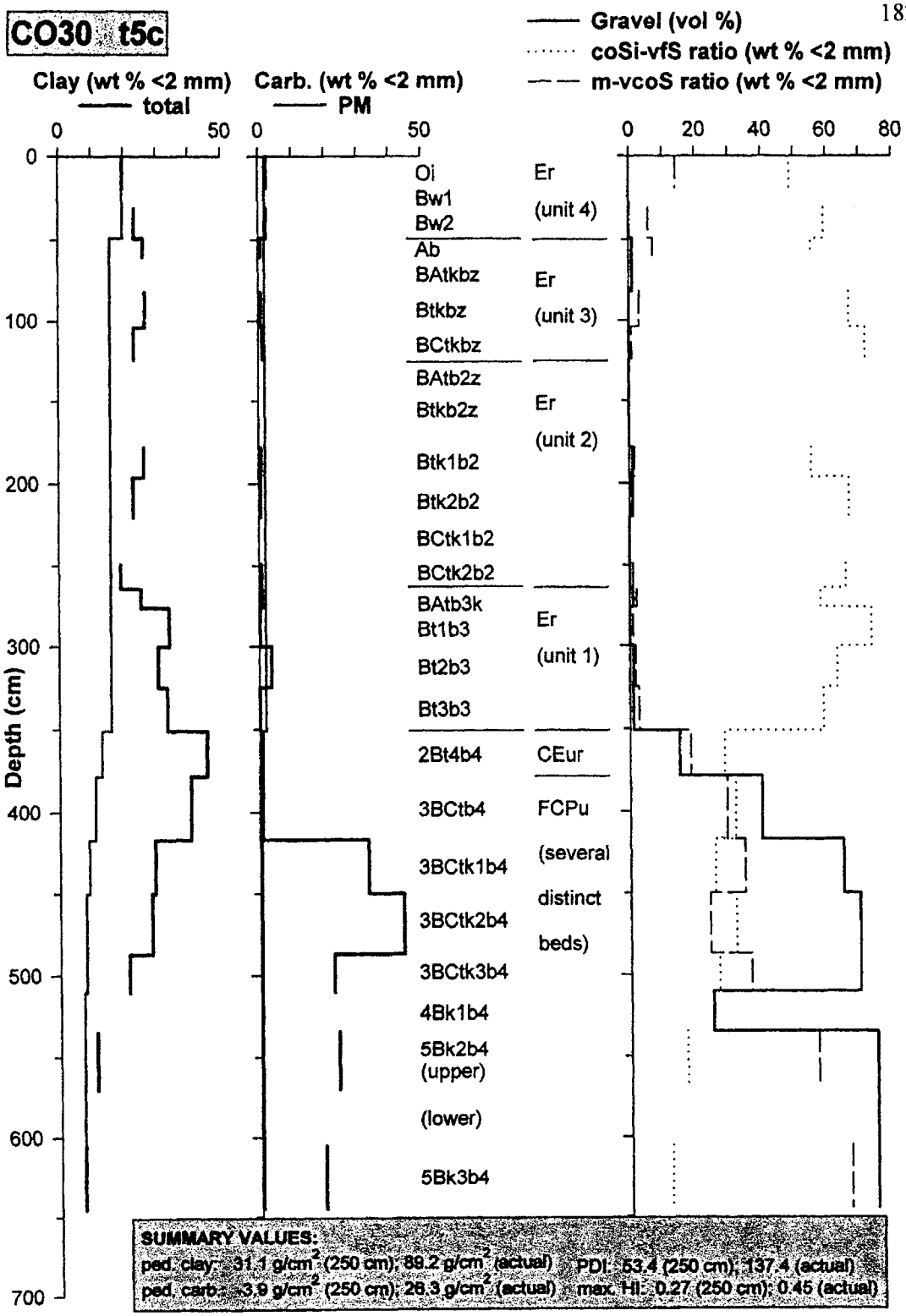


FIGURE 6.7 Depth plots for profile CO30 on t5c, illustrating a composite profile in loess and fluvial gravel, with strong weathering at the loess-gravel contact; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

eolian deposition has occurred at rapid but varying rates. The resulting profile illustrates compound soils in loess, as well as pedogenic mixing and weathering at the textural boundary between loess and fluvial gravel. Due to the soil's great depth, laboratory data were not obtained for some horizons, and estimated values (Table B.7) were used as needed to calculate weights of secondary clay and carbonate.

The upper part of the profile includes four overlapping soils with slight variations in clay and carbonate contents. Parent-material clay for the weak, surface soil was set at its present value in the epipedon. In the other soils, which are less sandy, all horizons contain secondary clay, so the parent-material value was set arbitrarily at 15 %, or slightly below present minima. Most tested horizons contain less carbonate than the assumed parent-material value of 2 %. This could mean that the assumed parent-material value is too high, or that relatively deep leaching has occurred.

Clay and carbonate bulges indicate another buried soil in the top of the fluvial gravel and in a transitional unit (CE) that may have formed partly by colluviation before the loess accumulated and partly by later pedogenic mixing. Many saprolized clasts in the upper part of the gravel indicate strong weathering near this textural boundary. From 487 to 351 cm, the upward decrease in gravel suggests that some saprolized clasts have been incorporated into the matrix. Chromas up to 5, which are rare in this area, probably reflect assimilation of reddish-brown sedimentary rocks, mineral weathering, and formation of iron compounds.

Profile NM21 on t1u

This profile (Figure 6.8), on a terrace of the oldest Animas River group, illustrates maximum soil development in the drier, New Mexico area. Although the profile appears to

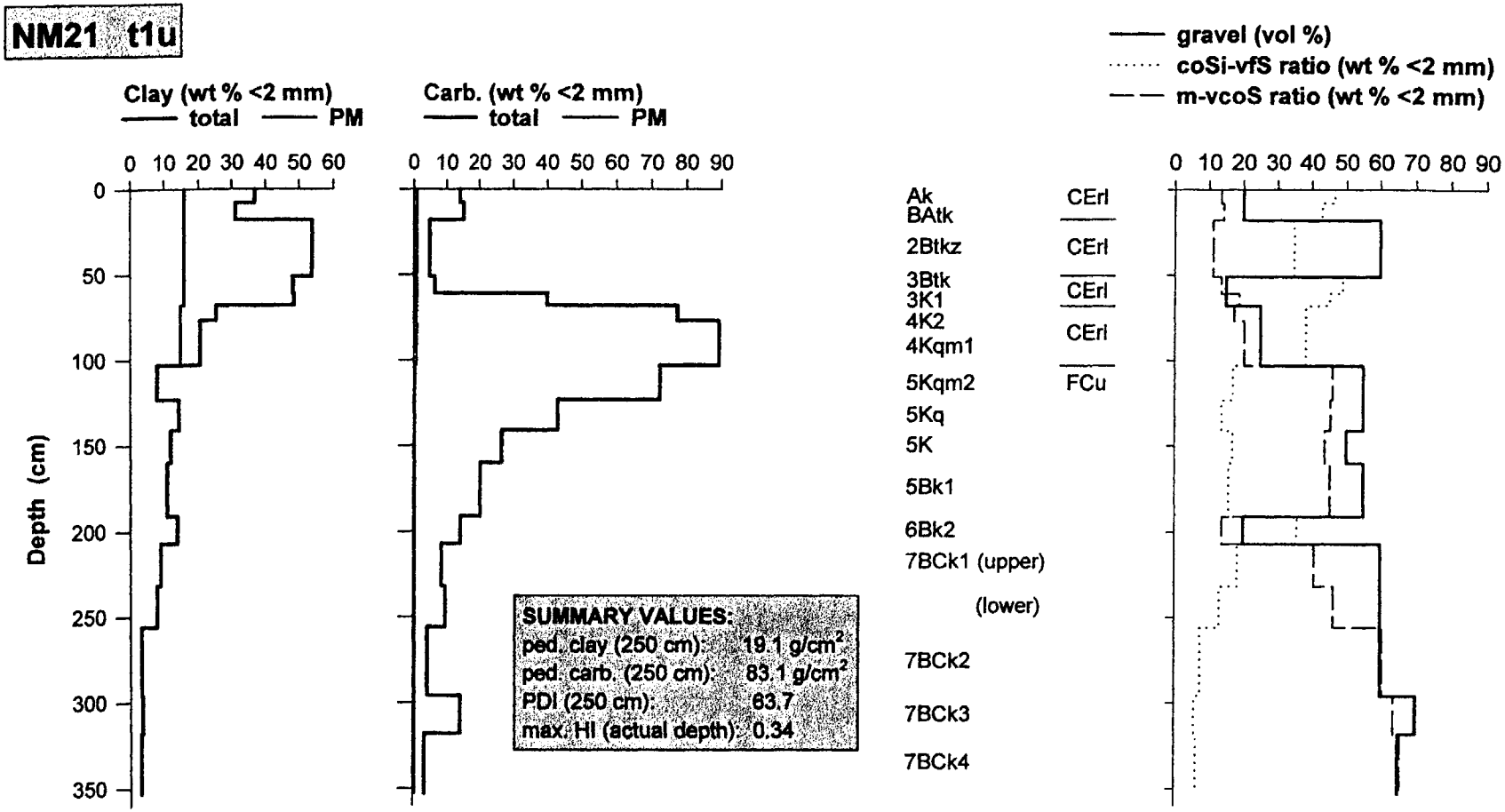


FIGURE 6.8 Depth plots for profile NM21 on t1u, illustrating a welded and truncated profile in colluvial-eolian and fluvial gravel deposits, with textural controls on horizon depths; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand.

consist of a single, simple soil, it is probably welded and truncated. It is located on a spur that extends from the main terrace area of Slane Knob, but has slightly lower elevations.

This strongly developed soil displays large clay and carbonate bulges with contents of clay and carbonate up to 54 and 89 %, respectively. Maximum carbonate stage is IV, but only III+ at nearby sites on the main terrace area. Similar increases in carbonate morphology occur on shoulder slopes throughout the study area because slow erosion exposes the top of the carbonate to leaching, solution and re-precipitation. In this profile, most carbonate is shallower than 250 cm, but carbonate still exceeds parent-material levels at 350 cm. Minor clay peaks within the fluvial gravel are probably not pedogenic (for example, the apparent peak at 123 to 141 cm may result from destruction of clay in the overlying sample during pretreatment to remove silica cement.

In the upper part of the profile (parent material CE), textural variations suggest several episodes of colluviation. Also, minor clay and carbonate peaks in the top 18 cm show that clay and carbonate were reworked from soils on the higher part of the terrace and transported in colluvium. Episodic deposition, inclusion of reworked soil materials, and surface slopes indicate that this profile is welded and truncated. The depth of truncation may be slight, but is unknown. Several meters of alluvial and eolian deposits may have existed here, but been stripped before the present eolian mantle accumulated on the larger terrace area. If so, the profile does not reflect the full age of the fluvial gravel.

Profile CO37 on tbt

This profile (Figure 6.9) illustrates maximum soil development in the moister, Colorado area. It has developed on a terrace of the La Plata River that is higher and may be much older than the oldest Animas River terraces (Chapter 7). Like NM21, this profile appears simple but is probably welded and truncated. Unlike other profiles, it contains no

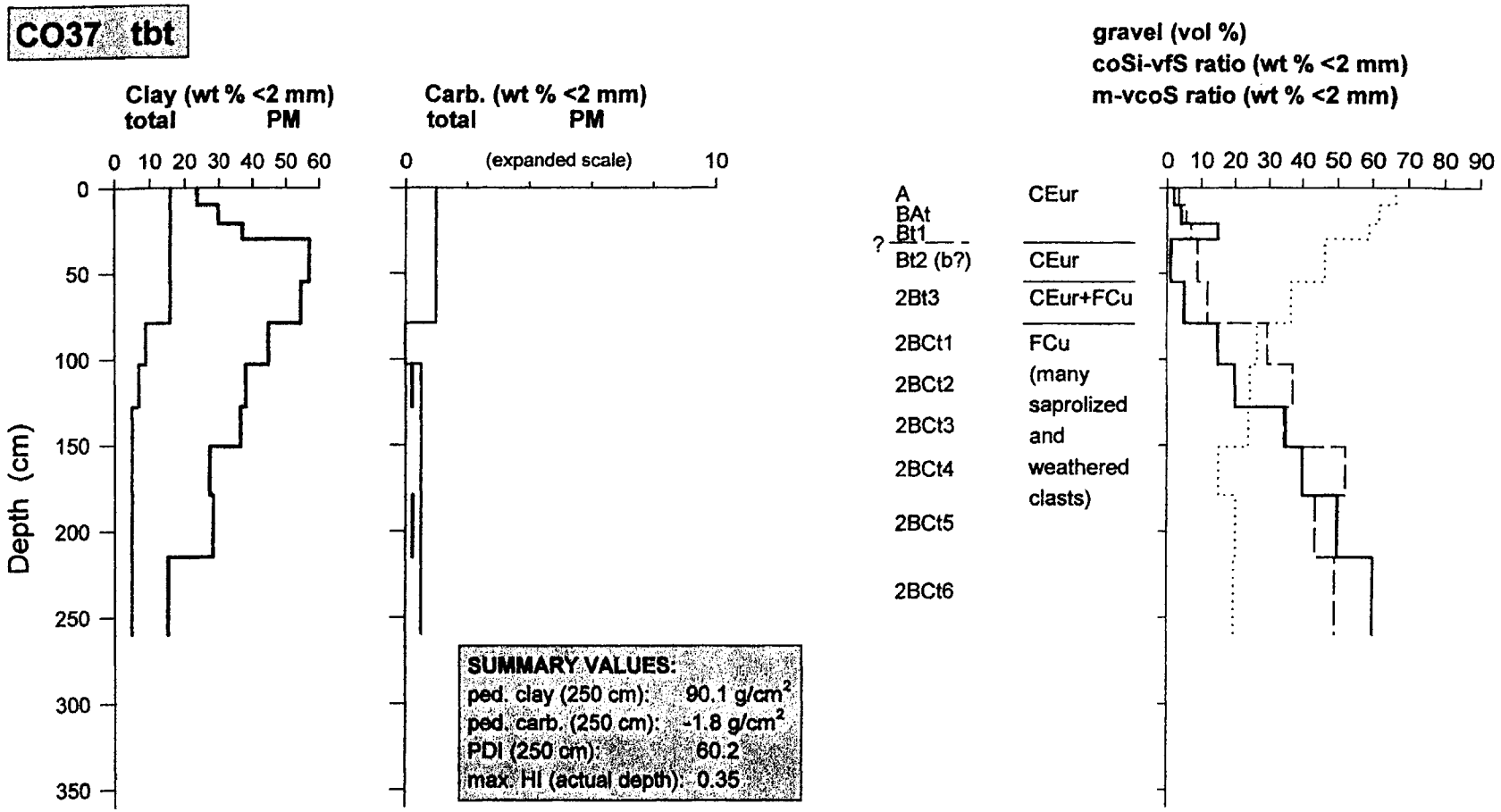


FIGURE 6.9 Depth plots for profile CO37 on tbt at Bridge Timber Mountain, illustrating a welded, truncated profile in colluvial-eolian and fluvial gravel deposits, with textural controls on horizon depths; coSi-vfS -- ratio of total coarse silt and very fine sand to total silt and sand; m-vcoS -- ratio of total medium, coarse, and very coarse sand to total silt and sand. Due to greater leaching at the highest site, this soil is noncalcareous.

carbonate because effective precipitation is high enough at this site to leach all carbonate from shallow exposures (trace values for carbonate in tested horizons are probably artifacts of the measurement procedure). Upward decreases in gravel and sand result from intense weathering and saprolization of clasts. All of the remaining clasts are strongly weathered to at least 250 cm (below exposure depth). As in NM21, textural variations in the upper units (CE) suggest episodic colluvial and eolian deposition. The thinness of these units, slight convexity of the gravel top, and local gullying also indicate truncation. Although the soil is very strong, its features probably formed during a much shorter period than the age of the gravel.

Summary

The preceding examples show the variety and complexity of soil profiles on moraines and terraces. Over the long term, geomorphic position in relation to winds and sediment sources determines soil stratigraphy, but site factors change with time because of depositional patterns and topographic reversal. Some parent-material properties are ambiguous, even in relatively weak soils. When profiles include many parent-material types, all of which may vary, consistent distinction between parent-properties and pedogenic change is very difficult.

Trends in Soil Development with Landform, Time, and Climate

The profiles fall into three groups that demonstrate broad variations in soil development with landform, climate, and time, even though each of these factors varies within the groups or is imprecisely known. Landform (moraine or terrace) roughly determines each profile's topographic setting and parent-material combinations (Chapter

5), but its effect changes with time as discussed above. Relative height of the landform is used as a proxy for potential duration of soil development, but the relationship between relative height and landform age is approximate, and some soils do not reflect the age of underlying landforms because of intervals of deposition or erosion. Climate varies more with elevation than with latitude (Chapter 2), so local climates at higher or more northerly sites in New Mexico may resemble those at lower or more southerly sites in Colorado. Nevertheless, profiles on terraces in Colorado and New Mexico, as groups, vary in ways that are due mainly to climate and possibly to differing eolian inputs. Profiles on moraines and terraces in Colorado vary with topographic setting and parent-material combinations. Finally, profiles in each group exhibit broad trends with relative age. However, trends for profiles on moraines are poorly defined because of the moraines' limited age range.

Three types of information are used here to illustrate soil variations with landform, time, and climate: profile weights of pedogenic (or secondary) clay and carbonate, selected field properties, and codified field properties. Profile weights of pedogenic clay and carbonate, for the 16 soils with laboratory data, measure soil development most precisely, but estimates of primary clay and carbonate contents affect the accuracy of the results. Field properties such as horizon thickness and strength are less precise as indicators of soil development because they frequently depend on texture and because many properties are measured on ordinal scales. Indices based on field properties, such as the horizon index and profile development index (Harden, 1982; Harden and Taylor, 1983; Birkeland and others, 1990) integrate many soil-forming processes but are strongly influenced by the accuracy and consistency of soil descriptions (Reheis and others, 1989).

Because of the large variation in profile depths (Figure 6.1A), values that depend on depth are presented for a constant thickness of 250 cm by extrapolating the basal properties of shallower profiles and ignoring the deeper parts of other profiles (Reheis, 1987a,b). However, values for both 250 cm and the profiles' actual depths are presented in

Appendix B. Generally, scatter diagrams for soil properties versus relative height are similar if constructed with values for actual depths or for the 250-cm standard. Points that vary most in relative location between the two types of plots are those for profiles with strong buried soils. Values that measure the maximum development of a horizon property in the profile, such as maximum carbonate stage or total texture, are selected from all horizons regardless of depth.

Profile Weights of Pedogenic Clay and Carbonate

Pedogenic clay and carbonate (Appendix B; Table B.8) display varying trends with relative height (or approximate age) for the three profile groups (Figure 6.10). Generally, pedogenic clay and carbonate increase most rapidly on landforms as old as TG4, increase more slowly on older ones, and mostly decrease on TG1 and tbt. The small number of data points on landforms older than TG4 makes early trends uncertain, but decreases on older surfaces are consistent with expected degradation of very old soils. For Colorado terraces, the leaching environment on tbt controls the carbonate trend; however, since moisture increases with elevation, it is likely that intermediate terraces, if preserved, would show decreasing accumulation rates in the middle part of the curve.

Among profile groups, pedogenic clay increases most rapidly and attains much higher levels on terraces in Colorado than in New Mexico. This contrast may reflect not only climate, but also the finer texture of eolian and reworked eolian deposits (facies E and SE) in the Colorado area (Chapter 5). Pedogenic clay at two moraine sites is comparable to values on New Mexico terraces. Pedogenic carbonate is relatively similar on terraces as old as TG5 in both areas, but reaches much higher levels on older terraces in New Mexico. Pedogenic carbonate is higher at moraine sites than at terrace sites of similar age in both areas, possibly because more carbonate occurs at depths below 250 cm in terrace profiles.

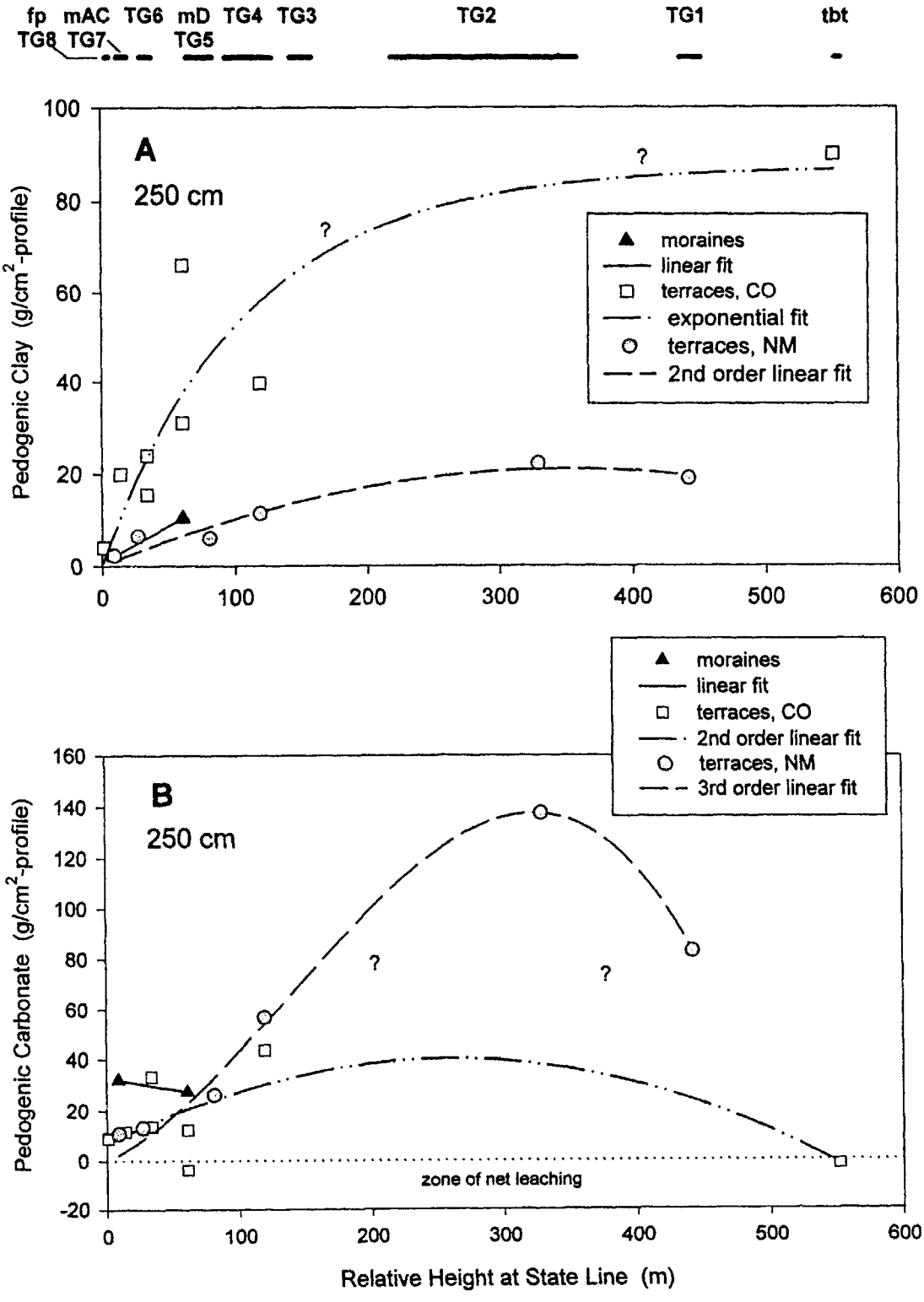


FIGURE 6.10 Trends in total pedogenic clay (A) and carbonate (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

Soil-Development Indices and Field Properties

Indices discussed here include normalized properties, which show the relative strength of specific features in single horizons; the horizon index (HI), or weighted average of the normalized properties; profile properties (PP), or products of the normalized property value and thickness of each horizon, summed for the 250-cm standard depth; and the profile development index (PDI), or sum of the profile properties (Harden, 1982; Harden and Taylor, 1983; Birkeland and others, 1990). In addition to these values, weighted means and values for actual profile depths are reported in Table B.9. Scatter diagrams are not given for weighted means because their distributions are identical to those of profile sums (except for differing y-axis scales) when both are calculated for standard depths. All profiles are included in the scatter diagrams except NM11, which shows near-surface variations from NM10.

Indices were calculated for ten properties, all of which are included in the HI and PDI values. Scoring for rubification, paling, melanization, lightening, total texture, clay films, and consistence either follows or differs slightly from published procedures (Harden, 1982; Harden and Taylor, 1983; Birkeland and others, 1990; Appendix B). Two other properties were defined for this study (Appendix B). The carbonate property combines stage, effervescence, lightening, and paling in a way that is more effective for these soils than previous carbonate indices. The saprolization property indicates reductions in gravel content, but has non-zero values in only two profiles (CO30 and CO37, described above).

Most measures of soil development increase logarithmically with time for all three profile groups, but some decrease in the oldest soils. Generally, trends are weak to very weak because scatter is moderate to very high. The trend lines shown are those with the best fits, but most values for r^2 are low (between 0.1 and 0.4).

In most cases, single values are higher and more variable for Colorado terraces and lower but less variable for moraines and New Mexico terraces. Indices or field measures showing this pattern include HI (Figure 6.11A); PDI (Figure 6.11B); total thickness of clay accumulation (Figure 6.12); total-texture maximum and profile property (Figure 6.13); rubification maximum and profile property (Figure 6.14), and structure maximum and profile property (Figure 6.15). In contrast, measures of carbonate accumulation tend to be highest for New Mexico terraces, intermediate for Colorado terraces, and lowest for moraines, though values for all three groups are comparable on landforms as old as TG6. Indices or field measures showing this pattern include total thickness and maximum stage of the carbonate accumulation (Figure 6.16) and carbonate index maximum and profile property (Figure 6.17). Finally, the consistence maximum and profile property are roughly equal in all groups (Figure 6.18).

Trends for specific measures reflect soil-forming processes and factors. For example, differing trends for maximum and total values (to 250 cm depth) reflect the depth distributions of soil properties. Greater scatter in the horizon index than in the profile development index (Figure 6.11) shows that overall variability is greater for maximum than for total values. Because many of the profiles are composite or compound, maxima do not increase as well as in simple soils. Differing trends for total-texture maximum and profile property (Figure 6.13) show this pattern clearly. Poor trends in rubification (Figure 6.14) may reflect both the number of soils per profile and difficulties in estimating colors for many parent-material types. Values for consistence (Figure 6.18) are remarkably similar among all groups because they integrate processes like clay and carbonate accumulation that vary in importance with local climate. However, development of clay films (not plotted) is unrelated to age, probably reflecting multistory development and differing parent-material textures.

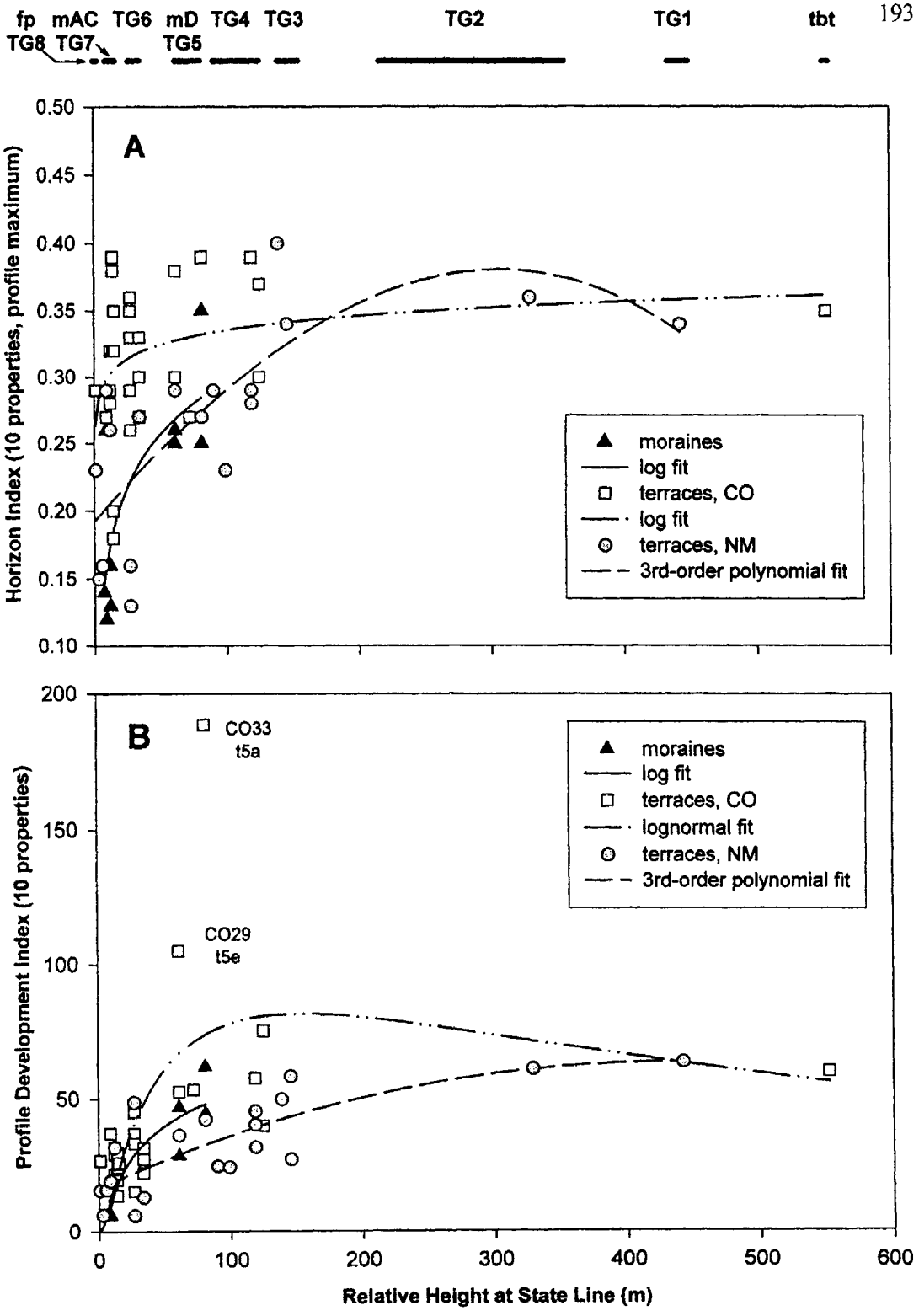


FIGURE 6.11 Profile-minimum values of the horizon index (A) and values of the profile development index (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

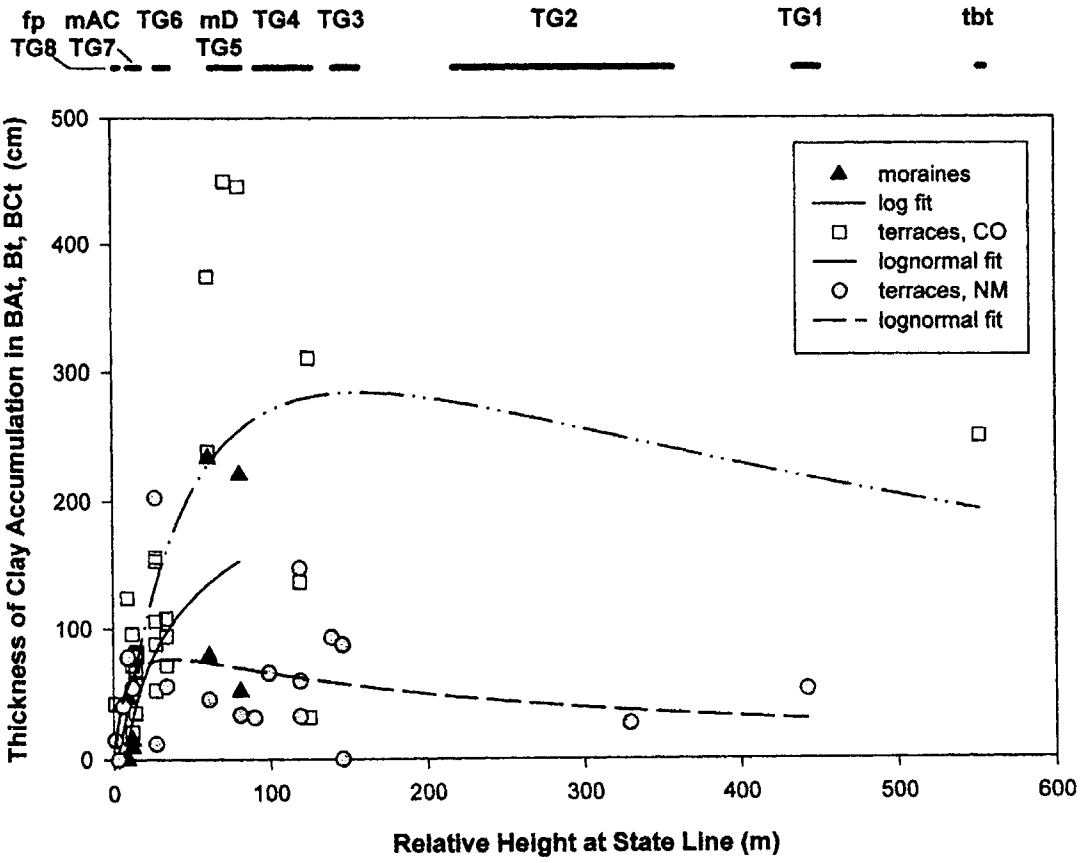


FIGURE 6.12 Total thickness of clay accumulation versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

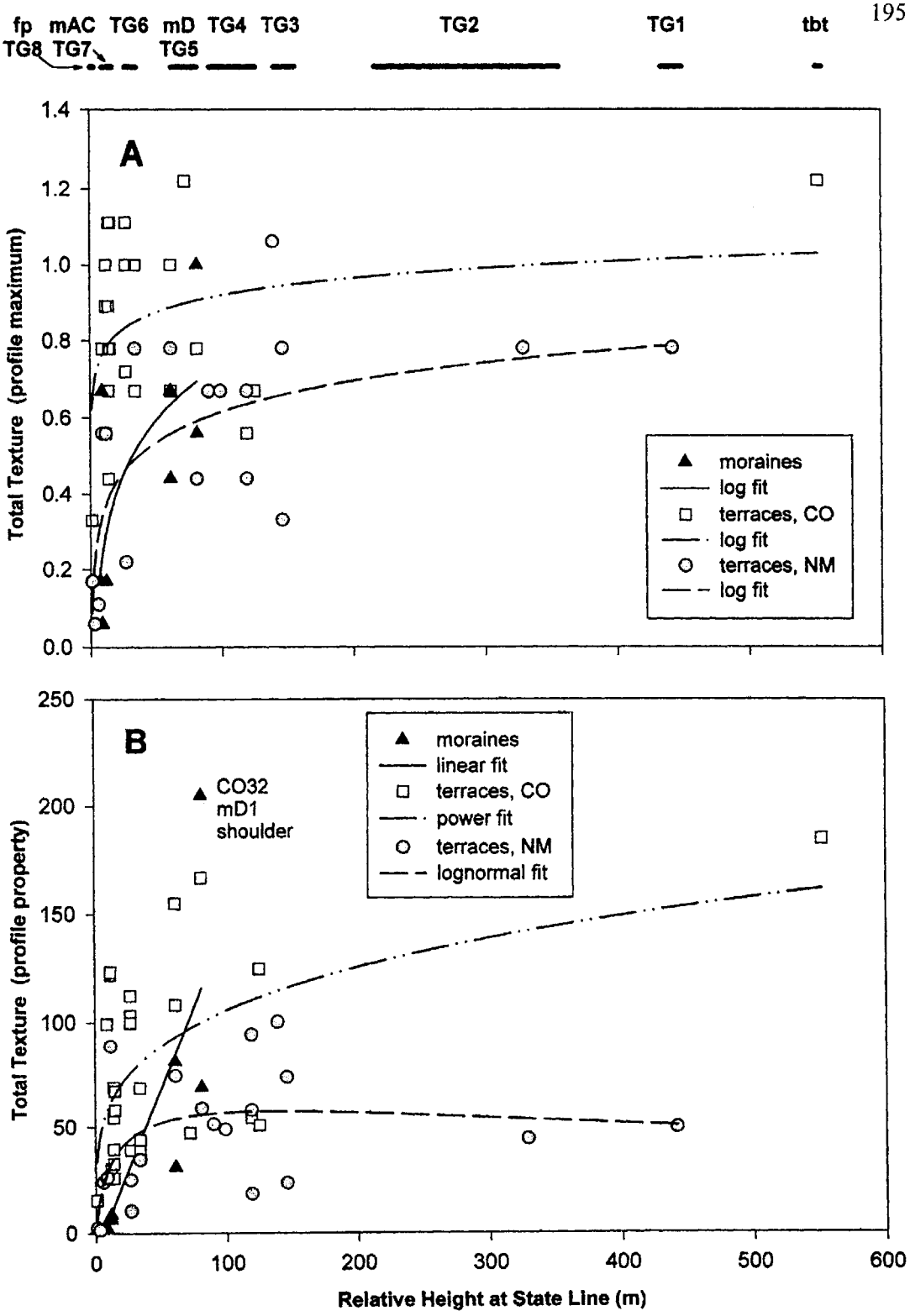


FIGURE 6.13 Profile-minimum values of total texture (A) and values of the total texture profile property (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

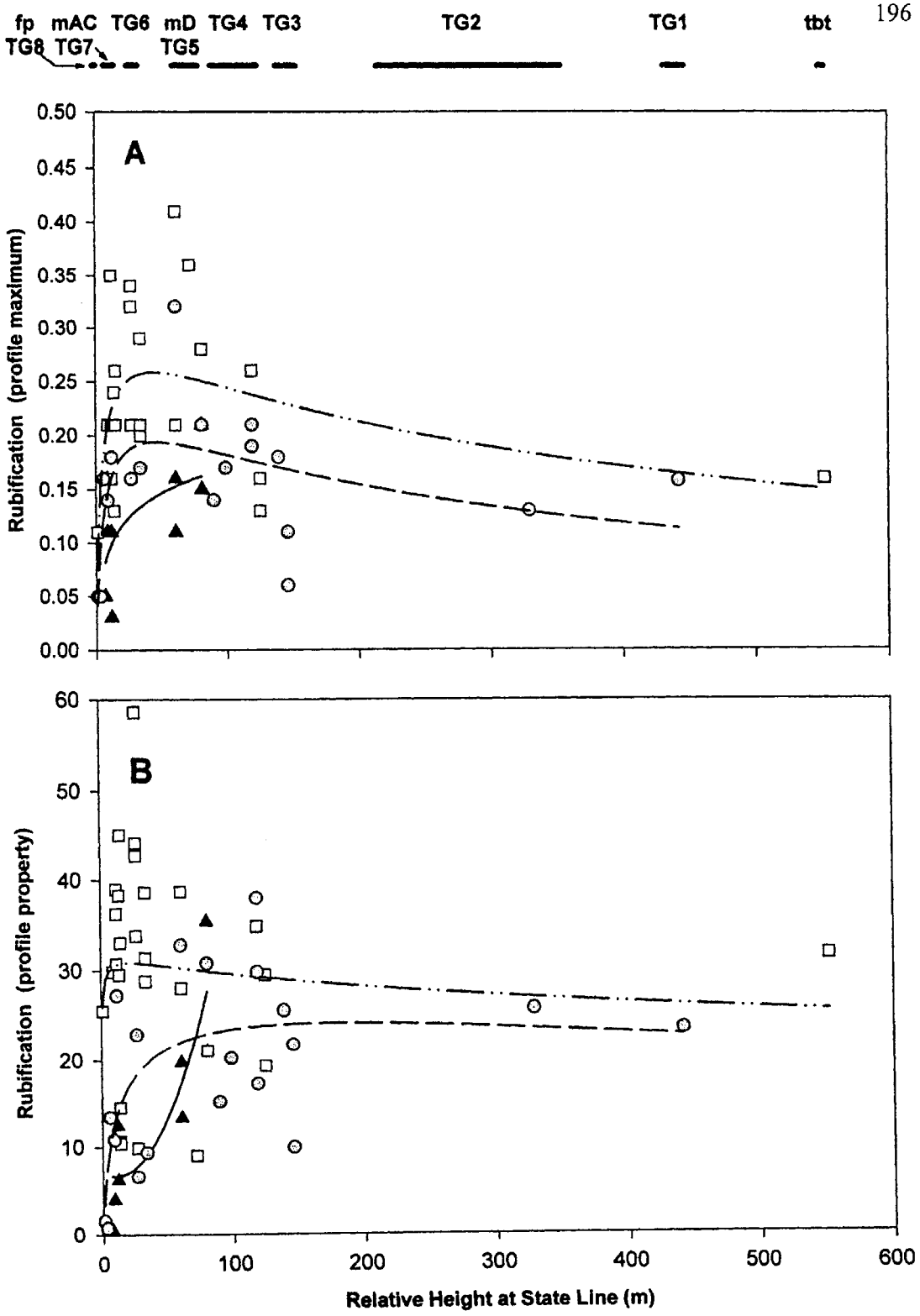


FIGURE 6.14 Profile-minimum values of rubification (A) and values of the rubification profile property (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

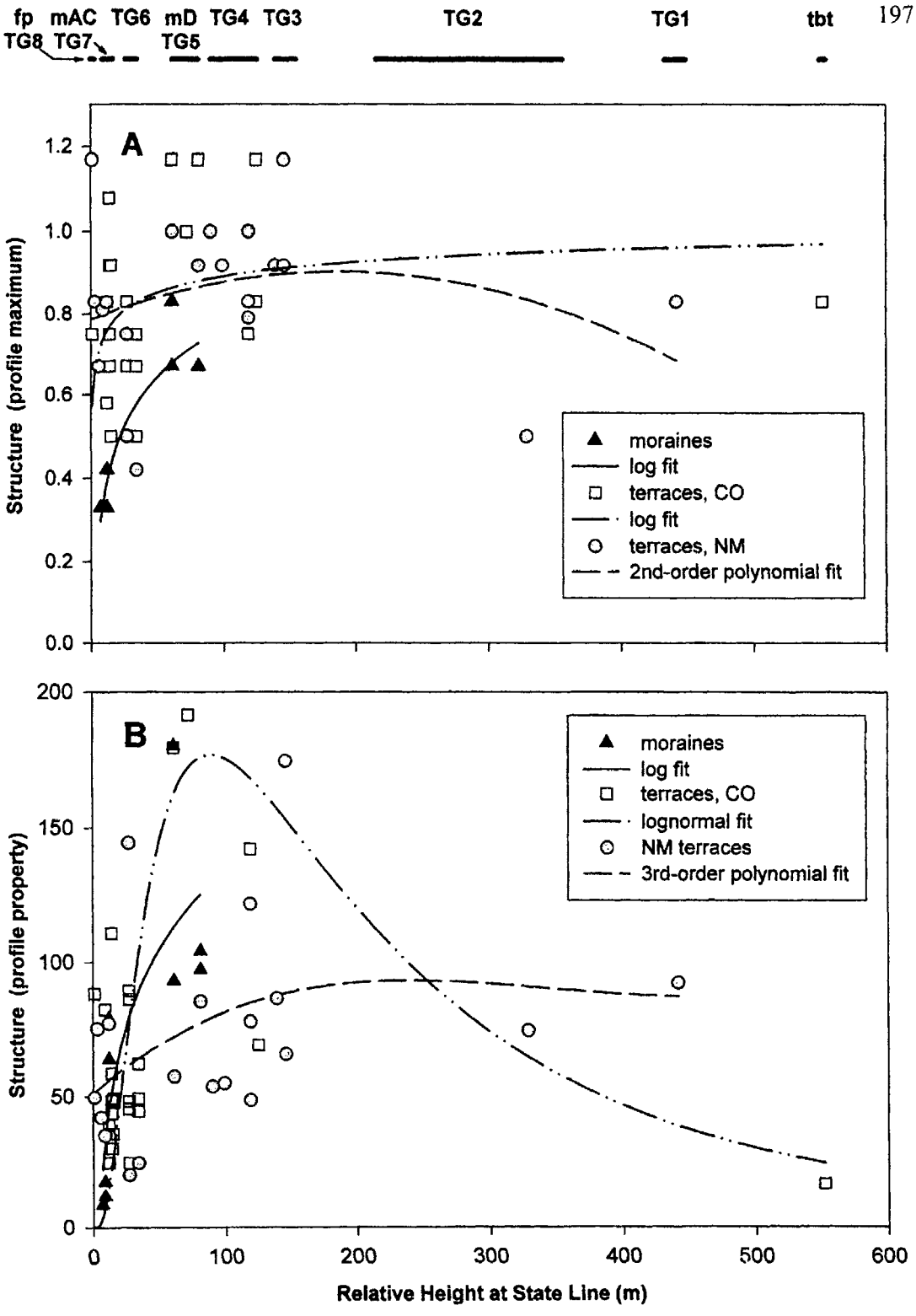


FIGURE 6.15 Profile-minimum values of structure (A) and values of the structure profile property (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

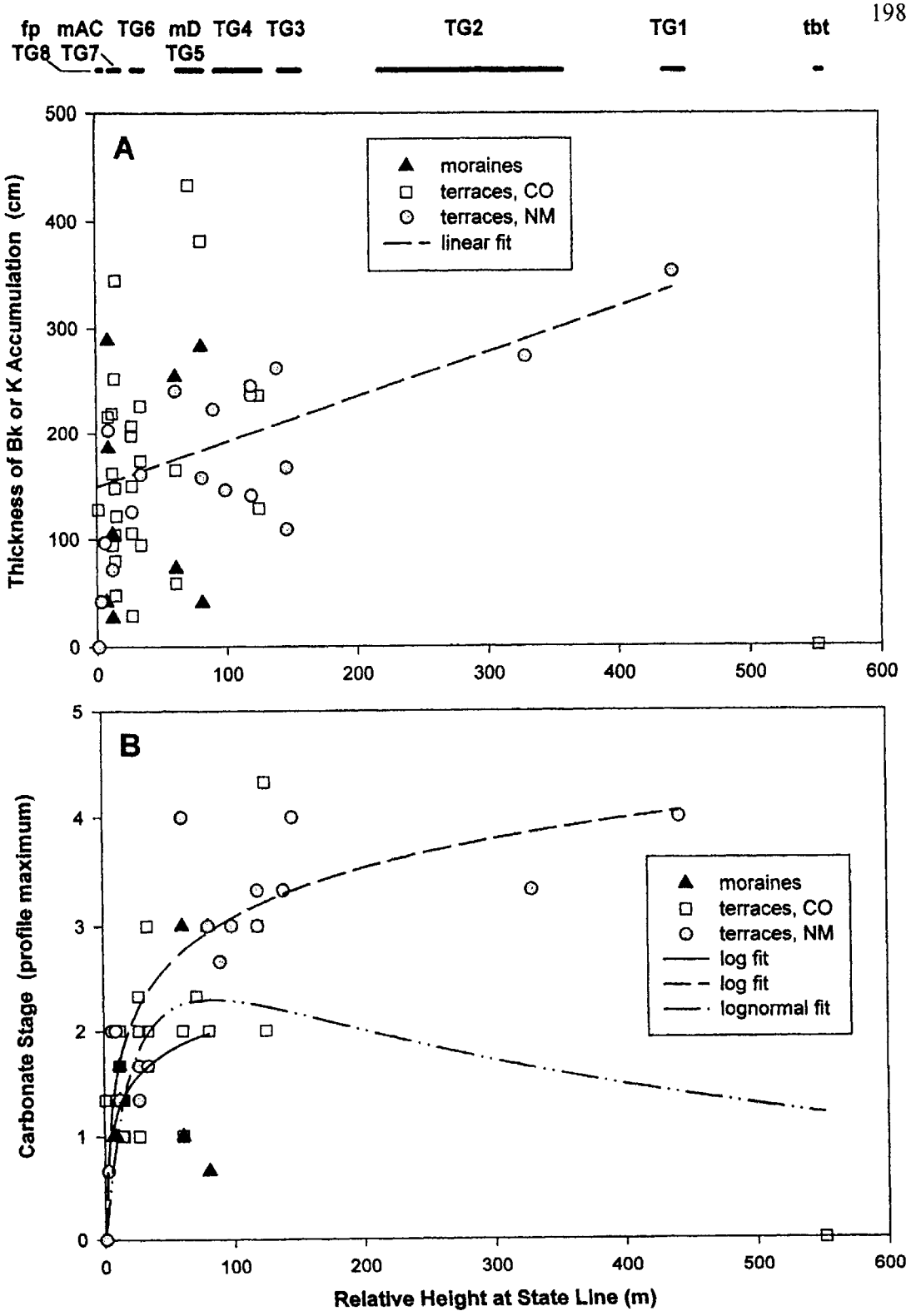


FIGURE 6.16 Total thickness of carbonate accumulation (A) and maximum carbonate stage (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

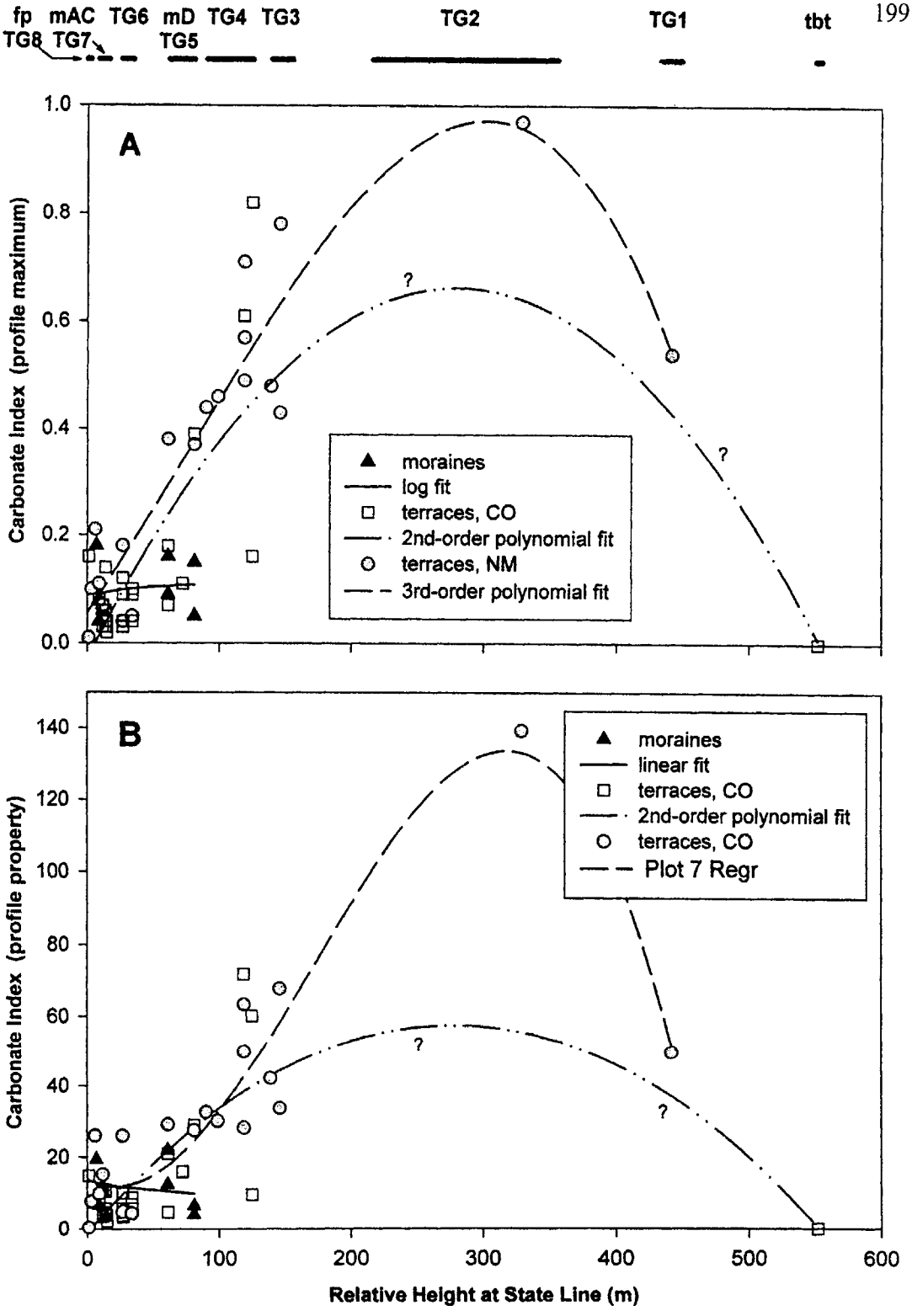


FIGURE 6.17 Profile-minimum values of the carbonate index (A) and values of the carbonate index (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

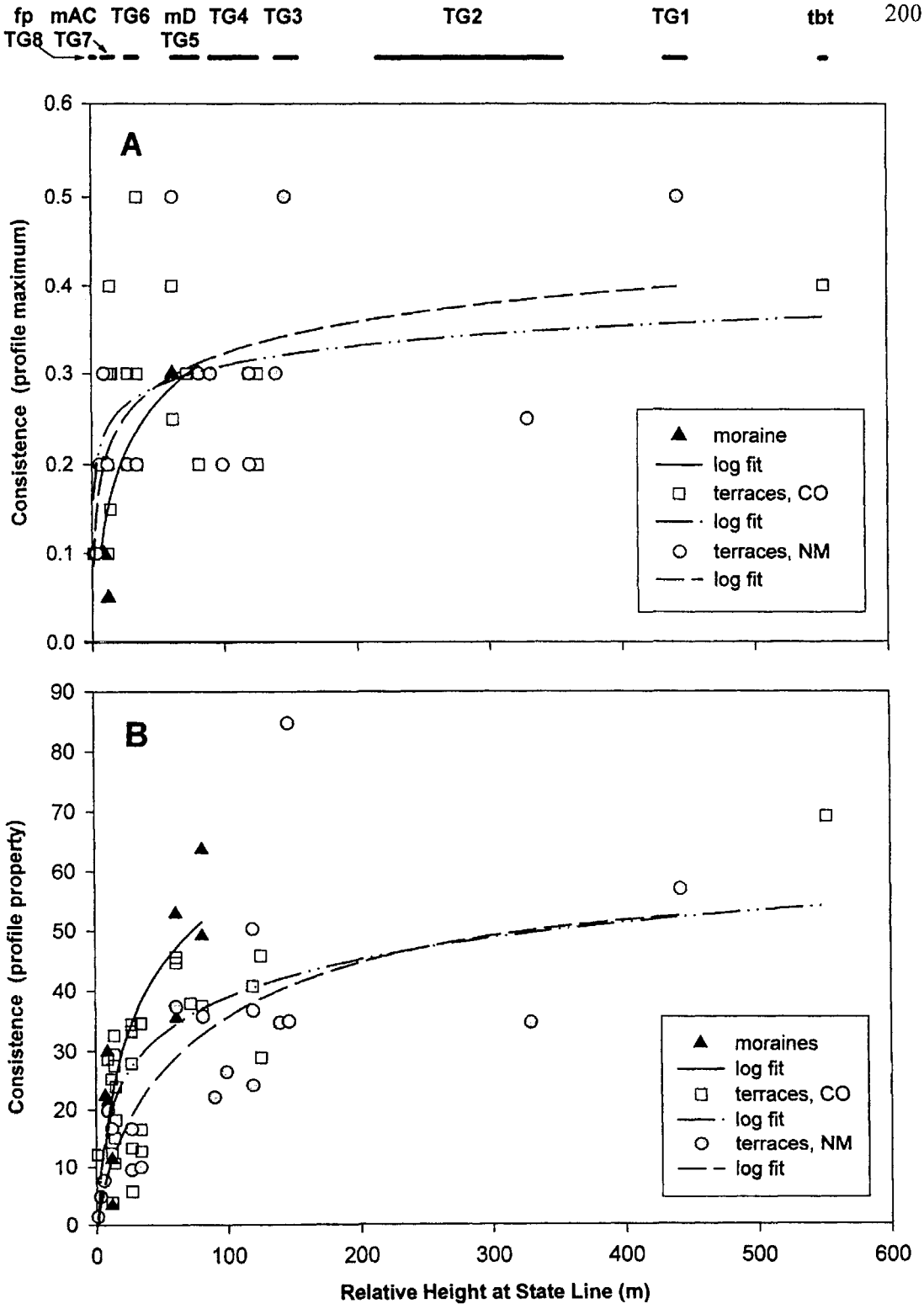


FIGURE 6.18 Profile-minimum values of consistence (A) and values of the consistence profile property (B) versus relative height of moraines and terraces, for three profile groups and 250-cm depths.

Discussion

The Animas valley is unsuitable for developing chronosequences and climosequences because the effects of other soil-forming factors cannot be eliminated, or even uniformly minimized, during selection of profile sites. The profiles do show weak trends in development with landform, climate, and age, but scatter for most properties is so great that soils which differ in age by one or two orders of magnitude may be similar in several ways. Thus, soils on the three landform groups are better considered chrono-associations (Mohindra and Parkash, 1992) than chronosequences.

In most cases, profiles on adjacent terraces are too similar to be used as a basis for correlation. However, the profiles fall into three developmental groups that are partly age-related. Profiles on TG7 and TG6 are mostly single-story and have similar averages for many properties, though variations occur at specific sites. For many profiles in this group, other processes must mask the effects of age, such as rapid weathering of shale and mudstone fragments, greater eolian input after formation of TG7 or partial leaching of carbonate from profiles on TG6 during the last glaciation. Where profiles are similar, terraces of both groups can be distinguished by minor differences in weathering of micaceous clasts. The second developmental group includes profiles on TG5 to TG3. Most of these profiles are composite or compound and have several features which are stronger or thicker than in younger soils. Profiles on the oldest terraces, TG1 and tbt, are welded and truncated, but display very strong clay or carbonate accumulations because of their great age. The single site on TG2 belongs to the intermediate group, but some soils on TG2 may belong to the third developmental group.

Profiles on terraces in New Mexico display the best trends with time for several reasons. These profiles show fairly consistent increases (to TG2) and narrow scatter in several properties such as pedogenic clay and carbonate (Figure 6.10), profile development

index (Figure 6.11B), thickness of carbonate accumulation (Figure 6.16A), maximum carbonate stage (Figure 6.16B), and carbonate index (Figure 6.17). Regional variations suggest the following reasons for relatively good trends. Although profiles in New Mexico have roughly similar numbers of parent materials and soils as other profiles (Figures 6.1B and 6.2A), the proportion of upper parent materials is usually smaller (Figure 6.2B). Therefore, parent-material variations may have less influence and profile maxima may be more like those in simple soils. Second, parent materials in New Mexico may be more uniform than those in Colorado, regardless of type. For example, eolian and reworked eolian deposits are more sandy, reflecting the greater importance of local sources, and thus are more similar to sandy alluvium and to the matrix of fluvial gravels. Also, percentages of easily-weathered and calcareous clasts are lower and more constant than in Colorado profiles (Table 5.3). Finally, lower leaching in New Mexico has promoted more consistent increases in carbonate. If terrace ages were to be estimated from soil properties, better results would be obtained from profiles in New Mexico than in Colorado.

Approximate, long-term accumulation rates for pedogenic clay and carbonate were calculated from two profiles on t4b, which is overlain by the Lava Creek B ash and near 615 ka in age (Chapter 6). For actual profile depths, pedogenic clay contents are 39.11 g/cm^2 in CO34 and 11.5 g/cm^2 in NM16 (Table B.8), giving accumulation rates of 0.02 to 0.06 $g/cm^2/ka$. Pedogenic carbonate contents of 39.7 g/cm^2 in CO34 and 44.1 g/cm^2 in NM16 yield rates of 0.06 to 0.07 $g/cm^2/ka$.

CHAPTER 7

AGES OF MORAINES AND TERRACES

Age estimates for the moraines and terraces are based mainly on correlation to moraine sequences elsewhere in the Rocky Mountains, the geomorphic position of the Lava Creek B ash, and average river incision rates. Supporting information includes radiocarbon dates elsewhere in the San Juan Mountains, amino acid racemization in fossil snails, paleomagnetic polarity determinations, and correlation to marine oxygen-isotope records. Soil development was not used, except in a broad relative sense, because of large variations among soils of similar age.

Age estimates based on these methods are summarized in Tables 7.1 and 7.2. Following a discussion of dating methods, age estimates are presented in order of increasing age.

Basis for Age Estimates

Final age estimates reflect numeric ages (Lava Creek B ash), calibrated ages (incision rates, amino acid racemization), and correlated ages (matching to glacial and marine sequences with numeric or calibrated ages). Definitions for Quaternary chronostratigraphic terms follow the timescale of Richmond and Fullerton (1986a) with updated boundary ages (Berggren and others, 1995). For marine oxygen-isotope stages, which record mainly global ice volume, the astronomically calibrated timescales of Berger and others (1994), Bassinot and others (1994), and Chen and others (1995) are in close

TABLE 7.1 ESTIMATED AGES OF MORAINES

MORAINE	AGE, BEST ESTIMATE (ka)	OXYGEN-ISOTOPE STAGE OF ICE ADVANCE	BASIS, COMMENTS
"BAKERS BRIDGE"	ca. 14	2	Correlated age (14-C yr) [1]
ANIMAS CITY			
3	ca. 15-16	2	Correlated age (14-C yr)
2	ca. 15-16	2	Correlated age (14-C yr)
1	ca. 20-25	2	Correlated age (14-C yr)
SPRING CREEK			
2	ca. 85-120	5b-5e	Correlated age; terrace relations
1	ca. 135-160	6	Correlated age; amino acid racemization [2]
DURANGO			
2	ca. 250-275	8	Incision rate and correlated ages for t5e
1	ca. 345-360	10	Incision-rate age for t5a

1. "Bakers Bridge moraine" may not be a terminal or recessional moraine, as discussed in text.
2. Alan R. Nelson, U.S. Geological Survey, written communication, 1997.

TABLE 7.2 ESTIMATED AGES OF TERRACES

TERRACE	AGE OF ABANDONMENT, BEST ESTIMATE (ka)		OXYGEN-ISOTOPE TIMESCALE		BASIS, COMMENTS
	MEAN AGE	ERROR RANGE	STAGE OF ICE ADVANCE	TERMINATION (ka) [1]	
t8u	Holocene		–	–	Relative to "Bakers Bridge moraine" or t7u
t8a	12	+/- 2	2	12	Relative to Animas City 3 and deglaciation
t7c	14	+5 -14	2	12	Correlated ages, closely preceding ice retreat
t7b	16	+5 -16	2	12	
t7a	25	+5 -15	2	12	Correlated age, late Wisconsin maximum
t6b	100	+/- 15	6	128	Correlated age, Eowisconsin
t6a	130	+/- 15	6	128	Correlated ages, "classic" Bull Lake maximum
t5e	240	+/- 20	8	244	Correlated age (stage 7/8); incision rate
t5d	245	+/- 20	8	244	Closely precedes t5e (arbitrary interval)
t5c	250	+/- 20	8	244	Closely precedes t5e (arbitrary interval)
t5b	255	+/- 20	8	244	Closely precedes t5e (arbitrary interval)
t5a	340	+/- 40	10	338	Incision rate; amino acid racemization [2]
t4e	430	+40 -50	12	425	Incision rate
t4d	520	+50 -60	14	525	Incision rate; amino acid racemization [2]
t4c	530	+/- 60	14	525	Closely precedes t4d (arbitrary interval)
t4b	615	+15 -5	16	621	Overlain by Lava Creek B ash
t4a	625	+15 -5	16	621	Closely precedes t4b (arbitrary interval); overlain by Lava Creek B ash
t3b	740	+60 -70	18	708	Incision rate
t3a	800	+70 -80	20	790	Incision rate
t2l	1320	+60 -80	?		Incision rate
t2h	1370	+90 -110	?		Incision rate
t2g	1490	+110 -150	?		Incision rate
t2f	1580	+110 -150	?		Incision rate
t2e	1820	+130 -170	?		Incision rate
t2d	1870	+110 -150	?		Incision rate; reversed polarity (?) [3]
t2c	1950	+110 -160	?		Incision rate; reversed polarity (?) [3]
t2b	2020	+120 -170	?		Incision rate; reversed polarity (?) [3]
t2a	2070	+130 -170	?		Incision rate; reversed polarity (?) [3]
t1u	2430	+220 -260	?		Incision rate; reversed polarity (?) at Slane Knob [3]
Bridgetimber Gravel	ca. 3-11 Ma ?		?		Incision rate; relations to t1u and regional erosion surfaces

1. Average of ages from Imbrie and others (1984), Ruddiman and others (1989), Berger and others (1994), Bassinot and others (1994), and Chen and others (1995).
2. Alan R. Nelson, U.S. Geological Survey, written communication, 1997.
3. John D. Strobell, U.S. Geological Survey, written communication, 1978.

agreement. The earlier timescales of Imbrie and others (1984) and Ruddiman and others (1989) support newer timescales back to stage 18.

Lava Creek B Ash

Tephra have been found at 17 or more sites in the Animas valley (Plates 1 and 2; Appendix C, Tables C.1 and C.2). Eight sites, including the only four in northwestern New Mexico, were located for this study. Twelve sites are on Animas River terraces (one on t4a, eight on t4b, two on either t4a or t4b where specific levels have not been identified, and one on t4bx).

At terrace sites, ash usually forms lenses within alluvial and eolian deposits that overlie fluvial gravels, but rarely it rests on gravels and is buried by younger deposits. Fine ripple or flat laminations indicate that reworked, air-fall ash accumulated in alluvial or lacustrine environments. Relatively pure ash is 0.1 to 0.6 m thick and the total thickness of ashy sediment is up to 2 m (Table C.1). Lens widths are unknown, but exposure widths are several meters to tens of meters. The lack of buried soils between gravels and ashy deposits indicates relatively continuous deposition from fluvial to alluvial environments. In comparison, the largest ash deposit not associated with a terrace is up to 15 m thick and at least 500 m wide (Table C.1, site A1).

As discussed in Appendix C, all tephra are probably Lava Creek B ash from the Yellowstone caldera, located 800 to 920 km north-northwest of the Animas valley on the Idaho-Wyoming border. Ash at four sites was identified here from elemental concentrations measured by XES (Tables C.3 and C.4). Izett and Wilcox (1982) identified three sites from unspecified data and another four were identified here by similar appearance (Table C.1). The remaining sites are assumed to be Lava Creek B because they

occupy the same stratigraphic positions and because no other ashes have been found in the area.

The age of the Lava Creek B may be about 620 ka (Izett and Wilcox, 1982), near the boundary between stages 15 and 16. This age is consistent with the stratigraphic position of the ash in glacial and related deposits of the western United States and Canada and with marine oxygen-isotope timescales (David Fullerton, U.S. Geological Survey, oral communication, 1997). It is also close to the mean of the five most reliable K-Ar dates from Yellowstone, 617 ± 4 ka (as reported by John Obradovich, U.S. Geological Survey, to David Fullerton). In contrast, some workers have used 660 ka as the age of the ash (e.g. Jaworowski, 1993, 1994; Chadwick and others, 1994). This age is based on dates of 0.66 to 0.67 Ma by laser total-fusion ^{40}Ar-^{39}Ar on multiple sanidine crystals (Izett and others, 1992). However, an analysis of 24 sanidine crystals using single-crystal laser-fusion techniques has resulted in an ^{40}Ar-^{39}Ar age of 0.602 ± 0.004 Ma for the Lava Creek B (Gansecke and others, 1998). Less reliable ages for the ash and Lava Creek Tuff, member B, include K-Ar dates on sanidine from 0.60 to 0.72 Ma and fission-track ages on zircon or glass from 0.52 to 0.76 Ma (Izett and others, 1992, and summary by Richmond and Fullerton, 1986a). The ^{40}Ar-^{39}Ar ages determined by Gansecke and others (1998) were just published at the completion of this report, and have not been used to recalculate the relative ages of the terraces.

Incision-Rate Method

Terrace ages may be estimated from average incision rates that are calculated from two or more calibration levels such as a dated terrace and the modern flood plain (Palmquist, 1983 and unpublished manuscript, 1989). Ages for other terraces are estimated by dividing their heights by these rates. Though terraces result from temporary channel

stability or aggradation, this method gives useful age estimates in valleys with net incision (e.g. Reheis, 1984; Reheis and others, 1991; Jaworowski, 1993; Chadwick and others, 1994). Best results are expected for strath terraces in areas of tectonic stability or constant uplift rate, and where terrace spacing, bedrock erodibility, and climate are relatively uniform.

In this study, three incision-rate models are used (Figure 7.1). Model IR1 has two calibration points with known ages, the modern channel and t4b. In contrast, Models IR2 and IR3 each have a third calibration point with interpreted ages, t6a and t5e respectively. Except for the modern channel, calibration ages are intended as times when terrace incision began, and reflect lag times between ice maxima and incision for TG7 (as discussed below). Thus, the age of 615 +15/-5 ka for t4b is based on a 5-ka lag after deposition of the Lava Creek B ash. The age of 130 ± 15 ka for t6a is after most numeric ages for the Bull Lake glacial maximum (as summarized by Richmond, 1986a, and discussed below). Finally, the age of 240 ± 20 ka for t5e is several thousand years after the termination of stage 8. These age assignments for t6a and t5e are justified by their geomorphic positions and by preliminary but more variable age estimates from Model IR1. Unlike terrace calibration points, parts of the modern channel are at different phases in the terrace-forming cycle. In most places, the channel is cutting a strath, so postglacial incision may be nearly complete, but near Flora Vista, the channel is probably within gravels of TG7 and incision has just begun. Fortunately, this phase difference has little effect on ages for middle Pleistocene and older terraces, and is not a factor in Models IR2 and IR3.

Ages were estimated for TG1 to TG5 in the southern part of the study area (0-50 km on Plate 2), where terraces are mostly straths and their vertical spacing is relatively constant, except for the convergence and intersection of t6b with t5e. Ages were calculated at horizontal intervals of roughly 1.5 to 3 km using the local heights of calibration terraces. Heights used are for the tops of fluvial gravels (Plates 1 and 2). This approach ignores both

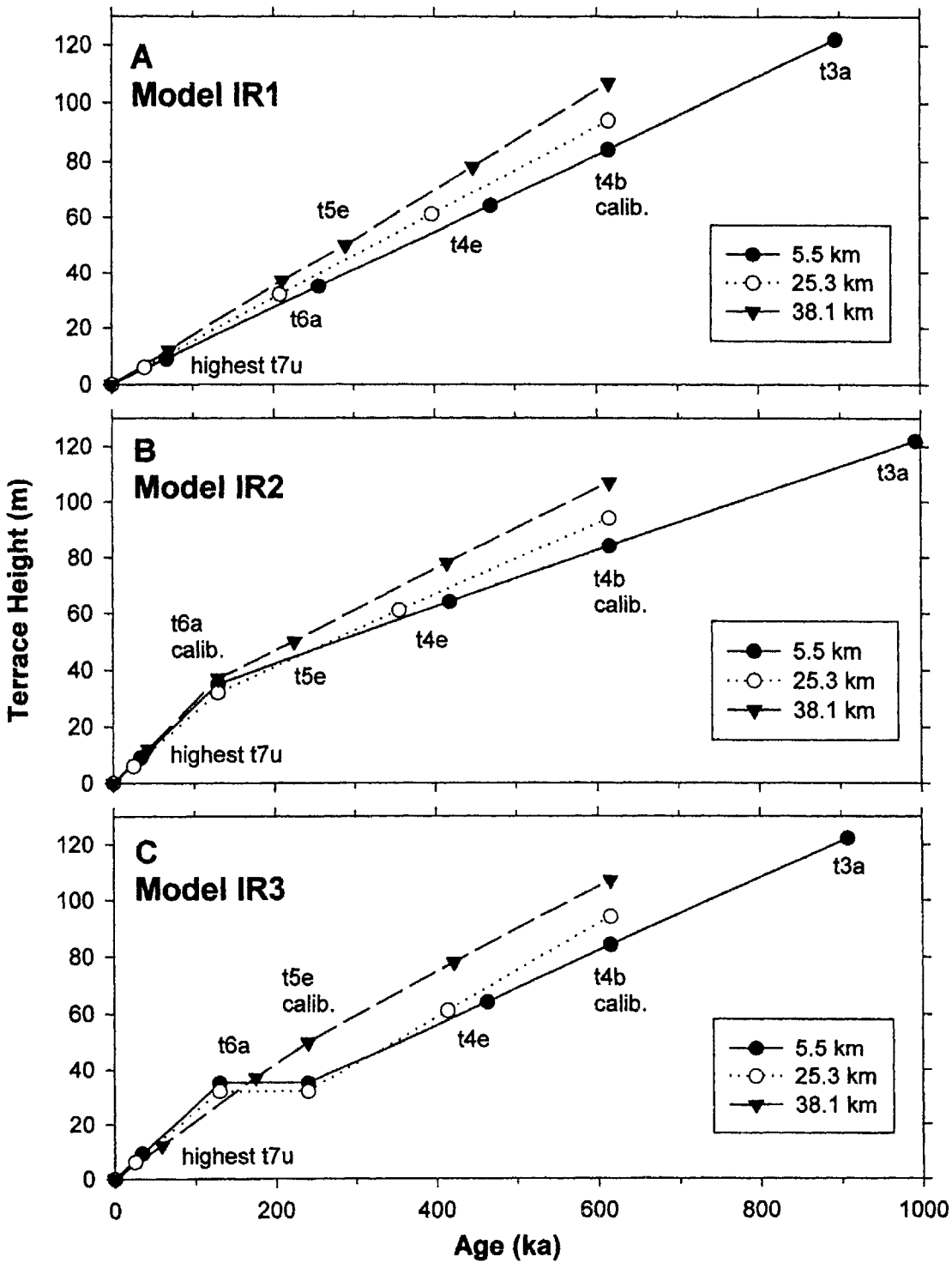


FIGURE 7.1 Incision-rate models IR1 (A), IR2 (B), and IR3 (C). For each model, calibration points and incision-rate curves are drawn for three typical locations. Scatter in calculated ages for other terraces illustrates the effects of varying terrace heights for single models, as well as differences between the models.

the thickness of overlying deposits and the depth to the sub-alluvial bedrock strath or paleovalley. At locations where incision-rate ages are calculated, height differences among the land surface, gravel top, and buried bedrock surface are small compared to heights of gravel tops above the modern channel; thus, the choice of datum for height measurements has a small effect on resulting ages. This is the first study to analyze spatial variability in multiple age estimates.

Error in individual age estimates arises from uncertainties in mapped terrace heights and in ages of calibration terraces. In addition, scatter among multiple age estimates for each terrace reflects local variation in terrace heights and differing results from the three models. Error terms for final age estimates were calculated as the square root of the sum of the squares of the following terms: the standard deviation of multiple age estimates, the effect from error ranges for calibration ages, and a mapping accuracy of ± 3 m.

Amino Acid Racemization

Amino acid analysis of fossil snails was used to date the Spring Creek 1 moraine, t8u, t5a, and t4d (Table 7.3). Alan R. Nelson (INSTAAR, University of Colorado, written communication, 1984 and U.S. Geological Survey, written communication, 1997) measured D-alloisoleucine/L-isoleucine (alle/ile) ratios on several common species using standard methods (Miller and Hare, 1980; Oches and others, 1996). The methods, assumptions, and limitations of using amino acid ratios for relative or calibrated dating are discussed by Wehmiller (1993) and other references in Table 7.3. Because diagenesis of amino acids depends strongly on temperature, the large uncertainty in the temperature histories of most fossils limits the accuracy of age estimates. However, calibration of the racemization rate

TABLE 7.3 D-ALLOISOLEUCINE / L-ISOLEUCINE RATIOS AND CALCULATED AGES FOR QUATERNARY SNAILS

UNIV. OF COLORADO INSTAAR LAB NO. [1]	SPECIES	DEPTH BELOW SURFACE (m)	MEAN SAMPLE WEIGHT (mg)	AVERAGE NO. OF SHELLS ANALYZED	NO. OF SAMPLE PREPAR-ATIONS	MEAN TOTAL ALLE/ILE RATIO [2]	AGE ESTIMATES (ka) [3]			
							LINEAR MODELS [4]			PARABOLIC MODEL
							MODEL AA1 (HOL. EQT EQUALS CMAT) [5]	MODEL AA2 (QUAT. EQT EQUALS CMAT - 8°C) [6]	MODEL AA3 (QUAT. EQT FROM INCISION-RATE AGE FOR t4d NEAR FARMINGTON) [7]	MODEL AA4 (CALIBRATED WITH INCISION-RATE AGE AND *CATINELLA* RATIO FOR t4d NEAR FARMINGTON [8]
					t8u, site S4 (CMAT = 10.8°C)					
DAN-178	*cf. Catinella*	1	6.0	1	3	0.146 ± 0.011	19 ± 9 (NA)	84 ± 43	162 ± 86	NA
DAN-182	*Hawaiia minuscula*	1	5.1	3	2	0.070 ± 0.011	[9]	[9]	[9]	NA
DAN-181	*Physella gyrina*	1	9.4	1	3	0.015 ± 0.001	[9]	[9]	[9]	NA
DAN-180	*Pupilla blandi*	1	7.7	3	1	0.129	19 ± 8 (NA)	77 ± 61	142 ± 135	NA
DAN-179	*Vallonia cyclophorella*	1	7.0	6	3	0.117 ± 0.031	17 ± 18 (NA)	69 ± 75	128 ± 140	NA
					mSC1, site S5 (CMAT = 8.3°C)					
DAN-183	*Oreohelix cf. strigosa*	1.8	6.2	<1	3	0.166 +/- 0.013	[9]	[9]	[9]	[9]
DAN-185	*Pupilla blandi*	1.8	5.5	2	2	0.129 +/- 0.003	30 ± 30 (NA)	121 ± 128	142 ± 151	NC
DAN-184	*Vallonia cyclophorella*	1.8	5.3	3	4	0.164 +/- 0.014	39 ± 39 (NA)	158 ± 167	185 ± 197	125 ± 38
					t5a, site S9 (CMAT = 10.8°C)					
DAN-186	*cf. Catinella*	2.1	6.4	1	2	0.299 ± 0.012	41 ± 19 (NA)	180 ± 91	345 ± 181	260 ± 78
					t4d, site S10 (CMAT = 10.8°C)					
DAN-187	*cf. Catinella*	1.9	15.8	1	3	0.439 ± 0.026	62 ± 29 (NA)	>270 ± 138	520 ± 60 [11]	520 ± 60 [11]
DAN-188	*cf. Pupilla*	1.9	6.8	3	1	0.37 ± 0.100 [10]	NC	NC	NC	NC

TABLE 7.3 D-ALLOISOLEUCINE / L-ISOLEUCINE RATIOS AND CALCULATED AGES FOR QUATERNARY SNAILS, CONTINUED

1. Site data is given in Table 5.6.
2. D-alloisoleucine/L-isoleucine (alle/ile) ratio (peak area) was measured by methods of Miller and Hare (1980) and Oches and others (1996). Means are given with one standard deviation. Ratios for samples with very low concentrations of amino acids are not included in means.
3. Ages calculated using linear or parabolic kinetic models of isoleucine racemization (Mitterer and Kriausakul, 1989; Wehmiller, 1993; Oches and others, 1996).
4. Arrhenius parameters for linear models were determined for *Vallonia* by Nelson and others (1984) and for *Catinella* by Oches and others (1996). Arrhenius parameters for *Vallonia* were used for *Pupilla* because both racemize at similar rates (Nelson and others, 1984). Modern ratios were 0.011 for *Catinella* and 0.014 for *Vallonia* and *Pupilla*. Assumed uncertainty in effective Quarternary temperature (EQT of Whemiller, 1993), was ± 2°C. Errors on ages were calculated by method of McCoy (1987).
5. Age calculated by assuming that the EQT for these samples equals the current instrumental mean annual air temperature (CMAT) for Durango (8.3°C) or Farmington (10.8°C), depending on sample location.
6. Age calculated by using an EQT for the late Quaternary in the Rocky Mountain region equal to CMAT for Durango or Farmington minus 8°C (Nelson and others, 1984; e.g. Oches and others, 1996)
7. Age calculated by using an EQT for the late Quaternary at Farmington (-0.6°C) derived by assuming that the incision-rate age for t4d, 560 ± 60 ka (Table 6.2) is correct, and that the age of the deposits containing the snails is roughly equal to the time of incision. Because recemization kinetics become nonlinear near ratios of 0.3, some older ages from this model are probably maximum age estimates.
8. Age calculated by using a parabolic model of racemization (Mitterer and Kriausakul, 1989; Wehmiller, 1993) calibrated with the incision-rate age for t4d. Errors estimated at about ± 30%, based on reasoning of Dethier and McCoy (1993).
9. Too little is known about the rate of racemization in this species to make age estimates.
10. Two distinct groups of ratios (0.22 and 0.25; 0.41 and 0.47) suggest a mixed or leached assemblage of at least two ages, so this mean has little meaning.
11. Calibration point for t4d.

CMAT, current instrumental mean annual air temperature
NA, model not applicable.
NC, age not calculated.

for individual species and climatic areas may provide age estimates with accuracies comparable to those of other dating methods.

Nelson used four models of racemization kinetics to estimate ages for snail assemblages from four sites that were sampled before 1984. Models AA1 to AA3 incorporate linear reaction rates. The first model, which applies only to Holocene samples, assumes that the effective temperature (EQT of Wehmiller, 1993) is equal to the current instrumental mean annual air temperature (CMAT), or 8.3°C at Durango and 10.8°C at Farmington[1]. The second and third models use lower effective temperatures that attempt to average the effects of temperature changes during the last several hundred thousand years. Specifically, Model AA2 uses an EQT that is 8°C lower than local CMAT, a previous estimate for several sites in the Rocky Mountains (Nelson and others, 1984). Model AA3 uses a lower EQT of -0.6°C, which was derived by calibration with the incision-rate age for t4d (560 ± 60 ka, as discussed below) and with *Catinella* ratios for this terrace near Farmington (Table 7.3). Age estimates from the third model for ratios >0.3 are probably maxima because the racemization rate decreases markedly, becoming nonlinear, in carbonate fossils with ratios >0.3-0.5 (Wehmiller, 1993). Model AA4 assumes an exponentially decreasing (parabolic) racemization rate (e.g. Mitterer and Kriausakul, 1989; Dethier and McCoy, 1993). Because it is calibrated with the incision-rate age for t4d and with *Catinella* ratios for snails on t4d near Farmington, this model gives minimum ages for the cooler Durango area. Due mainly to uncertainties in temperature history, errors in age estimates are probably 30 to 100 percent (e.g. Dethier and McCoy, 1993).

Alle/ile ratios for several genera (mainly *Catinella*, *Pupilla*, and *Vallonia*, but also *Oreohelix*, *Physella*, and *Hawaiia*) vary from about 0.02 to 0.4 (Table 7.3). Age interpretations for specific sites are discussed below.

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[1] CMAT's used in racemization models vary slightly from those in Chapter 2 because of different averaging periods.

Paleomagnetic Polarity

In addition to the methods above, John D. Strobell (U.S. Geological Survey, written communication, 1978) has found possibly reversed magnetic polarity in samples from Mt. Nebo (associated with either t2a, t2b, t2c, or t2d) and Slane Knob (t1u). However, sample locations and demagnetization data are unavailable.

"Bakers Bridge Moraine" and Group 8 Terraces

"Bakers Bridge Moraine"

As discussed in Chapter 3, part of the ridge-shaped feature called the "Bakers Bridge moraine" (Richmond, 1965b, 1986b) is an erosional remnant of lodgement till that accumulated under active ice (Johnson, 1990). Another part, located higher along the valley side, may be a hogback ridge of limestone that is thinly covered by glacial deposits, or "palimpsest" moraine. Even if the "Bakers Bridge moraine" is not a terminal or recessional moraine, its exposure age indicates the time when ice melted from the area. This may have occurred about 1,000 to 2,000 years after the Animas City 2 and 3 moraines formed, or about 14 ka, based on distance upvalley, ages for the Animas City moraines, and ages for deglaciation (see below). Richmond (1986b) estimated the age of the "Bakers Bridge moraine" as about 18 ka, based on then-accepted deglaciation by about 15 ka.

Terrace Group 8

Terraces of this group postdate the Animas City moraines and TG7. At Bakers Bridge, t8a extends through and is cut on lodgement till of the lower "Bakers Bridge moraine." Terrace heights suggest ages from latest Pleistocene to Holocene.

Amino acid (ale/ile) ratios were measured on five species of snails from mainstream, fine-grained alluvium of t8u in Farmington (Table 5.B, site S4; Table 7.3). Ratios for *Physella gyrina*, a freshwater snail, are 0.015 ± 0.001, similar to ratios for both freshwater and land snails of modern and late Holocene age (Nelson and others, 1984; Oches and McCoy, 1995). Ratios for four other species (0.07-0.14) are much higher than expected for Holocene samples and yield age estimates from 17 to 162 ka based on Models AA1 to AA3. This assemblage of snails from two or more age groups suggests either that the older snails were reworked, that the sampling interval included beds of different ages, or that snails of different ages were mixed in situ by bioturbation. In any case, the uppermost alluvium at this site must be late Holocene; it may form a thin cover on late Pleistocene alluvium that extends horizontally from adjacent t7u. Ages from Model AA3 seem excessive for alluvium at this site because of the geomorphic positions of t8u and t7u.

Richmond (1965b) correlated t8a with the late Pinedale Glaciation, but no ages have been given previously for the other terraces.

Animas City Moraines and Group 7 Terraces

Geomorphic position, preservation, soils, and weathering indicate that the Animas City moraines and related terraces formed during the last glaciation (Atwood and Mather, 1932; Richmond, 1965b). Age estimates are based on correlation to dated deposits outside the study area.

Animas City 2 and 3 Moraines

Evidence for rapid construction of the Animas City 2 and 3 moraines suggests that they formed just before ice retreated from the terminal area (Johnson and Gillam, 1995; Chapter 3). Therefore, ages for these moraines are estimated from dates obtained elsewhere for the youngest moraines in terminal areas and for initial ice retreat.

In the San Juan Mountains, no numeric ages have been obtained for moraines. The only numeric ages that constrain the time of ice retreat are from glacial Lake Atwood, an ice-dammed lake in the Rio Grande drainage (Atwood and Mather, 1932; MacGregor, 1993). Magnetic secular variations in lake sediments show that the lake existed from before 16 ka to after 13.5 ka. (Leonard and others, 1994). These ages do not date initial retreat because the lake is roughly 14 km upvalley from the ice terminus, but they do indicate that ice was still extensive after 16 ka. In contrast, radiocarbon dates, fossil insects, and plant macrofossils from Lake Emma, a tarn at 3,740 m near the head of the Animas River, indicate that some cirques were ice-free probably by 10 ka. and possibly by 11 ka. (Elias and others, 1991). This conclusion is based on the oldest of several radiocarbon dates on wood and insect parts, 9,580 ± 130 yr B.P. (USGS-1341) (Carrara and others, 1984). The authors conclude that older radiocarbon dates from the area are invalid, although these dates have been cited in earlier reports as evidence of deglaciation by about 15 ka (e.g. Porter and others, 1983; Carrara and others, 1984; Richmond, 1986b). The invalid dates include those on moss from Lake Emma, as old as 14,940 ± 140 yr B.P. (W-4525) (Carrara and others, 1984; Elias and others, 1991) and a date of 15,450 ± 220 yr B.P. (Y-1147) on basal organic matter from Molas Lake (Maher, 1972), located at 3205 m in the upper Animas River valley south of Silverton.

In areas surrounding the San Juan Mountains, the oldest well-constrained date for postglacial warming is from the Chuska Mountains of northwestern New Mexico. Pollen spectra in a radiocarbon-dated core show that significant warming occurred at or slightly after 13.5 ka. (Wright and others, 1973). In the southern San Juan basin, noble-gas paleothermometry on radiocarbon-dated groundwater indicates that warming began after about 19 ka (Stute and others, 1995). Age control for deuterium paleothermometry in the same area (Phillips and others, 1986) appears less reliable.

Other parts of the Rocky Mountains provide dates for the youngest moraines in terminal areas or for initial ice retreat, which may apply to the Animas valley. In several areas, the youngest moraines near ice limits are roughly 15,000 to 16,000 yr old. Dates in this range include the following : ^{10}Be exposure ages on moraines as young as 14,400 ± 400 yr B.P., and on ice-scoured bedrock as old as 15,800 ± 500 yr B.P., from the Half Moon Lake area, Wind River Range, Wyoming (Gosse and others, 1995); a ^{36}Cl exposure age of 16 ka at Bull Lake, Wind River Range (Zreda and Phillips, 1995); and a uranium-series date on travertine of 15,500 ± 100 yr B.P. in the north Yellowstone area (Sturchio and others, 1994). In several areas, retreat was well underway by 14 to 13 ka (Madole, 1986, and earlier work summarized by Porter and others, 1983).

Based on the dates above, I speculate that the ages of the Animas City 2 and 3 moraines may be about 15 to 16 ka. Richmond (1965b, 1986b) recognized these moraines as late Wisconsin, without estimating specific ages. Gillam and others (1984) placed the moraines between 16 and 36 ka based on an approximate age range for the late Wisconsin Glaciation (Porter and others, 1983).

Animas City 1 Moraine

The Animas City 1 moraine could date from either the late Wisconsin glacial maximum, an earlier Wisconsin ice advance, or the Eowisconsin. Among these alternatives, formation during the late Wisconsin maximum is most likely for the following reasons. First, the apparent absence of early Wisconsin moraines in many areas (e.g. Porter and others, 1983; Richmond and Fullerton, 1986b; Zreda and Phillips, 1995) suggests that early Wisconsin ice was less extensive in most valleys than both earlier and later advances. Second, t7a, graded to the Animas City 1 moraine, is the highest aggradation surface that formed after the Spring Creek moraines and most likely formed when the ice front was at its maximum downvalley position. Also, terraces graded to the Animas City 1 and 2 moraines (t7a and t7b) probably merge in the Koshak Mesa area 10 km downstream, indicating that channel incision between formation of the terraces was restricted to a limited reach. Finally, extensive meltwater erosion in the terminal area makes it unlikely that early Wisconsin moraines would be preserved.

In several areas of the Rocky Mountains, radiocarbon dating shows that the late Wisconsin ice maximum occurred roughly 22,000 to 21,000 ^{14}C yr B.P. (as summarized by Porter and others, 1983, and Richmond and Fullerton, 1986b). In the North Yellowstone area, however, uranium-series dates on travertine indicate that the late Wisconsin ice maximum occurred earlier, about 30 to 22.5 ka (Sturchio and others, 1994). If the radiocarbon dates were corrected to calendar years, they would be more consistent with the uranium-series dates (Sturchio and others, 1994). Based on both age ranges, I speculate that the Animas City 1 moraine may be roughly 20,000 to 25,000 years old. Previously, Richmond (1965) interpreted this moraine as late Bull Lake and Richmond (1986b) considered it late Wisconsin. Gillam and others (1984) proposed an age of either 30 to 40 ka or 60 to 70 ka.

Terrace Group 7

Surface ages for TG7 should be identical at Durango to ages for related Animas City moraines, but terrace ages probably decrease downstream due to downvalley migration of incision. Whenever ice retreated from a moraine, the adjacent terrace was incised rapidly because the bedrock basin north of the moraine would have trapped most bedload derived from the glacier (Johnson and Gillam, 1995). However, a lag time for incision farther downstream is indicated by relationships between TG7 and the modern river channel. The river has incised below TG7 in most places, but the top of t7u deposits may be at or near flood-plain level in the Flora Vista area (Chapter 4). If the Animas City 3 moraine is about 15,000 years old, the lag time for incision to progress to Farmington is approximately 15,000 years or more. Thus, surface ages (based on times of incision) probably range from the age of the Animas City 3 moraine (estimated as 20 to 25 ka for t7a near Durango, to perhaps 0 yr near Flora Vista. However, most terraces may be between about 20,000 and 10,000 years old.

Previously, Richmond (1965b) correlated lower terraces with the Pinedale Glaciation and t7a with the Bull Lake Glaciation. Gillam and others (1984) proposed an age range from 16 ka to possibly 70 ka.

Spring Creek Moraines and Terrace Group 6

Relative-age criteria indicate that the Spring Creek moraines and terraces of group 6 predate the last glaciation. Ages for these landforms are estimated from correlation to dated deposits elsewhere in the Rocky Mountains and from amino acid racemization.

Incision-rate ages are invalid because Models IR1 and IR2 yield unreasonably old ages for t6a, the oldest extensive terrace of TG6 in the southern part of the area (Table 7.4).

Spring Creek Moraines

Dating elsewhere in the western United States suggests that moraines of intermediate relative age may correlate with one of three ice advances: late or early Eowisconsin (both late Pleistocene), or late Illinoian (late middle Pleistocene; "classic" Bull Lake). Dating by several methods places these advances at about 85 to 100 ka, 110 to 120 ka, and 135 to 160 ka. The youngest range is based on K-Ar ages for underlying or lake-damming lava flows in Yellowstone National Park (summarized by Richmond, 1986a) and on ^{36}Cl exposure ages for the Bull Lake area of the Wind River Range (Chadwick and others, 1994; Zreda and Phillips, 1995). The middle range is based on K-Ar ages for ice-contact lava flows in Yellowstone National Park (summarized by Richmond, 1986a) and on ^{36}Cl exposure ages for the Bull Lake area and several areas in the Sierra Nevada (Chadwick and others, 1994; Zreda and Phillips, 1995). The oldest range is based on obsidian hydration rates, the K-Ar age for an underlying lava flow, two uranium-trend dates, and a uranium-series date on travertine from Yellowstone National Park (summarized by Richmond, 1986a; Sturchio and others, 1994); also, on two uranium-trend dates from Allens Park in the Front Range and Fremont Lake in the Wind River Range (Shroba and others, 1983; Rosholt and others, 1985); and on ^{36}Cl exposure ages for the Bull Lake area and several areas in the Sierra Nevada (Chadwick and others, 1994; Zreda and Phillips, 1995).

Extreme erosion of the Spring Creek moraines makes it impossible to correlate them to a specific advance by relative-age methods based on moraine morphology and soil

development. However, tentative correlations are based on amino acid ratios and matching between moraines and outwash terraces.

Amino acid (ale/ile) ratios were measured on snails from alluvium that accumulated against the Spring Creek 1 moraine at site S5 (Tables 5.6 and 7.3). Ratios on three species range from 0.13 to 0.17. Ages calculated with Model AA1 are approximately 17 to 19 ka, indicating that this model (based on current instrumental mean air temperature) is inappropriate. Ages of 121 ± 128 ka and 158 ± 167 ka from Model AA2 (based on estimated Quaternary EQT for the Rocky Mountains) and ages of 142 ± 151 ka and 185 ± 197 ka from Model AA3 (EQT derived from incision-rate age of t4d) suggest that the Spring Creek 1 moraine correlates with the "classic" Bull Lake Glaciation during stage 7. Because Model AA4 (using an exponentially decreasing racemization rate) is based on *Catinella* ratios, and this genus is absent here, *Vallonia* ratios were converted to *Catinella* equivalents with the regression equation of Nelson and others (1984). The resulting age, 125 ± 38 ka, is probably a minimum because Model AA4 is calibrated with data for t4d near Farmington, which is warmer than Durango. In summary, amino acid ratios suggest that the Spring Creek 1 moraine correlates with the earliest "intermediate" advance between 135 and 160 ka.

The presence of two Spring Creek moraines and two outwash terraces (t6a and t6b) at roughly comparable heights in Durango suggests that each moraine is related to a terrace (Richmond, 1965). Because both terraces extend as straths to Farmington, where they are separated by an interval of channel incision into bedrock, the terraces must be related to different ice advances. Therefore, the Spring Creek 2 moraine is attributed to one of the two Eowisconsin advances between 85 and 120 ka.

Previously, Richmond (1965b) correlated these moraines with early and late Bull Lake moraines in the Wind River Range. Gillam and others (1984) concluded that they

formed between 88 and 150 ka, a less-inclusive age range for the Eowisconsin and classic Bull Lake than given above. Richmond (1986b) agreed with this tentative age assignment.

Terrace Group 6

As the highest terrace of this group, t6a probably formed during the earliest advance between 135 and 160 ka. Because TG6 is associated with two distinct gravel bodies downstream from Durango, two periods of aggradation were separated by an interval of channel incision into bedrock. This relationship suggests that t6b formed during one of the later advances between about 85 and 120 ka. Previously, Richmond (1965b) interpreted these terraces as outwash of the Bull Lake Glaciation. Richmond (1986b) implied either a Bull Lake or Eowisconsin age.

Terrace Groups 5 to 3 and Durango Moraines

Ages for TG5 to TG3 are based mainly on the position of the Lava Creek B ash and on average incision rates, with support from amino acid racemization in fossil snails from two terraces. Ages for the Durango moraines are inferred from ages for related terraces.

Age of t4b

As described above, the Lava Creek B ash overlies terraces t4a, t4b, and t4bx. The position of the ash, usually within alluvial and eolian deposits that overlie fluvial gravels, is relatively constant with distance and suggests that t4b is not strongly time-transgressive. Based on an age of 620 ka for the ash (Izett and Wilcox, 1982), the time for incision of t4b is estimated as 615 +15/-5 ka.

Ages for Other Terraces

Age estimates for other terraces depend on incision rates that vary with time interval and location along the study reach (Figure 7.2). When averaged over the last 615 ka (Model IR1), these rates decrease downstream from 0.32 m/ka just south of Durango at the Hogback monocline to 0.13 m/ka at Flora Vista. However, when rates are calculated for shorter periods, temporal and spatial variations increase. For example in Model IR2, the rate from 130 to 615 ka is generally half to three-quarters of the earlier rate from 0 to 130 ka. In Model IR3, the rate downstream from the intersection of terraces t6a and t5e is assumed to be zero between 130 and 240 ka. Upstream from the narrows, higher incision rates are related in part to cutting though thick gravel fills.

Incision-rate ages for TG5 to TG3 vary with model and location (Table 7.4 and Figures 7.3 to 7.5). For each model, the age ranges of adjacent terraces may overlap, but more restricted ranges, defined as the average plus or minus one standard deviation, usually are distinct. Age ranges for single terraces from all models usually overlap. Generally, overlap is greater and coefficients of variability are lower for terraces near the common calibration point, t4b. Compared to Models IR2 and IR3, Model IR1 gives older ages for terraces below t4b and younger ages for terraces above t4b.

Age estimates for some terraces vary with location in ways that are not random, and that suggest systematic controls on patterns of incision in space and time (Figures 7.3 and 7.4). Later in this section, these controls are considered qualitatively to derive "best age estimates." Non-random patterns include the convergence of ages for t5e and t6b, downstream decreases in some ages for t4e and t5a, and peaks in ages for most terraces at profile kilometers 5 to 10. Because terraces t5e and t6b intersect between profile kilometers 25 and 30, one complete incision cycle is missing downstream from this area.

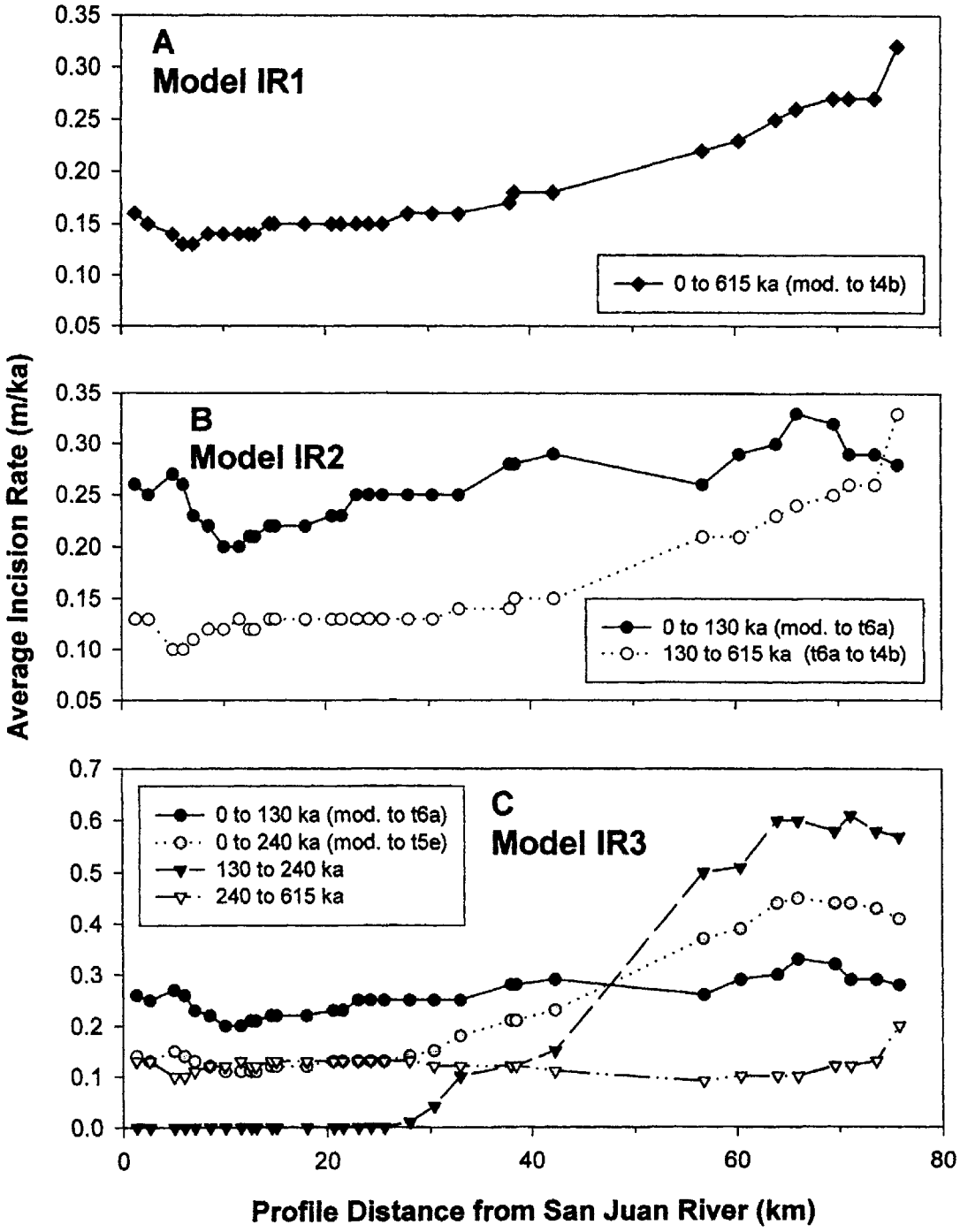

FIGURE 7.2 Incision rates versus distance along the Animas valley for different time periods, as incorporated in models IR1 (A), IR2 (B), and IR3 (C). Vertical scale for diagrams A and B is twice as large as for diagram C.

TABLE 7.4 TERRACE AGE ESTIMATES FROM INCISION RATES

TERRACE	AGES (ka) FOR REACH 1.3 TO 49.9 KM FROM SAN JUAN RIVER												NUMBER OF MEASURE-MENTS
	MODEL IR1 [1,4]				MODEL IR2 [2,4]				MODEL IR3 [3,4]				
	RANGE	MEAN	STD. DEV.	COEFF. OF VARIATION (%)	RANGE	MEAN	STD. DEV.	COEFF. OF VARIATION (%)	RANGE	MEAN	STD. DEV.	COEFF. OF VARIATION (%)	
t1u	2226 - 2520	68	0	0	2520 - 2886	82	0	0	2162 - 2713	191	0	0	4
t2a	0 - 1821	29	--	--	0 - 1978	58	--	--	0 - 2085	21	--	--	2
t2b	0 - 1837	40	--	--	0 - 2050	65	--	--	0 - 2046	33	--	--	2
t2c	0 - 1761	22	--	--	0 - 1961	37	--	--	0 - 1957	0	--	--	2
t2d	0 - 1685	20	--	--	0 - 1872	35	--	--	0 - 1868	0	--	--	2
t2e	0 - 1573	36	--	--	0 - 1654	82	--	--	0 - 1831	14	--	--	2
t2f	0 - 1392	14	--	--	0 - 1477	32	--	--	0 - 1562	18	--	--	2
t2g	0 - 1253	16	--	--	0 - 1262	21	--	--	0 - 1466	34	--	--	2
t2h	0 - 1342	45	--	--	0 - 1491	129	--	--	0 - 1292	100	--	--	2
t2i	0 - 1333	12	--	--	0 - 1541	26	--	--	0 - 1331	20	--	--	2
t3a	0 - 906	40	0	0	0 - 1009	64	0	0	780 - 920	49	0	0	7
t3b	0 - 802	28	0	0	0 - 838	33	0	0	0 - 787	26	0	0	6
t4b	615 - 615	615	0	0	615 - 615	615	0	0	615 - 615	615	0	0	NA
t4d	0 - 547	28	0	0	0 - 531	35	0	0	446 - 545	29	0	0	13
t4e	0 - 478	28	0	0	0 - 444	33	0	0	394 - 483	23	0	0	9
t5a	0 - 327	31	0	0	0 - 272	37	0	0	306 - 350	18	0	0	11
t5e	0 - 327	23	0	0	0 - 316	28	0	0	240 - 240	240	0	0	9
t6a	183 - 253	8	0	0	130 - 130	130	0	0	175 - 229	194	22	11	23 (Model 1) 5 (Model 3)

1. Average incision rate calibrated at modern channel (0 ka) and top of t4b gravel (assigned age 615 ka).
2. Average incision rate calibrated at top of t6b gravel (assigned age 130 ka) and top of t4b gravel (assigned age 615 ka).
3. Average incision rate calibrated at top of t5e gravel (assigned age 240 ka) and top of t4b gravel (assigned age 615 ka).

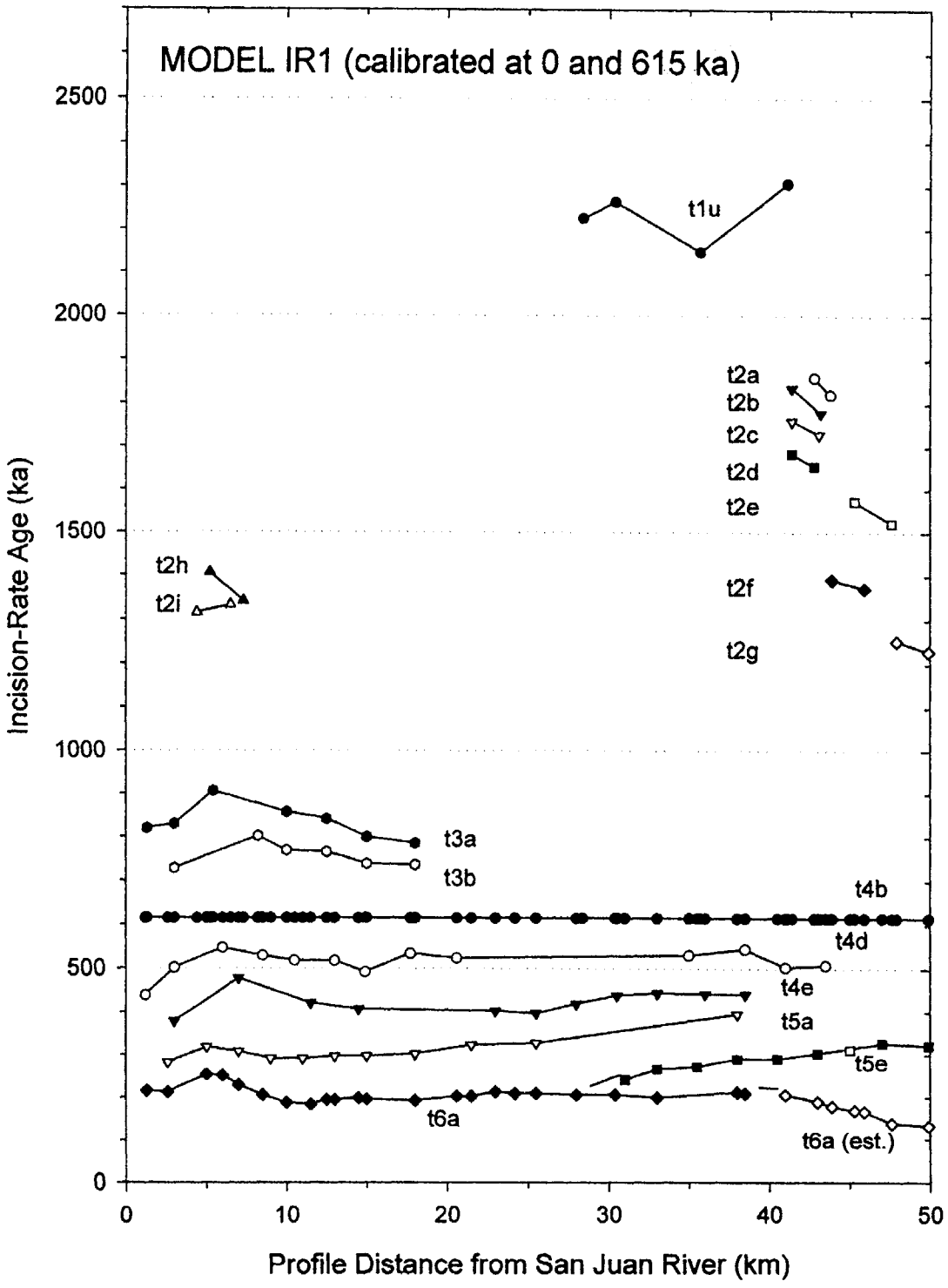

FIGURE 7.3 Incision-rate ages from Model IR1 versus distance along the Animas Valley.

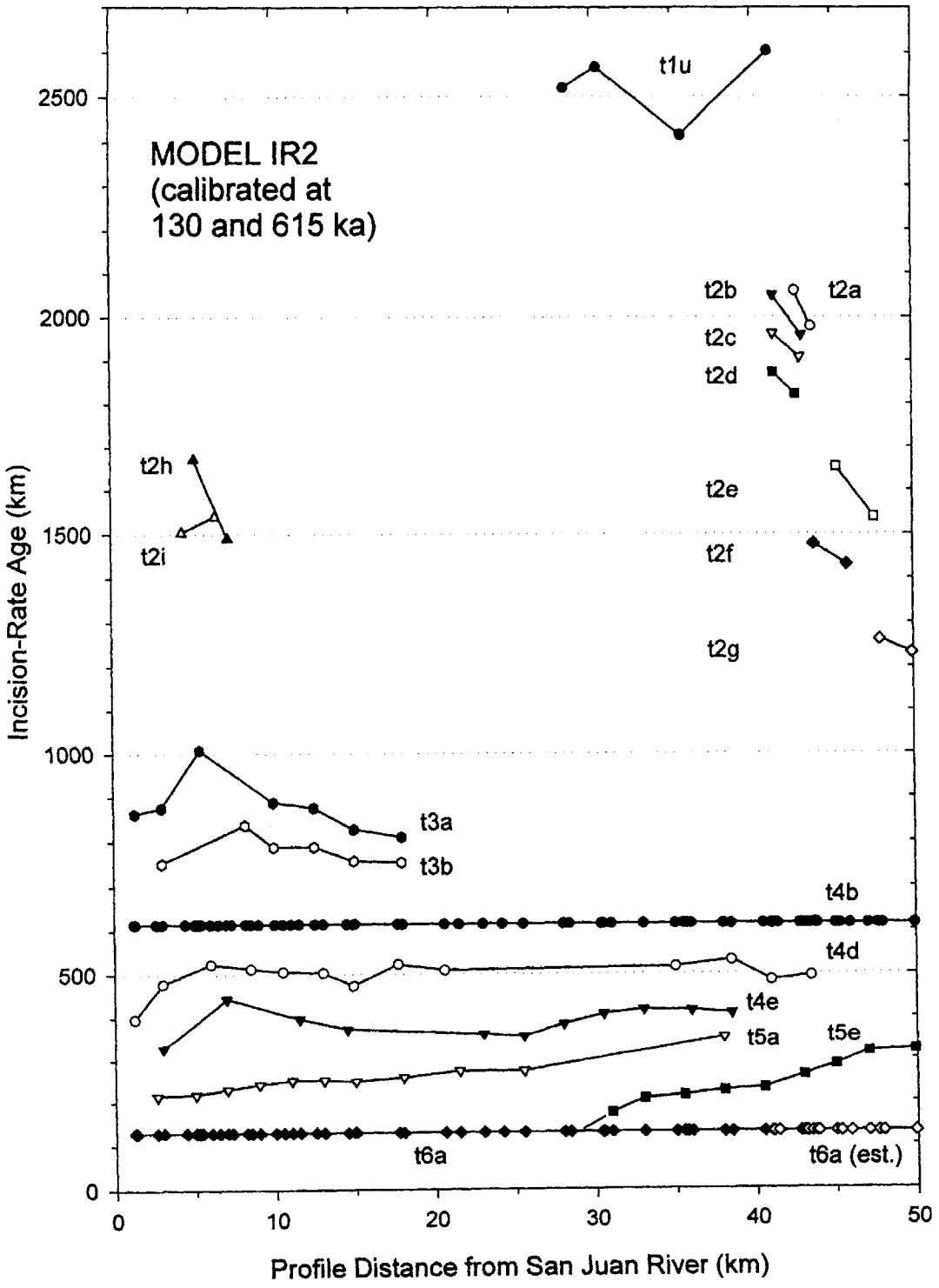

FIGURE 7.4 Incision-rate ages from Model IR2 versus distance along the Animas valley.

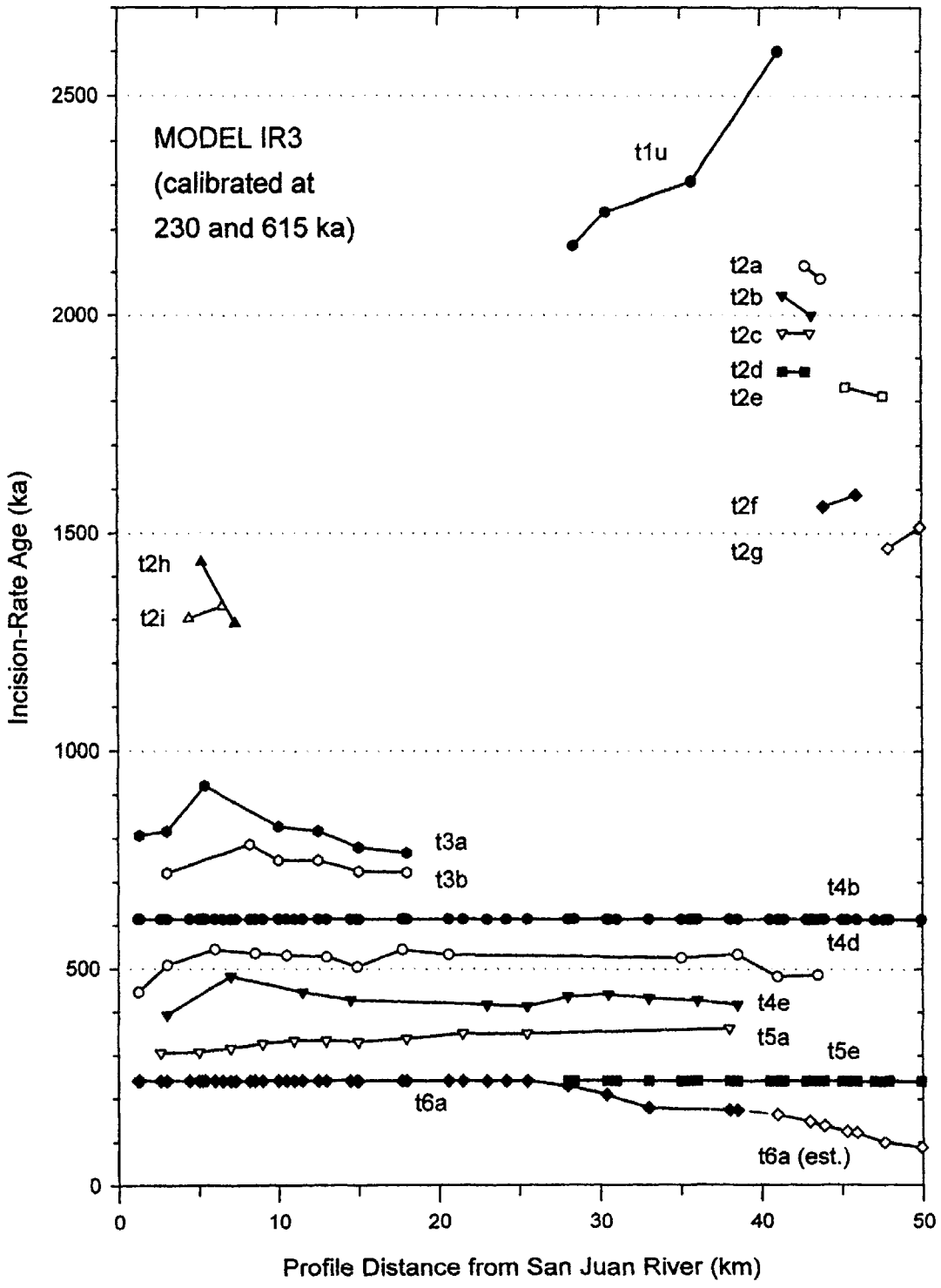

FIGURE 7.5 Incision-rate ages from Model IR3 versus distance along the Animas valley.

These patterns are due mainly to base-level effects of the Ojo Alamo Sandstone in Farmington and to related shifts in the junction of the Animas and San Juan rivers (Chapter 4).

The Ojo Alamo Sandstone crops out in north and east Farmington (O'Sullivan and Beikman, 1963; Ward, 1990). Due to its gentle eastward dip (about 1 degree), it slopes obliquely up the Animas River valley and directly up the San Juan River valley. During deposition of terraces t3a to t4b, the rivers probably joined upstream from or on the Ojo Alamo Sandstone and their combined flow cut through the base of the sandstone west of Farmington. As both valleys deepened through time, the point where the combined rivers cut through the sandstone shifted eastward across central Farmington. As the knickpoint at the base of the sandstone migrated upstream, base level for the Animas River decreased. Vertical spacing of terraces along the Animas River indicates that a wave of incision moved upstream during several terrace-forming cycles. In Figures 7.3 and 7.4, this wave appears as a time-transgressive shift in apparent terraces ages. The zone of most rapid incision, indicated by the greatest difference between ages of successive terraces, is in the confluence area (0 to 5 km) after t4b and t4d. However, after t4e it is between 5 and 20 km; after t5a, between 20 and 30 or 35 km; and after t5e, upstream from 30 km.

Other patterns in Figures 7.3 and 7.4 illustrate secondary effects of this process. Ages for t4e, t5a, and t5e become older from 26 to 43 km because a resistant, sandy sequence in the San Jose Formation reduced incision in the latter area. Near the Animas/San Juan confluence, peaks in the apparent ages of many terraces are caused by local base-level effects that influence terrace gradients and heights. A southward shift in the confluence probably caused t5e and t6a to intersect (Chapter 4).

Given these incision patterns and model features, the most accurate ages for TG5 to TG3 should come from Model IR3 when applied upstream from the Ojo Alamo Sandstone. Model IR1 (Figure 7.3) has the advantages of simplicity and independently dated

calibration points, but it also has several disadvantages: it overestimates the age of t6a, ages for some terraces are relatively scattered, and it doesn't adjust for the missing incision episode between t5e and t6a below their intersection. In Model IR2 (Figure 7.4), the assigned age of t6a, 130 ± 15 ka , is probably closer to its true age than the Model IR1 prediction, so Model IR2 is an improvement even if the assigned age is slightly inaccurate. However, Model IR2 doesn't adjust for the missing incision episode and is biased from 41 to 50 km, where the only remnants of TG6 may be t6b, not t6a. In this reach, low heights for TG6 increase the apparent time-transgression of t5e. In Model IR3 (Figure 7.5), the assigned age of 240 ± 20 ka for t5e is based on several factors. Relative-age criteria (geomorphic position, preservation, and soil development) indicate that this terrace is older than TG6. Incision-rate ages from Models IR1 and IR2 suggest that it is most likely formed near end of stage 8. Therefore, the assigned age is several thousand years after the stage 7/8 boundary (Table 7.2). Even if the assigned age for t5e is slightly inaccurate, Model IR3 has strong advantages over Models IR1 and IR2: it adjusts for the missing incision interval, avoids confusion between t6a and t6b, reduces scatter in the ages of superjacent terraces (t5a and t4d), and provides mean ages that agree closely with stage terminations.

Final age estimates for TG5 to TG3 (Table 7.2) include correlated or ash-controlled ages for calibration terraces (t5e and t4b), calibrated incision-rate ages for strath terraces that extend into the southern part of the study area, and arbitrary relative ages for fill and fill-cut terraces farther north. To avoid effects of the Ojo Alamo Sandstone, incision-rate data from 0 km to 8 or 10 km are omitted. The resulting "best estimates" for t5a, t4e, and t4d are within a few thousand years of the terminations of stages 10, 12, and 14. Age estimates for t3b and t3a are farther within stages 18 and 20, but may be skewed toward older values by local peaks resulting from the Ojo Alamo Sandstone (Figure 7.5). If final ages for t3b and t3a are calculated from their lowest single ages, which are less affected by the sandstone, they fall closer to stage terminations. Assigned ages for fill and fill-cut

terraces are arbitrary, but the age spans of related terraces correspond roughly to the coldest substages.

Amino acid ratios in snails from two sites are broadly consistent with incision-rate ages for t5a and t4d. At site S9, one *Catinella* shell was collected from sandy alluvium that overlies fluvial gravels of t5a (Tables 5.6 and 7.3). The average alle/ile ratio in two preparations from this shell is 0.3. This ratio indicates a pre-Holocene age, so Model AA1 is inapplicable and the locally calibrated models, AA3 (linear) and AA4 (parabolic), should give the most accurate ages. Because reaction kinetics become nonlinear near ratios of 0.3, however, the age from Model AA3, 345 ± 181 ka (stage 10), is probably a maximum estimate. Model AA4 gives a younger and more reasonable age of 260 ± 78 ka (stage 8). In contrast, incision-rate ages for t5a indicate that it is related to glaciation during stage 10 (Table 7.2). Because the *Catinella* shell is from alluvium that overlies the gravel, the shell may have been deposited after terrace incision; it so, its younger age is consistent with its stratigraphic position.

At site S10 on t4d, average alle/ile ratios in *Catinella* and *Pupilla* are 0.37 to 0.44 (Tables 5.6 and 7.3). The *Catinella* ratio is significantly higher than that at site S9, suggesting a much greater age, but none of the kinetic models gives accurate or independent ages for this site. Ages from Model AA1 are minima because of inappropriate (instrumental) EQT, and those from Model AA2 are minima because of decreasing reaction rates for ratios greater than 0.3. Models AA3 and AA4 do not yield independent ages because both were calibrated with the incision-rate age for this terrace.

The incision-rate ages here differ slightly from earlier ranges (Gillam and others, 1994; Love and Gillam in Patton and others, 1991) based on a different version of Model IR1. Richmond (1965b) interpreted TG5 and TG4 as outwash of the Sacagawea Ridge Glaciation, whereas Richmond (1986b) tentatively assigned them to stages 8 to 18. Here,

t4a and t4b are both assigned to stage 16 and t3a, absent in Richmond's study area, is assigned to stage 18.

Durango Moraines

Relative-age criteria indicate that the Durango moraines are much older than the Spring Creek moraines. As discussed above, t5e is probably close in age to the stage 8 termination, so the Durango 2 moraine must have formed during stage 8. The incision-rate age for t5a (340 ± 40 ka) shows that the Durango 1 moraine group formed during stage 10. The moraines may have formed at times of maximum global ice volumes, or about 250 to 275 ka for stage 8 and 340 to 360 ka for stage 10 (e.g. Imbrie and others, 1984; Ruddiman and others, 1989; Bassinot and others, 1994; Chen and others, 1995).

Previously, Richmond (1965b) correlated the Durango moraines with the Sacagawea Ridge Glaciation in the Wind River Mountains. Gillam and others (1984) estimated their ages as 250 and 330 ka, based on earlier estimates for the culminations of stages 8 and 10. Richmond (1986b) proposed alternative correlations to either the Bull Lake Glaciation (stage 6) or the Sacagawea Ridge Glaciation (stages 12 and 14) in the Wind River Range. However, relative-age criteria (Chapters 3 and 5; Appendix B) show that the Durango moraines are older than Bull Lake; also, two terraces that project above the moraines (t4d and t4e) are correlated here with stages 12 and 14. The term "Sacagawea Ridge" is not used in this study because recent work shows that some deposits in the Wind River Range, previously called Sacagawea Ridge, formed during stage 16 and before (Jaworowski, 1993; Chadwick and others, 1994).

Terrace Groups 2 and 1

Ages for TG2 and TG1 are based on ash-calibrated incision rates and on magnetic polarity measurements at two sites (John D. Stobell, U.S. Geological Survey, written communication, 1978). No ash beds of Lava Creek B or older age have been located in poor exposures of the terrace deposits.

Similar to incision-rate ages for younger terraces, ages for TG2 and TG1 vary with model and location (Table 7.4 and Figures 7.3 to 7.5). Because few terrace remnants exist, only two ages were calculated for most levels by each model and trends in apparent age with location are indeterminate. For single models, the age ranges of adjacent terraces rarely overlap. When all three models are compared, age ranges for single terraces overlap less than for younger terraces and in some cases do not overlap at all. The validity of these incision-rate ages is uncertain because the terraces have heights that far exceed the calibrated ranges of the models. Moreover, incision rates must have varied during the long period before t4b. In this situation, can the age estimates be evaluated or constrained to derive "best estimates?" Major diversions of the river's course occurred at least two and possibly three times before t3a formed (Chapter 4), but not afterward. At present, no tributaries in the Animas River basin have lower gradients than the river and such diversion cannot occur. These factors suggest that the average basin-wide incision rate was lower before t3a than later. Therefore, Models IR2 and IR3 are likely to provide better age estimates than Model IR1.

In the state line area, Model IR3 gives much older ages for t2e to t2g than Model IR2 (Table 7.4; Figures 7.4 and 7.5). The ages from Model IR3 are considered more accurate for two reasons. First, bedrock strata between its calibration terraces, t5e and t4b, are more similar to strata between t4b and t2a, so average incision rates in both intervals should be more comparable. Second, remnants of these terraces are located where

remnants of TG6, at their lowest heights, may be t6c instead of t6b. In contrast, both models give comparable ages for t2a to t2d. For these terraces, data from both models are combined in the final ages, on the assumption that the larger number of individual age estimates may mimic the variability that would occur with distance if the terrace remnants were more extensive.

Each model suggests different correlations between TG2 remnants in north Farmington and more numerous TG2 levels in the state line area (Figures 7.3 to 7.5). In north Farmington, Model IR3 probably gives the most reliable ages for TG2, as for younger terraces. By chance, Model IR1 gives comparable ages, so individual age estimates from both models are used in the final ages for the reasons above.

Models IR2 and IR3 also provide broadly similar age ranges for t1u, although the relative ages of individual remnants vary greatly (Table 7.4; Figures 7.4 and 7.5). In Model IR3, downstream divergence between the calibration terraces, t5e and t4b, imparts a strong, downstream-decreasing trend on age estimates for t1u. Nevertheless, age estimates from both models are used because there is no reason to believe that either model is more accurate.

The final ages for TG2 and TG1 (Table 7.2) range from 1.3 to 2.6 Ma (early Pleistocene to late Pliocene) including standard errors. Based on preceding model selections, the TG2 remnants in north Farmington appear younger than all of the remnants in the state line area.

Ages for TG2 and TG1 are consistent with possibly reversed magnetic polarity in samples from Mt. Nebo (including terraces t2a to t2d) and Slane Knob (t1u) (Strobell, written communication, 1978). Incision-rate ages place these terraces within the Matuyama epoch, from 0.78-0.79 Ma to 2.58-2.60 Ma (e.g. Berger and others, 1994; Berggren and others, 1995; Chen and others, 1995). Error ranges for t2a to t2d are so broad that any of

these terraces could have formed during the Olduvai normal event. The incision-rate age for Slane Knob, 2.40 +0.26/-0.30 Ma, is mostly within the Matuyama epoch.

Previously, Richmond (1965b) correlated gravels of the Mesa Mountains (including TG1, TG2, and gravels reworked by colluvial and alluvial processes) with the Cedar Ridge Glaciation in the Wind River Mountains, which he later assigned to stage 16 (Richmond, 1986b). Richmond (1986b) correlated the same gravels with stages 20 and 22 at approximately 788 to 900 ka. Love and Gillam (in Patton and others, 1991) estimated the age of TG2 as 1.2 to 1.7 Ma (early Pleistocene) and that of TG1 as approximately 2 Ma (late Pliocene).

Bridgetimber Gravel

Although the Bridgetimber Gravel (tbt) was deposited by the La Plata River, its age is pertinent to the geomorphic history of the Animas Valley and to soil development. Unfortunately, incision-rate ages may be less accurate than for other terraces because the Bridgetimber surface and nearby calibration terraces are fill terraces. Like TG1 and TG2, its height is well above the calibrated ranges of the models.

Incision rates along the La Plata River and its closest tributary to Bridge Timber, Long Hollow, yield relatively old ages. Scott and Moore (1981) located an outcrop of Lava Creek B ash on the edge of Long Hollow, showing that the Red Mesa surface correlates with t4a and t4b in the Animas valley. Using Model IR1, incision rates for the La Plata River or Long Hollow, and several projections from Bridge Timber Mountain to each channel, calculated ages range from roughly 5 to 11 Ma.

Alternatively, the location of Bridge Timber Mountain, obliquely crossing the Hogback monocline, could indicate that the La Plata River was a tributary of the Animas River when the gravel accumulated. If so, incision rates along the Animas would be more

appropriate for dating the Bridgetimber Gravel. These ages would be maxima, because the La Plata River upstream from the confluence would have had a steeper gradient than the Animas and therefore higher elevations for identical terraces. These assumptions yield ages of about 2.6 Ma with Model IR1 and 4 to 6 Ma with Model IR3.

The preceding estimates, from 2.6 to 11 Ma, probably encompass the range that would be obtained from other approaches not explored here. Information that could constrain this range, such as fossils or pebble counts, is unavailable. At a minimum, the Bridgetimber Gravel could correlate with TG1, whose age is estimated as 2.2 to 2.6 Ma. Deep saprolization of clasts, very strong soils, and greater height suggest that the Bridgetimber Gravel is more likely older than TG1, although comparisons are uncertain because of differing microclimates and river gradients. Bridge Timber Mountain may lie just below the projection of possible Tertiary erosion surfaces along the southwestern flank of the San Juan Mountains, such as the Lime Mesa-Missionary Ridge divide between the present Animas and Florida Rivers (Steven, 1968). The height of Bridge Timber Mountain and its position relative to the San Juan Tertiary erosion surface suggests that tbt may be as old as Miocene in age.

Previously, most workers have considered the Bridgetimber Gravel as possibly late Pliocene (Atwood and Mather, 1932; Moore and Scott, 1981; Scott and Moore, 1981; Gillam and others, 1984; Love and Gillam in Patton and others, 1991). However, Richmond (1965b) speculated that it could be outwash of the Washakie Point Glaciation, which he later (1986a,b) correlated with stage 18 at approximately 718 to 782 ka. Richmond (1986b) considered it early Pleistocene (?), preceding stage 22 and thus between roughly 900 ka and 1.65 Ma. However, this age is too young for the gravel's deep weathering, strong soil development, and height of 300 to 650 m above modern rivers.

Discussion

These age estimates suggest that the Animas River terraces form three clusters at roughly 2.6 to 2.2 Ma (TG 1), 2.1 to 1.3 Ma (TG 2), and 800 to several ka (TG 3 to TG8). In contrast, the moraines range in age from perhaps 14 to 370 ka.

Although phase relationships between mountain glaciations and marine oxygen-isotope records are uncertain, the marine record provides a useful framework for interpreting the continental record (Fullerton and Richmond, 1986). This usefulness is confirmed here by the nearly 1:1 correspondence of cold stages with strath terraces. The mean age used here for the Lava Creek B ash, 620 ka, provides a better match between cold stages and terrace ages than an older mean age, 660 ka (based on Izett and others, 1992).

In the youngest terrace cluster, at least one strath exists in the southern part of the study reach for nine of the ten major cold stages from 2 to 20 (stage 4 may not be represented). Therefore, the Animas River terrace sequence appears more complete during this period than most others in the western United States. This period includes much of the last 900 ka, beginning with stage 22, when marine records show that glaciations were longer and more intense than earlier (e.g. Shackleton and Opdyke, 1976; Pisias and Moore, 1981; Ruddiman and others, 1989; Chen and others, 1995).

Time gaps between the terrace clusters could reflect either incision without terrace formation, or formation and later erosion of terraces. For example, the gap between terraces t3a and t2g, from 800 ka to 1.3 Ma, corresponds roughly to the period from 900 ka to 1.5 Ma when Fullerton and Richmond (1986) found "no convincing evidence" of mountain glaciation in the United States. Since cold periods were shorter and less intense at this time than later, it is possible that terraces formed along the Animas River at this time, but were narrower and more easily eroded than younger terraces. The absence of

TG3 in most areas and the lack of a terrace related to stage 22 suggest that terraces formed on softer rocks in this area are removed in less than 900 ka.

The upper part of the age range for TG1, 2.4 to 2.6 Ma, closely matches the onset of moderate-scale glaciations in the northern hemisphere, between 2.4 and 2.55 Ma as interpreted from marine oxygen-isotope records and ice-rafted debris in the North Atlantic Ocean (e.g. Backman, 1979; Shackleton and others, 1984; Raymo and others, 1989). Although one could speculate that TG1 formed because of increasing climatic fluctuations, its age is uncertain and the association could be fortuitous. Since TG1 is preserved only on the highest drainage divides, where underlain by relatively resistant rocks, it is more likely that 2.6 m.y. is roughly the time needed to erode most terraces in locations that are favorable for preservation.

The terraces are regarded as diachronous time lines whose age span probably lies within the error ranges given in Table 7.2. These age spans are large in proportion to the average age of the youngest terraces, but decrease in significance with increasing average age and are insignificant for most terraces (Bull, 1990). Relations between TG7 and the modern channel suggest that the age span of individual terraces may be as much as 15,000 yr or more. For t4b, the absence of downstream changes in the stratigraphic position of the Lava Creek B ash suggests that 15,000 yr may closer to the maximum age span than to the average. In the case of soil development, variations in age of the gravel top along a single terrace may be partly offset by the timing of alluvial fan deposition. For example, the oldest alluvial fans on TG7 in the Flora Vista area are incised and their surfaces have stabilized, although the river may not have incised the underlying fluvial gravels. Therefore, stable surfaces of terrace-capping deposits may have smaller age spans than the tops of fluvial terrace gravels.

Age control for the moraines clearly requires further work. However, an unexpected result is the likely association between the Durango 1 moraine group and stage

10. In a recent review of mountain glaciation in the United States, the only diamicton tentatively assigned to this stage is at Crater Lake, Oregon (Richmond and Fullerton, 1986b).

Many possibilities exist for improved dating. Organic material suitable for radiocarbon dating may be present in moraine-dammed lakes and in channel scours on the youngest terraces near Durango. Uranium-series dating of tufas north of Durango could determine rates of ice retreat during the last deglaciation. Thermoluminescence dating of eolian and alluvial deposits could evaluate time-transgression of individual terraces. With recent snail collections, further amino acid dating is now possible. Surface exposure dating with cosmogenic ^{36}Cl and ^{10}Be could work for the Animas City moraines, but would not work for most moraines and terraces which are buried by younger deposits.

CHAPTER 8

SYNTHESIS

The Animas River valley is significant as the former site of the largest glacier bordering the Colorado Plateau. With an area of 600 km^2, this icefield-outlet glacier system was one of the largest in the Rocky Mountains of the United States and descended to relatively low terminal elevations (Chapter 2). Glacial mass flux, meltwater discharge, and fluvioglacial stream power have not been calculated, but were probably high. In addition to terminal moraines at Durango, the valley exhibits relatively well-preserved terraces that extend much farther back in time. Before the present study, previous work by many authors had provided an overview of the moraine and terrace sequence, but was poorly integrated and incomplete. This study has reassessed the distribution, age, and genesis of the moraines and terraces and has addressed trends in soil development on these landforms with time and local climate.

Moraine Sequence

The moraine sequence in northern Durango includes three groups at progressively lower heights above present river level and decreasing distances upvalley (Chapter 3; Plates 1A and 2). The Durango, Spring Creek, and Animas City moraines are further distinguished by differences in erosional dissection, loess accumulation, and soil development, although the Spring Creek moraines are very poorly preserved. This study mainly affirmed previous subdivisions (Richmond, 1965b) that correlated the moraines

with pre-Bull Lake, Bull Lake, and Pinedale equivalents, respectively, in the Wind River Range. However, the Animas City 1 moraine was reclassified from Richmond's local Bull Lake group to his local Pinedale group (Gillam and others, 1984), and the origins of some proposed moraine remnants are ambiguous.

No numeric ages are available from this area, so age estimates were based on correlation to dated moraine sequences elsewhere, on amino acid racemization in fossil snails from sediment beneath the Spring Creek 1 moraine, and on incision-rate ages for related outwash terraces (Chapter 7). These data suggest the following approximate ages, which should be tested by other methods: Animas City 3, 2, and 1 – 15 to 25 ^{14}C ka (during marine oxygen-isotope stage 2); Spring Creek 2 – probably 85 to 120 ka (stages 5b to 5e), but possibly older; Spring Creek 1 – 135 to 160 ka (stage 6); Durango 2 – 250 to 275 ka (stage 8); and Durango 1 – 345 to 360 ka (stage 10). D-alloisoleucine/L-isoleucine ratios in several common species of snails, which were collected from alluvium beneath and probably close in age to the Spring Creek 1 moraine, yield ages from >125 ± 38 ka to 185 ± 197 ka (Alan R. Nelson, U.S. Geological Survey, written communication, 1997). The apparent relationship between the Durango 1 moraine group and stage 10 is unusual because moraines of this age are rare in the United States (Richmond and Fullerton, 1986b).

Terrace Sequence

The terrace sequence (Chapter 4) is much more complex than shown by earlier studies that addressed separate or overlapping areas at differing scales. Some of the features documented here include major and readjustment terraces that merge or emerge in the downvalley direction, minor terraces that formed during pauses in incision between major terraces, and major terraces that are preserved only in certain areas. In all, 34 levels

were identified, including 22 that formed when stable or aggrading profiles existed from Durango to Farmington and 12 that represent local readjustments of regional profiles (Plates 1 and 2). Terrace groups TG7, TG6, and TG5 are graded or project to the Animas City, Spring Creek, and Durango moraines, respectively, whereas groups TG4 to TG1 project above the moraines at increasing heights possibly up to 480 m for t1u? in the northern Mesa Mountains. The highest terrace in the present Animas River drainage, which forms Bridge Timber Mountain, was deposited by the La Plata River.

Gravelly deposits beneath moraine-related terraces form wedge-like bodies that vary in shape and become thinner downstream. Near the moraines, these deposits form paleovalley fills with concave basal contacts and thicknesses that locally exceed 46 m. Fill-top terraces are flanked by one or more lower terraces that merge with them at distances up to 20 km from the moraines. These lower terraces (either fill-cut or smaller fill terraces) formed during partial readjustments of the river's profile. With increasing distance, gravel bodies become tabular and their thickness decreases typically to 3 to 7 m. Thus, fill-top terraces in the upper reaches become strath terraces in the lower reaches.

Ages for TG7 (0 to 30 ka) and TG6 (100 to 130 ka) are estimated from those of the Animas City and Spring Creek moraines and from the lag time for incision after the last glaciation to occur in most of the area (Chapter 7). In contrast, ages for older terraces are based on calibrated long-term incision rates, with support from amino acid racemization in fossil snails, paleomagnetic polarity determinations, and correlation to marine oxygen-isotope stages. In three incision-rate models, the most important calibration point is t4b, the younger of two terraces overlain by the Lava Creek B ash. Assuming an approximate age of 620 ka for the ash (Izett and Wilcox, 1982), an age of 615 ka was assigned to the t4b gravel top. Resulting age estimates are roughly 240 to 340 ka for TG5, 430 to 625 ka for TG4, 740 to 800 ka for TG3, 1.3 to 2.1 Ma for TG2, and 2.2 to 2.6 Ma for TG1. These ages appear consistent with several imprecise dates from amino-acid racemization (Alan R.

Nelson, U.S. Geological Survey, written communication, 1997) and with possibly reversed paleomagnetic polarity at sites on an unknown terrace of TG2 and on tlu (John D. Strobell, written communication, 1978). The highest terrace of the La Plata River, tbt, could correlate with TG1, but very strong weathering and soil development show that it is probably older. Long-term incision rates for the La Plata River and its closest tributary to tbt yield ages from 5 to 11 Ma, but an inclusive range allowing for possible equivalence to TG1 is 3 to 11 Ma.

Many of these age estimates are considerably older than earlier ones, and they permit interesting comparisons with the marine oxygen-isotope record. Although dating of the marine record involves many assumptions, and phase relations with mountain glaciations are uncertain, there is nearly a one-to-one correspondence between cold stages and major strath terraces in the Farmington area for stages 2 to 20. Stage 4 may be either unrepresented or related to unidentified parts of TG7. The upper age range for TG1 matches the onset of moderate-scale glaciations in the northern hemisphere (e.g. Raymo and others, 1989, but this relationship could be coincidental.

Moraine and Terrace Deposits

Studies of the Animas City 2 and 3 moraines indicate that they are composed mainly of debris-flow deposits and fluvial deposits of outwash streams, but they also contain lacustrine sediment and rare melt-out till (Johnson, 1990; Johnson and Gillam, 1995; Chapter 5). Lodgement till was not observed, but forms the Bakers Bridge "moraine" north of Durango. Similar deposits appear to be present in older moraines (Harrington, 1970 and unpublished; Richmond, 1965b; Gillam and others, 1984; Moore and Gillam 1984).

Terrace and other deposits are typical of those in many areas, but their characteristics are important for distinguishing terrace gravels from other kinds of gravelly deposits and for interpreting soil genesis (Chapter 5 and Appendix A). Fluvial channel deposits of the Animas River are mostly gravel to muddy sandy gravel with pebbles, cobbles, and boulders of highly varied rocks (volcanic, metamorphic, plutonic, and sedimentary) mainly from the upper basin north of Durango. Some sections in and near Durango contain many fragments of shale to muddy sandstone that decompose rapidly in soils. Limestone forms roughly 17 % of clasts in some areas near Durango, but averages 2 % in most places. Overbank deposits are most prominent in the New Mexico area.

Associated deposits include sidestream alluvium, loess, sheetwash containing reworked eolian silty sand, and colluvium, with rare lenses of volcanic ash. Alluvium and colluvium contain pebbles and cobbles which have been reworked from main-river fluvial gravels, so distinctions among gravelly deposits are critical for accurate terrace mapping. Misinterpretation of dense, gravelly pavements or lag deposits as main-stream fluvial deposits accounts for many differences in terrace mapping and correlation between this and earlier studies. Northward fining of eolian deposits probably reflects wind patterns, differences among local source areas, and terrace heights that increase upstream.

Lenses of reworked volcanic ash overlie t4a, t4b, t4bx, tributary stream terraces, and bedrock slopes at 17 known sites from Durango to the Flora Vista area (Appendix C). Eight of these sites, including the only four in northwestern New Mexico, were first located for this study. Four samples were identified as Lava Creek B from elemental concentrations measured by XRF, and seven more were identified petrographically (three by Izett and Wilcox, 1982). The remaining deposits are assumed to be Lava Creek B because they occupy similar stratigraphic positions and because no other ash beds have been identified in the region. Older ash falls must have occurred here, but the deposits were not preserved. The positions of known lenses and absence of older lenses indicate

that, in this area, the potential for preservation is greatest on recently abandoned terraces where alluvial fans are prograding rapidly.

Soil Development on Moraines and Terraces

Soils on the moraines are mainly Aridisols, Alfisols, and Mollisols that formed under varying interglacial and glacial climates (Chapter 6). Modern soil-forming conditions range from mesic and aridic to frigid and ustic, but glacial conditions may have been frigid and ustic to cryic and udic (Chapter 2). The main soil-forming processes investigated here are clay and carbonate accumulation, although concurrent deposition and erosion strongly influenced profile stratigraphy. Minor silica cement occurs in some K horizons and gypsum is present in some older profiles near Farmington.

Because of variations in basal sediments (fluvial gravel, till, and glacial diamicton) and deposition of younger sediments (alluvial, colluvial, eolian, and sheetwash deposits), most profiles contain several parent materials and are multistory. Thus, it is impossible to select large suites of profiles that meet the criteria for chronofunctions and climofunctions.

Simple profiles are restricted to sites on eroding moraine crests and on younger terraces (TG8 to TG6) with low sedimentation rates after fluvial abandonment. Profiles on the oldest terraces are welded and truncated. Trends in soil development with time (represented by the relative height of moraines and terraces) and climate are generally weak for several reasons. First, few data points are available for older landforms. Second, parent-material numbers and variability greatly complicate interpretations of parent-material properties. Third, horizon maxima do not increase consistently with time in multistory soils. Finally, large and varying profile depths affect profile weights of secondary clay and carbonate and profile totals for developmental indices.

Despite profile complexity, many properties display weak, usually logarithmic trends with time and climate. Profiles on terraces in New Mexico display the best trends with time because they are simpler and more uniform, on average, than those on Colorado terraces. Trends with climate are complicated by different leaching environments for tbt (with carbonate-free soils) and younger terraces in Colorado. Due to considerable scatter in property development with time, profiles can be assigned to one of three broad developmental groups, but they are more useful for identifying pauses in deposition than for distinguishing or dating landforms of different ages.

Controls on Geomorphic Evolution

As in many areas, the formation of these terraces reflects a combination of glacial-interglacial climatic cycles and long-term channel incision (e.g. Ritter, in Madole and others, 1987; Bull, 1991). Until recently, continuous late Cenozoic incision was attributed only to concurrent tectonic uplift (e.g. Larson and others, 1975; Scott, 1975). Later hypotheses have included changes in discharge due to intensification of northern-hemisphere glaciations (e.g. Gregory and Chase, 1992; Meyer, 1992; Wolfe and others, 1998) and isostatic compensation for landscape denudation (e.g. Small and Anderson, 1998). While these processes may contribute to incision depths, geologic evidence from the southern Rocky Mountains, Colorado Plateau, and Rio Grande Rift indicates that regional and differential uplift during late Cenozoic time is ultimately driven by tectonics (e.g. Morgan and Swanberg, 1985; Eaton, 1986; Lucchitta, 1990; Parsons and McCarthy, 1995; Steven and others, 1995, 1997).

In the Animas valley, continuing incision from late Tertiary time to the present may result from the processes above and from tectonically-caused, base-level fall for the Colorado River system. Most incision of the Grand Canyon, which is upstream from the

relatively active, southwestern boundary of the Colorado Plateau, occurred between lava flows dated at 5.5 and 3.8 Ma (Damon and others, 1978; Lucchitta, 1990). Since that time, episodic aggradation and incision to near present levels has resulted from lava dams that formed between 1.8 and 0.4 Ma (Hamblin, 1994). If waves of headward erosion from base-level falls have reached upper tributaries like the Animas River, the waves have probably lengthened and attenuated so that they are indistinguishable from other processes causing incision.

This study does not identify the causes of long-term incision, but it shows how deposition and erosion are related to climatic cycles and how average incision rates vary with time. These rates have increased from late Tertiary time to the present, but differential tectonic movements were absent or minor in the northwestern San Juan Basin during this period. An understanding of local bedrock controls is important for interpreting both the climatic and incision records.

Bedrock Controls on Moraines and Terraces

Bedrock structure and erodibility have influenced the large-scale distribution of moraines and terraces through general controls on relief, but variations at formation and smaller scales have also affected specific features of terraces. The locations of preserved end moraines within a 1-km belt on the upper limb of the Hogback Monocline strongly suggest structural control (Johnson and Gillam, 1995), as does the tendency for progressively younger moraine loops to step to the northwest. The Animas City and Spring Creek moraines lie on or near the outcrop belt of the Dakota Sandstone (Johnson and Gillam, 1995), whereas the Durango moraines lie on Mancos shale upstream from a hogback ridge underlain by the late-Cretaceous Mesa Verde Group (Chapter 3).

On smaller scales, variations among sedimentary rocks in the monocline and northwestern San Juan Basin have affected terrace formation and preservation. A relatively sandy section of the San Jose Formation at the basin axis north of Cedar Hill and the Ojo Alamo Sandstone in the Farmington area formed local base levels that influenced terrace gradients for many kilometers upstream and downstream (Chapter 4). Incision through these base levels caused waves of incision that migrated upstream during several climatic cycles. In addition, terraces are relatively narrow where they cross harder rocks, wider in softer rocks, and widest upstream from local base levels that retarded incision (for example, at Florida Mesa). Harder rocks also influenced preservation, initially by defending against lateral erosion of the river channel and, after channel incision, by affecting the relative erosion rates of tributaries.

Climatic Controls on Glacial and Fluvial Processes

As widely known, moraine and terrace sequences yield fundamentally different records of climate change. End moraines record only maximum or near-maximum locations of the ice terminus, but evidence of smaller advances is rarely preserved and recessional moraines record only the last deglaciation (e.g. Sturchio and others, 1994). In contrast, proglacial terraces record entire glacial-interglacial cycles over much longer periods, but detailed interpretations are limited by exposures and dating (e.g. Ritter, in Madole and others, 1987; Bull, 1991).

Moraine construction. In the Animas valley, features of the Animas City moraines indicate rapid construction in settings with abundant meltwater and supraglacial debris (Johnson and Gillam, 1995). Specifically, the dominance of debris-flow and stream sediments, rarity of melt-out till, lack of glaciotectonic features, and foreset arrangement of depositional units (Chapter 5) indicate that the Animas City 2 and 3 moraines were built

mainly as proglacial aprons in contact with active ice. In one area downvalley from the Animas City 1 moraine, a possible kame and locally hummocky terrace surface suggest an earlier episode of ice stagnation (due to urban growth, these features are now visible only on aerial photographs). However, ice stagnation was not significant in construction of existing moraines, as inferred by Small (1995).

Several features suggest that the Animas City 2 and 3 moraines formed in several decades or less (Johnson and Gillam, 1995). These include the small number of sedimentarion units and lack of widespread erosion sufaces; rapid sedimentation rates for debris flows on modern glaciers (e.g. Boulton, 1968; Lawson, 1979); and interfingering between melt-out till and clast-rich diamicton, which resembles features that formed during annual fluctuations of Myrdalsjökull in Iceland (Krüger, 1993).

Rapid growth suggests that the Animas City moraines are close in age and formed immediately before deglaciation, whereas the volume of outwash in related terraces (t7b and t7c) indicates that the glacier stood at this position for a much longer time. This apparent conflict suggests that similar moraines formed earlier at roughly comparable positions, but were destroyed by migrating outwash streams or by ice-marginal fluctuations (Price, 1973). If so, this model explains both the small size of existing moraines, compared to the huge volume of the Animas glacier (first noted by Howe and Cross, 1906) and poor preservation of the Animas City 1 moraine. Structural controls on moraine location probably facilitated erosion of moraines by confining ice-marginal fluctuations and meltwater flows to a narrow, topographically confined belt.

Terrace formation. Models of fluvial response to climatic cycles generally attribute aggradation or stability to glaciations and incision to interglaciations, reflecting presumed controls on discharge and sediment load, although all processes are time-transgressive (e.g. Church and Ryder, 1972; Schumm, 1975; Bull, 1991). Some models further suggest two episodes of erosion per cycle, resulting from vegetation changes and

destabilization of slopes during both cooling and warming transitions (e.g. Clague, 1986). Although dating control for stages in the fluvial cycle is poor in the Animas valley, features of TG7 and some older terraces validate or bear on parts of the models.

Both suballuvial contacts, reflecting the transition from incision to stability or aggradation, and terrace surfaces, reflecting the transition back to incision, are regarded as diachronous surfaces. Prograding growth of the Animas City moraines and upward fining of adjacent fluvial deposits suggest that most fluvial deposition near the moraines occurred during the late stages of ice advance and at the ice maximum. Conversely, minor ice retreat probably caused instantaneous incision below fill-top levels, because bedload released by the glacier would have been trapped in the deep bedrock basin north of the moraines (Plate 2) until sediment filled the basin and overflowed. Minor terraces that merge downstream with fill-top terraces indicate that river level fluctuated near the moraines, either because of shifts in the ice terminus or because of fluvial complex-response; however, they show that incision below fill-top levels generally migrated downstream. Before the present, late-interglacial phase, the river stabilized and began to cut a strath terrace below TG7.

In the downstream area, field relations suggest that incision below TG7 is either small or incomplete near Flora Vista (Chapter 4; Plate 2). If so, this situation reflects sediment loads delivered by the river from upstream reaches and by tributary streams. In addition, base-level control by the Ojo Alamo Sandstone has delayed headcutting related to postglacial incision by the San Juan River at Farmington. Thus it appears that, for some terraces and areas, incision in the distal reach may be delayed well into the interglacial phase. The lag time for incision to affect the entire proglacial reach may be as long as 15 ka, based on estimated minimum ages for the Animas City moraines. Relatively large amounts of locally-derived sand in the matrix of gravels at some sites from Aztec to Farmington also suggests that some deposits were last reworked during interglacial phases, and are not outwash. On the other hand, presence of a cold-climate snail, *Vertigo*

binneyana, at the top of t5e gravels between Aztec and Flora Vista shows that parts of some terraces were incised earlier in the deglaciation phase, before most warming had taken place. Strath cutting probably occurs in the downstream area during most of the climatic cycle, but rates of sediment transport may increase during deglaciation.

Bridge borings and pipeline trenches, which were excavated within the modern channel at roughly 15 locations from Durango to Farmington, indicate that the river has not aggraded significantly during the present interglacial as proposed by Brown (1976), although alluvial fans along the valley sides are as much as 25 m thick. In the Flora Vista area, where aggradation is most likely, deposits beneath the modern channel are approximately 4.4 to 7.0 m thick (San Juan Testing Laboratory, Inc., 1981), within the range for nearby terraces. Thicker gravel may be present in a gas well on the flood plain north of Cedar Hill (Todd Gilmer, Gilmer Geophysics, oral communication, 1997), but if significant aggradation has occurred at this site, it probably filled a local scour.

One feature that may support local incision during early glacial advances is the large body of landslide (?) and locally-derived fluvial deposits at the base of the section beneath terraces t5c to t5e in the Durango-Hogback Monocline area (Chapter 5). Because these deposits are overlain by more typical, upstream-derived gravels, they apparently accumulated before climatically-driven aggradation began. Preceding incision may have triggered a landslide.

Implications of Incision Rates and Terrace Gradients

Incision rates. Regional geomorphic relations indicate that average incision rates have generally increased from late Tertiary time to the present, although poor preservation and age control for most surfaces mean that rate changes are qualitative or semi-quantitative. The oldest potential erosion surface in the area is represented by parts of the

drainage divide between the Animas and Florida rivers, extending from the rim of the Dakota hogback northeast of Durango nearly to the northern limit of sedimentary rocks (Atwood and Mather, 1932; Steven, 1968; Figure 2.1). Although local relief along the divide is high, parts are accordant and cut across bedrock dips at lower angles. The relationship of this divide to the highest outcrops of the Eocene San Jose Formation at Bridge Timber Mountain and in nearby areas suggests that it could be part of a dissected, Tertiary erosion surface that formed during deposition of Eocene or younger, unpreserved rocks in the San Juan Basin. Younger rocks may have included the upper Eocene to lower Oligocene Chuska Sandstone, now limited to the Lukachukai Mountains (Fassett, 1985; Figure 1.1), and volcaniclastic sediments from the San Juan Volcanic Field (Figure 2.1; Law, 1992). No exotic clasts have been found on the divide, but their absence could be due to prolonged weathering.

Younger but very poorly preserved surfaces include tbt at Bridge Timber Mountain, which is probably older than 2.6 Ma and younger than 11 Ma, and TG1, with an estimated age range from 2.2 to 2.6 Ma (Chapter 7). The relative heights of tbt and TG1 are uncertain because of differing gradients and poor preservation, but their height difference is probably no less than 25 m and no greater than 160 m. Using an arbitrary but possibly realistic age range of 3 to 5 Ma for Bridgetimber Mountain, and the preceding values, possible incision rates range from 0.009 to 0.4 m/ka and the median is 0.08 m/ka. No rates are calculated for incision from the possible older surface to tbt, because the origin and age of the older surface are uncertain. Nevertheless, this calculation indicates that incision could have been very slow in late Tertiary time.

The distribution of terrace remnants shows that the course of the Animas River was diverted at least three and possibly four times between formation of the oldest parts of TG1 and t3a, but was never diverted after then (Chapter 4). This relationship suggests either that the Animas River may have incised more slowly, on average, from TG1 to t3a than

later, or alternatively that total incision occurred at nearly the same rate during both periods, but was differently distributed among the Animas River and its tributaries. Rate changes cannot be determined because ages for both t3a and TG1 were estimated by assuming constant incision rates.

Incision rates for later periods from t4b to t6a and from t6a to the present were estimated from Model IR2 (Figure 7.2). For the reach downstream from the narrows, where most terraces are straths, this model yields rates from 0.10 to 0.15 m/ka between 615 and 130 ka and from 0.20 to 0.28 m/ka between 130 ka and the present.

In summary, average incision rates appear to increase when different time periods from late Tertiary to late and late-middle Pleistocene are considered. Whether this increase is caused by some autocyclic process involving basin geometry, or by external processes, is uncertain.

Terrace Gradients. Terrace gradients that decline with decreasing age are often interpreted as evidence of continuous tilting during formation of the terrace sequence (e.g. Rockwell and others, 1985). Although some gradients in the study area decrease toward the present, this pattern could result entirely from nontectonic factors such as discharge, aggradation, base-level controls, and channel efficiency for bedload transport.

The oldest terrace, tbt, has the steepest gradient (Plate 2), but it is a fill terrace of the La Plata River. It may be steeper than fill terraces of the Animas River, such as t4a and t5e, because the La Plata River has much lower discharges and is steeper because of a higher relief-to-length ratio. Terraces of TG1 and TG2 are straths, but their gradients are not good evidence for tilting because existing remnants are small and located on relatively resistant bedrock. Gradients of larger TG2 remnants near the state line vary considerably (Figure 8.1). Older levels probably have steeper gradients because they cut down-section through the sandstone-rich part of the San Jose Formation, whereas younger levels are roughly parallel to bedding.

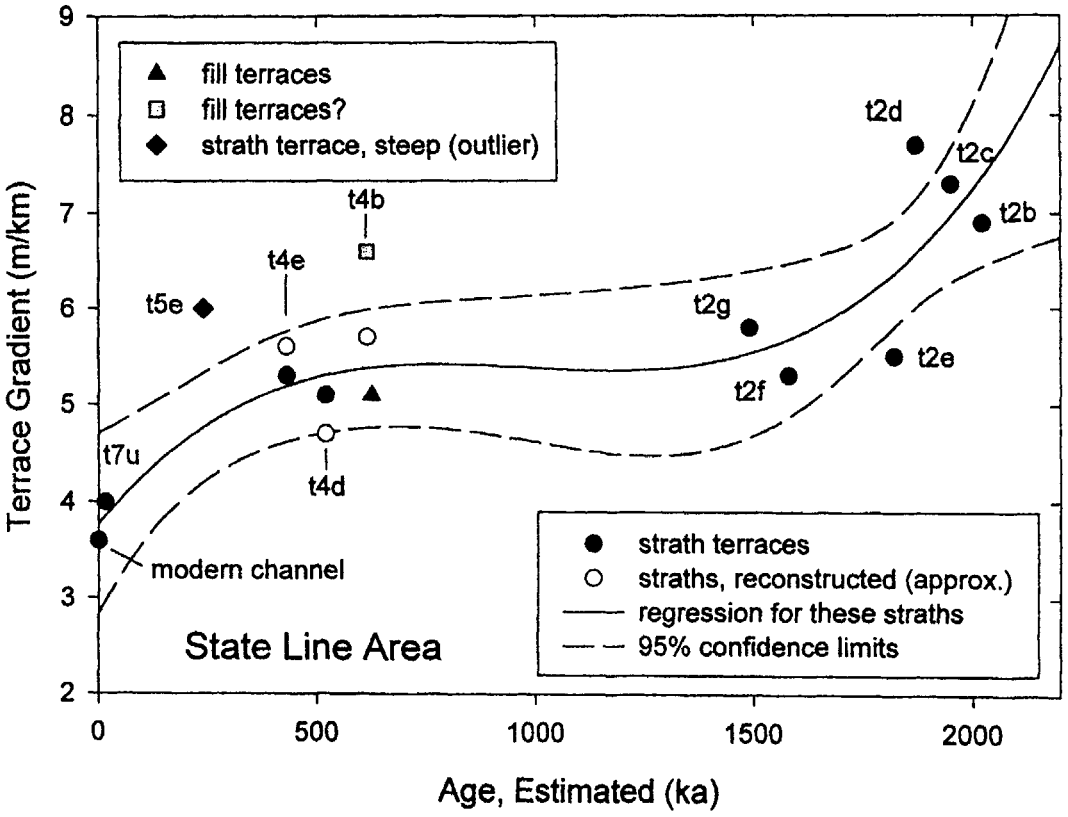

FIGURE 8.1 Terrace gradients versus estimated terrace age in the state line area. Most existing and reconstructed straths are included in a third-order polynomial regression. Fill, possible fill, and unusually steep strath terraces are also plotted for comparison.

Two relatively continuous fill terraces, t4a and the t5b-t5e surface, are steeper than TG6, TG7, and the modern channel, but their steepness reflects thicker aggradations and base-level controls. The maximum thickness of fluvial gravels beneath t4a is approximately 47 m in water wells on Florida Mesa (Robson and Wright, 1995; Colorado Department of Water Resources, unpublished records; Figure 4.9, sections I and J), reflecting a concavity in the sub-alluvial profile upstream from a local base level in the San Jose Formation at the narrows. It is also possible, but speculative, that t4a developed a high gradient because its relatively large width created a fan-like setting with shallower channels that were less efficient for bedload transport. Maximum thicknesses of fluvial gravels are more than 76 m beneath t5b-t5e at the Hogback Monocline and are 33 m beneath the related Durango 2 moraine. An approximate sub-alluvial profile, developed by linking the deepest deposits beneath the moraine and associated terraces, is roughly parallel to younger terraces and the modern channel from the moraine to the state line. Relatively thick aggradation to the t5b-t5e surface, compared to maximum thicknesses in the 20-m range for TG6 and TG7, may reflect the thickness of landslide (?) and locally-derived fluvial gravels in the lower part of the TG5 fill.

Future Work

The most pressing need for further studies in the Animas valley is better dating for all surficial deposits. (Several potential approaches are listed in Chapter 7.) Other needs include detailed sedimentological studies of fluvial and older moraine deposits, additional soil profiles on TG1 and TG2, and more pebble counts to verify the sources of older, fluvial deposits.

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APPENDIX A

LABORATORY DATA FOR SURFICIAL DEPOSITS

This appendix gives particle-size distributions and carbonate contents for surficial deposits that are parent materials for soils in Appendix B. The deposits include till or diamicton (undifferentiated), fluvial, alluvial, eolian, sheetwash, and colluvial sediments. Data are presented for samples of modern sediments, for older sediments with minor pedogenic alteration, or rarely for sediments with moderate alteration if they help to illustrate sediment types.

In Table A.1, total gravel content is given as the weight and volume percentages of whole soil. These values are roughly the same as for carbonate-free soil because the carbonate content of most samples is less than 5 %. For the fraction finer than 2 mm, weight percentages are reported on a carbonate-free basis. Among these sediments, two size ratios are useful indicators of sediment origin. The ratio of total very coarse, coarse, and medium sand to total sand and silt is relatively high for fluvial channel and alluvial sediments. In contrast, the ratio of total very fine sand and coarse silt to total sand and silt is relatively high for eolian sediments. Finally, weight percentiles, mean, sorting, and skewness for the fine fraction were calculated according to Folk (1974). Laboratory methods and additional data for samples from soil horizons are presented in Appendix B.

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS
PART 1-L SUMMARY

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE) GRAVEL (vol %) [1]	GRAVEL (wt %) [2]	GRAVEL dominant size [3]	SAND (wt %)	MUD (wt %)	<2 mm FRACTION (CARBONATE-FREE) SAND (wt %)	SILT (wt %)	CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	TEXTURAL CLASS SCS	Folk and others (1970)	CARB-ONATE (wt % <2 mm) [4]
Till or glacial diamicton, undifferentiated (TD)																
35N/9W/15/2	174-218	mD2	Bk	25	28.0	s cb	40.3	31.8	56.0	37.4	6.7	17.0	37.5	gfSL-	gmS	12.0 (R?)
35N/9W/15/2	218-262	mD2	Bk	25	35.0	s cb	38.2	26.8	58.8	34.6	6.6	20.8	36.3	gfSL-	msG	13.1 (R?)
35N/9W/15/4	A	mAC2	deep cut	ND	ND	ND	ND	ND	36.3	54.4	9.3	7.4	46.8	gSiL	gM	15.4 (R?)
35N/9W/16/4	A	mAC2	deep cut	ND	ND	ND	ND	ND	64.9	28.8	6.3	38.8	28.2	gfSL	gmS	16.9 (R?)
35N/9W/16/8	B	mAC2	deep cut	ND	ND	ND	ND	ND	64.2	27.6	8.2	46.1	22.5	gf-coSL	gmS	16.1 (R?)
35N/9W/21/3	A	mD2	deep cut	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.6 (R?)
35N/9W/15/4	B	mAC2	deep cut	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.0 (R?)
35N/9W/16/4	B	mAC3	deep cut	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18.2 (R?)
AVERAGE				25	31.5		39.27 *	29.3	56.1	36.6	7.4	26.0	34.3			
STD. DEV.				0	3.5		1.05	2.49	10.4	9.6	1.1	14.3	8.4			
NO. OBS.				2	2		2	2	5	5	5	5	5			
Fluvial channel deposits, less sorted (FCP)																
35N/9W/20/1	487-510	t5c	BCtk	75	80.0	e c	9.0	11.0	44.8	34.0	21.1	36.7	27.0	vgL		NR
35N/9W/16/3	53-71	mAC3	Bk	80	85.0	s cp	11.7	3.3	78.1	15.5	6.4	52.2	17.1	vgvcoLS		NR
35N/9W/16/3	71-95	mAC3	Bk	80	85.0	s cp	12.2	2.8	81.4	12.9	5.8	59.0	14.3	vgcoLS		NR
35N/9W/16/3	194-217	mAC3	Bk	45	58.0	e pc	35.8	6.0	85.2	10.7	3.6	65.9	11.7	vgco-vcoL	msG	NR
35N/9W/16/3	217-239	mAC3	Bk	ND	ND	pc	ND	ND	64.8	30.2	5.0	33.5	32.2	sg(?)fSL-	(g?)mS	NR
35N/9W/17/1	145-157	t6a	Bk	70	77.0	s c	13.4	9.6	58.4	32.5	9.1	41.5	25.9	vgcoSL	msG	NR
34N/9W/8U/1	169-179	fp	Bk	60	70.0	s cb	18.2	11.8	60.7	29.7	9.6	52.3	18.3	vgvcoSL	msG	NR
AVERAGE				68.3	75.8		16.7	7.4	67.6	23.6	8.7	48.7	20.9			
STD. DEV.				13.7	10.4		9.8	3.9	15.9	10.1	5.9	11.9	7.5			
NO. OBS.				6	6		6	6	7	7	7	7	7			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 1-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Till or glacial diamicton, undifferentiated (TD)																
35N/9W/15/2	174-218	2.8	5.9	7.2	26.3	13.7	21.3	12.9	3.2	1.6	ND	ND	5.0	fS	coSi	Probably MDS of Johnson (1990).
35N/9W/15/2	218-262	4.8	6.9	7.7	25.6	13.7	20.2	11.7	2.7	1.6	ND	ND	5.0	fS	coSi	Probably MDS of Johnson (1990).
35N/9W/15/4	A	1.4	2.1	3.1	15.0	14.7	27.8	21.4	5.2	2.0	ND	ND	7.3	coSi	m+fC	Probably MDS of Johnson (1990).
35N/9W/16/4	A	12.2	13.5	10.6	17.8	10.9	15.5	10.1	3.2	2.4	ND	ND	3.9	fS	coSi	May be MDS of Johnson (1990).
35N/9W/16/8	B	18.3	13.9	10.1	14.8	7.2	13.5	10.0	4.1	1.8	ND	ND	6.4	vcoS	fS	May be MDS of Johnson (1990).
35N/9W/21/3	A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/15/4	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Probably MDS of Johnson (1990).
35N/9W/16/4	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	May be MDS or F of Johnson (1990).
AVERAGE		7.9	8.5	7.8	19.9	12.0	19.6	13.2	3.7	1.9			5.5			
STD. DEV.		6.4	4.6	2.7	5.1	2.8	5.0	4.2	0.9	0.3			1.2			
NO. OBS.		5	5	5	5	5	5	5	5	5			5			
Fluvial channel deposits, less sorted (FCP)																
35N/9W/20/1	487-510	10.4	12.1	6.4	9.4	6.5	14.8	13.7	5.6	3.6	ND	ND	17.6	co-fSi	co-vcoS	
35N/9W/16/3	53-71	18.5	17.4	13.0	21.6	7.6	8.4	5.5	1.7	1.2	ND	ND	10.9	fS	vco-coS	
35N/9W/16/3	71-95	19.4	20.3	15.8	19.4	6.4	7.0	5.0	0.8	1.8	ND	ND	4.0	co-vcoS	fS	
35N/9W/16/3	194-217	24.2	24.6	14.3	17.3	5.3	5.9	4.2	0.6	0.9	ND	ND	2.7	co-vcoS	fS	
35N/9W/16/3	217-239	11.5	11.9	8.5	19.6	13.5	17.1	10.4	2.7	1.3	ND	ND	3.7	fS	coSi	Fine interbed.
35N/9W/17/1	145-157	12.5	15.7	9.5	12.8	7.9	15.7	13.7	3.1	2.7	ND	ND	6.5	coS	coSi	Clay secondary & mechan. infiltrated.
34N/9W/8U/1	169-179	22.6	16.9	7.8	10.6	2.7	13.8	11.5	4.5	2.1	0.9	6.5	7.5	vcoS	coSi	Mechanically infiltrated clay.
AVERAGE		17.0	17.0	10.8	15.8	7.1	11.8	9.1	2.7	1.9			7.5			
STD. DEV.		5.6	4.5	3.6	4.8	3.3	4.6	4.2	1.9	0.9			5.2			
NO. OBS.		7	7	7	7	7	7	7	7	7			7			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 1-R STATISTICAL MEASURES FOR FINE FRACTION

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)														
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]			
		5 % (ϕ)	16 % (ϕ)	50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)	verbal		Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)		verbal
Till or glacial diamicton, undifferentiated (TD)																
35N/9W/15/2	174-218	0.49	2.00	3.91	6.52	10.09	4.14	0.057	2.26	2.58	very	poor	0.15	0.22		fine-skewed
35N/9W/15/2	218-262	-0.97 x	0.33	3.00	6.25	10.09	3.19	0.109	2.96	3.16	very	poor	0.10	0.19		fine-skewed
35N/9W/15/4	A	1.53	2.93	4.97	7.43	11.22 x	5.11	0.029	2.25	2.59	very	poor	0.09	0.19		fine-skewed
35N/9W/16/4	A	0.04	1.66	3.72	6.36	9.49	3.91	0.066	2.35	2.61	very	poor	0.12	0.17		fine-skewed
35N/9W/16/8	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/21/3	A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/15/4	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/16/4	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
AVERAGE			1.73	3.90	6.64		4.09	0.0653	2.46				0.12			
STD. DEV.			0.93	0.70	0.47		0.685	0.0289	0.29				0.02			
NO. OBS.			4	4	4		4	4	4				4			
Fluvial channel deposits, less sorted (FCP)																
35N/9W/20/1	487-510	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/16/3	53-71	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/16/3	71-95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
35N/9W/16/3	194-217	?	-0.46	1.06	3.99	7.17	1.53	0.346	2.23	?	very	poor	0.32	?	strongly	fine-skewed
35N/9W/16/3	217-239	-0.97 x	0.43	3.22	5.96	8.98	3.20	0.109	2.77	2.89	very	poor	-0.01	0.07	near-	symmetrical
35N/9W/17/1	145-157	-0.87 x	0.27	3.23	6.76	10.71 x	3.42	0.093	3.25	3.38	very	poor	0.09	0.19		fine-skewed
34N/9W/8U/1	169-179	?	-0.52 x	2.32	7.27	?	3.02	0.123	3.90	?	very	poor	0.27	?		fine-skewed
AVERAGE			-0.07	2.46	6.00		2.79	0.168	3.03		very	poor	0.17			fine-skewed
STD. DEV.			0.49	1.02	1.44		0.86	0.120	0.71				0.15			
NO. OBS.			4	4	4		4	4	4				4			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 2-L SUMMARY, continued

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE) GRAVEL (vol %) [1]	GRAVEL (wt %) [2]	GRAVEL dominant size [3]	SAND (wt %)	MUD (wt %)	<2 mm FRACTION (CARBONATE-FREE) SAND (wt %)	SILT (wt %)	CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	TEXTURAL CLASS SCS	Folk and others (1970)	CARB-ONATE (wt % <2 mm) [4]
Fluvial channel deposits, less sorted (FCP)																
34N/9W/8U/3	210-238	t7ab	Bk	90	93.0	s cb	4.8	2.2	67.9	22.7	9.4	63.9	14.1	vgvcoSL	msG	NR
35N/9W/17/1	157-182	t6a	Bk	35	45.0	s p	43.5	11.5	79.2	16.3	4.5	71.7	10.3	gco-vcoLS	msG	NR
34N/9W/8U/6	203-250	t6a	Bk	75	82.0	s c	14.7	3.3	81.4	16.9	1.7	72.0	11.3	vgvcoLS	G	NR
35N/9W/20/1	605-645	t5c	Bk	80	85.5	e pc	10.7	3.8	73.8	18.9	7.2	67.0	12.2	vgco-vcoS	G	NR
34N/9W/29/1	235-287	t4b	BAtk	55	66.5	e cb	26.9	6.6	80.4	16.6	3.0	72.6	12.1	vgcoLS	msG	0.6
35N/9W/15/5	B	mAC3	deep cut	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17.6 (NR?)
AVERAGE				67.0	74.4		20.1	5.5	76.5	18.3	5.2	69.4	12.0			
STD. DEV.				22.0	19.1		15.4	3.7	5.6	2.7	3.1	3.8	1.4			
NO. OBS.				5	5		5	5	5	5	5	5	5			
Fluvial channel deposits, better sorted (FC)																
34N/9W/29/1	B	t4b	deep cut	70	77.5	e c	18.4	4.1	81.7	9.6	8.7	74.0	7.2	vgcoLS	msG	NR
34N/9W/29/1	C	t4b	deep cut	70	77.5	e c	20.9	1.6	92.9	3.8	3.3	71.0	5.1	vgm-coLS	sG	0.5
29N/13W/21/1B	174-210	t7u	Bk	60	70.0	s pc	28.3	1.7	94.2	2.6	3.2	81.7	3.1	vgcoS	sG	NR
30N/12W/27/1B	643-673	t6b	Bk	65	74.0	e c	23.0	3.0	88.6	7.3	4.2	67.8	7.3	vgcoS	msG	1.7
30N/10W/10/1	318-353	t1u	Bk	65	81.0	s cp	17.4	1.5	91.8	5.0	3.1	65.5	6.4	vgmS	G	NR
29N/12W/5/2	238-263	t4b	Bk	75	83.0	s cp	14.6	2.4	85.7	8.2	6.1	57.6	11.9	vgcoLS	G	0.7
35N/9W/17/3	B	modern	channel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
29N/12W/16/4	B	modern	channel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7
30N/11W/9/1	A	modern	channel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
AVERAGE				67.5	77.1		20.4	2.4	89.1	6.1	4.8	69.6	6.8			
STD. DEV.				5.2	4.7		4.8	1.0	4.8	2.7	2.2	8.1	3.0			
NO. OBS.				6	6		6	6	6	6	6	6	6			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 2-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Fluvial channel deposits, less sorted (FCP)																
34N/9W/8U/3	210-238	35.0	16.6	6.3	7.2	2.8	10.0	8.8	4.0	2.8	1.1	5.6	6.6	vcoS	coSi	Mechanically infiltrated clay.
35N/9W/17/1	157-182	29.0	27.5	12.0	7.8	2.9	7.0	7.7	1.6	1.4	ND	ND	3.1	vco-coS	coSi	
34N/9W/8U/6	203-250	34.0	27.2	9.5	8.2	2.5	8.6	6.2	2.1	0.4	0.9	0.4	1.3	vcoS	coSi	
35N/9W/20/1	605-645	24.0	25.3	12.8	8.4	3.2	8.1	7.9	3.0	2.9	ND	ND	4.3	co-vcoS	coSi	Clay partly secondary?
34N/9W/29/1	235-287	24.6	36.0	9.9	7.6	2.3	9.4	5.0	2.2	1.1	0.0	1.9	1.9	coS	coSi	
35N/9W/15/5	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Groundwater carbonate?
AVERAGE		29.3	26.5	10.1	7.8	2.7	8.6	7.1	2.6	1.7			3.4			
STD. DEV.		5.1	6.9	2.5	0.5	0.4	1.2	1.5	0.9	1.1			2.1			
NO. OBS.		5	5	5	5	5	5	5	5	5			5			
Fluvial channel deposits, better sorted (FC)																
34N/9W/29/1	B	12.4	32.8	22.4	11.9	2.2	4.4	3.5	1.7	2.1	ND	ND	6.6	coS	m+fC	Mechanically infiltrated clay.
34N/9W/29/1	C	2.8	32.9	33.0	21.4	2.9	2.0	1.5	0.3	1.1	ND	ND	2.2	m-coS	m+fC*	
29N/13W/21/1B	174-210	3.3	41.6	34.3	13.7	1.5	1.5	0.8	0.3	1.7	ND	ND	1.5	coS	coC*	
30N/12W/27/1B	643-673	8.3	30.9	25.8	20.2	3.4	3.6	2.8	0.9	0.3	ND	ND	3.9	coS	m+fC	
30N/10W/10/1	318-353	5.1	23.9	34.5	24.7	3.7	2.5	1.6	0.9	1.4	ND	ND	1.8	mS	–	
29N/12W/5/2	238-263	13.4	21.9	18.8	25.1	6.5	4.7	2.8	0.7	0.7	ND	ND	5.4	fS	coS	Includes sediment from local sources
35N/9W/17/3	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
29N/12W/16/4	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
30N/11W/9/1	A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Includes sediment from local sources
AVERAGE		7.5	30.7	28.1	19.5	3.4	3.1	2.1	0.8	1.2			3.6			
STD. DEV.		4.6	7.1	6.7	5.6	1.7	1.3	1.0	0.5	0.7			2.1			
NO. OBS.		6	6	6	6	6	6	6	6	6			6			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 2-R STATISTICAL MEASURES FOR FINE FRACTION, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)															
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]				
		5 % (ϕ)	16 % (ϕ)		50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)	verbal		Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)		verbal
Fluvial channel deposits, less sorted (FCP)																	
34N/9W/8U/3	210-238	?	-1.51	x	1.89	6.95	11.68	x 2.44	0.184	4.23	?	extremely	poor	0.20	?		fine-skewed
35N/9W/17/1	157-182	?	-0.62		0.67	5.18	8.62	1.74	0.299	2.90	?	very	poor	0.56	?	strongly	fine-skewed
34N/9W/8U/6	203-250	?	-0.87	x	0.58	4.69	7.10	1.47	0.362	2.78	?	very	poor	0.48	?	strongly	fine-skewed
35N/9W/20/1	605-645	?	-0.43	x	1.07	8.00	10.71	2.88	0.136	4.22	?	extremely	poor	0.64	?	strongly	fine-skewed
34N/9W/29/1	235-287	?	-0.53	x	0.94	4.78	7.79	1.73	0.301	2.66	?	very	poor	0.45	?	strongly	fine-skewed
35N/9W/15/5	B	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
AVERAGE			-0.79		1.03	5.92	9.18	2.05	0.256	3.36		very	poor	0.46		strongly	fine-skewed
STD. DEV.			0.43		0.52	1.48	1.95	0.59	0.093	0.80				0.17			
NO. OBS.			5		5	5	5	5	5	5				5			
Fluvial channel deposits, better sorted (FC)																	
34N/9W/29/1	B	-0.48	0.13	x	1.21	5.00	10.90	x 2.11	0.231	2.44	2.94	very	poor	0.56	0.63	strongly	fine-skewed
34N/9W/29/1	C	0.18	0.60		1.43	2.78	5.81	1.60	0.329	1.09	1.40		poor	0.24	0.40	strongly	fine-skewed
29N/13W/21/1B	174-210	0.12	0.48		1.13	2.44	4.99	1.35	0.392	0.98	1.23		poor	0.34	0.46	strongly	fine-skewed
30N/12W/27/1B	643-673	0.11	0.44		1.42	3.22	8.52	1.69	0.309	1.39	1.97		poor	0.29	0.49		fine-skewed
30N/10W/10/1	318-353	-0.02	0.59		1.62	2.86	6.49	1.69	0.310	1.14	1.55		poor	0.09	0.29		fine-skewed
29N/12W/5/2	238-263	0.78	1.33		2.51	4.44	9.79	2.76	0.148	1.56	2.14		poor	0.24	0.43	strongly	fine-skewed
35N/9W/17/3	B	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
29N/12W/16/4	B	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
30N/11W/9/1	A	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
AVERAGE		0.12	0.60		1.55	3.46	7.75	1.87	0.287	1.43	1.87		poor	0.29	0.45	strongly	fine-skewed
STD. DEV.		0.40	0.40		0.50	1.02	2.35	0.50	0.085	0.54	0.63			0.15	0.11		
NO. OBS.		6	1 6		6	6	6	6	6	6	6			6	6		

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 3-L SUMMARY, continued

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE) GRAVEL (vol %) [1]	GRAVEL (wt %) [2]	GRAVEL dominant size [3]	SAND (wt %)	MUD (wt %)	<2 mm FRACTION (CARBONATE-FREE) SAND (wt %)	SILT (wt %)	CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	TEXTURAL CLASS SCS	Folk and others (1970)	CARB-ONATE (wt % <2 mm) [4]
Fluvial channel deposits, better sorted, finer interbeds (FC)																
29N/13W/21/1B	109-125	t7u	Bk	1	1.0	s p	82.5	16.5	83.4	11.1	5.6	36.0	15.5	fLS	(g)mS	NR
30N/10W/10/1	191-207	t1u	Btk	20	29.0	s cp	41.0	30.0	57.7	28.3	14.0	13.8	35.6	gfSL	gmS	NR
Fluvial channel, mechanically infiltrated silt and clay (Fl)																
34N/9W/29/1	A	t4b	deep cut	0	0.0	a –	2.3	97.7	2.3	52.0	45.6	2.6	2.7	SiC	M	NR
34-1/2N/9W/33/3	A	t5b	deep cut	0	0.0	a –	2.6	97.4	2.6	59.6	37.9	1.3	5.0	SiCL-	M	0.3
34N/9W/10/1	B	t5d	deep cut	0	0.0	a –	3.3	96.7	3.3	0.2	96.5	ND	ND	C	C	0.8
AVERAGE				0	0.0		2.7	97.3	2.7	37.3	60.0	1.9	3.9			
STD. DEV.				0	0.0		0.5	0.5	0.5	32.3	31.9	1.0	1.6			
NO. OBS.				3	3		3	3	3	3	3	2	2			
Fluvial overbank deposits (FO)																
30N/12W/27/1B	555-574	t7u	Bk	0.3	0.4	s p	43.1	56.5	43.2	43.0	13.7	1.2	69.8	L	(g)M	NR
30N/12W/27/1B	574-590	t7u	CB	0	0.0	s –	24.1	75.9	24.1	60.0	15.9	1.7	63.5	SiL	gM	NR
31N/10W/4/1	C1	t5e	deep cut	0	0.0	s –	2.4	97.6	2.4	77.6	20.0	0.6	23.9	SiL	Z	10.4 (NR?)
31N/10W/4/1	B3	t5e	deep cut	0	0.0	s –	52.7	47.2	52.7	31.4	15.8	2.6	48.1	fSL	mS	5.2 (NR?)
29N/12W/5/3	A	t4d	deep cut	0	0.0	s –	55.8	44.3	55.8	33.3	11.0	7.0	38.5	fSL	zS	3.8 (NR?)
36N/9W/15/1	C	modern	channel	0	0.0	s –	16.9	83.1	16.9	75.3	7.9	1.9	36.2	SiL+	Z	7.1 (NR?)
35N/9W/17/3	C	modern	channel	0	0.0	s –	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5

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TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 3-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Fluvial channel deposits, better sorted, finer interbeds (FC)																
29N/13W/21/1B	109-125	0.2	9.6	24.2	40.0	9.4	5.2	2.9	2.9	1.0	ND	ND	4.6	fS	m+fC	
30N/10W/10/1	191-207	0.9	3.9	7.1	29.7	16.1	14.5	10.0	3.8	3.2	ND	ND	10.8	fS	m+fC	Mechanically infiltrated clay and silt.
Fluvial channel deposits, better sorted, finer interbeds (FC)																
34N/9W/29/1	A	0.4	0.6	0.5	0.6	0.3	1.2	24.8	26.0	10.4	ND	ND	35.3	m+fC	vf-mSi	
34 1/2N/9W/33/3	A	0.1	0.3	0.4	0.9	0.9	2.2	34.2	23.2	9.7	ND	ND	28.2	m+fSi	m+fC	Silty & clayey lams., mixed in sample.
34N/9W/10/1	B	0.7	1.1	0.6	0.7	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	
AVERAGE		0.4	0.7	0.5	0.7	0.5	1.7	29.5	24.6	10.0			31.7			
STD. DEV.		0.3	0.4	0.1	0.2	0.4	0.7	6.6	2.0	0.5			5.0			
NO. OBS.		3	3	3	3	3	2	2	2	2			2			
Fluvial overbank deposits (FO)																
30N/12W/27/1B	555-574	0.5	0.4	0.2	12.4	29.8	30.4	9.0	3.6	2.3	ND	ND	11.4	coSi-vfS	m+fC	
30N/12W/27/1B	574-590	0.3	0.8	0.3	7.1	15.6	37.8	16.5	5.7	2.5	ND	ND	13.4	coSi	m+fC	
31N/10W/4/1	C1	0.0	0.1	0.4	4.5	0.2	19.0	47.8	10.8	4.6	ND	ND	15.4	m+fSi	m+fC	
31N/10W/4/1	B3	0.1	0.2	2.0	26.5	24.1	16.4	9.0	6.0	5.4	ND	ND	10.5	f-vfS	m+fC	
29N/12W/5/3	A	0.2	1.5	4.6	33.7	15.8	18.5	11.3	3.5	2.1	ND	ND	8.9	fS	coSi	
36N/9W/15/1	C	0.1	0.5	1.2	8.7	6.4	26.9	42.8	5.5	1.8	ND	ND	6.0	m-coSi	fS	Carb. in red mudst.? Incl. local sed.
35N/9W/17/3	C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

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TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 3-R STATISTICAL MEASURES FOR FINE FRACTION, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)															
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]				
		5 % (ϕ)	16 % (ϕ)	50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)	verbal		Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)	verbal	
Fluvial channel deposits, better sorted, finer interbeds (FC)																	
29N/13W/21/1B	109-125	-0.61 x	0.24	1.90	4.44	9.53	2.19	0.219	2.10	2.59	very	poor	0.21	0.36		fine-skewed
30N/10W/10/1	191-207	1.02	2.25	3.85	8.25	?	4.78	0.036	3.00	?	very	poor	0.47	?	strongly	fine-skewed
Fluvial channel deposits, better sorted, finer interbeds (FC)																	
34N/9W/29/1	A	5.90	6.93	8.75	12.23 x	?	9.30	>0.002	2.65	?	very	poor	0.31	?	strongly	fine-skewed
34 1/2N/9W/33/3	A	5.67	6.61	8.26	11.65 x	?	8.84	<0.002	2.52	?	very	poor	0.35	?	strongly	fine-skewed
34N/9W/10/1	B	≈9?	?	≈11?	?	?	≈11?	<0.001	?	?		poor	?	?	?	
AVERAGE		5.79	6.77	8.51	11.94		9.07	0.002	2.59		very	poor	0.33		strongly	fine-skewed
STD. DEV.		0.16	0.23	0.35	0.41		0.33	0.000	0.09				0.02			
NO. OBS.		2	2	2	2		2	2	2				2			
Fluvial overbank deposits (FO)																	
30N/12W/27/1B	555-574	2.72	3.44	4.62	8.18	?	5.41	0.023	2.37	?	very	poor	0.50	?	strongly	fine-skewed
30N/12W/27/1B	574-590	2.34	2.93	4.19	8.94	?	5.35	0.024	3.01	?	very	poor	0.58	?	strongly	fine-skewed
31N/10W/4/1	C1	4.69	5.42	6.88	9.83	?	7.38	0.006	2.21	?	very	poor	0.34	?	strongly	fine-skewed
31N/10W/4/1	B3	2.89	3.88	5.24	8.96	?	6.03	0.015	2.54	?	very	poor	0.46	?	strongly	fine-skewed
29N/12W/5/3	A	1.82	2.57	3.95	7.32	?	4.61	0.041	2.38	?	very	poor	0.42	?	strongly	fine-skewed
36N/9W/15/1	C	2.58	3.97	5.92	7.72	10.70	5.87	0.017	1.87	2.17		poor	-0.04	0.07	near-	symmetrical
35N/9W/17/3	C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	

continued on next page

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 4-L SUMMARY, continued

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE)					<2 mm FRACTION (CARBONATE-FREE)					TEXTURAL CLASS		CARB-ONATE (wt % <2 mm) [4]
				GRAVEL			SAND (wt %)	MUD (wt %)	SAND (wt %)	SILT (wt %)	CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	SCS	Folk and others (1970)	
				(vol %) [1]	(wt %) [2]	domi-nant size [3]										
Fluvial overbank deposits (FO), continued																
32N/9W/7/2	A	modern	channel	0	0.0	s --	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.5
29N/12W/16/4	C1	modern	channel	0	0.0	s --	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
32N/9W/7/2	B	late Hol.	flood plain	0	0.0	s --	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.8
AVERAGE				0.03	0.04		32.5	67.4	32.5	53.4	14.0	2.5	46.7			
STD. DEV.				0.1	0.1		21.4	21.4	21.4	20.5	4.2	2.3	17.4			
NO. OBS.				10	10		6	6	6	6	6	6	6			
Alluvium																
34N/9W/29/1	208-235	t4b	Bk	<1	2.0	s p	37.4	60.7	38.2	57.1	4.8	20.3	40.9	sgSiL-	(g)M	0.3
31N/10W/4/1	B1	t5e	deep cut	0?	0.0	s --	92.2	7.8	92.2	4.6	3.2	83.3	4.0	coS	S	0.4
31N/10W/23/1	A	t5e	deep cut	0?	0.0	s --	84.6	15.3	84.6	7.3	8.0	66.4	8.1	coLS	mS	0.6
30N/11W/5/2	A	modern	channel	2	4.2	s p	86.9	8.9	90.7	4.8	4.5	86.1	3.7	coS	(g)S	0.3
30N/12W/33/3	A	modern	channel	1	2.1	s p	90.3	7.5	92.3	3.9	3.8	91.1	2.4	coS	(g)S	1.0
AVERAGE				0.7	1.7		78.3	20.0	79.6	15.5	4.9	69.4	11.8			
STD. DEV.				0.7	1.8		23.0	22.9	23.4	23.3	1.9	29.0	16.4			
NO. OBS.				5	5		5	5	5	5	5	5	5			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 4-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Fluvial overbank deposits (FO), continued																
32N/9W/7/2	A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
29N/12W/16/4	C1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
32N/9W/7/2	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
AVERAGE		0.2	0.6	1.4	15.5	15.3	24.8	22.7	5.9	3.1			10.9			
STD. DEV.		0.2	0.5	1.7	11.8	10.9	8.4	17.8	2.7	1.5			3.3			
NO. OBS.		6	6	6	6	6	6	6	6	6			6			
Alluvium																
34N/9W/29/1	208-235	5.4	8.7	5.2	10.5	8.4	30.6	20.9	5.6	1.8	1.3	1.6	3.0	coSi	fS	From Animas Fm; incl. Lava Creek B.
31N/10W/4/1	B1	28.3	36.6	15.7	10.0	1.7	2.2	1.0	1.5	0.3	ND	ND	2.9	coS	m+fC	From San Jose & Nacimiento Fms.
31N/10W/23/1	A	6.7	32.2	22.2	19.2	4.4	3.1	3.4	0.8	1.6	ND	ND	6.4	coS	m+fC	From San Jose & Nacimiento Fms.
30N/11W/5/2	A	26.4	42.6	13.2	6.8	1.7	1.8	1.8	1.2	0.4	ND	ND	4.1	coS	m+fC	From Nacimiento Fm.
30N/12W/33/3	A	29.0	49.5	9.1	3.6	1.1	1.2	1.1	1.6	0.8	ND	ND	3.0	coS	m+fC	From Ojo Alamo Ss.
AVERAGE		19.2	33.9	13.1	10.0	3.5	7.8	5.6	2.1	1.0			3.9			
STD. DEV.		12.0	15.6	6.5	5.8	3.0	12.8	8.6	1.9	0.7			1.5			
NO. OBS.		5	5	5	5	5	5	5	5	5			5			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 4-R STATISTICAL MEASURES FOR FINE FRACTION, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)														
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]			
		5 % (ϕ)	16 % (ϕ)	50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)	verbal		Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)		verbal
Fluvial overbank deposits (FO), continued																
32N/9W/7/2	A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
29N/12W/16/4	C1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
32N/9W/7/2	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND	ND	
AVERAGE		2.84	3.70	5.13	8.49		5.78	0.021	2.40		very	poor	0.38		strongly	fine-skewed
STD. DEV.		0.98	1.00	1.12	0.92		0.93	0.012	0.37				0.22			
NO. OBS.		6	6	6	6		6	6	6				6			
Alluvium																
34N/9W/29/1	208-235	-0.10 x	1.39	4.82	6.95	8.90	4.39	0.048	2.78	2.75	very	poor	-0.23	-0.16		coarse-skewed
31N/10W/4/1	B1	?	-0.47 x	0.59	1.89	6.90	0.67	0.629	1.18	?		poor	0.10	?	near-	symmetrical
31N/10W/23/1	A	-0.13 x	0.41	1.50	4.12	10.65 x	2.01	0.248	1.86	2.56		poor	0.41	0.55	strongly	fine-skewed
30N/11W/5/2	A	?	-0.33	0.57	2.32	8.34	0.85	0.554	1.33	?		poor	0.32	?	strongly	fine-skewed
30N/12W/33/3	A	?	-0.33	0.40	1.56	7.98	0.54	0.686	0.95	?		poor	0.23	?		fine-skewed
AVERAGE			0.13	1.58	3.37	8.55	1.69	0.433	1.62			poor	0.17			fine-skewed
STD. DEV.			0.78	1.86	2.23	1.38	1.61	0.274	0.73				0.25			
NO. OBS.			5	5	5	5	5	5	5				5			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 5-L SUMMARY, continued

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE) GRAVEL (vol %) [1]	GRAVEL (wt %) [2]	GRAVEL dominant size [3]	WHOLE SOIL SAND (wt %)	WHOLE SOIL MUD (wt %)	<2 mm FRACTION SAND (wt %)	<2 mm FRACTION SILT (wt %)	<2 mm FRACTION CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	TEXTURAL CLASS SCS	TEXTURAL CLASS Folk and others (1970)	CARBONATE (wt % <2 mm) [4]
Eolian deposits, sandy loess (E)																
35N/9W/20/1	104-124	t5c	BCtk	0	0.0	s --	22.5	77.6	22.5	54.3	23.3	0.8	72.0	L+	sZ	1.2
35N/9W/20/1	249-264	t5c	BCtk	0	0.0	s --	27.5	72.6	27.5	53.6	19.0	1.1	65.9	SiL	sZ	0.6
35N/9W/20/4	A	modern	patio	0	0.0	s --	25.7	74.2	25.7	55.1	19.1	1.0	71.8	SiL	sZ	ND
34N/8W/29/1	A	modern	rooftop	0	0.0	s --	28.9	71.1	28.9	54.6	16.6	9.4	52.1	SiL	sZ	4.1
AVERAGE				0	0.0		26.2	73.9	26.2	54.4	19.5	3.1	65.5			
STD. DEV.				0	0.0		2.8	2.8	2.8	0.6	2.8	4.2	9.3			
NO. OBS.				4	4		4	4	4	4	4	4	4			
Eolian deposits, silty sand (E)																
35N/9W/20/1	0-19	t5c	Oi	0	0.0	s --	47.6	52.5	47.6	32.6	19.9	14.2	49.0	L	sM	2.4
35N/9W/20/1	31-49	t5c	Bw	0	0.0	s --	36.9	63.1	36.9	39.7	23.4	5.8	59.4	L+	sM	2.3
31N/10W/19/1	A	modern	C	0	0.0	s --	63.7	36.3	63.7	24.9	11.4	24.4	49.3	vfSL	zS	0.1
AVERAGE				0	0.0		49.4	50.6	49.4	32.4	18.2	14.8	52.6			
STD. DEV.				0	0.0		13.5	13.5	13.5	7.4	6.2	9.3	5.9			
NO. OBS.				3	3		3	3	3	3	3	3	3			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 5-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Eolian deposits, sandy loess (E)																
35N/9W/20/1	104-124	0.0	0.2	0.4	4.4	17.4	37.9	13.0	3.4	2.7	ND	ND	20.6	coSi	m+fC	
35N/9W/20/1	249-264	0.2	0.3	0.4	8.9	17.7	35.7	13.9	4.0	3.3	ND	ND	15.7	coSi	m+fC	Carbonate partly leached?
35N/9W/20/4	A	0.1	0.4	0.3	3.6	21.4	36.7	17.6	0.8	2.9	ND	ND	16.2	coSi	m+fC	Very small sample.
34N/8W/29/1	A	2.9	2.4	2.6	8.8	12.2	31.3	19.5	3.8	2.9	ND	ND	13.7	coSi	m+fC	Durango-La Plata Co. airport _terminal.
AVERAGE		0.8	0.8	0.9	6.4	17.2	35.4	16.0	3.0	3.0			16.5			
STD. DEV.		1.4	1.0	1.1	2.8	3.8	2.9	3.0	1.5	0.2			2.9			
NO. OBS.		4	4	4	4	4	4	4	4	4			4			
Eolian deposits, silty sand (E)																
35N/9W/20/1	0-19	2.5	4.0	4.9	17.8	18.4	20.9	8.3	3.3	2.8	ND	ND	17.1	coSi-vfS	m+fC	Ridge dune?
35N/9W/20/1	31-49	0.3	1.4	2.8	12.3	20.2	25.3	10.8	3.6	3.5	ND	ND	19.9	coSi	m+fC	Ridge dune?
31N/10W/19/1	A	4.8	8.9	7.9	18.3	23.9	19.8	3.9	1.2	1.1	ND	ND	10.3	vfS	m+fC	Blown from channel with similar seds.
AVERAGE		2.5	4.8	5.2	16.1	20.8	22.0	7.6	2.7	2.4			15.8			
STD. DEV.		2.2	3.8	2.6	3.4	2.8	2.9	3.5	1.3	1.2			4.9			
NO. OBS.		3	3	3	3	3	3	3	3	3			3			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 5-R STATISTICAL MEASURES FOR FINE FRACTION, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)																
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]					
		5 % (ϕ)	16 % (ϕ)	50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)		verbal	Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)		verbal		
Eolian deposits, sandy loess (E)																		
35N/9W/20/1	104-124	3.31	4.05	5.29	12.38	x ?	7.24	0.007	4.17	?	extremely	poor	0.70	?	strongly	fine-skewed		
35N/9W/20/1	249-264	2.89	3.76	5.15	9.90	?	6.27	0.013	3.07	?	very	poor	0.55	?	strongly	fine-skewed		
35N/9W/20/4	A	3.38	4.00	5.29	10.04	?	6.44	0.011	3.02	?	very	poor	0.57	?	strongly	fine-skewed		
34N/8W/29/1	A	0.87	3.26	5.28	9.19	?	5.91	0.017	2.97	?	very	poor	0.32	?	strongly	fine-skewed		
AVERAGE		2.61	3.77	5.25	10.38		6.47	0.012	3.31		very	poor	0.54		strongly	fine-skewed		
STD. DEV.		1.18	0.36	0.07	1.39		0.56	0.004	0.57				0.16					
NO. OBS.		4	4	4	4		4	4	4				4					
Eolian deposits, silty sand (E)																		
35N/9W/20/1	0-19	0.71	2.09	4.50	10.75	x ?	5.78	0.018	4.33	?	extremely	poor	0.44	?	strongly	fine-skewed		
35N/9W/20/1	31-49	2.11	3.27	5.01	11.26	x ?	6.51	0.011	4.00	?	extremely	poor	0.56	?	strongly	fine-skewed		
31N/10W/19/1	A	0.05	1.30	3.76	6.31	?	3.79	0.072	2.51	?	very	poor	0.02	?	near-	symmetrical		
AVERAGE		0.96	2.22	4.42	9.44		5.36	0.034	3.61		very	poor	0.34		strongly	fine-skewed		
STD. DEV.		1.05	0.99	0.63	2.72		1.41	0.034	0.97				0.29					
NO. OBS.		3	3	3	3		3	3	3				3					

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 6-L SUMMARY, continued

SITE	SAMPLE NO. OR DEPTH (cm)	LAND-FORM OR AGE	SETTING OR GENERAL SOIL HORIZON	WHOLE SOIL (CARBONATE-FREE) GRAVEL (vol %) [1]	GRAVEL (wt %) [2]	GRAVEL dominant size [3]	SAND (wt %)	MUD (wt %)	<2 mm FRACTION (CARBONATE-FREE) SAND (wt %)	SILT (wt %)	CLAY (wt %)	vco-mS/ total sand + silt (%)	coSi + vfS/total sand + silt (%)	TEXTURAL CLASS SCS	Folk and others (1970)	CARB-ONATE (wt % <2 mm) [4]
Sheetwash deposits containing mostly eolian material (SE)																
30N/12W/27/1B	186-215	t6b	Btk	0	0.0	s –	42.0	58.0	42.0	40.0	18.0	3.5	61.7	L	sZ	1.1
30N/12W/27/1B	235-251	t6b	BCtk	<1	0.3	s p	48.0	51.7	48.1	35.5	16.4	5.9	57.6	L	(g)M	1.2
30N/12W/27/1B	275-300	t6b	Bk	3	4.0	s p	64.0	32.0	66.6	19.8	13.6	22.3	39.8	sgfSL	(g)mS	0.9
29N/12W/5/2	0-8	t4b	A	<1	1.0	s p	50.9	48.1	51.4	33.5	15.1	2.1	69.3	L	(g)mS	6.4 (NR)
29N/12W/5/2	112-129	t4b	Kq	2	4.0	s p	64.8	31.2	67.5	19.7	12.9	15.9	42.5	fSL	(g)mS	NR
29N/12W/5/3	0-10	t4d	A	1	1.0	s p	71.7	27.3	72.4	14.8	12.8	24.4	33.3	fSL	(g)mS	3.3
30N/12W/33/1A	0-15	t5a	Ap	<1	1.0	s p	53.6	45.4	54.2	28.6	17.3	8.2	63.1	fSL+	(g)mS	5.2
29N/12W/4/1B	0-9	t3a	A	3	5.0	s p	55.3	39.7	58.2	27.7	14.1	1.9	63.0	sgvfSL	gmS	5.2
32N/10W/23/1	107-140	t2c	Kq	1	2.0	s p	54.2	43.8	55.3	31.0	13.8	10.4	48.3	sgf-vfSL	(g)mS	NR
AVERAGE				1.4	2.0		56.0	41.9	57.3	27.8	14.9	10.5	53.2			
STD. DEV.				1.0	1.8		9.2	10.2	9.9	8.3	1.9	8.5	12.6			
NO. OBS.				9	9		9	9	9	9	9	9	9			
Colluvium containing some eolian material (CE)																
35N/9W/16/3	0-6	mAC3	A	35	53.0	s cb	25.7	21.3	54.7	30.5	14.8	29.8	33.1	vgfSL	msG	1.6
34N/9W/8U/3	0-9	t7ab	A	5	8.0	s p	25.9	66.1	28.1	58.9	13.0	15.6	54.5	sgSiL	gM	0.2
35N/9W/17/1	0-6	t6a	A	10	14.0	s p	24.5	61.5	28.5	54.9	16.7	8.8	60.1	sgSiL	gM	0.2
34N/9W/8U/6	0-9	t6a	A	5	11.0	s p	36.8	52.2	41.4	49.8	8.8	24.6	55.9	sgL-	gM	0.2
30N/12W/33/1A	86-109	t5a	Bk	10	13.3	e c	54.8	31.9	63.2	24.3	12.5	35.1	38.6	sgfSL	gmS	NR
30N/10W/10/1	77-103	t1u	Kmq	25	31.1	e cp	35.3	33.6	51.3	28.2	20.6	20.3	38.4	gfSCL	msG	NR
AVERAGE				15.0	21.7		33.8	44.4	44.5	41.1	14.4	22.4	46.8			
STD. DEV.				12.2	17.3		11.6	18.1	14.4	15.1	4.0	9.5	11.4			
NO. OBS.				6	6		6	6	6	6	6	6	6			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 6-C PARTICLE SIZE OF FINE FRACTION AND GENERAL COMMENTS, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE) Weight Percent: vco sand <2000-1000µ	co sand <1000-500µ	med sand <500-250µ	fi sand <250-100µ	vfi sand <100-50µ	co silt <50-20µ	med+ fi silt <20-5µ	vfi silt <5-2µ	co clay <2-1µ	med clay <1-0.5µ	fi clay <.5µ	med+ fi clay <1µ	MODES first	MODES second	COMMENTS
Sheetwash deposits containing mostly eolian material (SE)																
30N/12W/27/1B	186-215	1.1	0.9	0.9	17.3	21.8	28.7	8.0	3.3	1.7	ND	ND	16.3	coSi	m+fC	Clay films 1npf.
30N/12W/27/1B	235-251	0.9	2.0	2.0	22.1	21.1	27.0	5.8	2.6	1.4	ND	ND	15.0	coSi	fS	Clay films v1npf.
30N/12W/27/1B	275-300	2.8	8.4	8.2	28.0	19.4	15.1	3.1	1.7	1.6	ND	ND	12.0	fS	m+fC	Clay films 3nco.
29N/12W/5/2	0-8	0.3	0.7	0.8	15.3	34.3	24.6	5.6	3.3	2.0	ND	ND	13.1	vfS	m+fC	Detrital carbonate fragments.
29N/12W/5/2	112-129	2.4	6.7	4.7	29.4	24.3	12.8	4.5	2.4	1.8	ND	ND	11.0	fS	m+fC	
29N/12W/5/3	0-10	1.1	9.1	11.1	31.6	19.5	9.5	3.6	1.7	1.0	ND	ND	11.9	fS	m+fC	Derived from local alluvium.
30N/12W/33/1A	0-15	0.8	3.0	3.0	15.6	31.9	20.4	5.0	3.2	1.9	ND	ND	15.3	vfS	m+fC	
29N/12W/4/1B	0-9	0.1	0.5	1.0	23.3	33.2	20.9	4.3	2.5	1.6	ND	ND	12.5	vfS	m+fC	
32N/10W/23/1	107-140	1.1	2.6	5.3	21.2	25.1	16.6	10.9	3.5	0.9	ND	ND	12.9	vfS	m+fC	
AVERAGE		1.2	3.8	4.1	22.6	25.6	19.5	5.6	2.7	1.5			13.3			
STD. DEV.		0.9	3.4	3.6	6.0	6.0	6.6	2.4	0.7	0.4			1.8			
NO. OBS.		9	9	9	9	9	9	9	9	9			9			
Colluvium containing some eolian material (CE)																
35N/9W/16/3	0-6	5.6	10.1	9.7	17.7	11.6	16.6	11.0	2.9	2.1	ND	ND	12.7	fS	coSi	
34N/9W/8U/3	0-9	4.7	5.1	3.8	6.9	7.6	39.8	14.8	4.3	2.9	1.2	8.9	10.1	coSi	fC	
35N/9W/17/1	0-6	2.8	2.4	2.1	6.2	15.0	35.1	14.8	5.0	4.3	ND	ND	12.4	coSi	m+fC	
34N/9W/8U/6	0-9	9.7	8.2	4.6	8.1	10.8	40.1	7.1	2.6	1.9	0.7	6.2	6.9	coSi	vcoS	
30N/12W/33/1A	86-109	2.6	12.6	15.5	16.9	15.6	18.2	4.9	1.2	1.8	ND	ND	10.7	coSi	mS*	
30N/10W/10/1	77-103	3.6	5.1	7.5	20.4	14.7	15.8	8.8	3.6	2.8	ND	ND	17.8	fS	m+fC	Secondary clay?
AVERAGE		4.8	7.2	7.2	12.7	12.6	27.6	10.2	3.3	2.6			11.7			
STD. DEV.		2.6	3.7	4.9	6.3	3.1	11.9	4.1	1.3	0.9			3.6			
NO. OBS.		6	6	6	6	6	6	6	6	6			6			

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 6-R STATISTICAL MEASURES FOR FINE FRACTION, continued

SITE	SAMPLE NO. OR DEPTH (cm)	<2 mm FRACTION (CARBONATE-FREE)																	
		CUMULATIVE WEIGHT PERCENTILES [5]					MEAN		SORTING [5]				SKEWNESS [5]						
		5 % (ϕ)	16 % (ϕ)	50 % (ϕ)	84 % (ϕ)	95 % (ϕ)	Graphic (Mz) (ϕ)	(mm)	Graphic (σG) (ϕ)	Inclusive Graphic (σI) (ϕ)		verbal	Graphic (SkG) (ϕ/ϕ)	Inclusive Graphic (SkI) (ϕ/ϕ)		verbal		
Sheetwash deposits containing mostly eolian material (SE)																			
30N/12W/27/1B	186-215	2.30	3.07	4.76	10.23	x ?	6.02	0.015	3.58	?	very	poor	0.53	?	strongly	fine-skewed			
30N/12W/27/1B	235-251	2.00	2.83	4.41	9.30	?	5.51	0.022	3.24	?	very	poor	0.51	?	strongly	fine-skewed			
30N/12W/27/1B	275-300	1.30	2.51	4.12	7.90	?	4.84	0.035	2.70	?	very	poor	0.40	?	strongly	fine-skewed			
29N/12W/5/2	0-8	2.52	x 3.27	4.29	8.71	?	5.42	0.023	2.72	?	very	poor	0.62	?	strongly	fine-skewed			
29N/12W/5/2	112-129	0.52	2.13	3.59	7.35	?	4.36	0.049	2.61	?	very	poor	0.44	?	strongly	fine-skewed			
29N/12W/5/3	0-10	0.64	1.60	3.21	6.80	?	3.87	0.068	2.60	?	very	poor	0.38	?	strongly	fine-skewed			
30N/12W/33/1A	0-15	1.49	2.89	4.19	9.70	?	5.59	0.021	3.40	?	very	poor	0.62	?	strongly	fine-skewed			
29N/12W/4/1B	0-9	2.44	3.03	4.07	7.99	?	5.03	0.031	2.48	?	very	poor	0.58	?	strongly	fine-skewed			
32N/10W/23/1	107-140	0.37	1.62	3.46	6.86	?	3.98	0.063	2.62	?	very	poor	0.30	?	strongly	fine-skewed			
AVERAGE		1.51	2.55	4.01	8.32		4.96	0.036	2.88		very	poor	0.49		strongly	fine-skewed			
STD. DEV.		0.85	0.63	0.50	1.24		0.76	0.019	0.41				0.11						
NO. OBS.		9	9	9	9		9	9	9				9						
Colluvium containing some eolian material (CE)																			
35N/9W/16/3	0-6	-0.11	x 1.03	3.90	8.20	?	4.38	0.048	3.58	?	very	poor	0.20	?		fine-skewed			
34N/9W/8U/3	0-9	0.08	2.48	5.03	7.80	?	5.10	0.029	2.66	?	very	poor	0.04	?	near-	symmetrical			
35N/9W/17/1	0-6	0.91	3.52	5.09	9.11	?	5.91	0.017	2.80	?	very	poor	0.44	?	strongly	fine-skewed			
34N/9W/8U/6	0-9	-0.87	0.81	4.59	6.13	?	3.84	0.070	2.66	?	very	poor	-0.42	?	strongly	coarse-skewed			
30N/12W/33/1A	86-109	0.33	1.04	3.20	6.55	?	3.60	0.083	2.76	?	very	poor	0.22	?		fine-skewed			
30N/10W/10/1	77-103	0.36	1.97	4.19	10.59	x ?	5.58	0.021	4.31	?	extremely	poor	0.48	?	strongly	fine-skewed			
AVERAGE		0.12	1.81	4.33	8.06		4.74	0.045	3.13		very	poor	0.16			fine-skewed			
STD. DEV.		0.59	1.06	0.72	1.65		0.94	0.027	0.68				0.33						
NO. OBS.		6	6	6	6		6	6	6				6						

TABLE A.1 PROPERTIES OF SURFICIAL DEPOSITS, continued
PART 7 EXPLANATORY NOTES

1. ND – not determined; –, absent; gravel volume percent is approximate visual estimate.
2. Method for determining gravel weight percent: a – assumed, e – estimated, s – sieved.
3. Dominant clast size: b – boulders, c – cobbles, p – pebbles; for combinations, most abundant size is given first.
4. Carbonate concentration: R? – sample may represent fresh sediment, although it could include some secondary carbonate; NR – not representative, assumed to include secondary carbonate.
5. Percentiles and related calculations: x – percentile estimated reasonably well by straight-line extrapolation, ? – percentile could not be estimated.

APPENDIX B

SOIL DESCRIPTIONS, LABORATORY DATA, AND DEVELOPMENTAL INDICES

This appendix contains descriptions, laboratory data, and index values for as many as 58 soil profiles in the lower Animas River valley. Data tables follow brief discussions of field, laboratory, calculation, and classification methods.

Field Methods

Site Selection

Sites were chosen to characterize soils on moraines and terraces, to support correlations of moraine and terrace remnants, and to show how soils vary with age and climate. These objectives required that some factors of soil formation (Jenny, 1941) be held constant among groups of profiles, while others were allowed to vary. Initially, it was assumed that moraines and terraces, as groups, would have similar parent materials and topography. Therefore, soils on a series of moraines or terraces, at the same slope positions, should vary mainly in age (forming a chronosequence). Climatic and biotic variations among sites on terminal moraines were assumed to be minor because of the moraines' limited extent, but these variations are significant among terrace sites in the study area (Chapter 2). In theory, therefore, variations in soil development for the two landform groups, age, and climate can be determined by describing three chronosequences

located on moraines at Durango, on terraces in the Durango area, and on terraces in the Farmington area. The first two chronosequences should differ mainly in parent materials and topography, whereas the second two should maximize differences in climate (with soils on single terraces forming a series of climosequences).

Sites were selected to fit this strategy as well as possible, subject to landform preservation, parent-material variations, accessibility, and mapping status. Because these limitations were significant and largely unavoidable, subsets of the profiles generally do not meet the criteria for chronosequences or climosequences, although small numbers of relatively comparable profiles may be selected from the group described. The most important limitation is the lack of parent-material uniformity among moraine or terrace sites, partly because of facies variations within morainal and fluvial sediments, but mainly because younger eolian or alluvial deposits may form part or all of the profile (Chapter 5).

At least one profile was described on most moraines and major terraces, for a total of 58 profiles. However, no descriptions were obtained for the Spring Creek moraines because sites intended to illustrate these soils were located on landforms that were later reinterpreted as terraces. Only one description each, from the middle of the study area, is available for TG1 and TG2 because of poor preservation, difficult access, and late recognition of some levels. Moraine sites were located mainly on ridge crests because soils in those positions had been studied most frequently at the time. Terrace sites were located mainly on treads, if possible near the toes of overlying alluvial fans so that profiles would penetrate to fluvial gravels. A few terrace sites were on shoulder slopes where soil tops were eroded slightly, but lower horizons were deeply exposed. Exposures included backhoe pits, hand-dug pits, gravel pits, construction excavations, and outcrops. Most profiles were 1.5 to 2.5 m deep and extended below the zones of clay and most carbonate accumulation. However, relatively few profiles reached the carbonate-free zone because of deep carbonate translocation.

Soil Description and Sampling

Standard terms and symbols (Soil Survey Staff, 1974, 1981; Guthrie and Witty, 1982) were used to describe most horizons and properties, but other terms and symbols were used because of acceptance among geologists, or were adapted for this study. Among nonstandard uses, "K" indicates a master horizon dominated by secondary carbonate (Gile and others, 1965), but its divisions are numbered sequentially from the top (Guthrie and Witty, 1982); "v" indicates vesicular structure in A horizons (Springer, 1958; Birkeland, 1974), not plinthite (Guthrie and Witty, 1982); "j" indicates juvenile or incipient development of a feature (National Soil Survey Committee of Canada, 1974; Birkeland, 1974); and an arrow (→) indicates partial conversion of one horizon to another (Birkeland, 1984). Buried soils and parent materials are emphasized because of their importance for soil genesis, even if they do not meet criteria for burial depth or contrast (Soil Survey Staff, 1981; Guthrie and Witty, 1982).

Among soil properties, carbonate accumulations are indicated by morphologic stages (Gile and others, 1966; Shroba, 1977; Machette, 1985) and described in detail. Standard terms for some properties, such as clay films (Soil Survey Staff, 1974, 1981), have been adapted to others, such as silt caps. Finally, some codes were introduced, such as "g" to indicate location for coatings on gravel (but in horizon symbols, "g" indicates gleying; Guthrie and Witty, 1982).

Bulk and clod samples were collected from most profiles. To show vertical trends, sampling intervals typically corresponded to single horizons and were less than 25 cm thick. Most thicker horizons were sampled arbitrarily in halves or thirds, except for a few thick Bk horizons that varied little with depth.

Laboratory Methods

Particle size, carbonate content, and bulk density were determined for 16 profiles selected to show the range of soil development on moraines and terraces with varying ages and parent materials. Data are given with respect to the USDA particle-size scale and reported on an oven-dry basis.

Particle Size Distribution

Gravel content, given as the weight or volume percent of whole soil, was determined by either visual estimate of volume percent, measurement of weight percent, or a combination method (e.g. Soil Conservation Service, 1972). Because of local variations in gravel content, loss of fines from the outcrop face, and possible error, initial estimates were rounded either to the nearest 0.1% (for values ≤1 %), the nearest 1 % (for values between 1 and 5 %), or the nearest 5 % (for values >5 %). Conversions between weight and volume percent are based on measured bulk densities for the fine fraction and an assumed bulk density (2.65 g/cm$^{3)}$ for gravel. The accuracy of gravel contents is estimated as plus or minus several percent for values <10 %, ± 15 % for values between 10 and 30 %, and ± 10 % for values >30 %.

Particle size distribution in the fine fraction (≤2 mm) was determined by the sieve-pipette method (e.g. Singer and Janitzky, in Singer and Janitzky, 1986), using sodium pyrophosphate for dispersant (Jackson, 1969). For greater accuracy, untreated samples typically weighed about 25 g and up to 75 g if they contained much secondary carbonate. Nearly all samples were pretreated to remove secondary carbonate and organic matter (in untreated samples, these materials were insignificant). Organic matter was digested with

H_2O_2 (Singer and Janitzky, in Singer and Janitzky, 1986) and carbonate was dissolved in one of several solutions: 1N NaOAc buffered at pH 5 (Jackson, 1969) or pH 3 (Rabenhorst and Wilding, 1984), or 0.5N HCl (Rolf Kihl, University of Colorado, written communication, 1980). Sixteen samples with remaining aggregates were treated to remove amorphous silica cement by boiling in 0.5N KOH (Torrent and others, 1980; Taylor, 1986). The initial ratio of soil to KOH solution was 1:20, but because some aggregates survived, the ratio was raised to 1:50 for most samples. After treatment, no samples contained enough clay to increase the viscosity of the settling fluid.

Error from destruction of primary carbonate grains during pretreatment is generally very small because most sediments contain only 0.5 to 2 % primary carbonate (mainly limestone; Appendix A). However, pretreatment may have a small effect on moraine sediments, which contain as much as 15 % primary carbonate.

Carbonate Content

The weight percentage of $CaCO_3$ in the fine fraction was determined by the Chittick method (Dreimanis, 1962; Machette, in Singer and Janitzky, 1986) with pressure-temperature correction factors from Machette (written communication, 1975).

Bulk Density

Bulk densities for the fine fraction were measured by the clod or core method (Soil Conservation Service, 1972), and some were estimated. The value given for most horizons is the weighted average for three clods. Most clods from very gravelly horizons were checked for grains larger than 2 mm. If traces of coarse material were present in unchecked clods, they would have a small effect on bulk density values. Core samples, taken from

soft or loose materials with low gravel content, gave densities similar to those from clods. Estimates were used where measured values were inconsistent with profile trends, or for loose, gravelly materials that could not be sampled by either method.

Calculation of Soil Development Indices

Developmental indices fall into four dimensional groups: the basic strength or concentration of a property in a single horizon; the property multiplied by horizon thickness; the sum of these products for the profile; and the sum divided by profile thickness, or weighted average per centimeter (e.g. Harden and Taylor, 1983). Indices that depend on profile thickness are reported for both the described depth and a standard depth of 250 cm (e.g. Reheis, 1987a, 1987b). A standard depth facilitates comparisons among profiles, but it selectively emphasizes different parts of the profiles by extrapolating the basal properties of shallower profiles and ignoring deep parts of thicker profiles.

Weights of Secondary Clay and Carbonate

Profile weights of secondary (pedogenic) clay and carbonate in the fine fraction were calculated from the following equation (Taylor, 1986; Machette, 1988):

$$\sum C_s = (C_p - C_i)/100 \times \rho_p \times D_p \times (1 - \%V_{gp}/100)$$, where:

C_s = weight of secondary constituent in fine fraction, in g/cm^2-profile

C_p = present concentation of constituent in fine fraction, in weight percent

C_i = initial concentration of constituent in fine fraction, in weight percent

ρ_p = present bulk density of fine fraction, in g/cm^3

D_p = present horizon thickness, in cm

V_{gp} = present gravel content of horizon, in volume percent

and $\sum$ indicates summation of both positive and negative values for all horizons in a profile. This approach is a simplification because horizon thickness, density, and gravel content may all change during accumulation of secondary clay and carbonate, particularly in K horizons (Machette, 1985).

Initial (parent-material) concentrations of clay and carbonate were estimated from values for relatively fresh sediments (Appendix A) and from depth trends of clay and carbonate in each profile. For example, if depth trends and comparison with fresh sediments suggested that basal horizons contained little or no secondary clay, the basal concentration was used as the initial value for other horizons with the same parent material. If the basal horizons appeared to contain secondary clay, an average value for fresh sediment was used as the initial concentration. For parent materials at near-surface and intermediate profile positions, averages for fresh sediments were used more widely because few of these horizons appeared free of secondary clay. Initial carbonate concentrations in fresh sediment vary less than initial clay concentrations (Appendix A). Due to deep translocation of carbonate, values for fresh sediment were used in most cases. Alternate calculations of secondary carbonate are given for soils formed in diamicton, which may have higher initial concentrations of carbonate than other sediments. Calculated weights of secondary carbonate are minima for most profiles because the profiles do not reach the base of carbonate accumulation and because carbonate coatings on gravel are not included.

Harden Indices

Soil development indices based on field descriptions were introduced by Harden (1982) and modified by Harden and Taylor (1983) and Birkeland and others (1990).

Calculations are based on standard procedures except as noted. Some changes (for example, in total texture and clay films) result in higher quantified values or in normalized values that exceed the original range from 0 to 1. However, Birkeland and others (1990) considered higher values acceptable. Point changes suggested by Birkeland and others (1990) were not used because most calculations were complete when their paper appeared.

Color Properties. Rubification, paling, melanization, and lightening were calculated by standard methods, but may display unusual vertical trends because of difficulties in assigning logical parent-material colors, especially for colluvial or mixed sediments in which primary colors may vary with depth. While I could have adjusted parent-material colors to increase the values of some color properties, and to reduce them for others, I rejected this approach as too subjective, possibly unrealistic, and very time-consuming. In using uniform parent-material colors for each sediment type, and in allowing several color properties in a horizon, I assumed that manipulation of parent-material colors would not greatly change the total points per horizon or per profile. All color properties reflect processes that could occur in these soils, but possibly not the processes intended. For example, Birkeland and others (1990) proposed that melanization points be assigned only above 1 m to indicate near-surface organic matter. In these soils, the melanization index may also reflect deeper organs, buried surface horizons, or clay accumulation in light-colored materials.

Standard color indices are based on average colors for each horizon. Multiple colors for horizons with varying carbonate content were combined as follows:

Carbonate Stage	Weighting Factor (%)	
	Darker Color	Lighter Color
I	100	0
II-	90	10
II	30	70
II+	70	30
III	0	100

Mottling is rare, so Kneupfer's (1988) mottling index was not used.

Total Texture. Total texture combines points for changes in textural class, stickiness, and plasticity (Harden, 1982). The standard scoring for textural class is 10 points for each class boundary crossed toward clay on the soil textural triangle. However, I assigned 10 points for each boundary crossed toward either clay or silt, because both were affected by translocation or mixing in some soils.

Consistence. Consistence was calculated for either dry or moist conditions, depending on the state of the soil when described.

Clay Films. Scoring for clay films was modified to address other locations and very thick films, as shown below (changes are marked with asterisks and abbreviations are defined in Table B.6 below):

Thickness	vn	n	mk	k (<3 mm)*	vk (≥3 mm) *
Location	po	br	co pf* g, gt*		
Points	10	20	30	40*	50*

Instead of one primary and one secondary class (Harden, 1982; Harden and Taylor, 1983), I used one primary and two secondary classes to include more locations for films.

Structure. Different point values were used for platy structure in some horizons. Harden (1982) and Harden and Taylor (1983) treated all platy structure as weak (5 points), but I gave it 20 points in Bk and K horizons where it indicates stronger development.

Carbonate. A new carbonate index was developed because previous indices are insensitive to some carbonate accumulations or do not account for the effect of gravel on carbonate morphology. Previous indices include the sum of paling and lightening (Reheis,

1987b); the sum of paling and lightening, multiplied by carbonate stage (Sowers and others, 1988; Birkeland and others, 1990); and the sum of stage in the matrix, stage on clasts, and effervescence (Manley, in Ostenaa and others, 1990). In Animas valley soils, paling and lightening may have zero or very low values for carbonate accumulations in light-colored parent materials. As in other areas, variations in gravel content affect other measures of carbonate accumulation such as effervescence and stage. A new carbonate index was developed by combining selected carbonate indicators (paling, lightening, stage, and effervescence) in various ways and then comparing the results to measured carbonate concentration in 187 horizons with carbonate accumulations up to stage IV. The following combination yielded the highest correlation coefficient ($r = 0.84$; $r^2 = 0.71$) between a proposed index and carbonate content (as expressed by its weight percent in the fine fraction):

$X_{cn} = \{[(X_{cl}/80 + X_{cp}/60) \times X_e/50 + X_s/60] \times [1-V_g/100]\}/2.3$, where:

X_{cn} = carbonate index, normalized

X_s = points for carbonate stage (Sowers and others, 1988)

60 = maximum possible points for carbonate stage (Sowers and others, 1988)

X_{cl} = points for color lightening (Harden and Taylor, 1983)

80 = maximum possible points for color lightening (Harden and Taylor, 1983)

X_{cp} = points for color paling (Harden and Taylor, 1983)

60 = maximum possible points for color paling (Harden and Taylor, 1983)

X_e = points for effervescence

50 = maximum possible points for effervescence

V_g = volume percent of gravel in whole soil

2.3 = maximum index value in Animas valley soils

Points for carbonate stage and effervescence were assigned as follows (stage assignments follow Sowers and others, 1988):

Stage	I	II	III	IV	V	VI
Effervescence	none	slight	mod.	strong	violent	
Points	10	20	30	40	50	60

In this index, normalized paling is added to normalized lightening, the sum is multiplied by normalized effervescence, normalized stage is added, and the result is adjusted to the fractional volume of fines. The index differs from Harden property indices in several ways: it combines several properties; it is optimized with respect to laboratory data; it is adjusted to the volume of fines, as suggested by Machette (1985); and points for each property are normalized before they are combined. The maximum possible value of this carbonate index is 3.0.

Saprolization. Points were assigned for reduction of gravel content through saprolization; 10 points were given for each reduction from very gravelly, to gravelly, to slightly gravelly, to nongravelly, for a maximum of 30 points (used as the quotient for normalization). This index reflects strong weathering in a few profiles. Less intense weathering was not recorded, as needed for a more comprehensive index of clast weathering (Kneupfer, 1988).

Soil Classification

Many soils were classified to the subgroup level according to Soil Survey Staff (1975). Because classification is a minor aspect of this study, these assignments were not updated to reflect recent changes for Aridisols (Soil Survey Staff, 1994, 1997).

Data Tables

In subsequent tables, the soils are ordered first by age (youngest to oldest), then by landform (moraines and terraces), and finally by location (north to south). The first tables summarize soil sites by landform and area (Table B.1) and give site locations and conditions for soils in Colorado (Tables B.2) and New Mexico (Table B.3). Site locations are also shown on Plates 1 and 2.

Coded field descriptions for all soils are presented in Tables B.4 (Colorado) and B.5 (New Mexico). Because of the large number of soil properties, both tables are three pages wide. Each group of left (L), center (C), and right (R) pages, respectively covering basic field properties, other field properties, and inferred parent material properties, is bound sequentially so that all information for each soil is adjacent. Table B.6 explains the descriptive codes.

Laboratory data for 16 selected profiles, including particle size distribution, carbonate content, and bulk density, are given in Table B.7. Based on this data and inferred parent-material properties (also in Table B.7), Table B.8 shows calculated weights of secondary clay and carbonate in these profiles.

Soil development indices based on descriptive data, including the horizon index, profile development index, weighted profile development index, and related single-property

indices (Harden, 1982; Harden and Taylor, 1983) are summarized for all 58 profiles in Table B.9.

TABLE B.1 SUMMARY OF SOIL SITES BY LANDFORM AND AREA

LAND-FORM [1]	AREA: BAKERS BRIDGE		DURANGO-FLORIDA MESA		BONDAD-CEDAR HILL		FLORA VISTA-FARMINGTON	
	PROFILE NUMBER [2,3]	DATA TYPES [3,4]	PROFILE NUMBER [2,3]	DATA TYPES [3,4]	PROFILE NUMBER [2,3]	DATA TYPES [3,4]	PROFILE NUMBER [2,3]	DATA TYPES [3,4]
flood plain	–		**CO1**	D,S,L	–		NM1	D,S
t8u	–		–		–		NM2	D,S
mBB	CO2	D,S						
mAC3			CO3	D,S				
			CO4	D,S,L				
t7c			CO5	D,S				
mAC2			CO6	D,S	t7u NM5	D,S	t7u NM3	D
			CO7	D,S			**NM4**	D,S,L
t7b			CO8	D	CO10	D		
			CO9	D				
t7ab			**CO11**	D,S,L	CO13	D		
			CO12	D	CO14	D		
					CO15	D		
t7a			CO16	D,S	absent?		absent?	
			CO17	D				
mSC2			–					
t6b			CO18	D,S	CO22	D	**NM7**	D,S,L
			CO19	D	NM6	D,S		
			CO20	D,S				
			CO21	D				
mSC1			–					
t6a			**CO23**	D,S,L	mostly absent		NM8	D
			CO24	D,S				
			CO25	D,S,L				
mD2			**CO26**	D,S,L				
			CO27	D,S				
t5e			**CO28**	D,S,L	NM9	D		
			CO29	D,S				
t5d			–					
t5c			**CO30**	D,S,L				
t5b			–					
mD1			CO31	D,S				
			CO32	D,S				
t5a			CO33	D,S	–		**NM10**	D,S,L
							NM11	D,S
t4e					–		NM12	D,S
t4d			–		–		NM13	D,S
t4b			**CO34**	D,S,L	–		**NM14**	D,S,L
							NM15	D
t4a			CO35	D	**NM16**	D,S,L		
			CO36	D,S				
t3b							NM17	D,S
t3a							NM18	D,S
							NM19	D,S
t2l					–		–	
t2h					–		–	
t2g					–			
t2f					–			
t2e					–			
t2d					–			
t2c					**NM20**	D,S,L		
t2b					–			
t2a					–			
t1u					**NM21**	D,S,L		
tbt			**CO37**	D,S,L				

1. Landform symbols from Plate 1.
2. Boldface emphasizes soil profiles with lab data and calculated weights of secondary clay and carbonate. Dashes (–) indicate no description done, but observations made in some areas.
3. Shading indicates areas where landform is absent because of nondeposition or erosion.
4. D, description and developmental-index calculations; S, sampled; L, lab data and calculated secondary

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					flood plain						
CO1 34N/9W/8U/1 (lab data)	FO/FC/FCP	179 1	yes; no	mesic, aridic to ustic	apple trees, grasses; orchard	backhoe pit	Aridic Argiustoll	Sycle	1925 6310	SW/4 NW/4 SW/4 SE/4 Sec 8U T34N R9W	Loma Linda (1968)
					mBB crest ("Bakers Bridge moraine")						
CO2 37N/9W/24/1 (sampled)	CE/BBM	51 1	yes; no	frigid, ustic	ponderosa, oak scrub; fallow	hand-dug pit	--	Shawa Variant & Valto	2138 7010	NE/4 NW/4 NE/4 NW/4 Sec 24 T37N R9W	Hermosa (1963)
					mAC3 crest (Animas City 3 moraine)						
CO3 35N/9W/9/1 (sampled)	CE/TD	296 1	yes; yes?	mesic, aridic to ustic	sagebrush, pinyon, shrubs; fallow	road cut	Aridic Haplustoll	Haploborolls-rubble land complex	2019 6620	SE/4 SE/4 SW/4 SW/4 Sec 9 T35N R9W	Durango East (1963)
CO4 35N/9W/16/3 (lab data)	CE/FCP	239 1	yes; yes?	mesic, aridic to ustic	sagebrush, grasses, shrubs; fallow	road cut	Aridic Argiustoll	Torriorthents & Haplargids	2016 6610	SW/4 NE/4 NW/4 SW/4 Sec 16 T35N R9W	Durango East (1963)
					t7c (graded to Animas City 3 moraine?)						
CO5 35N/9W/8U/2 (sampled)	CE/FOU?/ FCP	280 1	yes; yes?	mesic, aridic to ustic	weeds, grasses	backhoe pit	Aridic Argiustoll	Torriorthents & Haplargids	1928 6320	SE/4 NE/4 SE/4 SW/4 Sec 8U T34N R9W	Loma Linda (1968)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					mAC2 crest (Animas City 2 moraine)						
CO6 35N/9W/16/1A (sampled)	TD	128 1	yes; no	mesic, aridic to ustic	shrubs, grasses, sagebrush; fallow	hand-dug pit	Aridic Haplustoll	Torriorthents & Haplargids	2030 6655	SW/4 NE/4 NW/4 SE/4 Sec 16 T35N R9W	Durango East (1963)
CO7 35N/9W/16/1B (sampled)	CE?/TD	50 1	yes; no	mesic, aridic to ustic	shrubs, grasses, sagebrush; fallow	hand-dug pit	Aridic Haplustoll	Torriorthents & Haplargids	2028 6650	SW/4 NE/4 NW/4 SE/4 Sec 16 T35N R9W	Durango East (1963)
					t7b (graded to Animas City 2 moraine)						
CO8 35N/9W/29/3	CE+FO/FCP	146 1	yes; no	mesic, aridic to ustic	weeds; parking lot	backhoe pit	Aridic Argiustoll	Harlan	1989 6520	NW/4 NE/4 SW/4 NW/4 Sec 29 T35N R9W	Durango West (1963)
CO9 34N/10W/36/3	CE/FO?/FCP	207 1	yes; yes?	mesic, aridic to ustic	sagebrush, weeds; grazing	road cut	Ustollic Haplargid	Agua Fria	1894 6210	SW/4 NW/4 SW/4 NE/4 Sec 36 T34N R10W	Basin Mountain (1968)
CO10 33N/9W/31/3	CE/FCP	230 1	yes; yes?	mesic, aridic to ustic	sagebrush; fallow	outcrop	–	Sedillo	1845 6050	NE/4 SW/4 NE/4 SW/4 Sec 31 T33N R9W	Bondad Hill (1968)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					t7ab (graded to Animas City 2 or 1 moraine)						
CO11 34N/9W/8U/3 (lab data)	CE+FO?/ FCP	238 1	yes; yes?	mesic, aridic to ustic	sagebrush, pinyon; grazing	backhoe pit	Ustollic Haplargid	Nehar	1937 6350	SW/4 NW/4 NW/4 SE/4 Sec 8U T34N R9W	Loma Linda (1968)
CO12 34N/10W/36/2	CE+FO?/ FCP	148 1	yes; yes?	mesic, aridic to ustic	sagebrush; grazing	septic tank excavation	Ustollic Haplargid	Agua Fria	1903 6240	SW/4 SE/4 SW/4 NE/4 Sec 36 T34N R10W	Basin Mountain (1968)
CO13 33N/9W/31/5	CE+FO?/ FC	106 1	yes; no	mesic, aridic to ustic	sagebrush; fallow	hand-dug pit	-- Haplargid	Sedillo	1848 6060	SE/4 NE/4 NE/4 SW/4 Sec 31 T33N R9W	Bondad Hill (1968)
CO14 32N/10W/1/1	CE/FC	159 1	yes; no	mesic, aridic to ustic	weeds; hayfield, drilling pad	gravel pit	Aridic(?) Haplargid	Nehar	1848 6060	NW/4 NW/4 SE/4 NE/4 Sec 1 T32N R10W	Long Mountain (1968)
CO15 32N/10W/12/1	A/FO/CE?/ FC	491 2	yes; yes	mesic, aridic to ustic	sagebrush, few pinyon & juniper; grazing	outcrop	--	Torriorthents & Haplargids	1836 6020	NW/4 NE/4 SE/4 SE/4 Sec 12 T32N R10W	Long Mountain (1968)
					t7a (graded to Animas City 1 moraine)						
CO16 35N/9W/16/7 (sampled)	CE/FCP	179 1	yes; yes?	mesic, aridic to ustic	weeds; vacant lot	foundation excavation	--	Sedillo	2019 6620	NW/4 SE/4 SE/4 SW/4 Sec 16 T35N R9W	Durango East (1963)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
t7a (graded to Animas City 1 moraine), continued											
CO17 35N/9W/32/3	CE+FO+A?/ FCP	420 1	yes; yes	mesic, aridic to ustic	weeds; fallow	road cut	Typic Argiustoll	Harlan	1989 6520	SW/4 NE/4 NE/4 NW/4 Sec 32 T35N R9W	Durango West (1963)
t6b (Richmond, 1965, interpreted as Spring Creek 2 moraine of this report)											
CO18 35N/9W/17/2 (sampled)	CE/FCP	256 1	yes; yes?	mesic, aridic to ustic	rabbitbush, weeds, sagebrush; fallow	backhoe pit	Udic or Typic Argiustoll	Torriorthents & Haplargids	2025 6640	SW/4 NW/4 SE/4 SW/4 Sec 17 T35N R9W	Durango West (1963)
t6b (graded to SC2 moraine)											
CO19 35N/9W/30/1	CE/FCP	264 1	yes; yes?	mesic, aridic to ustic	weeds, sagebrush; fallow	road cut	Ustollic Haplargid	Umbarg	2037 6680	SE/4 SW/4 NE/4 NE/4 Sec 30 T35N R9W	Durango West (1963)
CO20 35N/9W/8U/4A (sampled)	CE/FO?/FCP	153 1	yes; yes	mesic, ustic to aridic	sagebrush, pinyon; grazing	backhoe pit	Aridic Haplargid	Sedillo	1949 6390	NE/4 SW/4 NE/4 SW/4 Sec 8U T34N R9W	Loma Linda (1968)
CO21 34N/9W/31/1	CE/FO?/FC	266 1	yes; no	mesic, ustic to aridic	sagebrush; railroad right-of-way	road cut	Aridic Argiustoll	Torriorthents & Haplargids	1940 6360	NW/4 NW/4 SW/4 SW/4 Sec 31 T34N R9W	Loma Linda (1968)
CO22 33N/9W/31/6	CE/FO?/FC	65 1	yes; no	mesic, aridic to ustic	sagebrush; grazing	hand-dug pit	Aridic Haplustoll	Torriorthents & Haplargids	1827 5990	SW/4 NE/4 NW/4 SE/4 Sec 31 T33N R9W	Bondad Hill (1968)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					t6 (Richmond, 1965, interpreted as Spring Creek 1 moraine of this report)						
CO23 35N/9W/17/1 (lab data)	CE/FCP	182 1	yes; yes?	mesic, aridic to ustic	sagebrush, oak, pinyon, ponderosa; fallow	hand-dug pit	Typic Argiustoll	Torriorthents & Haplargids	2040 6690	NW/4 SW/4 SW/4 SW/4 Sec 17 T35N R9W	Durango West (1963)
					t6a						
CO24 34N/9W/8U/5 (sampled)	CE/FCP	254 1	yes; yes?	mesic, ustic to aridic	sagebrush, pinyon; grazing	backhoe pit	Aridic Argiustoll	Sedillo	1958 6420	NE/4 NW/4 NE/4 SW/4 Sec 8U T34N R9W	Loma Linda (1968)
CO25 34N/9W/8U/6 (lab data)	CE/FCP	250 1	yes; yes?	mesic, ustic to aridic	sagebrush, pinyon; grazing	backhoe pit	Aridic Arguistoll	Sedillo	1964 6440	NW/4 NW/4 NE/4 SW/4 Sec 8& T34N R9W	Loma Linda (1968)
					mD2 crest (Durango 2 moraine)						
CO26 35N/9W/15/2 (lab data)	TD	262 1	yes; yes?	mesic, ustic to aridic	sagebrush, shrubs, pinyon; grazing	backhoe pit	Aridic Argiustoll	Falfa	2147 7040	NW/4 SW/4 SW/4 SW/4 Sec 15 T35N R9W	Durango East (1963)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					mD2 crest (Durango 2 moraine), continued						
CO27 35N/9W/15/3 (sampled)	E	259 4	yes; yes?	mesic, ustic to aridic	sagebrush, shrubs, pinyon; grazing	backhoe pit	Aridic Argiustoll	Falfa	2150 7050	SE/4 NW/4 SW/4 SW/4 Sec 15 T35N R9W	Durango East (1963)
					t5e (graded to Durango 2 moraine)						
CO28 34N/9W/7U/1 (lab data)	E/CE/FCP?/ FC	260 3	yes?; no	mesic, ustic to aridic	sagebrush, weeds; fallow	backhoe pit	Typic(?) Haplargid	Falfa	2022 6630	NE/4 NE/4 SE/4 SW/4 Sec 7U T34N R9W	Loma Linda (1968)
CO29 34N/9W/30/1 (sampled)	A/E/CE?/ FCP	384 3	yes?; no	mesic, ustic to aridic	wheat; farming	mud pit for gas well	Aridic Argiustoll	Falfa	2001 6560	NE/4 SE/4 NW/4 SE/4 Sec 30 T34N R9W	Loma Linda (1968)
					t5c (graded to Durango 2 moraine)						
CO30 35N/9W/20/1 (lab data)	E/CE/FCP	645 5	yes; yes?	mesic, ustic to aridic	shrubs; viewpoint	outcrop	Aridic Argiustoll	Falfa	2098 6880	NW/4 SE/4 SW/4 SE/4 Sec 20 T35N R9W	Durango East (1963)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					mD1 crest (Durango 1 moraine)						
CO31 35N/9W/21/1 (sampled)	E/TD	230 1	yes; yes	mesic, ustic to aridic	oak scrub; grazing	sewer trench	--	Falfa	2129 6980	SE/4 NW/4 SE/4 NE/4 Sec 21 T35N R9W	Durango East (1963)
					mD1 backslope (Durango 1 moraine)						
CO32 35N/9W/21/2 (sampled)	E/CE/FCP	378 1	yes; no	mesic, ustic to aridic	oak scrub; grazing	sewer trench	--	Torriorthents & Haplargids	2105 6900	SW/4 NE/4 NW/4 SE/4 Sec 21 T35N R9W	Durango East (1963)
					t5a						
CO33 34N/9W/7U/2 (sampled)	E/CE/FO/FCP	486 2-3	yes; yes	mesic, ustic to aridic	juniper, pinyon, sagebrush; fallow	gravel pit	Typic Argiustoll	Falfa	2050 6720	SW/4 SE/4 NW/4 SW/4 Sec 7U T34N R9W	Loma Linda (1968)
					t4b						
CO34 34N/9W/29/1 (lab data)	E/A/FCP/FC	317 1 (welded)	yes; yes	mesic, ustic to aridic	pinyon, juniper; fallow	gravel pit	--	Falfa	2040 6690	NE/4 SE/4 SW/4 SE/4 Sec 29 T34N R9W	Loma Linda (1968)

TABLE B.2 SITE DATA FOR SOIL PROFILES IN COLORADO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					t4a						
CO35 34N/8W/7U/2	E	343 4	no; no	mesic, ustic to aridic	grasses; farmyard	foundation excavation	–	Falfa	2083 6830	SW/4 SW/4 SE/4 SW/4 Sec 7U T34N R8W	Loma Linda (1968)
CO36 34N/9W/20/1 (sampled)	CE/FCP	160 1 (welded?)	yes; yes	mesic, ustic to aridic	sagebrush, grasses, pinyon; highway right-of-way	roadcut	–	Falfa	2111 6920	SE/4 SE/4 SE/4 SE/4 Sec 20 T34N R9W	Loma Linda (1968)
					tbt (Bridgetimber Gravel, La Plata River)						
CO37 34N/11W/25/1 (lab data)	CE/FC	260 1- 2 (welded?)	no? yes (truncated?)	frigid, ustic	ponderosa, oak, grasses; grazing	backhoe pit	Mollic Eutroboralf	Pinata	2532 8300	NW/4 SE/4 NE/4 SW/4 Sec 25 T34N R11W	Basin Mountain (1968)

1. Parent-material abbreviations simplified from Table B.4 and defined in Table B.6.

TABLE B.3 SITE DATA FOR SOIL PROFILES IN NEW MEXICO

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					flood plain (San Juan River)						
NM1 29N/13W/17/1 (sampled)	FO	82 2	yes; yes	mesic, aridic	phreatophytes; fallow	foundation excavation	--	Werlog	1598 5240	SE/4 NW/4 SE/4 SE/4 Sec 17 T29N R13W	Farmington South (1965)
					t8u						
NM2 29N/13W/21/1A (sampled)	FO/FC	136 1	yes; yes	mesic, typic aridic	phreatophytes; *near irrigation ditch*	gravel pit	--	Fruitland	1612 5285	NE/4 NW/4 SE/4 NE/4 Sec 21 T29N R13W	Farmington South (1965)
					t7u (ordered by increasing height within local sequence)						
NM3 29N/13W/16/1	FO/FC	123 2	yes; yes?	mesic, typic aridic	cottonwoods, grasses; house yard	roadcut	--	Blackston	1613 5290	NE/4 SE/4 NW/4 SE/4 Sec 16 T29N R13W	Farmington South (1965)
NM4 29N/13W/21/1B (lab data)	FO/FC	210 1	yes; yes?	mesic, typic aridic	weeds; *near irrigation ditch*	gravel pit	--	Garland	1617 5300	SW/4 NE/4 SE/4 NE/4 Sec 21 T29N R13W	Farmington South (1965)
NM5 32N/10W/33/2 (sampled)	FO/FC	99 1	yes; no	mesic, aridic to ustic	weeds; house yard	septic leach field ditch	Aridic(?) Haplargid	Garland	1790 5870	SW/4 NE/4 SW/4 SE/4 Sec 33 T32N R10W	Cedar Hill (1985)

TABLE B.3 SITE DATA FOR SOIL PROFILES IN NEW MEXICO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
						t6b					
NM6 32N/10W/22/1 (sampled)	CE/FC	131 1	yes; yes?	mesic, aridic to ustic	sagebrush; grazing	hand-dug pit	Aridic? Haplargid	Haplargids, Blackston, Torriorthents complex	1818 5960	NE/4 SE/4 SW/4 SW/4 Sec 22 T32N R10W	Mount Nebo (1985)
NM7 30N/12W/27/1B (lab data)	SE/A/FO/FC	673 3-5	yes; yes	mesic, typic aridic	weeds; right-of- way	road cut	--	Avalon	1699 5570	SW/4 SW/4 SE/4 NE/4 Sec 27 T30N R12W	Flora Vista (1963)
						t6a					
NM8 30N/11W/5/1	A+CE?/FC	200 1	yes; yes	mesic, typic aridic	sagebrush, grasses; fallow	outcrop	--	Haplargids, Blackston, Torriorthents complex	1739 5700	NE/4 SW/4 SE/4 SE/4 Sec 5 T30N R11W	Flora Vista (1963)
						t5e					
NM9 32N/10W/33/3	SE/FO/FC	281 2	yes; yes	mesic, typic aridic	grasses, juniper	outcrop	--	Doak	1832 6005	NW/4 SE/4 NW/4 NE/4 Sec 33 T32N R10W	Cedar Hill (1985)

TABLE B.3 SITE DATA FOR SOIL PROFILES IN NEW MEXICO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
						t5a					
NM10 30N/12W/33/1A (lab data)	SE/CE/FC	191 2	yes; yes?	mesic, typic aridic	weeds, grasses; hayfield	septic tank excavation	--	Avalon	1702 5580	NE/4 NW/4 NE/4 NE/4 Sec 33 T30N R12W	Flora Vista (1963)
NM11 30N/12W/33/1B (sampled)	SE/CE?/FC	68 1	no?; no (variation of NM10)	mesic, typic aridic	sagebrush; grazing	hand-dug pit	--	Blackston	1702 5580	NE/4 NW/4 NE/4 NE/4 Sec 33 T30N R12W	Flora Vista (1963)
						t4e					
NM12 30N/12W/21/1 (sampled)	SE/A/FC	239 2	yes; yes?	mesic, typic aridic	grasses; fallow	pipeline trench	--	Blackston	1722 5645	SE/4 SW/4 SE/4 SW/4 Sec 31 T30N R12W	Flora Vista (1963)
						t4d (shoulder)					
NM13 29N/12W/5/3 (sampled)	SE/A	207 2-3	yes; yes?	mesic, typic aridic	weeds, yucca, Mormon tea, juniper; fallow	pipeline cut	--	Avalon	1723 5650	SW/4 NE/4 NE/4 NW/4 Sec 5 T29N R12W	Flora Vista (1963)

TABLE B.3 SITE DATA FOR SOIL PROFILES IN NEW MEXICO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
						t4b					
NM14 30N/12W/34/1	E/SE/FC	161 2	yes; yes?	mesic, typic aridic	grasses; grazing	backhoe pit	--	Blackston	1745 5720	SW/4 SW/4 NE/4 NW/4 Sec 34 T30N R12W	Flora Vista (1963)
NM15 29N/12W/5/2 (lab data)	SE/CE/FC	263 3	yes; yes?	mesic, typic aridic	grasses; grazing	backhoe pit	--	Avalon	1735 5690	SE/4 SE/4 NW/4 NE/4 Sec 5 T29N R12 W	Flora Vista (1963)
						t4a					
NM16 31N/10W/10/1 (lab data)	SE/CE/A	269 1	yes; yes	mesic, ustic to aridic	sagebrush, few pinyon; house yard	septic tank excavation	Petrocalcic Paleorthid	Doak-Avalon association	1906 6250	SW/4 SE/4 NE/4 SE/4 Sec 10 T31N R10W	Mount Nebo (1985)
						t3b					
NM17 29N/12W/4/2 (sampled)	SE/CE/FC	282 2	yes; yes?	mesic, typic aridic	weeds; grazing	backhoe pit	--	Avalon	1763 5780	SE/4 SW/4 SE/4 NE/4 Sec 4 T29N R12 W	Flora Vista (1963)

TABLE B.3 SITE DATA FOR SOIL PROFILES IN NEW MEXICO, continued

PROFILE NO., SITE NO.	PARENT MATERIALS [1]	DEPTH (cm), NO. SOILS IN PROFILE	REACHES MOST CLAY & CARB.?	TEMP. & MOIST. REGIMES	RECENT VEGETATION & LAND USE	TYPE OF EXPOSURE	SOIL CLASSIFI-CATION	SOIL UNIT AS MAPPED BY SCS	ELEV-ATION (m), (ft)	LOCATION, N. MEX. BASE LINE & PRINCIPAL MERIDIAN	TOPO-GRAPHIC QUAD.
					t3a						
NM18 29N/12W/4/1B (sampled)	SE/FC	150 2	yes; no	mesic, typic aridic	weeds; grazing	backhoe trench	--	Avalon	1777 5825	SW/4 SE/4 NE/4 SE/4 Sec 4 T29N R12W	Flora Vista (1963)
					t3a (shoulder)						
NM19 29N/12W/4/1A (sampled)	SE/CE/FC	176 2-3	yes; yes?	mesic, typic aridic	weeds; grazing	backhoe pit	--	Blackston	1775 5820	SW/4 SE/4 NE/4 SE/4 Sec 4 T29N R12W	Flora Vista (1963)
					t2c						
NM20 32N/10W/23/1 (lab data)	SE/AE/E	273 3	yes; no	mesic, ustic to aridic	grasses, Mormon tea, juniper; fallow	backhoe pit	Petrocalcic Paleorthid	Twick-Silver association	2040 6690	NE/4 NW/4 SW/4 SW/4 Sec 23 T32N R10W	Mount Nebo (1985)
					t1u (shoulder)						
NM21 30N/10W/10/1 (lab data)	CE/FC	353 1	no?; yes	mesic, aridic to ustic	juniper, pinyon, sagebrush Mormon tea; fallow	outcrop	--	Twick-Silver association	2089 6850	NE/4 NE/4 SW/4 SE/4 Sec 10 T30N R10W	Turley (1985)

1. Parent-material abbreviations simplified from Table B.5 and defined in Table B.6.

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO
PART 1-L BASIC PROPERTIES

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					flood plain								
CO1	Ap	0-8	5YR 3/2	7.5YR 4/2	L	<1	2m pl-abk/ f pl-gr	so-sh	s,ps	3co	--	ve	c,s
34N/9W/8U/1													
(lab data)	BAt	8-23	5YR 3/2	6YR 4/2	L+	<1	2 co-vco pl-abk	sh	s,p	1npo,1npf	--	--	c,s
	2Bt	23-51	5YR 3/2	5YR 4/2	fSCL-	<1	1 vco pr, 2 co-vco abk	sh	vs,p	3nco,2nbr,1npo	--	ve	c,s
	2Bk1	51-95	5YR 3.5/2	5YR 5/2	L-	<1	2 vco pr	so-sh	ss,ps	--	I	em	g,w
	3Bk2	95-127	5YR 3.5/2	5YR 5/2.5	fSL	60	1-2 f-co abk	so	ss,ps	--	I+	em	c,s
	3Bk3	127-169	5YR 4/2	5YR 5/3	mSL	60	1 m abk	so-lo	ss,po-ps	--	I	e-em	g,w
	3Bk4	169-179+	5YR 4/3	5YR 5/3	coSL	60	sg	lo	ss,po-ps	--	I-	em	--
					mBB ("Bakers Bridge moraine")								
CO2	A1	0-1	10YR 3/2	10YR 4/2	f-mSL	5	sg	lo	so,po-ps	--	--	ve	a,s
37N/9W/24/1	A2	1-9	10YR 3/2	10YR 4/2	f-mSL	5	1 f gr	so	so,po-ps	--	I	es	c,s
(sampled)	2Bwk1	9-19	7.5YR 3.5/2	10YR 5/2	mLS	5	1 m sbk	so	so,po	--	I	es	c,s
	2Bwk2	19-27	10YR 4/3	10YR 6/2.5	mLS	5	1 m sbk	so	so,po	--	I	es	c,s
	2Bk	27-51+	10YR 4.5/3	10YR 6/3	mLS	5	mass	sh	so,po	--	I	es	--
					mAC3 (Animas City 3 moraine)								
CO3	A	0-7	5YR 3/2	5YR 4.5/2.5	fSL	30	sg/1 vf-m gr	lo	so,po	--	--	em	g,s
35N/9W/9/1	Bwk	7-21	5YR 3/4	5YR 4.5/3	fSL	30	sg/1 f-m sbk	lo	so-ss,po	--	I	em	c,s
(sampled)	Bk1	21-36	6YR 4/3	6YR 6/4	fSL	30	sg/1 m sbk	lo	so-ss,po	--	I	es	c,s
	Bk2	36-136	7.5YR 4/3	7.5YR 6/4	fSL	30	mass	sh	so,po	--	I	es	g,w
	2Bk3	136-216	7.5YR 4/3	7.5YR 6/4	fSL	70	mass	sh	so,po	--	I	es	g,w
	2Bk4	216-296+	7.5YR 4/3	7.5YR 6/4	fSL	70	mass	sh	so,po	--	I-	em	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 1-C OTHER PROPERTIES

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					flood plain						
CO1	Ap	0-8	3mi,3vf	3mii	–	–	–	–	ND	–	–
34N/9W/8U/1											
(lab data)	BAt	8-23	2mi	2mi,1vf	–	–	–	–	ND	–	–
	2Bt	23-51	1mi	3f-mt	–	–	–	–	ND	–	–
	2Bk1	51-95	1mi	3mii	4n mic gb, 2 sf gt	sf,d	–	–	ND	–	–
	3Bk2	95-127	–	ND	4n mic gb, 3-4n mic gt	–	–	–	ND	–	–
	3Bk3	127-169	–	ND	3n spr+mic gb,2 sf gt	sf,d	–	–	2br	–	–
	3Bk4	169-179+	–	ND	2n spr gb	–	–	–	ND	–	–
					mBB ("Bakers Bridge moraine")						
CO2	A1	0-1	3mi,2vf	ND	–	–	–	–	–	–	–
37N/9W/24/1	A2	1-9	3mi,2vf	ND	4vn mic gb	–	–	–	–	–	–
(sampled)	2Bwk1	9-19	1mi,1vf	ND	4vn mic gb,2 sf gt	–	–	–	–	–	–
	2Bwk2	19-27	1mi,1vf	ND	4vn mic gb,2 sf gt	–	–	–	–	–	–
	2Bk	27-51+	v1vf	ND	4vn mic gb,2 sf gt	–	–	–	–	–	–
					mAC3 (Animas City 3 moraine)						
CO3	A	0-7	3mi,3vf	3mii	–	–	–	–	ND	–	–
35N/9W/9/1	Bwk	7-21	3mi,3vf	3mii	4mk mic gb	–	–	–	ND	–	–
(sampled)	Bk1	21-36	2mi,2vf	ND	4mk mic gb	–	–	–	ND	–	–
	Bk2	36-136	–	ND	4n-mk mic gb	sf	–	–	ND	–	–
	2Bk3	136-216	–	ND	4n-mk mic gb	sf	–	–	ND	–	–
	2Bk4	216-296+	–	ND	4n-mk mic gb	sf	–	–	ND	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 1-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				flood plain						
CO1 34N/9W/8U/1 (lab data)	Ap	0-8	FOu	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
	BAt	8-23	FOu	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
	2Bt	23-51	FOu	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
	2Bk1	51-95	FOu	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
	3Bk2	95-127	FCu	7.5YR 4/3	7.5YR 5/3	fSL	lo	so,po-ps	cb	
	3Bk3	127-169	FCu	7.5YR 4/3	7.5YR 5/3	mSL	lo	so,po-ps	cb	
	3Bk4	169-179+	FCPu	7.5YR 4/3	7.5YR 5/3	coSL	lo	so,po-ps	cb	
				mBB ("Bakers Bridge moraine")						
CO2 37N/9W/24/1 (sampled)	A1	0-1	CEur	10YR 4.5/3	10YR 6/3	mLS	so	so,po	p	
	A2	1-9	CEur	10YR 4.5/3	10YR 6/3	mLS	so	so,po	p	
	2Bwk1	9-19	BBM	10YR 4.5/3	10YR 6/3	mLS	so	so,po	p	
	2Bwk2	19-27	BBM	10YR 4.5/3	10YR 6/3	mLS	so	so,po	p	
	2Bk	27-51+	BBM	10YR 4.5/3	10YR 6/3	mLS	so	so,po	p	
				mAC3 (Animas City 3 moraine)						
CO3 35N/9W/9/1 (sampled)	A	0-7	CEur	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	cb	
	Bwk	7-21	CEur	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	cb	
	Bk1	21-36	TDu(MDS?)	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	cb	
	Bk2	36-136	TDu(MDS?)	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	cb	
	2Bk3	136-216	TDu(CD?)	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	bc	
	2Bk4	216-296+	TDu(CD?)	7.5YR 4/3	7.5YR 6/4	fSL	so	so,po	bc	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 2-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					mAC3 (Animas City 3 moraine), continued								
CO4	A	0-6	7.5YR 3/2	7.5YR 4/3	fSL	35	1 f gr	lo	so,ps	--	--	ve	c,s
35N/9W/16/3	2BAt	6-13	7.5YR 3/3	7.5YR 4/3.5	L	70	1 m sbk	fr	s,p	3nco,3ng	--	ve	c,s
(lab data)	2Bt	13-29	7YR 3.5/3.5	7.5YR 4/4	fSCL-	75	1 m-co sbk	fr	vs,p	3mkbr,v1npf, 3ng,v1mkpf	--	--	c,w
	2BCt	29-53	7.5YR 4/4	7.5YR 4.5/4	vcoLS	80	1 f sbk - sg	lo	s,ps	3kco	l-	e	c,w-i
	2Bk1	53-95	7.5YR 4/3.5	7.5YR 5.5/4	coLS	80	mass/sg	vfr	ss,po	--	l	em	g,w
	3Bk2	95-147	7.5YR 4/3	7.5YR 6/3.5	coLS	50	mass/sg	vfr	so,po	--	l	es	c,w
	3Bk3	147-194	7.5YR 3.5/3	7.5YR 6/3	coLS	50	mass	vfr	so,po	--	l	em	c,w
	3Bk4	194-217	7.5YR 4/3	7.5YR 6.5/3	co-vcoLS	45	mass	fr	so,po	--	l-	em	a,w
	4Bk5	217-239+	7YR 4/4	7.5YR 6/3	fSL	25	mass	fi	ss,ps	--	l-	em	--
					t7c (graded to Animas City 3 moraine)								
CO5	Ap	0-10	6YR 3/3	6YR 4.5/3	SiL	1	2 f-m pl	so	ss,ps	--	--	--	c,s
34N/9W/8U/2	Bt	10-30	6YR 3/3	6YR 5/3	L+	2	1 vco pr - 1 vco pl	sh	ss,ps	1npf,1npo	--	--	c,w
(sampled)	2BCt	30-64	5YR 3.5/3	5YR 5/3	L-	40	1 vco sbk	sh	ss,ps	1npf,1npo	--	--	c,w
	3Btbk	64-113	5YR 4/3	5YR 5/4	SCL	60	3 f abk	sh	s,ps	3kpf,3kg	l+	e	g,w
	3BCk	113-134	5YR 3/4	5YR 5/4	SL	70	1 f-m abk	lo-so	s,ps	--	l+	e	c,w
	3Bk1	134-198	5YR 4/2.5	5YR 6/3	SL	70	mass/ 1 f-m abk	so	ss,ps	--	l+	es	g,i
	3Bk2	198-250	5YR 4/3	5YR 5/3	SL	70	mass/ 0-1 m-co abk	lo-so	ss,po-ps	--	l-	es	c,i
	3Bk3	250-280+	5YR 4/3	5YR 5/3	S	70	sg	lo	so,po	--	l	es	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 2-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					mAC3 (Animas City 3 moraine), continued						
CO4	A	0-6	3mi	3mii	–	–	–	–	3ng	–	–
35N/9W/16/3	2BAt	6-13	3mi	3mii	–	–	–	–	–	–	–
(lab data)	2Bt	13-29	3mi	3mii	–	–	–	–	–	c3p	–
	2BCt	29-53	3mi	3mii	4vn mic gb	–	–	–	4ngt	–	–
	2Bk1	53-95	2mi	2mii,1mit	4vn mic gb - 3 sf gb	–	–	–	2vngt	–	–
	3Bk2	95-147	1mi	3mii	4vn mic gb - 3 sf gb	sf	–	–	–	–	–
	3Bk3	147-194	–	3mii	4vn mic gb,sf gt - 4vn mic gt	vn sco,cw	–	–	–	–	–
	3Bk4	194-217	–	3mii	3 sf gb	vn sco,cw	–	–	–	–	–
	4Bk5	217-239+	–	1mit	1 sf gb	sf po	–	–	–	–	–
					t7c (graded to Animas City 3 moraine)						
CO5	Ap	0-10	3mi,3vf	2miv	–	–	–	–	ND	–	–
34N/9W/8U/2	Bt	10-30	2mi,2vf	3mit	–	–	–	–	ND	–	–
(sampled)	2BCt	30-64	2mi,2vf	3mit,3ft	2f gb	sf po	–	–	ND	–	–
	3Btbk	64-113	2mi,2vf	3mit	4n mic g	sf pf,sf po	–	–	ND	–	–
	3BCk	113-134	ND	ND	4n mic g	sf pf,sf po	–	–	ND	–	–
	3Bk1	134-198	ND	ND	4n mic gg,2 sf g	sf,d	–	–	ND	–	–
	3Bk2	198-250	ND	ND	3 sf g	dcvw	–	–	ND	–	–
	3Bk3	250-280+	ND	ND	4 n spr gb	–	–	–	ND	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 2-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
mAC3 (Animas City 3 moraine), continued										
CO4	A	0-6	CEur	7.5YR 4/3	7.5YR 6/3	fSL	lo	so,po	cb	
35N/9W/16/3	2BAt	6-13	FCPu	7.5YR 4/3	7.5YR 6/3	fSL	lo	so,po	cb	
(lab data)	2Bt	13-29	FCPu	7.5YR 4/3	7.5YR 6/3	coSL	lo	so,po	cb	
	2BCt	29-53	FCPu	7.5YR 4/3	7.5YR 6/3	coSL	lo	so,po	cb	Matrix color and texture variable.
	2Bk1	53-95	FCPu	7.5YR 4/3	7.5YR 6/3	coLS	lo	so,po	cb	Matrix color and texture variable.
	3Bk2	95-147	FCPu	7.5YR 4/3	7.5YR 6/3	coLS	lo	so,po	pc	
	3Bk3	147-194	FCPu	7.5YR 4/3	7.5YR 6/3	coLS	lo	so,po	pc	
	3Bk4	194-217	FCPu	7.5YR 4/3	7.5YR 6/3	co-vcoLS	lo	so,po	pc	
	4Bk5	217-239+	FCPu	7.5YR 4/3	7.5YR 6/3	fSL	vfr	ss,ps	pc	
t7c (graded to Animas City 3 moraine)										
CO5	Ap	0-10	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	so,ps	p	
34N/9W/8U/2	Bt	10-30	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
(sampled)	2BCt	30-64	FCPu+FOu+CEu	7.5YR 4/4	7.5YR 5/4	LS	lo	so,po	c	
	3Btbk	64-113	FCPu	7.5YR 4/3	7.5YR 3/3	LS	lo	so,po	c	
	3BCk	113-134	FCPu	7.5YR 4/3	7.5YR 3/3	LS	lo	so,po	c	
	3Bk1	134-198	FCPu	7.5YR 4/3	7.5YR 3/3	LS	lo	so,po	c	
	3Bk2	198-250	FCPu	7.5YR 4/3	7.5YR 3/3	LS	lo	so,po	c	
	3Bk3	250-280+	FCPu	7.5YR 4/3	7.5YR 3/3	S	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 3-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR		TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE		CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
			MOIST	DRY				DRY/MOIST	WET				
mAC2 (Animas City 2 moraine)													
CO6	A	0-7	7.5YR 3/2	7.5YR 4/2	SL	30	1 m sbk	vfr	so,po-ps	--	--	e	c,w
35N/9W/16/1A	Btj	7-16	7.5YR 3/3	7.5YR 4.5/3	L	30	1 f-m abk	vfr	so,po-ps	2vnco,2vng	I-	em	c,w
(sampled)	BC	16-23	7.5YR 3.5/3	7.5YR 4.5/3.5	L	35	0-1 f sbk	vfr	so-ss,ps	--	I-	em	c-a,w-i
	2Bk1	23-43	7.5YR 4/3.5	7.5YR 6/3.5	L	50	mass	so-sh	so-ss,ps	--	II-	es	d,w
	2Bk2	43-72	7.5YR 4/3.5	7.5YR 6/3.5	L/SL	60	mass	so-sh	so,po-ps	--	I+	es	g,w
	2Bk3	72-100	7.5YR 4/3.5	7.5YR 6/3.5	SL	60	1 f abk	so-lo	so,po	--	I+	es	d,w
	2Bk4	100-128+	7.5YR 4/3.5	7.5YR 6/3.5	SL	60	1-2 f-m abk	so-lo	so,po	--	I+	es	--
CO7	A	0-8	7.5YR 3/2	7.5YR 4/2	fSL	40	0-1 f sbk	vfr-lo	so,po-ps	--	I-	e	a,s
35N/9W/16/1B	Btj	8-23	5YR 3/2.5	5YR 5/3	fSL+	50	1 f-m sbk	fr	so-ss,ps	3vnco	I	em	a,w
(sampled)	BCk	23-43	5YR 3.5/3	6YR 5/3.5	fSL	60	0-1 f sbk	lo	so-ss,ps	--	I+	em	c,w
	2Bk	43-50+	7.5YR 4.5/3	7.5YR 6/3	SiL	60	0-1 f sbk	vfr	so-ss,ps	--	ND	ND	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 3-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					mAC2 (Animas City 2 moraine)						
CO6	A	0-7	3mi	3mii	–	–	–	–	–	–	–
35N/9W/16/1A	Btj	7-16	3vf	1mit	3mk mic mam cs gb	–	–	–	–	–	–
(sampled)	BC	16-23	3mi	3mii	3 mk mic mam cs gb	–	–	–	–	–	–
	2Bk1	23-43	1mi	2mit	4k mic mam cs gb,4n gt	d,sf,2% 1-2 smr	–	–	–	–	–
	2Bk2	43-72	1mi	2mit	4k mic mam cs gb,4n gt	d,sf	–	–	–	–	–
	2Bk3	72-100	–	2mii,2mit	4k mic mam cs gb, 3-4n gt	d,sf	–	–	–	–	–
	2Bk4	100-128+	–	2mii,2mit	4k mic mam cs gb,	d,sf	–	–	–	–	–
CO7	A	0-8	3mi,3vf	3mii	2n mic gb	–	–	–	–	–	–
35N/9W/16/1B	Btj	8-23	3mi,3vf	1mit	4n mic gb,1n mic gt	–	–	–	–	c3f	–
(sampled)	BCk	23-43	2mi	3mii	3-4 n-k mic mam cw gt, 0-4n mic gt	–	–	–	–	–	–
	2Bk	43-50+	2mi	1mit	ND	ND	?	?	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 3-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
					mAC2 (Animas City 2 moraine)					
CO6	A	0-7	TDu(MDS?) +Er?	7.5YR 4/3.5	7.5YR 6/3	SL	vfr	so,po	cb	
35N/9W/16/1A	Btj	7-16	TDu(MDS?)	7.5YR 4/3.5	7.5YR 6/3	L	vfr	so,po	cb	
(sampled)	BC	16-23	TDu(MDS?)	7.5YR 4/3.5	7.5YR 6/3	L	vfr	so,po	cb	
	2Bk1	23-43	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	L	so	so,po	cb	
	2Bk2	43-72	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SL	lo	so,po	cb	
	2Bk3	72-100	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SL	lo	so,po	cb	
	2Bk4	100-128+	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SL	lo	so,po	cb	
CO7	A	0-8	TDu(MDS) +Er?	7.5YR 4/3.5	7.5YR 6/3	fSL	lo	so,po	cb	Carb. on clasts partly dissolved.
35N/9W/16/1B	Btj	8-23	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SL	lo	so,po	cb	Carb. on clasts partly dissolved.
(sampled)	BCk	23-43	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SL	lo	so,po	cb	More carb. on limestone clasts.
	2Bk	43-50+	TDu(CD?)	7.5YR 4/3.5	7.5YR 6/3	SiL	vfr	so-ss,ps	cb	More carb. on limestone clasts.

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 4-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t7b (graded to Animas City 2 moraine)								
CO8	fill	+10-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	a,s
35N/9W/29/3	Bt→A	0-9	5YR 3/3	5YR 4.5/3	coSCL	25	3 vf pl	fi	s,ps	3mkg,3kpf,3kpo	–	e	c,w
	2Btk	9-51	5YR 4/4	5YR 5/4	coSC	50	2 m-c sbk	fi	vs,vp	3kgt,3mkpf, 3mkpo	l-	e	c,i
	2BCtk	51-96	5YR 4/3	5YR 5/3	coSL+	60	sg/1 m sbk	lo-so	ss,ps-p	3ngt,3mkco	l	em	g,w
	3Bk	96-146+	5YR 4/3	5YR 5/3	coSL+	90	mass/sg	lo-so	ss,ps-p	–	ll-	es	–
CO9	Av	0-5	7.5YR 4/2.5	7.5YR 5/3	fSL-	20	sg/1 f gr	so	so,po	–	–	–	a,s
34N/10W/36/3	BAt	5-12	5YR 3.5/3	5YR 4/3	SiC	20	1 vco sbk, 2 vf sbk	sh	s,vp	3br,3npf, 3npo,3ng	–	–	c,w
	2Bt1	12-32	5YR 4/3	5YR 4/4	SC	30	1 m pr,3 f abk	sh	s,vp	3br,3npf, 3n-mkg,3npo	–	–	c,w
	3Bt2	32-45	5YR 4/3	5YR 4/4	coSC	60	1 m sbk	sh	s,vp	4mkpf,4mkpo, 3mk-kg,3br	–	ve	g,w
	3BCtk	45-77	5YR 4/3	5YR 3.5/4	coSCL	70	mass/1 m sbk	so	ss,p	3nco,3nbr,3mkgt	l	em	g,i
	3Bk1	77-117	5YR 4.5/2.5	5YR 5/3	coSL+	80	mass	so	s,ps	–	ll	es	d,w
	3Bk2	117-207+	5YR 4/3	5YR 5/4	coSL+	85	sg	lo	s,ps	–	l	es	–
CO10	A	0-11	5YR 4/3	6YR 4.5/4	CL-	25	1 vco sbk,1 f gr	vfr	ss,p	3nco	–	–	c,s
33N/9W/31/3	2Btk	11-32	6YR 4.5/3	5YR 4/4	CL	50	1 m abk,2 vf abk	so	s,p	4mkpf,4mkpo, 4mkg	l-	o-ve	c,w
	2BCk1	32-51	6YR 4.5/3	5YR 5/4	coSCL	60	1 f sbk	so	s,ps	3mkco	l	ve	g,w
	2BCk2	51-67	5YR 4/3	5YR 6/4	mLS	70	sg/v1 f sbk	lo	ss,po	4nco	l	em	c,w
	2Bk1	67-115	6YR 4/2.5	7.5YR 6/3	coLS	70	sg/v1 f sbk	lo	so,po	–	ll	es	d,w
	2Bk2	115-180	7.5YR 5/2.5	7.5YR 6/2.5	coLS	70	sg	lo	so,po-ps	–	ll	es	d,w
	2Bk3	180-230+	7.5YR 5/2.5	7.5YR 6/2.5	coLS	80	sg	lo	so,po	–	l	es	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 4-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t7b (graded to Animas City 2 moraine)						
CO8	fill	+10-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
35N/9W/29/3	Bt→A	0-9	1mi	3mit	--	--	--	--	--	--	--
	2Btk	9-51	1mi	2mit	4n mic gb	sf po	--	--	--	--	--
	2BCtk	51-96	2mi	3mii	4mk mic mam cs gb, 3 sf gt	--	--	--	--	--	--
	3Bk	96-146+	--	2mii,2fi	4n mic + spr gb,	5% sm	--	--	3n-mkgt	--	--
CO9	Av	0-5	1mi	3miv, 2vfv,1fv	--	--	--	--	3mkgt	--	--
34N/10W/36/3	BAt	5-12	3mi,2vf,1m	3mii,1mit	--	--	--	--	--	--	--
	2Bt1	12-32	2mi	3mii,1mit	--	--	--	--	--	--	--
	3Bt2	32-45	1mi	3mii,2mit	--	--	--	--	--	c3f-dpf, c3f-dpo	--
	3BCtk	45-77	1mi	3mii	4n mic gb,1n mic gt	sf	--	--	--	--	--
	3Bk1	77-117	--	3mi-vfi	4n mic gb,2 sf gt - 4n mic gt	sco,10%d cvw	--	--	3ngt	--	--
	3Bk2	117-207+	--	3mi-fi	3n spr gb	--	--	--	4ngt	--	--
CO10	A	0-11	2mi,2vf	3mii	--	--	--	--	--	--	--
33N/9W/31/3	2Btk	11-32	1mi,1vf	3mii,2mit	4n mic gb,0-2 sf gt	--	--	--	--	--	--
	2BCk1	32-51	1mi	3mii,1mit	4n mic gb,0-2 sf gt	--	--	--	3ngt	--	--
	2BCk2	51-67	1mi	3mii	4n mic gb	5% cw	--	--	3ngt	--	--
	2Bk1	67-115	v1mi	3mii,3vfi	4n mic+spr gb,0-1vn gt	part cw	--	--	--	--	--
	2Bk2	115-180	--	3mii,3vfi	4n mic+spr gb,0-1vn gt	--	--	--	--	--	--
	2Bk3	180-230+	--	3mii,3vfi	4n spr br	--	--	--	--	--	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 4-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t7b (graded to Animas City 2 moraine)						
CO8	fill	+10-0	NA	7.5YR 4/3	7.5YR 5/3	coSL	lo	so,po	NA	Oil-stained.
35N/9W/29/3	Bt→A	0-9	CEur+FOu?	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cp	Oil-stained.
	2Btk	9-51	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	bc	
	2BCtk	51-96	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cb	
	3Bk	96-146+	FPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	pc	
CO9	Av	0-5	CEur	7.5YR 4/4	7.5YR 5/4	fSL-	so	so,po	c	
34N/10W/36/3	BAt	5-12	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	c	
	2Bt1	12-32	CEur+FOu?	7.5YR 4/3	7.5YR 5/3	fSL	so	so,po	c	
	3Bt2	32-45	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cb	
	3BCtk	45-77	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cb	
	3Bk1	77-117	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	
	3Bk2	117-207+	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	Carb. over clay films on clasts.
CO10	A	0-11	CEur	7.5YR 4/4	7.5YR 5/4	SiCL	so	ss,ps	c	
33N/9W/31/3	2Btk	11-32	FPu+CEur?	7.5YR 4/2.5	7.5YR 5/2.5	mSL	lo	ss,po	c	
	2BCk1	32-51	FCPu	7.5YR 4/2.5	7.5YR 5/2.5	mLS	lo	so,po	c	
	2BCk2	51-67	FCPu	7.5YR 4/2.5	7.5YR 5/2.5	mLS	lo	so,po	c	
	2Bk1	67-115	FCPu	7.5YR 4/2.5	7.5YR 5/2.5	mLS	lo	so,po	cb	
	2Bk2	115-180	FCPu	7.5YR 4/2.5	7.5YR 5/2.5	mLS	lo	so,po	c	
	2Bk3	180-230+	FCPu	7.5YR 4/2.5	7.5YR 5/2.5	mLS	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 5-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t7ab (graded to Animas City 2 or 1 moraine)													
CO11	A	0-9	6YR 3.5/3	7.5YR 6/3	SiL	5	1 f gr/1 co abk	lo-so	so,po	--	--	--	c,s
34N/9W/8U/3 (lab data)	BAt	9-28	5YR 3.5/4	5YR 4.5/4	CL-	2	1 vco pl-pr, 2 m-co sbk	so	s,p	3npf	--	--	c,w
	2Bt1	28-59	5YR 3/4	5YR 4/4	CL	20	3 m-co abk	h	vs,p	4kpf,4kg	l-	o-ve	g,w
	3Bt2	59-90	5YR 3/4	5YR 4/4	CL+	50	3 m-co abk	h	vs,p	4kpf,4kg	l-	o-ve	c,i
	3Bk1	90-152	5YR 4/3	5YR 5.5/3	vcoSL	70	mass,sg	so-h,lo	so,po	--	l	es	g,w
	3Bk2	152-238+	5YR 3.5/3	5YR 5.5/3	vcoSL	90	sg	lo-so	so,po	--	l-	es	--
CO12	A	0-10	7YR 3.5/3	7YR 5/3.5	fSL	15	1 co sbk, 0-1 f sbk	so	so,po-ps	--	--	--	c,s
34N/10W/36/2	BAt	10-18	5YR 4/3	6YR 5/3	SiCL	15	2 co sbk,3 f sbk	sh	ss,p	3co,3npf,4mkg	--	--	c,w
	2Bt1	18-34	5YR 4/3.5	5YR 4/4	C	30	1 f pr,3 f abk	vh	vs,vp	4k-mkpf,4kg	--	--	g,i
	3Bt2	34-44	5YR 4/3	5YR 4/4	coSC	60	3 m abk	h	vs,vp	4k-npf,4k-mkg	--	--	g,i
	3BCtk	44-69	5YR 4/3	5YR 4.5/5	coSCL+	65	1-2 f abk	sh	s,p	3br,1kpf,3mkg	l	e	c,i
	3Bk	69-148+	5YR 3.5/3	5YR 5.5/3	coLS	70	sg	lo	so,po	--	l	es	--
CO13	A	0-7	7.5YR 4/2	7.5YR 6/3	fSL	5	1 m sbk,1 f gr	so	ss,ps	--	--	--	c,s
33N/9W/31/5	BAt	7-16	6YR 4/3	6YR 5/3	L+	5	1 vco pl,1 f gr	so	s,p	3vnco,lvng	--	--	c,s
	Bt1	16-27	5YR 3/3.5	5YR 5/3.5	C	5	1 f pr,2 vf sbk	fr	vs,vp	3npf,3mkg	--	--	c,w
	2Bt2	27-43	5YR 3/4	5YR 4/3.5	coSC	25	3 f pr,2 f abk	fi	vs,vp	4mkpf,4mkpo, 4mkg	--	--	c,w
	3BCt	43-58	5YR 3.5/3	5YR 4/3	coSCL	50	2 m abk	fr	s,ps	4mkpf,4mkpo, 4mkg,3br	--	e	c,w
	3BCtk	58-76	5YR 3.5/3	7.5YR 5/4	LS+	60	1 f-m abk, sg	vfr	s,po-ps	3nco,3npf,3npo	l	em	c,w
	3Bk	76-106+	7.5YR 4/2.5	7.5YR 5/2.5	m-coS	70	sg	lo	so,po	--	l	es	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 5-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t7ab (graded to Animas City 2 or 1 moraine)						
CO11	A	0-9	3mi,3vf	3mi	–	–	–	–	ND	–	–
34N/9W/8U/3 (lab data)	BAt	9-28	2mi,2vf	3mi,3vf	–	–	–	–	ND	–	–
	2Bt1	28-59	3mi,3vf	3mit	2n mic g	–	–	–	ND	–	–
	3Bt2	59-90	3mi,3vf	3mit	2n mic g	–	–	–	ND	–	–
	3Bk1	90-152	ND	ND	4n mic gb,2 sf gt	cvw	–	–	ND	–	–
	3Bk2	152-238+	ND	ND	2n spr gb	cvw	–	–	ND	–	–
CO12	A	0-10	3mi	3mii	–	–	–	–	4ng	–	–
34N/10W/36/2	BAt	10-18	3mi	2mit	–	–	–	–	–	–	–
	2Bt1	18-34	2mi,2vf	2mit	–	–	–	–	–	c3dg	–
	3Bt2	34-44	2mi	1mit	–	–	–	–	–	c3fg	–
	3BCtk	44-69	–	2mii,1mit	4n mic gb	–	–	–	–	c3fg	–
	3Bk	69-148+	–	3mii	4n mic gb	–	–	–	2vngt	–	–
CO13	A	0-7	3mi,3vf	3mii,3vfi	–	–	–	–	–	–	–
33N/9W/31/5	BAt	7-16	ND	3mii	–	–	–	–	–	–	–
	Bt1	16-27	ND	2mii,2mit	–	–	–	–	–	c3vfpf	–
	2Bt2	27-43	ND	2mit	–	–	–	–	–	c3f-dpf, c3fpo,c3fg	–
	3BCt	43-58	ND	3mii	v1 sf gb	–	–	–	–	m3ppf,m3ppo, m3pg	–
	3BCtk	58-76	ND	3mii,1mit	4n mic gb,2 sf gt	–	–	–	3ngt	–	–
	3Bk	76-106+	ND	3mii	4vn mic+spr gb,v1 sf gt	–	–	–	2nco,3ngt	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 5-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t7ab (graded to Animas City 2 or 1 moraine)						
CO11	A	0-9	CEur+FOu?	7.5YR 4/4	7.5YR 5/4	SiL	lo-so	so,po	p	
34N/9W/8U/3 (lab data)	BAt	9-28	CEur+FOu?	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2Bt1	28-59	CEur+FOu?	7.5YR 4/3	7.5YR 5/3	L	so	so,po	pc	
	3Bt2	59-90	FCPu	7.5YR 4/3	7.5YR 5/3	coSL	lo	so,po	cb	
	3Bk1	90-152	FCPu	7.5YR 4/3	7.5YR 5/3	vcoSL	lo	so,po	cb	
	3Bk2	152-238+	FCPu	7.5YR 4/3	7.5YR 5/3	vcoSL	lo	so,po	cb	
CO12	A	0-10	CEur	7.5YR 4/4	7.5YR 5/4	fSL	so	so,po-ps	p	
34N/10W/36/2	BAt	10-18	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2Bt1	18-34	CEur+FOu?	7.5YR 4/3	7.5YR 5/4	SL	lo	ss,po	p	
	3Bt2	34-44	FCPu	7.5YR 3.5/3	7.5YR 5/3	coLS	lo	so,po	c	
	3BCtk	44-69	FCPu	7.5YR 3.5/3	7.5YR 5/3	coLS	lo	so,po	c	
	3Bk	69-148+	FCPu	7.5YR 3.5/3	7.5YR 5/3	coLS	lo	so,po	c	
CO13	A	0-7	CEur	7.5YR 4/4	7.5YR 5/4	fSL	so	ss,ps	p	
33N/9W/31/5	BAt	7-16	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	Bt1	16-27	CEur	7.5YR 4/4	7.5YR 5/4	L	vfr	ss,ps	p	
	2Bt2	27-43	CEur+FOu?	7.5YR 4/2.5	7.5YR 5/2.5	coSL	lo	so,po	c	
	3BCt	43-58	FCu	7.5YR 4/2.5	7.5YR 5/2.5	coS	lo	so,po	cp	
	3BCtk	58-76	FCu	7.5YR 4/2.5	7.5YR 5/2.5	S	lo	so,po	cp	
	3Bk	76-106+	FCu	7.5YR 4/2.5	7.5YR 5/2.5	m-coS	lo	so,po	cp	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 6-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t7ab (graded to Animas City 2 or 1 moraine), continued													
CO14	Ap1	0-5	7.5YR 4/3	7.5YR 5/4	fSL	3	1 f gr	lo-so	ss,ps	–	–	–	a,s
32N/10W/1/1	Ap2	5-12	6YR 4/3	6YR 5/4	SiCL	5	1 vco pr,1 vf pl	so	s,p	–	–	–	a,s
	2Bt	12-42	5YR 4/4	5YR 4.5/4	CL	15-30	2 f-m abk	sh	s,p	1npf,1mkg	–	–	c,w
	3BCt1	42-60	6YR 4/3	5YR 5/4	coLS+	60	0-1 vf sbk	lo-so	s,ps	0-1npf	–	ve-e	c,w
	3BCt2	60-79	6YR 4.5/3	7.5YR 6/4	coLS	60	0-1 vf sbk	lo-h	so,po-ps	–	I	es	g,w
	4Bk	79-159+	7.5YR 4/2	7.5YR 6/2	coS	15-25	sg/mass	lo,h	so-po	–	I	es	–
CO15	A	0-19	7.5YR 4/2	7.5YR 5/2	SL	1	1 vco pr/1 vf pl	so	so,po-ps	–	–	–	c,s
32N/10W/12/1	Bw	19-45	7.5YR 4/3	7.5YR 5/3	SL+	1	1 co pr, 2 m abk	so	ss,ps	–	–	–	c,s
	CB1	45-61	7.5YR 4/3	10YR 5/3	SL+	1	2 vco pr	sh	ss,ps	1npf	–	–	c,w
	CB2	61-83	10YR 4/2.5	10YR 5/3	SL	1	2 vco pr	h	ss,ps	1npf	–	–	g,w
	Ck	83-146	10YR 4/2.5	10YR 6/3	fLS	1	mass	h	so-ss, po-ps	–	I-	es	g,w
	C	146-169	10YR 5/3	7.5YR 6/3	mLS	5	sg	lo	so,po	–	–	–	a,s
	2Ck1	169-190	9YR 4/3	9YR 5/4	SiC	0	2 f-m pr, 2 vf-f abk	sh	s,p	–	I+	e	c,s
	2Ck2	190-224	9YR 4/4	7.5YR 5.5/4	SCL	3	2 m pr	sh	s,p	–	I-	o-ve	g,w
	3Btb	224-244	6YR 4/3	6YR 5/4	SiCL	5	1 f pr,2 f abk	sh	s,p	2npf,2npo	–	ve	c,w
	4BCtk1b	244-249	7.5YR 4/3	6YR 4/3	SCL	40	1 f sbk	so	s,p	3nco,3npf	I	e	c,w
	4BCtk2b	249-260	7.5YR 4/3	6YR 5/3	coLS+	50	1 f sbk	so	ss,ps	3nco,3npf	I	e	c,w
	4Bk1b	260-312	5YR 4/2	5YR 6/2	coS	50	sg	lo	so,po	–	I	em	g,w
	4Bk2b	312-441	5YR 4/2	5YR 6/2	coS	50	sg	lo	so,po	–	I-	em	d,w
	4Cb	441-491+	5YR 4/2	5YR 6/2	coS	50	sg	lo	so,po	–	–	e-em	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 6-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t7ab (graded to Animas City 2 or 1 moraine), continued						
CO14	Ap1	0-5	3mi	3mii	–	–	–	–	ND	–	–
32N/10W/1/1	Ap2	5-12	2mi	3mii,3mit	–	–	–	–	ND	c3fpf	–
	2Bt	12-42	–	3mit	–	–	–	–	ND	c3fpf	–
	3BCt1	42-60	–	3mii,3vfi	–	–	–	–	ND	–	–
	3BCt2	60-79	–	3mii,3vfi	4n-mk mic gb	d	–	–	ND	–	–
	4Bk	79-159+	–	3mii,3vfi	1n mic g	5% smi cw	–	–	ND	–	–
CO15	A	0-19	2mi	3mi	–	–	–	–	–	–	–
32N/10W/12/1	Bw	19-45	1mi,1vf	3mit	–	–	–	–	–	–	–
	CB1	45-61	1mi,1vf	3mit	–	–	–	–	–	–	–
	CB2	61-83	–	3mit	–	sf po	–	–	–	–	–
	Ck	83-146	–	2mii,2mit	2 sf g	sf po	–	–	–	–	–
	C	146-169	–	3mii	–	–	–	–	–	–	–
	2Ck1	169-190	1vf-f	3mi	–	sf pf,sf po	–	–	–	–	–
	2Ck2	190-224	v1vf	2vf,1f	–	sf po	–	–	–	–	–
	3Btb	224-244	v1vf	2mit	v1 sf g	sf pf,sf po	–	–	–	–	–
	4BCtk1b	244-249	1vf	3mii,3mit	2n mic gb,2 sf gt	sf po	–	–	–	–	–
	4BCtk2b	249-260	v1vf	3mii	2n mic gb,2 sf gt	sf po	–	–	–	–	–
	4Bk1b	260-312	v1vf	3mii	4n mic gb,0-2 sf gt	–	–	–	3vngt	–	–
	4Bk2b	312-441	–	3mii	2n mic gb,v1 sf gt	–	–	–	3ngt	–	–
	4Cb	441-491+	–	2mii	–	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 6-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t7ab (graded to Animas City 2 or 1 moraine), continued						
CO14	Ap1	0-5	CEul	7.5YR 4/4	7.5YR 5/4	fSL	lo	ss,ps	pc	
32N/10W/1/1	Ap2	5-12	CEul	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	pc	
	2Bt	12-42	FCu	7.5YR 4/3	7.5YR 5/3	SL	so	ss,ps	pc	
	3BCt1	42-60	FCu	7.5YR 4/2	7.5YR 5/2	coS	lo	so,po	c	
	3BCt2	60-79	FCu	7.5YR 4/2	7.5YR 5/2	coS	lo	so,po	c	
	4Bk	79-159+	FCu	7.5YR 4/2	7.5YR 5/2	coS	lo	so,po	cp	
CO15	A	0-19	Al	10YR 4/2.5	10YR 5/3	SL	so	so,po	p	
32N/10W/12/1	Bw	19-45	Al	10YR 4/2.5	10YR 5/3	SL	so	so,po	p	
	CB1	45-61	Al	10YR 4/2.5	10YR 5/3	SL	so	so,po	p	
	CB2	61-83	Al	10YR 4/2.5	10YR 5/3	fLS	so	so,po	p	
	Ck	83-146	Al	10YR 4/2.5	10YR 5/3	mLS	lo	so,po	p	
	C	146-169	Al	10YR 4/2.5	10YR 5/3	SiC	lo	s,p	c	
	2Ck1	169-190	FOl	9YR 4/4	9YR 5/4	SCL	sh	s,p	–	
	2Ck2	190-224	FOl	9YR 4/4	9YR 5.5/4	SiL	sh	ss,ps	p	
	3Btb	224-244	FOu+Eur?	7.5YR 4/3	7.5YR 5.5/4	LS	go	so,po	p	
	4BCtk1b	244-249	FCu	7.5YR 4/3	7.5YR 5.5/3	coS	lo	so,po	cp	
	4BCtk2b	249-260	FCu	7.5YR 4/3	7.5YR 5.5/3	coS	lo	so,po	pc	
	4Bk1b	260-312	FCu	7.5YR 4/3	7.5YR 5.5/3	coS	lo	so,po	c	
	4Bk2b	312-441	FCu	7.5YR 4/3	7.5YR 5.5/3	coS	lo	so,po	c	
	4Cb	441-491+	FCu	7.5YR 4/3	7.5YR 5.5/3	coS	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 7-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t7a (graded to Animas City 3 moraine)													
CO16 35N/9W/16/7 (sampled)	A	0-10	7.5YR 3/2	7.5YR 4.2	fSL	20	1-2 f abk, 2 m gr	so	ss,ps	–	–	o-ve	c,w
	2BAt	10-20	7.5YR 3/3	7.5YR 4.5/2.5	CL+	40	3 m-co abk, 2 f abk	h	ss,ps-p	3nbr,1npf,1mkpf	–	–	c,w
	3Bt	20-57	5YR 4/4	5YR 4.5/4	SC	60	3 m-co abk, 2 f abk	h	s,p	3kpf,3kpo,3kg	–	–	c,w
	3Btk	57-89	5YR 4/3	5YR 5/3	SCL-	80	mass	so	s,ps	–	l	es	g,w
	3Bk	89-179+	5YR 4/4	5YR 6/4	LS+/SL-	90	mass	lo	so,po	–	l-	es	–
CO17 35N/9W/32/3	A	0-15	7.5YR 3.5/2	7.5YR 4.5/2.5	L+	20	1 vf pl-gr	so	ss,ps	–	–	ve	c,s
	BAt	15-25	5YR 4/2	5YR 4/3	SiCL	20	2 vf abk	sh	ss,p	2vnpf,2vnpo, 2vng	–	–	c,s
	Bt1	25-54	5YR 4/3	5YR 4/4	C	30	2 f abk	h	vs,vp	3npf,3npo,3mkg	–	–	c,w
	2Bt2	54-63	5YR 4/4	5YR 4/5	C	60	2 f-m sbk	h	vs,vp	3br,2npf,3mkg	–	–	g,w
	2BCt	63-75	5YR 4/4	5YR 4/5	C	60	1 f-m sbk	sh	vs,vp	3br,3mkpf, 3npo,3ng	–	–	c,w
	2BCtk	75-97	5YR 4/3.5	5YR 4/5	SCL	60	sg/1 m sbk	so	s,p	3br,3ngt	l	em	c,w
	3Bk1	97-118	5YR 4/3.5	5YR 5/3	coLS	75	mass	so	ss,po	–	l+	es	g,w
	3Bk2	118-185	5YR 4/3	5YR 5.5/3	vcoLS/SL	80	mass/sg	so	ss,ps	–	l+	es	g,w
	3Bk3	185-240	5YR 4/3	5YR 5/3	vcoLS	85	sg	lo	so,po	–	l	es	g,w
	3Bk4	240-330	5YR 4/3	5YR 5/3	vcoSL/LS+	80	mass/sg	so	ss,ps	–	l	es	g,w
	3Bk5	330-420+	5YR 4/3	5YR 5.5/3	vcoLS+	80	mass	so	ss,po-ps	–	l-	em	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 7-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t7a (graded to Animas City 3 moraine)						
CO16 35N/9W/16/7 (sampled)	A	0-10	ND	ND	–	–	–	–	ND	ND	–
	2BAt	10-20	ND	ND	–	–	–	–	ND	ND	–
	3Bt	20-57	ND	ND	–	–	–	–	ND	ND	–
	3Btk	57-89	ND	ND	4mk mic mam gb,1ngt	–	–	–	ND	ND	–
	3Bk	89-179+	ND	ND	2n mic gb	–	–	–	ND	ND	–
CO17 35N/9W/32/3	A	0-15	3mi,3vf	3mii,1vf	–	–	–	–	3ngt	–	–
	BAt	15-25	2mi,2vf	3mii,1mit	–	–	–	–	–	–	–
	Bt1	25-54	2mi	3mit,2mii	–	–	–	–	–	–	–
	2Bt2	54-63	2vf,1mi	2mit,2mii	–	–	–	–	–	c3dg	–
	2BCt	63-75	2vf,1mi	3mit,3mii	–	–	–	–	–	–	–
	2BCtk	75-97	1mi	3mii,1mit	4n mic gb,v1 sf gt	–	–	–	–	–	–
	3Bk1	97-118	–	3mi-vfi	4n spr+mic gb, 3 sf gt - 4n gt	–	–	–	3ngt	–	–
	3Bk2	118-185	–	3mi-vcoi	4n spr+mic gb, 2n mic gt - 3 sf gt	cw	–	–	3ngt	–	–
	3Bk3	185-240	–	3mi-vcoi	4n spr gb,3 sf gt	cw	–	–	3ngt	–	–
	3Bk4	240-330	–	3mi-mi	2vn spr gb,2 sf gt	cw	–	–	3nco,3nbr, 3ng	–	–
	3Bk5	330-420+	–	3mi-coi	1vn spr g	cw	–	–	3nco,3nbr,	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 7-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t7a (graded to Animas City 3 moraine)						
CO16 35N/9W/16/7 (sampled)	A	0-10	CEur	7.5YR 4/4	7.5YR 5/4	fSL	lo	ss,ps	pc	
	2BAt	10-20	FCPu+CEur?	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3Bt	20-57	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3Btk	57-89	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
	3Bk	89-179+	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
CO17 35N/9W/32/3	A	0-15	CEur+FOu+Al?	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	
	BAt	15-25	CEur+FOu+Al?	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	
	Bt1	25-54	CEur+FOu+Al?	7.5YR 4/3.5	7.5YR 5/3.5	SL	so	ss,po	pc	
	2Bt2	54-63	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cp	
	2BCt	63-75	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cp	
	2BCtk	75-97	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cp	
	3Bk1	97-118	FCPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	cp	
	3Bk2	118-185	FCPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	ss,ps	cb	
	3Bk3	185-240	FCPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	cp	
	3Bk4	240-330	FCPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	ss,ps	cp	
	3Bk5	330-420+	FCPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	ss,po-ps	cb	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 8-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t6b (Richmond, 1965, interpreted as Spring Creek 2 moraine of this report)													
CO18 35N/9W/17/2 (sampled)	A	0-8	5YR 3/2.5	5YR 4.5/2	fSL	25?	1 m-co sbk, 1 f gr	lo-so	so,po	–	–	–	c,w
	Bt1	8-20	5YR 3/3.5	5YR 4/3.5	CL-	25?	2 vf-m abk	h	s,p	3mkpf	–	–	c,w
	Bt2	20-43	5YR 3/5	5YR 4/4	fSC	25?	3 f-m abk	h	vs,vp	3mkpf,3npf, 3mkg,3ng	–	–	c,w
	2Bt3	43-73	2.5YR 3/4, 5YR 4/4	2.5YR 4/4, 5YR 5/4	coSC	60	3 m-vco abk	fi	vs,vp	4kpf,4kg	l-	e	g,w
	2Bt4	73-106	5YR 4/4,4/5	5YR 4/6, 2.5YR 4/4	coSC	60	3 m-vco abk	fi	vs,vp	4kbr,3kg	–	e	g,w
	2BCtk1	106-142	2.5YR 4/4	2.5YR 4.5/4	vcoS/LS	65	1 m-co abk/sg	so	ss,po-ps	3kbr,3g	l-	em	g,w
	3BCtk2	142-164	4YR 4/4	5YR 5/4	vcoS/LS	85	1 m-co abk/sg	lo-so	so,po	3brgt,2-3mkgt	l-	em	g,w
	3Bk1	164-184	5YR 4/4	5YR 5.5/4	vcoS/LS	50-65	sg/1 m abk	lo	ss,po	–	l	em	g,w
	3Bk2	184-256+	5YR 4/4	5YR 5/4	vcoS	75	0-1 m abk	lo	so,po	–	l-	em	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 8-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
t6b (Richmond, 1965, interpreted as Spring Creek 2 moraine of this report)											
CO18 35N/9W/17/2 (sampled)	A	0-8	3mi	3mii	–	–	–	–	–	–	–
	Bt1	8-20	ND	2mit,2ft	–	–	–	–	–	c3dpf,c3dg	–
	Bt2	20-43	ND	3mit	–	–	–	–	–	c3dpf,c3dg	–
	2Bt3	43-73	ND	2mii, 2mit,2vfi	v1 sf g	sf	–	–	–	–	3vfpf
	2Bt4	73-106	ND	3mii	–	–	–	–	–	–	3vfpf
	2BCtk1	106-142	ND	3mii,3vfi	sf gb - 2n mic gb	–	–	–	–	–	–
	3BCtk2	142-164	ND	3mii,3vfi	2-4n spr gb	–	–	–	–	–	2vfgt
	3Bk1	164-184	ND	3mii,3vfi	sf gb - 4n mic+spr gb, sf gt - 4n gt	–	–	–	3-4gt	–	–
	3Bk2	184-256+	ND	3mii,3vfi	2n spr gb,v1 sf gt	–	–	–	3co,3ngt	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 8-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
t6b (Richmond, 1965, interpreted as Spring Creek 2 moraine of this report)										
CO18 35N/9W/17/2 (sampled)	A	0-8	CEur	7.5YR 4/4	7.5YR 5/4	fSL	lo	so,po	bc	
	Bt1	8-20	CEur	7.5YR 4/4	7.5YR 5/4	fSL	lo	so,po	bc	
	Bt2	20-43	CEur	7.5YR 4/4	7.5YR 5/4	fSL	lo	so,po	bc	
	2Bt3	43-73	FCPu	7.5YR 4/3	7.5YR 5/3	coS	lo	so,po	bc	
	2Bt4	73-106	FCPu	7.5YR 4/3	7.5YR 5/3	coS	lo	so,po	bc	
	2BCtk1	106-142	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	bc	
	3BCtk2	142-164	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	p	
	3Bk1	164-184	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	p	
	3Bk2	184-256+	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	p	Carb. fils. over clay films on clasts.

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 9-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t6b (graded to Spring Creek 2 moraine)													
CO19	A	0-8	5YR 3.5/2.5	5YR 4.5/2.5	L	30	1 co sbk,1 vf gr	so	ss,ps	--	--	ve	c,s
35N/9W/30/1	BAt	8-21	5YR 4/2.5	5YR 4/3	CL+	30	3 vf abk	h	s,p	4npf,4ng	--	--	c,w
	Bt1	21-32	5YR 4/3.5	5YR 4/4	C	30	3 vf-f abk	h	vs,vp	3mkpf,1npf,4mkg	--	--	c,w
	2Bt2	32-57	5YR 4/5	5YR 4.5/5	SC	70	2 m sbk	sh	vs,vp	4n-mkpf, 4n-mkpo,4n-kg	--	--	c,w
	2Btk	57-79	5YR 4/3	5YR 4.5/4	SCL+	75	1 m sbk	so	s,p	4br,3ng, 1mkg,1npf	I-	e	c,i
	2BCtk1	79-113	5YR 4/3.5	5YR 5/4	SCL	75	mass/1 m sbk	so	s,p	2-4co,0-2br	I	em	c-g,w
	2BCtk2	113-161	5YR 4/3	5YR 5/4	SCL	75	mass	so	s,p	2nbr	I	es	c,w
	3Bk1	161-182	5YR 4/2.5	5YR 6/2	coSL	80	mass	sh	ss,ps	--	II	es	c,w
	3Bk2	182-215	5YR 4/2.5	5YR 5.5/3	vcoLS	80	mass/sg	so	ss,po	--	I	em	g,w
	3Bk3	215-264+	5YR 4/2.5	5YR 5.5/3	vcoLS	85	mass/sg	so-lo	ss,po	--	I-	em	--
CO20	A	0-12	7.5YR 4/2	7.5YR 6/3	SiL	1	0-1 f gr/ 0-1 vf pl	lo-so	so-ss,po	--	--	--	c,s
35N/9W/8U/4A (sampled)	BA	12-40	5YR 4/2	5YR 5/3	L	1	1 m sbk	so	ss,ps	--	--	--	c,s
	Btk1	40-69	5YR 4/2.5	5YR 4.5/3	CL	2	2 f-m abk	h	s,p	1npf	I-	e	c,s-w
	2Btk2	69-92	5YR 4/4	5YR 5/4	vcoSCL+	15	3 m-vco abk	sh	s,p	3mkpf,3mkg	I-	ve	g,w
	3BCtk1	92-122	5YR 3/4	5YR 4/4	vcoSCL	40	1-2 f sbk	so	s,p	3br,1-2mkpf, 1-2mkg	I-	ve	g,w
	3BCtk2	122-146	5YR 4/4	5YR 5/4	vcoSCL-	50	0-1 f abk	lo-so	ss,ps	2br	I	ve	a,vs
	4Cr	146-153+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 9-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t6b (graded to Spring Creek 2 moraine)						
CO19	A	0-8	3mi	3mii	–	–	–	–	–	–	–
35N/9W/30/1	BAt	8-21	3mi	3mii,1mit	–	–	–	–	–	–	–
	Bt1	21-32	3mi	3mii,2mit	–	–	–	–	–	c3fpf	–
	2Bt2	32-57	2mi	3mi-vfi, 3mit	–	–	–	–	–	c3fpf	–
	2Btk	57-79	1mi	3mii,2vfi	4n mic gb	–	–	–	–	–	–
	2BCtk1	79-113	1mi	3mii,3vfi	4n mic gb	10% dmi	–	–	–	–	–
	2BCtk2	113-161	1mi	3mi-coi	4n mic gb,2-4n mic gt	–	–	–	2nco,2nbr	–	–
	3Bk1	161-182	–	3mii	4n mic gb	30% dmi,70% ss	–	–	3nco,3nbr	–	–
	3Bk2	182-215	–	3mi-vfi,1fi	3n spr+mic gb, v1 sf gt - 2n mic gt	cvw	–	–	2ngt	–	–
	3Bk3	215-264+	–	3mi-coi	2n spr gb	cvw	–	–	3ngt	–	–
CO20	A	0-12	3mi,3vf	3mi	–	–	–	–	ND	–	–
35N/9W/8U/4A (sampled)	BA	12-40	2mi,2vf	3mi	–	–	–	–	ND	c1fpo	–
	Btk1	40-69	1f	2mi,2vf	–	sf pf	–	–	ND	c3fpf,c3fpo	–
	2Btk2	69-92	1mi,1vf	3mi	2 sf g	–	–	–	ND	c3fpf,c3fg	–
	3BCtk1	92-122	ND	ND	2 sf g	–	–	–	ND	c1fco	–
	3BCtk2	122-146	ND	ND	2-3n-mk mic gb,3 sf gt	–	–	–	ND	–	–
	4Cr	146-153+	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 9-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t6b (graded to Spring Creek 2 moraine)						
CO19	A	0-8	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	c	
35N/9W/30/1	BAt	8-21	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	c	
	Bt1	21-32	CEur	7.5YR 4/3.5	7.5YR 5.5/3.5	L	so	ss,ps	c	
	2Bt2	32-57	FCPu	7.5YR 4/2.5	7.5YR 5/3	LS	lo	ss,po	bc	
	2Btk	57-79	FCPu	7.5YR 4/2.5	7.5YR 5/3	LS	lo	ss,po	bc	
	2BCtk1	79-113	FCPu	7.5YR 4/2.5	7.5YR 5/3	LS	lo	ss,po	cb	
	2BCtk2	113-161	FCPu	7.5YR 4/2.5	7.5YR 5/3	LS	lo	ss,po	cb	
	3Bk1	161-182	FCPu	7.5YR 4/2.5	7.5YR 5/3	coLS	lo	ss,po	c	
	3Bk2	182-215	FCPu	7.5YR 4/2.5	7.5YR 5/3	coLS	lo	ss,po	c	
	3Bk3	215-264+	FCPu	7.5YR 4/2.5	7.5YR 5/3	coLS	lo	ss,po	c	
CO20	A	0-12	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	so-ss,ps	p	
35N/9W/8U/4A										
(sampled)	BA	12-40	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	Btk1	40-69	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	2Btk2	69-92	FOu+CEur?	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	p	
	3BCtk1	92-122	FPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	pc	
	3BCtk2	122-146	FPu	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	pc	
	4Cr	146-153+	R	NA	NA	NA	NA	NA	NA	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 10-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
							t6b (graded to Spring Creek 2 moraine), continued						
CO21	fill	+50-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
34N/9W/31/1	Av	0-12	7.5YR 3.5/3	7.5YR 5/3	SiCL	20	1 vf pl	so	ss,p	–	–	–	c,s
	BAt	12-19	5YR 3.5/2.5	5YR 4/3	C	30	1 f pr,3 vf abk	sh	vs,vp	3npf,1mkpf, 3npo,1kg	–	–	c,w
	Bt1	19-32	5YR 3.5/4	5YR 4/4	C	30	2 f-m pr,3 f abk	h	vs,vp	4n-kpf,4n-kpo, 4kg	–	–	c,w
	2Bt2	32-68	5YR 3.5/4	5YR 4/4	mSC	55	3 m abk	h	vs,vp	3kbr,3mkpf, 3mkpo,4kg	–	–	g,w
	2BCtk1	68-85	5YR 4/4	5YR 4.5/4	mSCL	60	2 m-co abk	sh	s,p	3br,2ng,2mkg	I	ve	g,w
	2BCtk2	85-100	5YR 4/3	5YR 5/4	mLS+	60	mass/sg	so	s,ps	3nco	I	e	c,w
	2Bk1	100-131	5YR 6/4,4/3	5YR 8/2,5/3	mLS	70	mass	so-vh	ss,po-ps	–	II+	es	c,i
	2Bk2	131-159	5YR 4/3	5YR 5/3	coLS	70	mass	so	ss,po	–	I-	em	d,w
	2Bk3	159-214	5YR 4/3	5YR 5/3	coLS	70	mass/sg	so	ss,po	–	I-	em	d,w
	2Bk4	214-266+	5YR 4/3	5YR 5/2.5	coS	60	sg	lo	so,po	–	I-	em	–
CO22	A	0-7	7.5YR 4/3	7.5YR 5.5/4	fSL	10	1 m sbk/1 f gr	so	so,ps	–	–	–	c,s
33N/9W/31/6	Bt1	7-19	5YR 3/3	5YR 4.5/3	C-/CL+	10	2 m sbk	sh	vs,vp	4npf,4ng	–	–	c,w
	Bt2	19-36	5YR 3/4	5YR 4.5/4	C	20	1 f pr,3 f-m sbk	fi	vs,vp	3n-mkpf,3n-mkg	–	–	c,w
	2BCtk1	36-51	5YR 3/3	5YR 4/5	SC	60	1 f abk/sg	fr	vs,vp	3vnco,1npf,1ng	I	e	c,w
	2BCtk2	51-60	5YR 4/3	5YR 5/5	m-coS	70	sg	lo	so,po	2vnco	I	em	c,w
	2Bk	60-65+	7.5YR 3/3	7.5YR 5/3	m-coS	70	sg	lo	so,po	–	I	es	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 10-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t6b (graded to Spring Creek 2 moraine), continued						
CO21	fill	+50-0	NA	NA	NA	NA	NA	NA	NA	NA	–
34N/9W/31/1	Av	0-12	2vf,1f	3mii,1mit	–	–	–	–	4ng	–	–
	BAt	12-19	1mi-f	3mii,1mit	–	–	–	–	–	–	–
	Bt1	19-32	1mi-f	2mit	–	–	–	–	–	c3dpf,c3dg	–
	2Bt2	32-68	1mi-f	2mii,1mit	–	–	–	–	–	c3dg	–
	2BCtk1	68-85	1vf	3mii,2mit	4n mic gb	–	–	–	–	–	–
	2BCtk2	85-100	1vf	3mii,1mit	4n mic gb,2 sf gt	–	–	–	3ngt	–	–
	2Bk1	100-131	–	0-3mii, 0-2mit	4n mic gb - 4n mic g	50% dmi cw	–	–	3mkco	–	–
	2Bk2	131-159	–	3mii,3vfi	2n spr gb	cw	–	–	3n-mkco	–	–
	2Bk3	159-214	–	3mii,3vfi	2n spr gb	cvw	–	–	3n-mkco	–	–
	2Bk4	214-266+	–	3mii,3vfi	2n spr gb	sco	–	–	2nco,2ng	–	–
CO22	A	0-7	3mi	3mii	–	–	–	–	–	–	–
33N/9W/31/6	Bt1	7-19	2mi	2mit	–	–	–	–	–	–	–
	Bt2	19-36	2mi	2mit	–	–	–	–	–	–	–
	2BCtk1	36-51	–	3mii	4n mic gb,v1 sf gt	–	–	–	–	–	–
	2BCtk2	51-60	–	3mii	4n mic gb,v1 sf gt	–	–	–	2vngt	–	–
	2Bk	60-65+	–	3mii	4n mic gb,v1 sf gt	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 10-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t6b (graded to Spring Creek 2 moraine), continued						
CO21	fill	+50-0	NA	7.5YR 4/3	7.5YR 5/3	SiL	NA	ss,ps	NA	
34N/9W/31/1	Av	0-12	CEul+FOu?	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	
	BAt	12-19	CEul+FOu?	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	
	Bt1	19-32	CEul+FOu?	7.5YR 4/3	7.5YR 5/3	mLS	lo	so,po	p	
	2Bt2	32-68	FCu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	pc	
	2BCtk1	68-85	FCu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	cp	Clay films over carb. on clasts.
	2BCtk2	85-100	FCu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	cp	
	2Bk1	100-131	FCu	7.5YR 4/3	7.5YR 5/3	coS	lo	so,po	c	
	2Bk2	131-159	FCu	7.5YR 4/3	7.5YR 5/3	coS	lo	so,po	pc	Sparry carb. over clay films on clasts.
	2Bk3	159-214	FCu	7.5YR 4/3	7.5YR 5/3	coS	lo	so,po	pc	
	2Bk4	214-266+	FCu	7.5YR 4/3	7.5YR 5/2.5	coS	lo	so,po	pc	
CO22	A	0-7	CElu	7.5YR 4/4	7.5YR 5/4	fSL	so	so,ps	p	
33N/9W/31/6	Bt1	7-19	CElu	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
	Bt2	19-36	CElu+FOu?	7.5YR 4/3	7.5YR 5/3	SL	fr	so,ps	p	
	2BCtk1	36-51	FCu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	p	Clay films over carb. on clasts.
	2BCtk2	51-60	FCu	7.5YR 4/3	7.5YR 5/3	m-coS	lo	so,po	p?	
	2Bk	60-65+	FCu	7.5YR 4/3	7.5YR 5/3	m-coS	lo	so,po	p?	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 11-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t6a (Richmond, 1965, interpreted as Spring Creek 1 moraine of this report)													
CO23	A	0-6	7.5YR 3/3	7.5YR 5/3	SiL	10	1 vf-f gr	lo	ss,ps	--	--	--	c,s
35N/9W/17/1 (lab data)	AB	6-15	5YR 3/2.5	7.5YR 5/3	SiL+	10	1 vf-f gr/ 1 vf-f sbk	so	ss-s,ps-s	--	--	--	a-c,s
	BAt	15-24	5YR 3.5/3	5YR 5/3	CL	15	3 vf abk	vfi	s,p	4n-mkpf	--	--	c,s
	2Bt1	24-39	5YR 4/3	5YR 4.5/3	C-	35	3 m abk	vfi	vs,vp	4mkpf,4mkg	--	--	c,w
	2Bt2	39-65	4YR 3.5/3.5	4YR 4/3.5	C-	50	3 m-co abk	efi	vs,vp	4kpf,4kg	--	--	g,w
	2Bt3	65-87	5YR 4/4	5YR 4/3	CL	55	3 m-co abk	vfi	vs,vp	4kpf,4kg	--	e	c,w
	3BCtk	87-109	5YR 3.5/3	5YR 4.5/3	coSL	25	1 vco abk	lo-so	so,po	3br	I	em	c-g,w
	4Bk1	109-129	5YR 4/3	5YR 5.5/3	co-vcoSL	50	mass	so	so-ss,ps	--	II	es	c,w
	4Bk2	129-145	5YR 4/3	5YR 5.5/3	coSL	50	sg/0-1 f sbk	lo-so	so,po	--	I	em	c,w
	4Bk3	145-157	5YR 5/3	5YR 6.5/2	coLS	70	mass	so-sh	so-ss,ps	--	III	em	a,w
	5Bk4	157-182+	5YR 4/3	5YR 5.5/3	co-vcoLS	35	sg	lo	so,po	--	I-	em	--
t6a (graded to Spring Creek 1 moraine)													
CO24	A	0-8	7.5YR 3/3	7.5YR 4.5/4	SL	5	0-1 f-vf pl	lo-so	so,po	--	--	--	c,s
34N/9W/8U/5 (sampled)	BAt	8-24	5YR 3/3	5YR 4.5/3	L/L+	15	1 vco pl/ 1m-co sbk	sh	ss,p	3br	--	--	c,w
	2Bt	24-80	5YR 3.5/4	5YR 4/4	vcoSCL	30	2vco abk,2 m abk	h	s,ps	3br,3mkg	--	--	c-g,w
	3Bk1	80-105	5YR 4/3	5YR 5/3	vcoS	15	sg	lo	so,po	--	I-II	es	g,w
	4Bk2	105-149	5YR 3.5/3	5YR 5.5/3	vcoS	70	sg	lo	so,po	--	II	es	g,w-i
	4Bk3	149-254+	5YR 3/3	5YR 5/3	vcoS	40	sg	lo	so,po	--	I	es	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 11-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
t6a (Richmond, 1965, interpreted as Spring Creek 1 moraine of this report)											
CO23	A	0-6	3mi	3mii	–	–	–	–	ND	–	–
35N/9W/17/1	AB	6-15	ND	3mit,2vft	–	–	–	–	ND	–	–
(lab data)	BAt	15-24	ND	3mi	–	–	–	–	ND	–	–
	2Bt1	24-39	ND	3mi	–	–	–	–	ND	c3fpf,c3fg	–
	2Bt2	39-65	ND	3mit	–	–	–	–	ND	c3fpf,c3fg	–
	2Bt3	65-87	ND	ND	–	–	–	–	ND	c3fpf,c3fg	–
	3BCtk	87-109	ND	ND	3n mic gb,3 sf gt	–	–	–	ND	–	–
	4Bk1	109-129	ND	ND	4n mic g	d cw	–	–	ND	–	–
	4Bk2	129-145	ND	ND	2n mic gb,v1 sf gt	–	–	–	ND	–	–
	4Bk3	145-157	ND	ND	4n mic g	d	–	–	ND	–	–
	5Bk4	157-182+	ND	ND	2n mic gb	–	–	–	ND	–	–
t6a (graded to Spring Creek 1 moraine)											
CO24	A	0-8	3mi,3vf	3mi	–	–	–	–	ND	–	–
34N/9W/8U/5	BAt	8-24	1-2mi,1-2vf	3mi	–	–	–	–	ND	–	–
(sampled)	2Bt	24-80	1f,1vf	2mi,2vf	–	–	–	–	ND	–	–
	3Bk1	80-105	ND	ND	4n mic gb	sco	–	–	ND	–	–
	4Bk2	105-149	ND	ND	4n mic gb	5% smi	–	–	ND	–	–
	4Bk3	149-254+	ND	ND	3n mic gb	–	–	–	ND	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 11-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
t6a (Richmond, 1965, interpreted as Spring Creek 1 moraine of this report)										
CO23	A	0-6	CEIr	7.5YR 4/4	7.5YR 5/4	SiL	lo	ss,ps	p	
35N/9W/17/1	AB	6-15	CEIr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
(lab data)	BAt	15-24	CEIr	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	
	2Bt1	24-39	FCPu	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	c	
	2Bt2	39-65	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
	2Bt3	65-87	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
	3BCtk	87-109	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	
	4Bk1	109-129	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	
	4Bk2	129-145	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	
	4Bk3	145-157	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	c	
	5Bk4	157-182+	FCPu	7.5YR 4/3	7.5YR 5/3	co-vcoLS	lo	so,po	p	
t6a (graded to Spring Creek 1 moraine)										
CO24	A	0-8	CEur	7.5YR 4/4	7.5YR 5/4	SL	so	so,po	p	
34N/9W/8U/5	BAt	8-24	FCPu-CEur?	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
(sampled)	2Bt	24-80	FCPu-CEur?	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	pc	
	3Bk1	80-105	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	p	
	4Bk2	105-149	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	c	
	4Bk3	149-254+	FCPu	7.5YR 4/3	7.5YR 5/3	vcoS	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 12-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t6a (graded to Spring Creek 1 moraine), continued								
CO25	A	0-9	6YR 3.5/3	7.5YR 5/4	L-	5	0-1 f gr/l vf pl	lo	so,po	–	–	–	c,s
34N/9W/8U/6 (lab data)	BAt	9-24	5YR 3/3	5YR 4.5/3	L+	5	1 co-vco pl, 1m-co abk	so,sh	s,p	3br,v1npo,v1ng	–	–	c-g,w
	2Btk	24-77	5YR 3/4	5YR 4.5/5	CL-	45	2 vco abk	h	s,p	3n-mkpf, 3n-mkpo,3kg	I-	o-e	g,w
	3BCtk	77-117	5YR 3/4,4/6	5YR 4.5/4, 5YR 4.5/6	vcoSL	70	0-1 co sbk	lo	ss,po	3co	I	em-e	c,w
	3Bk1	117-203	5YR 4/3	5YR 5.5/3	vcoLS	75	sg	lo	so,po	–	II-	es	g,w
	3Bk2	203-250+	5YR 4/3	5YR 5.5/3	vcoLS-	75	sg	lo	so,po	–	I	em	–
					mD2 (Durango 2 moraine)								
CO26	A	0-8	5YR 3/2.5	5YR 4.5/3	coSL	15	0-1 co sbk	lo	ss,po	–	–	–	c,s
35N/9W/15/2 (lab data)	BAtk	8-26	5YR 3/3	5YR 4/3	CL	25	1-2 vco pl/ 1-2 co abk	so	s,ps	3br,v1ng	I	e	c,w
	Btk	26-61	5YR 4/4	5YR 4.5/5	L	20	3 vco abk	h	s,ps	3br,2n-kpf, 2n-kg	I	e	c-g,w
	BCtk	61-87	5YR 3/4	5YR 5/4	m-coSL	35	1 m-co abk/sg	lo-sh	ss,ps	2br,v1npf,v1npo	I+	es	a-g,w-i
	Bk1/K	87-174	6YR 4/3.5	7.5YR 6/4	fS,gfLS	30	1 m-vco abk	vfr-fr	ss,po	–	II-III	es	d,w
	Bk2	174-262+	7.5YR 4/4	7.5YR 6/4	fSL-	25	1 m-co abk	vfr	ss,ps	–	I	es	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 12-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t6a (graded to Spring Creek 1 moraine), continued						
CO25	A	0-9	2mi,2vf	3vf	–	–	–	–	ND	–	–
34N/9W/8U/6 (lab data)	BAt	9-24	3mi,3vf	3mi	–	–	–	–	ND	–	–
	2Btk	24-77	1-2mi,1-2vf	3mi,3vf	3-4n mic gb	–	–	–	ND	c3dpf,c3dpo	–
	3BCtk	77-117	ND	ND	3-4n mic gb	d	–	–	ND	–	–
	3Bk1	117-203	ND	ND	4n mic gb,2 sf gt - 4n mic gt	5% smi,d	–	–	ND	–	–
	3Bk2	203-250+	ND	ND	4n spr gb,2 sf gt	–	–	–	ND	–	–
					mD2 (Durango 2 moraine)						
CO26	A	0-8	3vf	3mii	–	–	–	–	ND	–	–
35N/9W/15/2 (lab data)	BAtk	8-26	ND	ND	3-4 mic gb,v1 sf gt	–	–	–	ND	–	–
	Btk	26-61	2mi,2vf	3mi,2vf	4n mic gb,2 sf gt	sf po	–	–	ND	c3fpf,c3fg	–
	BCtk	61-87	2-3mi	ND	4mk mic gb,3 sf gt - 2n mic gt	20% dmi,vcw	–	–	ND	–	–
	Bk1/K	87-174	ND	ND	4mk mic cw gb,3 sf gt - 4n mic gt	20% dmi,vcw	–	–	ND	–	–
	Bk2	174-262+	ND	ND	2-3 sf g - 2mk mic g	d	–	–	ND	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 12-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t6a (graded to Spring Creek 1 moraine), continued						
CO25	A	0-9	CEur+FOu	7.5YR 4/4	7.5YR 5/4	L	lo	so,po	p	
34N/9W/8U/6 (lab data)	BAt	9-24	CEur+FOu	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	2Btk	24-77	FCPu	7.5YR 4/3.5	7.5YR 5/3.5	SL	lo	so,po	cb	
	3BCtk	77-117	FCPu	7.5YR 4/3.5	7.5YR 5/3	coLS	lo	so,po	cb	
	3Bk1	117-203	FCPu	7.5YR 4/3.5	7.5YR 5/3	coLS	lo	so,po	c	
	3Bk2	203-250+	FCPu	7.5YR 4/3.5	7.5YR 5/3	coLS	lo	so,po	c	
				mD2 (Durango 2 moraine)						
CO26	A	0-8	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	SL	lo	ss,po	c	
35N/9W/15/2 (lab data)	BAtk	8-26	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	SL	lo	ss,po	c	
	Btk	26-61	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	SL	lo	ss,po	c	
	BCtk	61-87	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	SL	lo	ss,po	cb	
	Bk1/K	87-174	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	fS,fLS	lo	ss,po	cb	Thin K where gravel content high.
	Bk2	174-262+	TDu(MDS)	7.5YR 4/4	7.5YR 6/4	fSL	lo	ss,po	cb	Carb. on clasts partly dissolved.

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 13-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					mD2 (Durango 2 moraine), continued								
CO27	A	0-10	7.5YR 3/3	7.5YR 4/3	SL	<1	0-1 f-m sbk	lo-so	ss,po	--	--	--	c,s
35N/9W/15/3	BA	10-25	5YR 3.5/3	5YR 4.5/3	L+	<1	2 f-vco pl/ 1-2 vco sbk	sh	s,ps	--	--	--	a,s
	Bt1b	25-48	5YR 3/4	5YR 5/4	CL	<1	3 m-co abk/ 1 co pl	h	vs,p	3npf,3npo	--	--	g,w
	Bt2b	48-79	5YR 4/4	5YR 5.5/4	SiCL+	<1	2 m-co abk/ 1 f pr	sh	s,p	3npf	l-	--	g,w
	Bt1b2k	79-123	5YR 4/4	7.5YR 5/4	SiCL	<1	3 co-vco pr	h	s,p	3n-mkpf	l	em	d,w
	Bt2b2k	123-152	5YR 4/4	7.5YR 5.5/4	SiCL	<1	3 co-vco pr	vh	s,p	2mkpf	l	e-em	g,w
	Btb2	152-184	5YR 4/4	7.5YR 6/4	SiL	<1	2 co-vco abk,pr	h	ss,ps	2mkpo	l-	ve	c,w
	Bt1b3	184-209	5YR 4/4	5YR 5/4	C	<1	3 m-co pr	efi	vs,vp	4mk-kpf	l-	--	g,w
	Bt2b3	209-259+	5YR 4/4	5YR 5/4	SiC	<1	3 m-co pr	efi	s,p	3mkpf	l-	ve	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 13-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					mD2 (Durango 2 moraine), continued						
CO27	A	0-10	3mi	3mi	–	–	–	–	–	–	–
35N/9W/15/3	BA	10-25	3mi	3mi	–	–	–	–	–	–	–
	Bt1b	25-48	ND	3mi	–	–	–	–	–	c3fpf	–
	Bt2b	48-79	ND	3mit,3vft	–	sf po	–	–	–	–	–
	Bt1b2k	79-123	ND	3mit,3vft	–	sf pf	–	–	–	–	–
	Bt2b2k	123-152	ND	3mit	–	sco pf,sf pf	–	–	–	–	–
	Btb2	152-184	ND	3mit	–	sf pf,d	–	–	–	–	–
	Bt1b3	184-209	ND	3mit	–	sf pf	–	–	–	–	3vfpf
	Bt2b3	209-259+	ND	3mit	–	sf pf	–	–	–	–	3vfpf

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 13-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				mD2 (Durango 2 moraine), continued						
CO27	A	0-10	Er	7.5YR 4/4	7.5YR 5/4	LS	lo-so	ss,po	p	
35N/9W/15/3	BA	10-25	Er	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	Bt1b	25-48	Er	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	p	
	Bt2b	48-79	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt1b2k	79-123	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt2b2k	123-152	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btb2	152-184	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt1b3	184-209	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt2b3	209-259+	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 14-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t5e (graded to Durango 2 moraine)								
CO28	A	0-9	7.5YR 3/3	7.5YR 5/4	SiCL	<1	1 f gr/1 f pl	lo-so	s,p	–	–	–	c,w
34N/9W/7U/1	BAt	9-26	7.5YR 3/4	7.5YR 5/4	SiCL+	<1	2 vf-f abk	sh-h	s,p	–	–	–	c,w
(lab data)	Bt	26-45	5YR 3/4	5YR 4.5/4	SiCL-	0	3 f-m abk	sh-h	s,p	2npf,2npo	–	–	c,w
	BCt	45-79	5YR 3/4	6YR 5/4	SiL+	0	2 co-vco abk	h	ss,ps	v1npf,v1npo	–	–	a-c,w
	Btb	79-95	5YR 4/4,7/3	5YR 5/4,8/2	SiCL+	<1	3 m-co pr, 3m-co abk	h	vs,vp	4mkpf	–	ve-e	c,w
	Btk1b	95-126	5YR 4/4,7/3	5YR 5/4,8/2	SiCL	<1	3 m-vco pr, 3m-co abk	h	vs,vp	4kpf	I+	e-em	d,w
	Btk2b	126-161	5YR 4/4,6/4	5YR 5/4,8/2	SiCL	<1	3 co-vco pr, 3 m-vco abk	h	vs,vp	4mk-kpf	I+	e-em	g,w
	Btkb2	161-193	5YR 4/4	5YR 4/5	SiCL+	1	2 co pr, 3 m-co abk	h	vs,vp	4mk-kpf	I	e	a,i
	2BCtk1b2	193-215	5YR 4/4,8/4	5YR 4/5,7/2	CL+	25	2 f-co abk	sh	s,p	2mkpf	II	es	c-g,w
	2BCtk2b2	215-248	5YR 4/4,7/4	5YR 5/4,8/3	L+	30	mass	sh-h	s,p	–	II	es	g,w
	3Bkb2	248-260+	5YR 4/4	5YR 5.5/4	SL+	50	mass	so	s,po	–	I	es	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 14-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5e (graded to Durango 2 moraine)						
CO28	A	0-9	3mi,2vf	3mii	–	–	–	–	–	–	–
34N/9W/7U/1	BAt	9-26	3mi,3vf	3mit	–	–	–	–	–	–	–
(lab data)	Bt	26-45	3mi,1vf	3mit	–	–	–	–	–	c3fpf	–
	BCt	45-79	3mi,3vf	3mit,3vft	–	–	–	–	–	c3fpf	–
	Btb	79-95	2mi,2vf	2mit	–	sfl pf	–	–	–	c3fpf	1vfpf
	Btk1b	95-126	2mi,2vf	2mit	–	ss pf,sf pf, ss po,sf po	–	–	–	c3fpf	1vfpf
	Btk2b	126-161	2mi,2vf	2mit	–	ss pf,sf pf, ss po,sf po	–	–	–	m3fpf	1vfpf
	Btkb2	161-193	1-2mi,1-2vf	2mit	–	ss pf,sf pf, ss po,sf po	–	–	–	c3fpf	1vfpf
	2BCtk1b2	193-215	–	1mi	4n mic g	10% smi,sf pf,sf po	–	–	–	–	1vfpf
	2BCtk2b2	215-248	–	ND	4n mic g	10% smi,sf pf,sf po	–	–	–	–	–
	3Bkb2	248-260+	–	ND	4n mic g	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 14-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t5e (graded to Durango 2 moraine)						
CO28	A	0-9	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
34N/9W/7U/1	BAt	9-26	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
(lab data)	Bt	26-45	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	
	BCt	45-79	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	
	Btb	79-95	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btk1b	95-126	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btk2b	126-161	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btkb2	161-193	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2BCtk1b2	193-215	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	c	Many stress cutans.
	2BCtk2b2	215-248	CEur+FCPu?	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	Many stress cutans.
	3Bkb2	248-260+	FCu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 15-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR		TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE		CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
			MOIST	DRY				DRY/MOIST	WET				
t5e (graded to Durango 2 moraine), continued													
CO29	Ap	0-10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
34N/9W/30/1 (sampled)	Bt	10-50	7.5YR 4/3	7.5YR 5/3	C	0	3 vco pr, 3 m-co abk	efi	vs,vp	3n-mkpf,3n-mkpo	–	o-ve	d,w
	Btk1	50-79	7.5YR 4/3	7.5YR 5/3	C	0	3 vco pr, 3 co abk	efi	vs,vp	3n-mkpf	l	e	g,w
	Btk2	79-109	6YR 4/3	6YR 5/3	C	0	2 vco pl, 3 m-co abk	vfi	vs,vp	3npf,3npo	l	e	c,s
	2BAtb	109-130	6YR 4/3	5YR 5/3.5	SiCL	0	1 co pl, 2 m-co abk	h	s,vp	2npf,2npo	–	ve	c,s
	2Bt1b	130-173	5YR 4/4	7.5YR 5.5/4	CL	0	3 f pr	h	s,vp	2npf,2npo	–	–	g,w
	2Bt2b	173-196	5YR 4/3.5	5YR 5/5	SiCL	0	2 m pr,2 f abk	h	s,vp	1npf,1npo	–	–	c-g,w
	3Bt1b2	196-216	5YR 4/4	3YR 4/5	CL	50	2 m-co abk, 2 f abk	fi	vs,vp	4kpf,4kpo,4kg	–	–	d,w
	3Bt2b2	216-246	4YR 4/4	3YR 4/6	SCL+	60	3 m-co abk	vfi	vs,vp	4kpf,4kpo,4kg	–	–	g,w
	3Bt3b2	246-274	5YR 4/5	3YR 4/6	SCL+	60	3 m abk	fi	vs,vp	4kpf,4kpo,4kg	–	–	c,w
	3Bt4b2	274-293	5YR 4/4	5YR 4/6	SCL+	60	3 f-m abk	sh	s,p	4mk-kpf,4mk-kpo, 4mk-kg	–	–	g,w
	3BCt1b2	293-326	5YR 4/4	5YR 4/6	SCL-	50	1 m-co sbk	vfr	s,p	3n-mkco,3n-mkpo, 3n-mkg	–	–	g,w
	3BCt2b2	326-359	5YR 4/3	5YR 4/6	SCL	50	1 m gr/1 m sbk	lo	s,p	3n-mkco	–	–	d,w
	3BCt3b2	359-384+	5YR 4/3	5YR 4/5	SCL-	50	1 f-m gr	lo	s,p	2nco	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 15-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
t5e (graded to Durango 2 moraine), continued											
CO29	Ap	0-10	ND	ND	ND	ND	?	?	ND	ND	ND
34N/9W/30/1 (sampled)	Bt	10-50	ND	ND	--	--	--	--	--	--	1vfpf
	Btk1	50-79	ND	ND	--	1% 1smr cw	--	--	--	--	--
	Btk2	79-109	ND	ND	--	1% 1smr cw	--	--	--	--	--
	2BAtb	109-130	ND	ND	--	--	--	sf	--	c3fpf	2vfpf
	2Bt1b	130-173	ND	ND	--	--	--	sf,1smr	--	--	3vfpf,3vfpo
	2Bt2b	173-196	ND	ND	--	--	--	--	--	--	2vfpf,2vfpo
	3Bt1b2	196-216	ND	ND	--	--	--	--	--	c3fpf	1vfpf
	3Bt2b2	216-246	ND	ND	--	--	--	--	--	c3fpf	3vfpo
	3Bt3b2	246-274	ND	ND	--	--	--	--	--	c3fpf,c3fg	3vfpo
	3Bt4b2	274-293	ND	ND	--	--	--	--	--	c3fg	2vfpf
	3BCt1b2	293-326	ND	ND	--	--	--	--	--	c3fg	2vfpf,2vfpo
	3BCt2b2	326-359	ND	ND	--	--	--	--	--	--	--
	3BCt3b2	359-384+	ND	ND	--	--	--	--	--	--	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 15-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t5e (graded to Durango 2 moraine), continued						
CO29	Ap	0-10	Al	10YR 4/3	10YR 5/3	SiCL	sh	ss,ps	--	Disturbed.
34N/9W/30/1 (sampled)	Bt	10-50	Al	10YR 4/3	10YR 5/3	SiCL	sh	ss,ps	--	
	Btk1	50-79	Al	10YR 4/3	10YR 5/3	SiCL	sh	ss,ps	--	
	Btk2	79-109	Al	10YR 4/3	10YR 5/3	SiCL	sh	ss,ps	--	Many stress cutans.
	2BAtb	109-130	Er	7.5YR 4/4	7.5YR 5/4	SiL	sh	ss,ps	--	Common stress cutans.
	2Bt1b	130-173	Er	7.5YR 4/4	7.5YR 5/4	SiL	sh	ss,ps	--	Salts may be fertilizer.
	2Bt2b	173-196	Er	7.5YR 4/4	7.5YR 5/4	SiL	sh	ss,ps	--	Salts may be fertilizer.
	3Bt1b2	196-216	FCPu+CEur?	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3Bt2b2	216-246	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3Bt3b2	246-274	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3Bt4b2	274-293	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3BCt1b2	293-326	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3BCt2b2	326-359	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	
	3BCt3b2	359-384+	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	cb	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 16-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t5c (graded to Durango 2 moraine)								
CO30	Oi	0-19	7.5YR 3/3	7.5YR 4/3	fSL	0	sg	lo	so,ps	–	–	e	c,s
35N/9W/20/1	Bw1	19-31	7.5YR 3.5/3.5	7.5YR 5/4	L+	0	1 vc pr,2 vg pl	vfr	ss,p	1npf,1npo	–	e	c,w
(lab data,	Bw2	31-49	7.5YR 3.5/3.5	7.5YR 5/3.5	L+	0	1-2 m-co pr	vfr	ss,p	1npf,1npo	–	e	c,w,stl
most horizons)	Ab	49-60	7.5YR 3/3	7.5YR 4/3	L+	<1	1 vco pr	fr	ss,p	1npf,1npo	–	ve	c,w
	BAtkbz	60-82	6YR 3/3	6YR 4.5/3.5	L+	<1	1 co pr,2 co sbk	fi	s,p	2npf,2npo	l-	ve	a,w
	Btkbz	82-104	6YR 4/3.5	6YR 5/4	L+	0	3 m abk	fi	s,p	2npf,1mkpf, 2npo,1mkpo	l	e	g,w
	BCtkbz	104-124	6YR 4/4	7.5YR 5.5/4	SiL+	0	1 co pr,2 m abk	fi	ss,p	1npf,1npo	l	em	g,w
	BAtb2z	124-134	6YR 4/4	6YR 5/4	SiCL	0	1 m pr,2 f-m abk	fi	s,p	3npf,1mkpf, 3npo,1mkpo	l+	e	c,w
	Btkb2z	134-178	6YR 4/4	6YR 5/4	SiCL	0	2 m pr,3 m abk	fi	s,p	3mkpf,1vkpf	l	e	c,w
	Btk1b2	178-196	6YR 4/4	6YR 5/4	SiL+	<1	2 m pr,3 m abk	vfi	s,p	pr: 4mkpf,1vkpf; abk: 1npf	l	ve	c,w
	Btk2b2	196-220	6YR 4/4	6YR 5.5/4	SiL+	<1	2 co pr,3 m abk	fi	s,p	pr: 3mkpf,1vkpf; abk: 2vnpf,2kpo	l	e	g,w
	BCtk1b2	220-249	6YR 4/4	7.5YR 5.5/4	SiL	0	2 vco pr, 2 vco abk	fr	ss,p	pr: 3n-mkpf,1vkpf; abk: 3mkpf,3kpo	l	ve	c,w
	BCtk2b2	249-264	6YR 4/4	7.5YR 5.5/4	SiL	0	2 vco pr, 2 co abk	fr	ss,p	pr: 3vnpf,1vkpf; abk: 3mkpf,4kpo	l	ve	a,s
	BAtb3k	264-276	6YR 4/4	7.5YR 5.5/4	L+	<1	3 m pr	h	s,p	2n-mkpf, 2kpf,4kpo	l	ve	g,w
	Bt1b3	276-300	5YR 4/4	5YR 5/4	CL	0	2 m pr,3 f-m abk	h	vs,vp	pr: 2vkpf; 4m-kpf,4m-kpo	l-	ve	g,w
	Bt2b3	300-325	5YR 4/4	5YR 5/4	CL-	<1	1 m pr,3 f abk	h	vs,vp	pr: 1vkpf; 4k-npf,4k-npo	–	–	d,w
	Bt3b3	325-351	5YR 4/4	5YR 5/4	SiCL	<1	1 m pr,2 f abk	h	vs,vp	pr: 1vkpf; 4k-npf,4k-npo	–	–	c,w
	2Bt4b4	351-378	5YR 3.5/5	5YR 5/5	C-	15	1 co pr,3 f abk	h	vs,vp	pr: 1vkpf;4k-npf, 4k-npo,4k-ng	l-	–	c,w

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TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 16-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5c (graded to Durango 2 moraine)						
CO30 35N/9W/20/1 (lab data, most horizons)	Oi	0-19	3mi	3mii	–	–	–	–	–	c3fpf,c3fpo	–
	Bw1	19-31	3mi	2mii,2mit	–	–	–	–	–	c3fpf,c3fpo	–
	Bw2	31-49	3mi	3mi-ft,2mit	–	–	–	–	–	–	–
	Ab	49-60	2mi,2f	3mii, 2mit,1ft	2 sf gb	–	–	–	4ngt	–	–
	BAtkbz	60-82	3mi,3f,3m	3mii, 2mit,1vft	4n mic g	sf	–	sf po	–	–	–
	Btkbz	82-104	1mi,1vf	3mit	–	sf	–	sf po	–	c3dpf	–
	BCtkbz	104-124	2mi,1vf	3mit	–	sf pf,sf po	–	sf pf	–	–	–
	BAtb2z	124-134	1mi,1vf	3mit	–	sf po	–	sfl pf	–	–	–
	Btkb2z	134-178	1f	2mit	–	sf pf,sf po	–	sfl pf	–	–	–
	Btk1b2	178-196	–	3mit	–	sf pf	–	–	–	–	1vfpf
	Btk2b2	196-220	–	3mit	–	sco pf,sf po	–	–	–	–	1vfpf,1vfpo
	BCtk1b2	220-249	–	3mit	–	sco pf,sf po	–	–	–	–	1vfpo
	BCtk2b2	249-264	–	3mit	–	sco pf	–	–	–	–	3vfpf,3vfpo
	BAtb3k	264-276	–	3mit	–	sf pr	–	–	–	–	2vf-mpr,1fpo
	Bt1b3	276-300	–	2mit	–	sf pr	–	–	–	–	2f-mpf, abk: 3vfpf
	Bt2b3	300-325	–	3mit	–	–	–	–	–	–	3vfpf,3vfpo
	Bt3b3	325-351	–	2mit	–	–	–	–	–	–	pr: 2vf-mpf; abk: 3vfpf
	2Bt4b4	351-378	–	2mit	–	sf po	–	–	–	–	pr: 3vfpf; abk: 3vfpf, 3vfpo

(profile continued on next page)

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 16-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t5c (graded to Durango 2 moraine)						
CO30 35N/9W/20/1 (lab data, most horizons)	Oi	0-19	Er	7.5YR 3.5/3.5	7.5YR 5/3.5	fSL	lo	so,ps	--	
	Bw1	19-31	Er	7.5YR 3.5/3.5	7.5YR 5/3.5	L	vfr	ss,ps	--	
	Bw2	31-49	Er	7.5YR 3.5/3.5	7.5YR 5/3.5	L	vfr	ss,ps	--	
	Ab	49-60	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	
	BAtkbz	60-82	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	
	Btkbz	82-104	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Salts may be fertilizer.
	BCtkbz	104-124	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Salts may be fertilizer.
	BAtb2z	124-134	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Salts may be fertilizer.
	Btkb2z	134-178	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Salts may be fertilizer.
	Btk1b2	178-196	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	Salts may be fertilizer.
	Btk2b2	196-220	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	
	BCtk1b2	220-249	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Clay films redder than ped interiors.
	BCtk2b2	249-264	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	--	Clay films redder than ped interiors.
	BAtb3k	264-276	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	Clay films redder than ped interiors.
	Bt1b3	276-300	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	Clay films redder than ped interiors.
	Bt2b3	300-325	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt3b3	325-351	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2Bt4b4	351-378	CEur	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	p	Some saprolized clasts?

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TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 17-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR		TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE		CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
			MOIST	DRY				DRY/MOIST	WET				
t5c (graded to Durango 2 moraine), continued													
CO30, cont. 35N/9W/20/1 (lab data, most horizons)	3BCtb4	378-417	4YR 4/5	4YR 4.5/5	C-	40	2 vco sbk, 2 m abk	sh	vs,vp	4mk-kpf, 4mk-kpo,4kg	--	--	g,i
	3BCtk1b4	417-450	5YR 4/5	5YR 4.5/4,7/3	CL-	65	2 vco sbk	sh	s,p	1mkco,1mkbr, 2n-mkg,v1m-kpf	II+	e-em	d,i
	3BCtk2b4	450-487	5YR 4/4,5/4	5YR 4.5/4,7/3	CL-	70	1 m sbk	sh	s,p	1mkco,1mkbr, 2n-mkg,v1m-kpf	II+	em	d,i
	3BCtk3b4	487-510	5YR 4/3,4.5/3	5YR 4.5/4,6/3	L	70	1 m sbk	so	s,ps	2nco,2ng, 1mkg,1nbr	II	em	g,i
	4Bk1b4	510-534	6YR 4/3	6YR 5/3	coSL	25	mass	so-lo	so,po	3nco,3nbr	I	em	c,s
	5Bk2b4	534-605	5YR 4/3	5YR 5/3	coSCL	75	sg	so-lo	so,po-ps	--	II-	es	d,w
	5Bk3b4	605-645+	5YR 4/3	5YR 5/3	co-vcoSL-	75	sg	lo	ss,ps	--	I	em	--
mD1 (Durango 1 moraine)													
CO31 35N/9W/21/1 (sampled)	A	0-16	7.5YR 3/3	7.5YR 5/3	vfSL	0	1 f gr/1 m pl	so	so,po-ps	--	--	--	c,s
	BAt	16-25	7.5YR 4.5/4	7.5YR 4.5/4	SiL	0	2 f sbk	h	ss,ps	4nbr	--	--	c,s
	Bt1	25-33	6YR 4/3	6YR 5/3.5	SiCL-	0	2 co sbk,3 m abk	vh	s,ps	4npf,4npo	--	--	g,s
	Bt2	33-55	5YR 4/3.5	6YR 5/3.5	SiCL	0	3 m abk	vh	s,p	4npf,4npo, 1mkpf,1mkpo	--	--	g,s
	Btk	55-68	5YR 4/3.5	6YR 5/4	SiL+	1	3 co abk	h	ss,ps	2npf,2mkpf,2mkpo	I-	--	c,w,stl
	2BC1	68-94	6YR 4/4	6YR 5.5/3.5	mSCL	50	2 m-co sbk	h	s,p	2npf,2mkpf, 2npo,2mkpo	--	--	g,w
	2BC2	94-141	6YR 4/4	7.5YR 5.5/4	mSL+	40	2 m-co sbk	s,h	s,ps	2mkpo,2kpo,2npf, 2mkpf,1kpf	--	--	g,i
	2BC3	141-172	6YR 4/4	7.5YR 5.5/4	fiSL	40	2 m-co sbk	h	s,ps	2mkpo,2kpo,2npf, 1mkpf,v1kpf	I-	o-ve	g,i
	2BC4	172-202	7.5YR 4/4	7.5YR 5/4	mSL+	40	2 co sbk	h	s,ps-p	4kpo,1npf,v1mkpf	--	--	g,i
	3BCk	202-230+	7.5YR 4/3.5	9YR 5.5/4	SiL	0?	mass	h,vh	ss,ps	2kpo	I-	ve	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 17-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5c (graded to Durango 2 moraine), continued						
CO30, cont. 35N/9W/20/1 (lab data, most horizons)	3BCtb4	378-417	–	2mit	–	–	–	–	–	–	2vfpf,2vfpo
	3BCtk1b4	417-450	–	3mi-vfi	2-4mk mic gb, v1 mk mic gt	60% sdmr+ss	–	–	–	–	–
	3BCtk2b4	450-487	–	3mi-vfi	2-4mk mic gb, v1 mk mic gt	60% sdmr+ss	–	–	–	–	–
	3BCtk3b4	487-510	–	3mii	2-4mk mic gb, v1 mk mic gt	10-30% sdmr+ss	–	–	–	–	–
	4Bk1b4	510-534	–	3mii	4n mic gb	1% ss	–	–	–	–	–
	5Bk2b4	534-605	–	3mii	4n spr gb	5% sdmr,2% smi	–	–	3ngt	–	–
	5Bk3b4	605-645+	–	3mii	2-4n spr gb	–	–	–	2vngt	–	–
					mD1 (Durango 1 moraine)						
CO31 35N/9W/21/1 (sampled)	A	0-16	3mi,1f-vco	3mii	–	–	–	–	–	–	–
	BAt	16-25	2mi,2vf,1co	3mii,2mit	–	–	–	–	–	–	–
	Bt1	25-33	2mi,2vf,1co	3mit	–	–	–	–	–	–	–
	Bt2	33-55	2mi,2vf,1co	3mit	–	–	–	–	–	–	–
	Btk	55-68	2mi,2vf	3mit	–	sf pf,sf po	–	–	–	–	–
	2BC1	68-94	2mi,2vf	3mii,3mit	–	–	–	–	–	–	–
	2BC2	94-141	2mi,1vf	3mit,2mii	–	–	–	–	–	–	–
	2BC3	141-172	1vf	3mit,1vft	–	5% sf pf,sf po	–	–	–	–	–
	2BC4	172-202	–	2mii,2mit	–	–	–	–	–	–	–
	3BCk	202-230+	–	2mit	–	sf pf,sf po	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 17-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t5c (graded to Durango 2 moraine), continued						
CO30, cont. 35N/9W/20/1 (lab data, most horizons)	3BCtb4	378-417	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	pc	Many saprolized clasts.
	3BCtk1b4	417-450	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cp	Many saprolized clasts.
	3BCtk2b4	450-487	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cp	20% saprolized clasts. Mixed, carb.-rich areas are krotovinas?
	3BCtk3b4	487-510	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	cp	Mixed, carb.-rich areas are krotovinas?
	4Bk1b4	510-534	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	p	Mixed, carb.-rich areas are krotovinas?
	5Bk2b4	534-605	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	lo	so,po	pc	Mixed, carb.-rich areas are krotovinas?
	5Bk3b4	605-645+	FCPu	7.5YR 4/3	7.5YR 5/3	co-vcoLS	lo	so,po	pc	
				mD1 (Durango 1 moraine)						
CO31 35N/9W/21/1 (sampled)	A	0-16	Er	7.5YR 4/4	7.5YR 5/4	vfSL	lo	so,po	--	
	BAt	16-25	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	Bt1	25-33	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	Bt2	33-55	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	Btk	55-68	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2BC1	68-94	TDu(CD?)	9YR 4/3.5	9YR 5.5/4	mSL	so	so,po	p	
	2BC2	94-141	TDu(CD?)	9YR 4/3.5	9YR 5.5/4	mSL	so	so,po	p	
	2BC3	141-172	TDu(CD?)	9YR 4/3.5	9YR 5.5/4	fSL	so	so,po	p	
	2BC4	172-202	TDu(CD?)	9YR 4/3.5	9YR 5.5/4	mSL	so	so,po	c	
	3BCk	202-230+	TDu(CD?)	9YR 4/3.5	9YR 5.5/4	SiL	so	so-ss,po-ps	ND	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 18-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
mD1 (Durango 1 moraine), continued													
CO32	A1	0-4	7.5YR 3.5/3	7.5YR 4.5/3	L	15	sg	lo	so,po-ps	--	--	--	a,s
35N/9W/21/2	A2	4-10	7.5YR 3.5/3	5YR 4.5/3	L	15	1 m-co pl	lo	so,po-ps	--	--	--	c,s
(sampled)	Bt1	10-60	5YR 4/4.5	5YR 4.5/4	C	15	2 m pr, 3 m-co abk	h	vs,vp	4kpf,4kg	--	--	c,w
	2Bt2	60-95	5YR 4/4	5YR 4.5/4	SC	60	2 co sbk,3 m sbk	h	vs,vp	4kpf,4kg	--	--	c,i
	2Btk	95-167	5YR 4/4	6YR 4.5/4	SC	70	2 co sbk, 3 f-m abk	h	vs,vp	4kpf,4kpo,4kg	I-	e,ve	g,i
	2BCtk	167-231	6YR 3.5/4	6YR 5/3	SC-	70	sg/mass	sh	s,p	ND	I-II	es,e	c,w
	2K	231-256	7.5YR 5/2.5	7.5YR 7/2	SL+	70	mass	sh	ss-s,ps-p	--	III	es	c,w
	3Bk1	256-278	7.5YR 4/3.5	7.5YR 5/3.5	mS	0	sg	lo	so,po	--	I	e	c,w
	4Bk2	278-378+	7.5YR 4/4	7.5YR 6/3	vcoSL+/SC	60	mass/sg	so	ss-s,ps	2-4kbr,2-4ngr	I-II	es	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 18-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					mD1 (Durango 1 moraine), continued						
CO32	A1	0-4	3mi,2vf-f	3mii	–	–	–	–	–	–	–
35N/9W/21/2	A2	4-10	3mi,2vf-f	3mii	–	–	–	–	–	–	–
(sampled)	Bt1	10-60	2mi,1f,1vco	2mit	–	–	–	–	–	–	–
	2Bt2	60-95	2mi,1vco	2mii,2mit	–	–	–	–	–	–	–
	2Btk	95-167	2mi,1f,1vf	3mii,2mit	5% 3-4mk mic g	10% sf po	–	–	–	–	–
	2BCtk	167-231	vlmi	ND	ND	5% d cw,20% sf po	–	–	–	–	–
	2K	231-256	–	2mit	ND	100% d cw	–	–	–	–	–
	3Bk1	256-278	v1f	3mii,v1mit	–	1sm	–	–	–	–	–
	4Bk2	278-378+	1mi	3mii	ND	60% sf po,40% d,sm	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 18-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				mD1 (Durango 1 moraine), continued						
CO32	A1	0-4	CEur	7.5YR 4/4	7.5YR 5/4	L	lo	so,po-ps	pc	
35N/9W/21/2	A2	4-10	CEur	7.5YR 4/4	7.5YR 5/4	L	lo	so,po-ps	pc	
(sampled)	Bt1	10-60	CEur	7.5YR 4/4	7.5YR 5/4	L	lo	so,po-ps	pc	
	2Bt2	60-95	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
	2Btk	95-167	FCPu	7.5YR 4/3	7.5YR 5/3	L	lo	so,po	c	
	2BCtk	167-231	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	Clay over carb. on clasts.
	2K	231-256	FCPu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	Clay over carb. on clasts.
	3Bk1	256-278	FCPu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	--	
	4Bk2	278-378+	FCPu	7.5YR 4/3	7.5YR 5/3	vcoSL+/S	lo	ss-s,ps	pc	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 19-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t5a (graded to Durango 1 moraine)								
CO33	Bt→Av	0-15	6YR 4/3	7.5YR 5/4	C+	0	sg/2 f gr	so	vs,vp	–	–	–	c,s
34N/9W/7U/2	Bt→BA	15-20	5YR 4/4	5YR 5/3.5	C+	0	1 m abk,1 vf abk	sh	vs,vp	–	–	–	c-g,s
(sampled)	Bt1	20-32	5YR 4/4	5YR 5/3.5	SiC	0	2 f abk,1 f pr	sh	vs,vp	1vnpf	–	–	c-g,w
	Bt2	32-51	5YR 3/4	5YR 5/4	SiC	0	1 m pr,2 m abk	sh	vs,vp	1vnpf	–	–	c,w
	BCt	51-64	5YR 4/4	5YR 5.5/4	SiC	0	1-2 m pr, 2-3 m sbk	sh	vs,vp	1-2npf,1-2npo	–	–	c,w
	BAtkb	64-106	5YR 4.5/4,7/4	5YR 5/4,8/2	C+	0	3 co pr, 3 vco abk	h	vs,vp	4n-kpf	I	e	g,w
	Btk1b	106-151	5YR 4/4,6/4	5YR 5/4,7/3	C	0	3 co pr, 3 m-co abk	h	vs,vp	4mkpf	I	em	g,i
	Btk2b	151-204	5YR 4/4,7/4	5YR 5/4,8/3	C	0	3 f-m pr,3 m abk	h	vs,vp	4kpf	I+	em	c,w
	BCtgk1b	204-237	10YR 4/4	10YR 5/4, 5YR 8/2, mtl 5YR 4/4	C	1	1 f pr,3 f-m abk	sh	vs,vp	3kpf	II	em	d,w
	BCtgk2b	237-269	10YR 4/4,7/4	10YR 5/4, 5YR 8/2, mtl 5YR 3/3	C	5	1 f pr,3 f-m abk	sh	vs,vp	2kpf	II	es	c,w
	2BCtkb (b2?)	269-300	5YR 4/6,5/4	6YR 5/6,7/3	SCL+	25	2 f-m abk	sh	s,p	1npo	II	es	g,w
	3BCtk1b (b2?)	300-327	5YR 4/4,5.5/4	5YR 5/4,7/3	SCL	40	1 vco abk	sh	s,p	3br	II-	es	g,w
	3BCtk2b (b2?)	327-377	5YR 4/4,5.5/4	6YR 4.5/4,7/3	SL/SCL	50	mass/1 co abk	so	s,ps	3kco	II	es	g,w
	3BCtk3b (b2?)	377-446	5YR 3/4	5YR 4.5/4	SCL	50	mass/1 vco abk	so	s,p	3kco,1kg	I	es-em	g,i
	3Cb (b2?)	446-486+	5YR 4/2	5YR 5/3	coS	50	mass/sg	lo	so,po	–	I-	em	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 19-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5a (graded to Durango 1 moraine)						
CO33	Bt→Av	0-15	3mi,3vf	3mii,3vfi	–	–	–	–	–	–	–
34N/9W/7U/2	Bt→BA	15-20	2f	3mi,3vf	–	–	–	–	–	–	–
(sampled)	Bt1	20-32	1f	3mi	–	–	–	–	–	–	–
	Bt2	32-51	1vf	2mit,2vft	–	–	–	–	–	c3fpf	–
	BCt	51-64	vlf,v1m	ND	–	–	–	–	–	c3fpf	–
	BAtkb	64-106	1f	1mit	–	2% 1smr	–	–	–	c3fpf	1vfpf
	Btk1b	106-151	1f	2mi-vft	–	sf pf,sf po	–	–	–	m3fpf	1vfpf
	Btk2b	151-204	1f	2mit,2vft	–	1smr	–	–	–	–	1vfpf
	BCtgk1b	204-237	v1f	v1f	–	ss pf	–	–	–	c3dpf	1vfpf
	BCtgk2b	237-269	v1f	1f	–	ss pf	–	–	–	c3dpf	v1vfpf
	2BCtkb (b2?)	269-300	ND	ND	4vn mic gb,2 sf gt	10% 2smr,sf	–	–	–	–	–
	3BCtk1b (b2?)	300-327	ND	ND	4n mic gb,2 sf gt	5% 2smi cw	–	–	–	–	–
	3BCtk2b (b2?)	327-377	ND	ND	4n mic gb,3 sf gt - 4vn mic gt	20% 2 smi	–	–	–	–	–
	3BCtk3b (b2?)	377-446	ND	ND	3n mic gb	–	–	–	–	–	–
	3Cb (b2?)	446-486+	ND	ND	1n mic gb	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 19-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
				t5a (graded to Durango 1 moraine)						
CO33	Bt→Av	0-15	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
34N/9W/7U/2	Bt→BA	15-20	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
(sampled)	Bt1	20-32	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	Bt2	32-51	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	BCt	51-64	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	BAtkb	64-106	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	Local carb. filaments.
	Btk1b	106-151	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	Btk2b	151-204	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	--	
	BCtgk1b	204-237	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	Many stress cutans. Gleyed, iron-mottled.
	BCtgk2b	237-269	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	Many stress cutans. Gleyed, iron-mottled.
	2BCtkb (b2?)	269-300	CEur+FOu +FCPu	7.5YR 4/3	7.5YR 5/3	SL	lo	so,po	pc	
	3BCtk1b (b2?)	300-327	FCPu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	c	
	3BCtk2b (b2?)	327-377	FCPu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	c	
	3BCtk3b (b2?)	377-446	FCPu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	c	
	3Cb (b2?)	446-486+	FCPu	7.5YR 4/2	7.5YR 5/3	coS	lo	so,po	c	

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 20-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t4b								
CO34	fill	+50-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
34N/9W/29/1	A	0-12	7.5YR 4/2	7.5YR 5/3.5	SiCL-	<1	1 f pl	so	ss,ps	–	–	–	a-c,w
(lab data)	BA	12-28	7.5YR 4/3	7.5YR 5/4, mtl 5YR	CL	<1	3 vf-f abk	sh	s,p	–	–	–	c,w
	Bt1	28-43	5YR 3.5/2	5YR 4/3	SiCL+	<1	3 f-m abk	h	vs,vp	1npf	–	–	c,w
	Bt2	43-61	5YR 4/4	5YR 4/4	SiCL+	<1	3 m abk-pr	h	vs,vp	3npf	I	e	g,w
	Bt3	61-73	5YR 4.5/4	5YR 5/4	SiCL+	<1	3 m abk-pr	h	vs,vp	4n-mkpf	I	e	a,w,stl
	Btk/K	73-91	5YR 7/3,5/6	5YR 9/2,5.5/4	SiCL	<1	3 f-m abk	h	s,p	2npf	II+	es	g,w
	K/Btk	91-126	5YR 7/3,5.5/4	5YR 9/2,7/4	SiL+	<1	3 f-m abk	vh	s,p	1mkco,1mkbr	III	es-ev	g,i,stl
	Btk1	126-146	5YR 7/3,5.5/4	5YR 8/2,6/4	SiL+	<1	3 f-m abk	h	ss,p	2mkco,2mbkr	II	es-ev	g,i
	Btk2	146-164	5YR 7/4,5.5/5	5YR 8/2,6.5/3	SiL+	<1	2 m-co abk	sh	ss,p	2mkco,2mbkr	II	es-ev	c,i
	2K/BCk	164-186	5YR 7/4,5/5	5YR 8/2,6.5/3	SiL	<1	mass/3 f-m sbk	vh	ss,ps	–	III	es-ev	g,s
	2BCk1	186-208	5YR 8/2,5.5/5	6YR 9/2,6/4	SiL-	<1	3 m sbk	sh	ss,ps	–	II	ev	a,s
	2BCk2	208-235	6YR 6/4	7.5YR 4/6	SiL-	1	1 co abk/2 m sbk	so	so,po-ps	–	I-	e	c,w
	3Ck1?	235-287	5YR 3/4	5YR 5.5/5	coLS	15-65	1 m-co sbk	vfr	so-ss,po	3nco	I	em	g,w
	3Ck2	287-317+	5YR 3/4	5YR 5.5/5?	coSL	60	sg?	lo	so,po?	ND	–	em	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 20-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t4b						
CO34	fill	+50-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
34N/9W/29/1	A	0-12	2vf,2f	3mit,2vft	–	–	–	–	–	–	–
(lab data)	BA	12-28	2mi,2vf	3mit	–	–	–	–	–	–	–
	Bt1	28-43	1mi	2mit	–	–	–	–	–	m3dpf	1vfpf
	Bt2	43-61	1vf	1mit	–	–	–	–	–	c3fpf	–
	Bt3	61-73	1vf	1mit	–	1smr pf	–	–	–	c3f-dpf	–
	Btk/K	73-91	1vf	0-2mit	–	60% ver cw-cs smi	–	–	–	–	–
	K/Btk	91-126	1vf	0-1mit	–	90% hor cs smi, 60% cw d	–	–	–	–	–
	Btk1	126-146	–	0-1mit	–	40% ver cs smi, 60% cw d	–	–	–	–	0-2vfpf
	Btk2	146-164	–	0-1mit	–	20% ver cw ss,d	–	–	–	–	1vfpf
	2K/BCk	164-186	–	–	–	50-80% ver+hor cs ss,d	–	–	–	–	–
	2BCk1	186-208	–	–	–	10% hor cs ss,d	–	–	–	–	–
	2BCk2	208-235	–	–	–	sf	–	–	–	–	–
	3Ck1?	235-287	–	3mii	4n mic gb,2n gt	sf	–	–	–	–	–
	3Ck2	287-317+	–	3mii?	–	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 20-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
					t4b					
CO34	fill	+50-0	NA	NA	NA	NA	NA	NA	NA	
34N/9W/29/1	A	0-12	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
(lab data)	BA	12-28	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt1	28-43	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt2	43-61	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Bt3	61-73	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btk/K	73-91	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	Buried soil in adjacent area?
	K/Btk	91-126	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Btk1	126-146	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	Buried soil in adjacent area?
	Btk2	146-164	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	2K/BCk	164-186	Al	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	Buried soil in adjacent area?
	2BCk1	186-208	Al	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	Horiz. carb. bands along bedding.
	2BCk2	208-235	Al	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	Horiz. carb. bands along bedding.
	3Ck1?	235-287	FCPu	7.5YR 4/3	7.5YR 5/3	coLS	so	so,po	pc	Stronger chroma from iron?
	3Ck2	287-317+	FCu	7.5YR 4/3	7.5YR 5/3	coSL	lo	so,po	cb	Stronger chroma from iron?

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 21-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
						t4a							
CO35	Ap	0-10	7.5YR 3.5/3	7.5YR 4.5/3	SiL	0	2 f pl	so	so,ps	--	--	--	c,w
34N/8W/7U/2	BAp	10-32	7.5YR 3.5/3.5	7.5YR 4.5/3.5	SiL+	0	1 vco pr, 2 co sbk	sh	so-ss,ps	--	--	--	c,w
	Bt	32-73	5YR 4/3.5	5YR 5/4	C	0	2 f pr,3 f-m abk	h	vs,vp	3npf,1mkpf, 3npo,1mkpo	--	--	g,w
	BCt	73-107	6YR 4/3	6YR 5/4	SiCL	0	2 m pr	h	ss,p	2mkpf,2npf, 2mkpo,2npo	--	--	c,w
	BCtk	107-122	6YR 4/4	6YR 5/4	SiCl	0	2 m-co pr	h	s,ps	2npf,1mkpf, 2npo,1mkpo	I	ve	c,w
	Btgjkb	122-155	5YR 4/4	5YR 5/4,mtl 2.5YR 7/2	C	0	3 f-m pr	h	vs,vp	3mk-kpf,3mk-kpo	I-	ve	g,w
	Btk1b	155-181	5YR 4/4	6YR 5/4	C	0	2 m pr,3 m abk	h	vs,vp	4mkpf,4kpo	I	e	g,w
	Btk2b	181-208	5YR 4/4	6YR 5/5	C	0	2 m-co pr, 3 m abk	h	vs,vp	2mkpf,2npf, 3mk-kpo	I-	e	g,w
	Btk3b	208-233	5YR 4/4	6YR 5/5	SiC	0	2 m-co pr, 3 m abk	h	vs,vp	2mkpf,2npf,3mkpo	I	ve	c,w
	Btk1b2	233-246	5YR 4/4	5YR 5/4	C	0	3 f-m pr, 3 f-m abk	h	vs,vp	4k-mpf,2m-kpo	I	ve	g,w
	Btk2b2	246-258	5YR 4/4	5YR 5/4	C	0	2 f-m pr, 3 f-m abk	h	vs,vp	3mkpf,2npf,2kpo	I-II	ve	g,w
	Btk3b2	258-278	5YR 4.5/4	6YR 5/5	SiC	0	1 m pr,3 f-m sbk	h	vs,vp	2npf,v1mkpf, 2m-kpo	I-II	ve	g,i
	Btk4b2	278-311	6YR 4/5.4	7.5YR 6/4	SiL	0	2 vco pr, 2 co sbk	h	ss,p	1n-mkpf,3kpo	II-	e	c,w
	Btk1b3	311-333	5YR 4.5/4	5YR 5/4	SiC	0	2 f-m pr, 3 f-m abk	h	s,vp	3n-kpf,3n-kpo	II	e	c,w
	Btk2b3	333-343+	5YR 4/4	5YR 5/4	C	0	3 f-m pr,	fi	vs,vp	4m-kpf,3kpo	II	e	--

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 21-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t4a						
CO35	Ap	0-10	3mi	2mii	–	–	–	–	–	–	–
34N/8W/7U/2	BAp	10-32	3mi	3mit,2vf-ft	–	–	–	–	–	–	–
	Bt	32-73	2mi	2mit	–	–	–	–	–	–	1vfpf,1vfpo
	BCt	73-107	2mi	3mit	–	–	–	–	–	c3fpf,c3fpo	–
	BCtk	107-122	2mi-vf	3mit	–	sf pf,sf po	–	–	–	c3fpf,c3fpo	2mipf,2mipo
	Btgjkb	122-155	2vf	2mit	–	sf pf	–	–	–	–	2mi-vfpf, 2mi-vfpo
	Btk1b	155-181	2vf	3mit	–	sf pf,sf po	–	–	–	c3ppf	3mi-vfpf, 2mipo
	Btk2b	181-208	1vf	3mit	–	sf pf	–	–	–	c3ppf	3mi-vfpf, 3mi-vfpo
	Btk3b	208-233	1vf	2mit	–	sco pf,sf pf	–	–	–	–	2mipf,2mipo
	Btk1b2	233-246	1vf	2mit	–	sf pf,sco pf	–	–	–	c3fpf	2mipf,2mipo
	Btk2b2	246-258	vlvf	2mit	–	sf pf,sco pf	–	–	–	–	2mipf,2mipo
	Btk3b2	258-278	v1vf	2mit	–	sf pf,sco pf	–	–	–	–	3vfpf,3vfpo
	Btk4b2	278-311	v1vf	0-3mi-vft	–	ss ver cw pf, 1-2 smr cw pf, sf pf,sf po	–	–	–	–	2vfpo
	Btk1b3	311-333	–	3mit	–	ss ver,sf pf,sf po	–	–	–	–	1mipf,1mipo
	Btk2b3	333-343+	–	2mit	–	ss ver,sf po	–	–	–	–	2mipf,1mipo

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 21-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t4a					
CO35	Ap	0-10	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	so,ps	–	
34N/8W/7U/2	BAp	10-32	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	so,ps	–	
	Bt	32-73	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	
	BCt	73-107	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	BCtk	107-122	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btgjkb	122-155	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Common stress cutans. Ped interiors partly gleyed.
	Btk1b	155-181	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk2b	181-208	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk3b	208-233	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk1b2	233-246	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk2b2	246-258	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Some clay films redder than ped interiors.
	Btk3b2	258-278	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Some clay films redder than ped interiors.
	Btk4b2	278-311	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk1b3	311-333	Er	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	–	Clay films redder than ped interiors.
	Btk2b3	333-343+	Er	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	–	Some clay films redder than ped interiors.

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 22-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t4a, continued								
CO36 34N/9W/20/1 (sampled)	A	0-9	7.5YR 4/3	7.5YR 4.5/4	L	15	1 f gr	so	so-ss, po-ps	–	–	ve	c,s
	BAt	9-16	7.5YR 3.5/3.5	7.5YR 4/3	CL	10	2 f sbk	so	ss,p	2npf,2ng	–	–	c,s
	Bt	16-31	5YR 4/3.5	7.5YR 4.5/4	C	10	3 m abk,3 vf abk	h	vs,vp	3mkpf,3mkpo,4mkg	–	–	c,s
	BCtk	31-41	5YR 5/3.5	5YR 6/4	SiC	10	2 f abk	sh	s,p	2npf,2npo, 2mkpf,2mkpo	II+	es	c,i
	Km1	41-52	7.5YR 7/4.5	5YR 8/2	SiL	10	3 co pl	h	so-ss,po	2npf	III-	ev	c,w
	Km2	52-69	6YR 7.5/3	5YR 9/2	SiL?	10	3 vco pl	vh	ss,ps	–	IV	ev	c,w
	Km3	69-92	5YR 7.5/4	5YR 9/2	SiL?	10	2 co-vco pl	h	ss,ps	–	IV	ev	c,w
	2Km4	92-104	6YR 6/4	5YR 8/3	SiL?	20	2-3 co-vco pl	h	ss,po	–	IV+	ev	a,w
	2Kqm	104-116	6YR 6/4	5YR 8/3	SiL?	20	mass	h	ss,po	–	III+	ev	c,w
	3Kqmy	116-145	7.5YR 6/4,4.5/4	5YR 8/3,5.5/4	SiL	50	mass/2 f sbk	h,so	so-s, po-ps	–	III-	ev	a,w
	3Bky	145-160+	5YR 3.5/4	5YR 6/3	vcoLS	60	sg	lo	ss,po	–	–	es	–
					tbt (Bridgetimber Gravel, La Plata River)								
CO37 34N/11W/25/1 (lab data)	A	0-10	5YR 3/2	5YR 4/2	SiL+	2	1-2 co sbk-pl	so	ss,ps	–	–	–	c,s
	BAt	10-21	5YR 3/2.5	5YR 4/2.5	SiCL-	4	2 f abk	fr-fi	ss-s,ps-p	2npf,2npo,2ng	–	–	c,w
	Bt1	21-30	5YR 3/3	5YR 4/3.5	SiCL+	15	3 co-vco pr	vfi	vs,vp	1kpf	–	–	d,w
	Bt2 (b?)	30-55	5YR 4/4	5YR 4/5	C	1	mass	vfi	vs,vp	1kpf	–	–	c-g,w
	Bt3 (b?)	55-79	5YR 4/4	5YR 4/5	C	5	mass	vfi	vs,vp	1kpf	–	–	c,w
	2BCt1 (b?)	79-103	7.5YR 4/4	7.5YR 5/4	C-	15	mass	fi	vs,vp	3kbr,4vkg	–	–	c-g,i
	2BCt2 (b?)	103-128	7.5YR 4/4	7.5YR 5/4	CL+	20	mass	fi	vs,vp	3kbr,4vkg	–	–	d,w
	2BCt3 (b?)	128-151	7.5YR 4/5	7.5YR 5/4	CL	35	mass	fi	s,p	3kbr,4vkg	–	–	d,w
	2BCt4 (b?)	151-179	7.5YR 5/5	7.5YR 5.5/4	vcoSCL	40	mass	fi	s,p	3kbr,4vkg	–	–	d,w
	2BCt5 (b?)	179-215	7.5YR 4/5	7.5YR 5.5/4	co-vcoSCL	50	mass	fi	ss-s,ps-p	3kbr,4vkg	–	–	g,w
	2BCt6 (b?)	215-260+	7.5YR 4/4	7.5YR 5.5/4	coSL+	60	mass	fi	s,ps-p	3nbr,4kg	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 22-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYP-SUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t4a, continued						
CO36 34N/9W/20/1 (sampled)	A	0-9	ND	ND	–	–	–	–	–	–	–
	BAt	9-16	ND	ND	–	–	–	–	–	–	–
	Bt	16-31	ND	ND	–	–	–	–	–	c3fpf	–
	BCtk	31-41	ND	ND	4n mic cs gb	15-30% scr cs	–	–	–	–	–
	Km1	41-52	ND	ND	4vk lam cs gb	90% scr cw	–	–	–	–	–
	Km2	52-69	ND	ND	4n mic gb	lam+mic cw-cs	–	–	–	c3fpf	–
	Km3	69-92	ND	ND	4n mic gb	mic+lam cs	–	–	–	–	–
	2Km4	92-104	ND	ND	4n mic gb	lam+mic cs	–	–	–	–	–
	2Kqm	104-116	ND	ND	4n mic gb	d cs	–	–	–	–	–
	3Kqmy	116-145	ND	ND	4n mic gb	90% d cw	sm,po	–	–	–	–
	3Bky	145-160+	ND	ND	–	–	4n,gb	–	–	–	–
					tbt (Bridgetimber Gravel, La Plata River)						
CO37 34N/11W/25/1 (lab data)	A	0-10	3mi,3vf	3mi	–	–	–	–	–	–	–
	BAt	10-21	2f,2vf	3mi	–	–	–	–	–	m3dpf,m3dpo, m3dg	–
	Bt1	21-30	2f,2vf	1mi	–	–	–	–	–	m3dpf	–
	Bt2 (b?)	30-55	2f,2vf	1mi	–	–	–	–	–	m3dpf	–
	Bt3 (b?)	55-79	–	–	–	–	–	–	–	m3dpf	–
	2BCt1 (b?)	79-103	–	–	–	–	–	–	–	m3dpf	–
	2BCt2 (b?)	103-128	–	–	–	–	–	–	–	m3dg	–
	2BCt3 (b?)	128-151	–	–	–	–	–	–	–	c3dg	–
	2BCt4 (b?)	151-179	–	–	–	–	–	–	–	c3dg	–
	2BCt5 (b?)	179-215	–	–	–	–	–	–	–	c3dg	–
	2BCt6 (b?)	215-260+	–	–	–	–	–	–	–	–	–

TABLE B.4 DESCRIPTIONS OF SOIL PROFILES IN COLORADO, continued
PART 22-R PARENT-MATERIALS PROPERTIES (INFERRED) AND GENERAL COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t4a, continued						
CO36 34N/9W/20/1 (sampled)	A	0-9	CEur	7.5YR 4/4	7.5YR 5/4	L	so	so-ss,po-ps	pc	
	BAt	9-16	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	
	Bt	16-31	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	
	BCtk	31-41	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	
	Km1	41-52	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	Common petrocalcic frags.
	Km2	52-69	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc	Petrocalcic degraded.
	Km3	69-92	CEur	7.5YR 4/4	7.5YR 5/4	L	so	ss,ps	pc?	Root mats on horiz. partings.
	2Km4	92-104	FCPu+CEur?	7.5YR 4/3	7.5YR 5/3	vcoLS?	lo	so,po	pc?	Rotated clasts. Root mats on horiz. partings.
	2Kqm	104-116	FCPu+CEur?	7.5YR 4/3	7.5YR 5/3	vcoLS	lo	so,po	pc?	Multicyclic cement. Rotated, exploded clasts.
	3Kqmy	116-145	FCPu	7.5YR 4/3	7.5YR 5/3	?vcoS	lo	so,po	c	Few silica coats on clasts.
	3Bky	145-160+	FCPu	7.5YR 4/3	7.5YR 5/3	?vcoS	lo	so,po	c	
				tbt (Bridgetimber Gravel, La Plata River)						
CO37 34N/11W/25/1 (lab data)	A	0-10	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	BAt	10-21	CEur	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	
	Bt1	21-30	CEur	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	Many stress cutans. Vertical cracks with A matl., 3 mm wide. Clasts fresh, vertical.
	Bt2 (b?)	30-55	CEur	7.5YR 4/4	7.5YR 5/4	SiL	vfr	ss,ps	p	Similar to above.
	2Bt3 (b?)	55-79	CEur+FCu	7.5YR 4/3	7.5YR 6/3	L	lo	ss,ps	p	Many saprolized clasts.
	2BCt1 (b?)	79-103	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Many saprol. clasts. Organs over clay films.
	2BCt2 (b?)	103-128	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Many saprol. clasts. Organs over clay films.
	2BCt3 (b?)	128-151	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Saprolized clasts decrease.
	2BCt4 (b?)	151-179	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Saprolized clasts decrease.
	2BCt5 (b?)	179-215	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Saprolized clasts decrease.
	2BCt6 (b?)	215-260+	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Few saprolized, some grusified clasts.

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO
PART 1-L BASIC PROPERTIES

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					flood plain (San Juan River)								
NM1	A	0-4	9YR 3.5/2	10YR 5/2.5	fSL+/fSCL	1	1 f pl	fr	ss-s,ps-p	--	--	--	a,w,stl
29N/13W/17/1	Bw	4-15	9YR 3.5/2.5	10YR 5/3.5	fSL+	0	2 vco pr	fr	ss,ps	--	--	ve	g,w
(samples)	2C	15-21	10YR 3.5/2.5	10YR 5/3.5	fLS	0	1 vco pr	vfr	so-ss, po-ps	--	--	ve	a,s
	3Ab	21-28	10YR 4/3	10YR 5.5/3	SiC	0	3 f pr,3 vf abk	fi	s,vp	4mk-npf,4mk-npo	--	ve	c,w
	3Btb	28-43	10YR 4/3	10YR 5.5/3	C/SiC	0	3 f-m pr, 3 f abk	vfi	vs,vp	2mkpf,1npf, 2mkpo,1npo	--	e	g,w
	4BCb	43-62	10YR 4/2	10YR 5/3	SiL	0	2 vco pr	fr	ss,p	3nco,1npf,1npo	--	e	g,w
	5Cb	62-82+	10YR 4/2	10YR 5/3	SiL	0	sg	vfr	ss,p	1npo	--	e	--
					t8u								
NM2	fill	+200-0	NA	NA	NA	NA	NA	NA	NA	--	NA	NA	a,w
29N/13W/21/1A	Ak1	0-6	7.5YR 3/2	7.5YR 5/2	fSL	15	2 m sbk	sh	so-ss,ps	--	l-	e	c,s
(samples)	Ak2	6-19	7.5YR 3/1	7.5YR 5.5/2.5	fSL-	15	2 vco abk	sh	so,ps	--	l-	e	c-g,w
	Bwk1	19-27	7.5YR 3.5/2	7.5YR 5.5/3	fSL-	10	2 vco pr, 1 vco abk	sh	so,po-ps	--	l-	e	c,w
	2Bwk2	27-38	7.5YR 3.5/3	7.5YR 5.5/4	fSL	1	2 vco pr, 1 vco abk	sh	so-ss,ps	2nco	l-	e	a-c,w
	3C1	38-62	10YR 4/2.5	10YR 6.5/3	SiL-	0	2 vco pr	sh	so,ps	--	--	em	c,w
	4C2	62-69	7.5YR 4/3	7.5YR 6.5/3.5	SiCL	0	2 vco pr	so-sh	s,p	--	--	em	c-g,w
	4C3	69-82	7.5YR 4/2.5	7.5YR 6/3	SiCL	1	2 vco pr	so-sh	s,p	--	--	em	g,w
	5C4	82-113	10YR 4/3	10YR 6/3	SiCL	30	2 vco pr	so	s,p	--	--	e	g,w
	5Ck	113-136+	10YR 3.5/3	10YR 5/3,	SiL	50	mass	fr	so,ps	--	l-	e	--

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 1-C OTHER PROPERTIES

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					flood plain (San Juan River)						
NM1	A	0-4	1m	ND	–	–	–	–	–	–	–
29N/13W/17/1	Bw	4-15	3mi	2mit,2vft	–	–	–	–	–	–	–
(samples)	2C	15-21	ND	3mii,2mit	–	–	–	–	–	–	–
	3Ab	21-28	1mi,1vf	3mit	–	–	–	–	–	–	–
	3Btb	28-43	1mi,1vf	3mit	–	–	–	–	–	–	–
	4BCb	43-62	1mi,1vf	3mit,3mii	–	–	–	–	–	–	–
	5Cb	62-82+	1mi,1vf	3mit,3mii	–	–	–	–	–	–	–
					t8u						
NM2	fill	+200-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
29N/13W/21/1A	Ak1	0-6	1mi	3mii,1mit	2 sf g	–	–	–	–	–	–
(samples)	Ak2	6-19	1mi	1mit	2 sf g	sf po	–	–	–	–	–
	Bwk1	19-27	1mi	0-3mii,1mit	–	sf po	–	–	–	–	–
	2Bwk2	27-38	–	3mii,1mit	–	sf po	–	–	–	–	–
	3C1	38-62	–	3mit	–	–	–	–	–	–	–
	4C2	62-69	–	3mit	–	–	–	–	–	–	–
	4C3	69-82	–	3mit	–	–	–	–	–	–	–
	5C4	82-113	–	3mit,3vft	–	–	–	–	–	–	–
	5Ck	113-136+	–	3mii,1mit	2 sf g	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 1-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				flood plain (San Juan River)						
NM1	A	0-4	FOu	10YR 3.5/2.5	10YR 5/3.5	fSL+/fSCL	?	ss-s,ps-p	p	Pebbles and broken glass at base.
29N/13W/17/1	Bw	4-15	FOu	10YR 3.5/2.5	10YR 5/3.5	fSL+	?	ss,ps	–	
(samples)	2C	15-21	FOu	10YR 3.5/2.5	10YR 5/3.5	fLS	?	so-ss,po-ps	–	Detrital frags. of underlying soil at base.
	3Ab	21-28	FOu	10YR 4/2	10YR 5/3	SiC	?	s,vp	–	
	3Btb	28-43	FOu	10YR 4/2	10YR 5/3	SiC	?	s,vp	–	
	4BCb	43-62	FOu	10YR 4/2	10YR 5/3	SiL	?	ss,p	–	
	5Cb	62-82+	FOu	10YR 4/2	10YR 5/3	SiL	?	ss,p	–	
				t8u						
NM2	fill	+200-0	NA	NA	NA	NA	NA	NA	NA	
29N/13W/21/1A	Ak1	0-6	FOu	10YR 4/3	10YR 6/3	fSL	so	so,ps	c	Mechanically compacted on-site?
(samples)	Ak2	6-19	FOu	10YR 4/3	10YR 6/3	fSL-	so	so,ps	c	
	Bwk1	19-27	FOu	10YR 4/3	10YR 6/3	fSL-	so	so,ps	p	
	2Bwk2	27-38	FOu	10YR 4/3	10YR 6/3	fSL	so	so,ps	p	
	3C1	38-62	FOu	10YR 4/3	10YR 6/3	SiCL-	so-sh	so,ps	–	
	4C2	62-69	FOu	10YR 4/3	10YR 6/3	SiCL	so-sh	s,p	–	
	4C3	69-82	FOu	10YR 4/3	10YR 6/3	SiCL	so-sh	s,p	p	
	5C4	82-113	FCu	10YR 4/3	10YR 6/3	SiCL	so	s,p	c	
	5Ck	113-136+	FCu	10YR 3.5/3	10YR 5/3	SiL	so	so,ps	p	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 2-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
t7u (ordered by increasing height within local sequence)													
NM3	fill	+60-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	a,i
29N/13W/16/1	C1	0-15	10YR 4/2	10YR 6/3, mtl 7.5YR 5/8	SiL	0	1 f-m pl	so	ss,ps-p	--	--	e	a,s
	2C2	15-26	10YR 4/2	10YR 6/3, mtl 7.5YR 5/8	SiC	0	2 f-m pl	sh	vs,vp	--	--	ve	va,s
	3Btkb	26-41	7.5YR 4.5/4	7.5YR 5.5/4.5	mSL	5	2 vco pr	sh	ss,ps	3vnco	I	ve	c,w
	4Bk1b	41-67	7.5YR 5.5/4	7.5YR 7/3,8/2	mSL/SiL	5-50	1 vco pr, 1 co abk	sh	ss,ps	--	II	es	g,w
	4Bk2b	67-85	7.5YR 5/4	7.5YR 6.5/4, mtl 7.5YR 4/5	mLS	5-25	mass	sh	so,po-ps	--	I-II	es	g,w
	5Bk3b	85-123+	7.5YR 4.5/4	7.5YR 5.5/3, mtl 7.5YR 4/5	mS	5	sg	lo	so,po	--	I	em	--
NM4	fill	+10-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	a,s
29N/13W/21/1B (lab data)	Bt→Az	0-7	7.5YR 4/2	7.5YR 5.5/2.5	CL	5	3 vco pr, 2 m abk-pl	vh	vs,vp	3npf,1kpf,4kg	I	e	a,s
	2Btk	7-26	7.5YR 4.5/3	7.5YR 5.5/3.5,5/2	coSCL-	75	2 m-co sbk	h	ss,p	3mkbr,1npf, 1k-ngt	I	em	c,w
	2BCtk1	26-48	7.5YR 4.5/4	7.5YR 5/4	coSL+	75	1 f sbk	sh	so-ss, po-ps	3mkco,1nbr,4ngt	I	em	g,w
	2BCtk2	48-78	7.5YR 4/3.5	7.5YR 5.5/4	coLS-	75	0-1 f sbk	so	so,po	1nco,1n-mkgt	I-II	em	g,w
	2Bk1	78-109	7.5YR 4/3.5,5/3	7.5YR 5.5/3,6.5/3	m-coS	70	sg/mass	so	so,po	--	II	ev	a,s
	3Bk2	109-125	7.5YR 4/3,5/3	7.5YR 6/3,7/2.5	fLS-	1	1 m sbk	so	so,po-ps	--	I	em	a,s
	4Bk3	125-174	7.5YR 4/3	9YR 5.5/3	coS	60	sg	lo	so,po	--	I	em	d,w
	4Bk4	174-210+	7.5YR 4/3	8YR 6/2	coS	60	sg	lo	so,po	--	I-	e	--
NM5	Ap	0-12	7.5YR 4/2	7.5YR 5/3	SCL	20	2 f gr	so	s,p	--	--	em	a,w
32N/10W/33/2 (samples)	2Bt	12-27	5YR 4/3	5YR 4/4	CL+	10-30	3 co pr/3 vco pl	h	s,p	3npf,4mkg	--	--	c,s-w
	3Btk	27-45	5YR 4/4	6YR 5/4	SCL	50	1-2 m-co abk	sh	s,ps	4nco,3npo,3ngt	I	o-e	c,w
	3BCtk	45-67	6YR 4/3	6YR 5/4	SL-	60	0-1 f sbk	so-lo	ss,po-ps	3nco	I	es	g,w
	3Bk	67-99+	5YR 4.5/3	5YR 6/2.5	SL-	65	0-1 f-m abk	lo-so	so,po-ps	--	I+	ev	--

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 2-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
				t7u (ordered by increasing height within local sequence)							
NM3	fill	+60-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
29N/13W/16/1	C1	0-15	2mi-co	3mii,3mit	–	sfl pf,sfl po	–	–	–	–	–
	2C2	15-26	3mi-co	3mi-fi,2mit	–	sfl pf,sfl po	–	–	–	–	–
	3Btkb	26-41	1mi-co	3mii,3mi-mt	–	sfl pf,sfl po	–	–	–	–	–
	4Bk1b	41-67	2f-co	3mii,3mit, 1vft	4n mic gb,3 sf gt - 2n mic gt	smi ver,sf po, 5% 2smr	–	–	1vngt	–	–
	4Bk2b	67-85	1mi-co	3mii, 3mi-vft	4n mic gb,2n mic gt	2% smr,d	–	–	1vngt	–	–
	5Bk3b	85-123+	2m	3mii,3mt	4n mic gb,3 sf gt - 2n mic gt	d	–	–	–	–	–
NM4	fill	+10-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
29N/13W/21/1B (lab data)	Bt→Az	0-7	3mi	2mit	–	–	–	sfl pf	–	–	–
	2Btk	7-26	2mi	2mit	0-4n mic cs gb	2smr	–	–	–	c3dg	–
	2BCtk1	26-48	2mi-vf	2mii,2mit	4n lam cs gb	–	–	–	–	c3dgt	–
	2BCtk2	48-78	1mi	3mii,3mit	4n mic mam gb,2 sf gt	10% cvw	–	–	3ngt	–	–
	2Bk1	78-109	–	3mii,0-1mit	3-4 mic gb,0-4 mic gt	40% ver 3smi	–	–	1-3n-mkgt	–	–
	3Bk2	109-125	–	3mii	–	20% ver+hor 3smi	–	–	–	–	–
	4Bk3	125-174	–	3mii	4n mic gb,2 sf gt - 2n mic gt	2% 2smi	–	–	2ngt	–	–
	4Bk4	174-210+	–	3mii	2n mic gb,v1 sf gt	–	–	–	1ngt	–	–
NM5	Ap	0-12	3mi,3vf	3mii	–	–	–	–	–	–	–
32N/10W/33/2 (samples)	2Bt	12-27	2mi	1mii	–	–	–	–	–	c3dpf	–
	3Btk	27-45	2mi	3mii,1vft	4n mic gb,v1 sf gt	–	–	–	–	–	–
	3BCtk	45-67	1mi	3mii	4n mic gb,2 sf gt	–	–	–	–	–	–
	3Bk	67-99+	1mi	3mii	4mk spr+mic gb	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 2-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
t7u (ordered by increasing height within local sequence)										
NM3	fill	+60-0	NA	NA	NA	NA	NA	NA	NA	
29N/13W/16/1	C1	0-15	FOl	10YR 4/3	10YR 6/3	SiL	so	ss,ps-p	--	Laminar bedding, horiz. root mats.
	2C2	15-26	FOl	10YR 4/3	10YR 6/3	SiC	sh	vs,vp	--	Laminar bedding, horiz. root mats.
	3Btkb	26-41	FOl	7.5YR 4/3	7.5YR 6/3	mSL-	so	so,ps	p	Gray colloidal coatings on ped faces.
	4Bk1b	41-67	FCu	7.5YR 4/3	7.5YR 6/3	mSL	so	so,ps	pc	
	4Bk2b	67-85	FCu	7.5YR 4/3	7.5YR 6/3	mLS	lo	so,po	pc	
	5Bk3b	85-123+	FCu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	pc	
NM4	fill	+10-0	NA	NA	NA	NA	NA	NA	NA	
29N/13W/21/1B (lab data)	Bt→Az	0-7	FOu	7.5YR 4/3	9YR 5.5/3	CL	so	s,p	p	Bioturbation is mixing Az and 2Btk.
	2Btk	7-26	FCu	7.5YR 4/3	9YR 5.5/3	mSL	lo	so,po	cp	
	2BCtk1	26-48	FCu	7.5YR 4/3	9YR 5.5/3	mS	lo	so,po	c	
	2BCtk2	48-78	FCu	7.5YR 4/3	9YR 5.5/3	mS	lo	so,po	c	
	2Bk1	78-109	FCu	7.5YR 4/3	9YR 5.5/3	m-coS	lo	so,po	c	
	3Bk2	109-125	FCu	7.5YR 4/3	9YR 5.5/3	fLS	lo	so,po	p	
	4Bk3	125-174	FCu	7.5YR 4/3	9YR 5.5/3	coS	lo	so,po	cp	
	4Bk4	174-210+	FCu	7.5YR 4/3	9YR 5.5/3	coS	lo	so,po	pc	
NM5	Ap	0-12	FOu+fill	7.5YR 4/3	7.5YR 5/3	SL	so	ss,ps	pc	
32N/10W/33/2	2Bt	12-27	FOu/FCu?	7.5YR 4/3	7.5YR 5/3	SL	so	ss,ps	pc	
(samples)	3Btk	27-45	FCu	7.5YR 4/3	7.5YR 5/3	LS	lo	so,po	c	
	3BCtk	45-67	FCu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	c	
	3Bk	67-99+	FCu	7.5YR 4/3	7.5YR 5/3	S	lo	so,po	c	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 3-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t6b (graded to Spring Creek 2 moraine)								
NM6	A	0-5	7.5YR 4/2.5	7.5YR 6/3	fSL-	15	0-1 co sbk	vfr	so-po-ps	--	--	--	c,s
32N/10W/22/1	2Btjk	5-17	5YR 4/3	5YR 5.5/4	fSL	30	2 m-co sbk	fr	ss,ps	3nco	I-	e	c,w
(samples)	3Bk1	17-43	5YR 4.5/3	5YR 6/3	fSL	75	1 m sbk	fr	so-ss, po-ps	--	I+	es	g,w
	3Bk2	43-61	5YR 4.5/3	5YR 6/2.5	fLS	75	0-1 f-m sbk	vfr	so,po-ps	--	I	es	g,w
	3Bk3	61-84	7.5YR 4/3	7.5YR 6/3	fLS	70	sg	vfr	so,po	--	I	es	d,w
	3Bk4	84-115	7.5YR 4/3	7.5YR 6/3	mLS	70	sg	vfr	so,po-ps	--	I	es	g,w
	3Bk5	115-131+	6YR 4/3	6YR 6/3	coLS	80	sg	lo	so,po	--	I	em	--
NM7	fill	+5-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	a,s
30N/12W/27/1B	Az	0-7	8YR 4/4	8YR 5/4	L+	<1	1 vf pl/1 f pr	vfr	s,p	--	--	e	a,s
(lab data	Btkyz	7-19	7.5YR 4/4	7.5YR 5.5/4	L+	<1	1 m-co pr	vfr	s,p	2npf	--	em	c,w
0-300 cm &	Btkz	19-33	7.5YR 4/4	7.5YR 5/4	L	<1	1 vco pr, 1-2 m-vco abk	vfr	s,p	1npf	II-	em	c,w
555-673+ cm; samples)	BCtk	33-52	7.5YR 4.5/4	7.5YR 5.5/4	SiL	<1	2 m-co abk	sh	ss,ps-p	1vnpf	II-	em	c,w
(profile)	BCkz1	52-78	7.5YR 5/4	7.5YR 6/4	SiL	0	3 f-co abk	h	ss,ps-p	--	I+	es	c,w
continued on	BCkz2	78-126	7.5YR 5/4	7.5YR 6/4	SiL	<1	3 f-m abk	sh	ss,ps	--	I	em	g,w
next page)	BCk1	126-159	7.5YR 4.5/4	7.5YR 5.3/4	L	0	2 m-vco abk	vfr	so-ss,ps	--	I	em	g,i
	2BCk2	159-186	7.5YR 4.5/4	7.5YR 5.7/4	mSL	<1	1-2 m-vco abk	fr-lo	so,po-ps	--	I-	e	c,w
	3Btkb	186-215	7.5YR 4/3	7.5YR 5.5/4	L	0	1 m pr, 2 m-co abk	vfr	ss,ps-p	1npf	I	e	g,w
	3BCtk1b	215-235	7.5YR 4/3	7.5YR 5.5/4	L	<1	2 m-co abk	vfr	ss,ps	v1npf	I	e	g,w
	3BCtk2b	235-251	7.5YR 4/3	7.5YR 5.5/4	L	<1	2 m-co abk	vfr	ss,ps	v1npf	I	e	c,w
	3Bk1b	251-275	7.5YR 4/3	7.5YR 6/4	fSL	<1	3 m-vco abk	fr	ss,ps	--	I	e	d,w
	4Bk2b	275-300	7.5YR 4/3	7.5YR 5.5/4	fSL	3	1 co abk	vfr	s,ps	3nco	I	e	a,w
	5Bk3b	300-319	7.5YR 5/3	7.5YR 6/3.5	fSL	2	2 m-co abk	sh	ss,ps	--	I+	es	c-g,w
	5Bk4b	319-344	7.5YR 4.5/3	7.5YR 6/3	fS	<1	0-1 f-co sbk	lo-so	so,po	--	I	e	a,i
	6Bwkb2	344-376	7.5YR 4.5/3.5	7.5YR 6/4	fLS/SL	<1	2 m-co abk	fr	so,po	--	I-	em	g,w
	6Bk1b2	376-399	7.5YR 4.5/3.5	7.5YR 6/4	fSL	<1	1 m-vco abk	vfr	so,po-ps	--	I-	em	a,w
	6Bk2b2	399-428	7.5YR 5/3.5	7.5YR 6.5/4	fSL	<1	0-2 m-vco abk	vfr	so,ps	--	I	es	d,w
	7Cb2	428-439	7.5YR 5/4	7.5YR 6/4	mLS	<1	0-1 m sbk	fr-lo	so,po-ps	--	--	em	a,i,stl

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 3-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t6b (graded to Spring Creek 2 moraine)						
NM6	A	0-5	2mi	3mii	–	–	–	–	–	–	–
32N/10W/22/1	2Btjk	5-17	2mi,2vf	3mii,1mit	2n mic gb	–	–	–	3ngt	c3fg	–
(samples)	3Bk1	17-43	2mi,2vf	3mii,1mit	4n mic g	d	–	–	–	–	–
	3Bk2	43-61	–	3mii	4n mic gb,v1 sf gt	d	–	–	3ngt	–	–
	3Bk3	61-84	–	3mii	4n mic gb, v1 sf gt	–	–	–	3ngt	–	–
	3Bk4	84-115	–	3mii	4-3 mic+spr gb	–	–	–	3ngt	–	–
	3Bk5	115-131+	–	3mii	4-2 spr+mic gb	–	–	–	3ngt	–	–
NM7	fill	+5-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
30N/12W/27/1B	Az	0-7	ND	3mii	–	–	–	–	–	–	–
(lab data	Btkyz	7-19	ND	2mit	–	–	sf po	sfl pf	–	–	–
0-300 cm &	Btkz	19-33	ND	3mit	–	sf po,5% 1scr cw	–	sfl pf	–	–	–
555-673+ cm; samples)	BCtk	33-52	ND	3mit	–	sf pf,sf po, 5% 1scr cw	–	sfl pf	–	–	–
(profile	BCkz1	52-78	ND	2-3mi	–	sf pf,sf po	–	–	–	–	–
continued on	BCkz2	78-126	ND	3mi,3vf	–	sf po	–	sfl pf	–	–	–
next page)	BCk1	126-159	ND	3mi,3vf	–	sf po	–	sfl pf	–	–	–
	2BCk2	159-186	ND	3mit,3vft	–	sf po	–	–	–	–	–
	3Btkb	186-215	ND	3mit,3vft	–	sf po	–	–	–	c3dpf	–
	3BCtk1b	215-235	ND	3mit,3vft	–	sf po	–	–	–	–	–
	3BCtk2b	235-251	ND	3mit,3vft	–	sf po	–	–	–	–	–
	3Bk1b	251-275	ND	1mit,1vft	–	sf po	–	–	–	–	–
	4Bk2b	275-300	ND	1mit	2 sf g	sf po	–	–	–	–	–
	5Bk3b	300-319	ND	1mit	–	sf po	–	–	–	–	–
	5Bk4b	319-344	ND	1mit	–	sf po	–	–	–	–	–
	6Bwkb2	344-376	ND	2mit	–	sf po	–	–	–	–	–
	6Bk1b2	376-399	ND	1mit	–	sf po	–	–	–	–	–
	6Bk2b2	399-428	ND	2mit	–	sf po,sco pf	–	–	–	–	–
	7Cb2	428-439	ND	3mii	–	–	–	–	–	–	–

(profile continued on next page)

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 3-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t6b (graded to Spring Creek 2 moraine)						
NM6	A	0-5	CEuIr	7.5YR 4/3	7.5YR 6/3	fSL-	?	so,po-ps	p	
32N/10W/22/1	2Btjk	5-17	CElu+FCu?	7.5YR 4/3	7.5YR 6/3	fSL-	?	so,po-ps	p	
(samples)	3Bk1	17-43	FCu	7.5YR 4/3	7.5YR 6/3	LS	?	so,po	pc	
	3Bk2	43-61	FCu	7.5YR 4/3	7.5YR 6/3	fLS	?	so,po	pc	
	3Bk3	61-84	FCu	7.5YR 4/3	7.5YR 6/3	fLS	?	so,po	pc	
	3Bk4	84-115	FCu	7.5YR 4/3	7.5YR 6/3	mLS	?	so,po	pc	
	3Bk5	115-131+	FCu	6YR 4/3	6YR 6/3	coLS	?	so,po	pc	
NM7	fill	+5-0	NA	NA	NA	NA	NA	NA	NA	
30N/12W/27/1B	Az	0-7	SEr	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	Mechanically compacted on-site?
(lab data	Btkyz	7-19	SEr	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
0-300 cm &	Btkz	19-33	SEr	7.5YR 4/3	7.5YR 5/3	L	so	ss,ps	p	
555-673+ cm;										
samples)	BCtk	33-52	SEr	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	
			SEr							
(profile)	BCkz1	52-78	SEr	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	–	
continued on	BCkz2	78-126	SEr	7.5YR 4/3	7.5YR 5/3	SiL	so	ss,ps	p	
next page)	BCk1	126-159	SEr	7.5YR 4/3	7.5YR 5/3	fL	so	so-ss,ps	–	
	2BCk2	159-186	AuI	7.5YR 4/3	7.5YR 5/3	mSL	so	so,po-ps	p	
	3Btkb	186-215	SEr	7.5YR 4/3	7.5YR 5.5/3	L-	so	ss,ps	–	
	3BCtk1b	215-235	SEr	7.5YR 4/3	7.5YR 5.5/3	L-	fr-lo	so-ss,ps	p	
	3BCtk2b	235-251	SEr	7.5YR 4/3	7.5YR 5.5/3	L-	fr-lo	so-ss,ps	p	
	3Bk1b	251-275	SEr	7.5YR 4/3	7.5YR 5.5/3	fSL	fr-lo	so,ps	p	
	4Bk2b	275-300	AI	7.5YR 4/3	7.5YR 5.5/3	fSL	fr-lo	so,ps	p	
	5Bk3b	300-319	EuI?	7.5YR 4.5/3	7.5YR 6/3	fSL	so	so,ps	p	
	5Bk4b	319-344	EuI?	7.5YR 4.5/3	7.5YR 6/3	fS	lo-so	so,po	p	
	6Bwkb2	344-376	AI-SErI?	7.5YR 5/3	7.5YR 6/3	fLS/SL	fr-lo	so,po	p	
	6Bk1b2	376-399	SErI	7.5YR 5/3	7.5YR 6/3	fSL	vfr	so,po	p	
	6Bk2b2	399-428	AI-SErI?	7.5YR 5/3	7.5YR 6/3	fSL	vfr	so,po	p	
	7Cb2	428-439	SEr	7.5YR 5/3	7.5YR 6/3	mLS	vfr	so,po	p	

(profile continued on next page)

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 4-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t6b (graded to Spring Creek 2 moraine), continued								
NM7, cont.	7Btjk1b3	439-464	7.5YR 5/4	7.5YR 6/4	mSL	<1	2 m-vco abk	h	so,po-ps	v1nco	I-	em	c,w
30N/12W/27/1B	7Btjk2b3	464-479	7.5YR 5/4	7.5YR 6/4	mLS	<1	1-2 m-co abk	sh-so	so,po	1nco	I-	em	a,s
(lab data	8Bkyb3	479-487	7.5YR 4.5/4	7.5YR 5.5/4	fLS	<1	1 vco abk	fr	so,po-ps	–	I-	e	c,w
0-300 cm &	8Bk1b3	487-526	7.5YR 4.5/4	7.5YR 5.5/4	fLS	1	1 vco abk	vfr	so,po	–	I-	e	g,w
555-673+ cm;	9Bk2b3	526-555	7.5YR 4.5/4	7.5YR 5.5/4	fLS	5	1 vco abk	vfr	so,po	–	I-	e	a,s
samples)	10Bk3b3 [b4?]	555-574	5YR 4.5/3	5YR 5.5/3, mtl 5YR 5/4	L-	<1	1 vco pr	vfr	ss,ps	–	I-	em	c,s
	11CBb3 [b4?]	574-590	5YR 4/3	5YR 5/3, mtl 5YR 5/4	SiL	0	1 m-co abk	vfr	ss,ps	–	–	e-em	c,s
	12Bty1b4 [b5?]	590-605	6YR 4/3	7.5YR 5.5/3	SiC-	<1	3 f-m abk	fi	vs,vp	4mk-npf,4mk-npo	–	em	c,w
	12Bty2b4 [b5?]	605-624	5YR 4/3	5YR 5.5/4	SiC-	0	3 m-co abk	fi	vs,vp	4mk-npf,4mk-npo	–	e-em	c,w
	13BCtb4 [b5?]	624-643	5YR 4/3	5YR 5/3.5	gL	30	2 m abk	fr	s,p	3npf,1mkpf, 3npo,3ng	I-	e-em	c,w
	14Bkb4 [b5?]	643-673+	5YR 4/3	5YR 5/3	coS	65	sg	lo	so,po	–	I-	e	–
					t6a								
NM8	A	0-13	10YR 4/2.5	10YR 5/3	mLS	30	sg	lo	so,po-ps	–	–	em	c,s
30N/11W/5/1	2BAtk	13-25	7.5YR 4.5/3	7.5YR 5.5/4	mSL	50	0-1 f sbk	so	so-ss,p	2vnco	I-	em	c,w
	3Btk	25-54	7.5YR 4/4	7.5YR 5/4	mSCL	65	1-2 m sbk	fr	s,p	3mkco,3nbr, 2n-mkgt	I	es	c,w
	3BCtk	54-69	7.5YR 4/3.5	7.5YR 5/4	mLS	65	1 m-co sbk	vfr	so,ps	2vnco	I	es	g,w
	3Bk1	69-84	7.5YR 4.5/3	7.5YR 6/3	mLS	65	1 m sbk	vfr	so,ps	–	II-	es	d,w
	3Bk2	84-124	9YR 4/3	9YR 6/3	mS	65	sg	lo	so,po	–	I	es	d,w
	3Bk3	124-174	9YR 4/3	9YR 6/3	mS	65	sg	lo	so,po	–	I-	e	d,w
	3C	174-200+	9YR 4/3	9YR 6/3	mS	65	sg	lo	so,po	–	–	e	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 4-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t6b (graded to Spring Creek 2 moraine), continued						
NM7, cont.	7Btjk1b3	439-464	ND	2mit	–	sf po	–	–	–	–	–
30N/12W/27/1B	7Btjk2b3	464-479	ND	2mii,1mit	–	sf po	–	–	–	–	–
(lab data	8Bkyb3	479-487	ND	1mit	–	sf po	sf po	–	–	–	–
0-300 cm &	8Bk1b3	487-526	ND	1mit	–	sf po	–	–	–	–	–
555-673+ cm;	9Bk2b3	526-555	ND	1mit	–	sf po	–	–	–	–	–
samples)	10Bk3b3 [b4?]	555-574	ND	1mit,1vft	–	sf po	sf po, sfl pf	–	–	–	–
	11CBb3 [b4?]	574-590	ND	1mit	–	–	sf po	–	–	–	–
	12Bty1b3 [b5?]	590-605	ND	1mit	–	–	10% 2 smr	–	–	–	–
	12Bty2b3 [b5?]	605-624	ND	1mit	–	–	5% 2smr	–	–	–	3vfpf
	13BCtb3 [b5?]	624-643	ND	1mit	2 sf gb - 2n mic gb	–	–	–	–	–	–
	14Bkb3 [b5?]	643-673+	ND	3mii	2n spr gb	–	–	–	3ngt	–	–
					t6a						
NM8	A	0-13	3mi	3mii	–	–	–	–	–	–	–
30N/11W/5/1	2BAtk	13-25	3mi-vf	3mii	0-4n mic gb	–	–	–	3n-mkgt	–	–
	3Btk	25-54	3mi-vf	3mii,3mit	4n mic gb	–	–	–	–	–	–
	3BCtk	54-69	1mi	3mii,1mit	4n mic gb	–	–	–	2vngt	–	–
	3Bk1	69-84	1mi	2mii,3mit	4n mic gb,0-4n mic gt	2% 2smr	–	–	3nco, 2vngt	–	–
	3Bk2	84-124	–	3mii	4n spr+mic gb	–	–	–	1vngt	–	–
	3Bk3	124-174	–	3mii	1n spr gb	–	–	–	–	–	–
	3C	174-200+	–	3mii	–	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 4-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t6b (graded to Spring Creek 2 moraine), continued						
NM7, cont.	7Btjk1b3	439-464	SEr	7.5YR 4.5/3	7.5YR 5.5/3	mSL	so	so,po	p	
30N/12W/27/1B	7Btjk2b3	464-479	SErl	7.5YR 4.5/3	7.5YR 5.5/3	mLS	lo	so,po	p	
(lab data	8Bkyb3	479-487	SEr	7.5YR 4.5/3	7.5YR 5.5/3	fLS	lo	so,po	p	
0-300 cm &	8Bk1b3	487-526	SEr	7.5YR 4.5/3	7.5YR 5.5/3	fLS	lo	so,po	p	
555-673+ cm;	9Bk2b3	526-555	SEurl	7.5YR 4.5/3	7.5YR 5.5/3	fLS	lo	so,po	p	
samples)	10Bk3b3	555-574	FOu	7.5YR 4/3	7.5YR 5/3	L	vfr	ss,ps	p	Most or all clay is primary?
	11CBb3	574-590	FOu	7.5YR 4/3	7.5YR 5/3	SiL	vfr	ss,ps	--	Ripple cross-lamination
	12Bty1b3 [b4?]	590-605	FOu	7.5YR 4/3	7.5YR 5/3	SiC-	vfr	vs,vp	p	Most or all clay is primary?
	12Bty2b3 [b4?]	605-624	FOu	7.5YR 4/3	7.5YR 5/3	SiC-	vfr	vs,vp	--	Most or all clay is primary?
	13BCtb3 [b4?]	624-643	FOu+FCu	7.5YR 4/3	7.5YR 5/3	L-	vfr	s,p	c	
	14Bkb3 [b4?]	643-673+	FCu	7.5YR 4/3	7.5YR 5/3	mS	lo	so,po	c	
				t6a						
NM8	A	0-13	Al+CEur?	10YR 4/3	10YR 6/3	mLS	lo	so,po	p	
30N/11W/5/1	2BAtk	13-25	FCul	9YR 4/3	9YR 6/3	mLS	lo	so,po	cp	
	3Btk	25-54	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	cp	
	3BCtk	54-69	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	c	
	3Bk1	69-84	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	c	
	3Bk2	84-124	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	c	
	3Bk3	124-174	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	c	
	3C	174-200+	FCul	9YR 4/3	9YR 6/3	mS	lo	so,po	c	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 5-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t5e (graded to Durango 2 moraine)								
NM9 32N/10W/33/3	Av	0-6	10YR 4/3	9YR 5.5/4	fiSL	0	1 f gr	so	so-ss, po-ps	–	–	e	a,s
	C	6-16	10YR 4/3	10YR 5/4	fiSL	0	sg	lo	so,po	–	–	e	a,s
	BAb	16-26	7.5YR 4/4	7.5YR 5/4	fiSCL	0	2vco pr, 2 co sbk	so	ss,ps	–	I-	e	c,s
	Btb	26-41	6YR 4/4	6YR 5.5/4	fiSCL	0	2 m-co pr	so	s,ps	3npf,3npo	I	em	c,w
	2Btkyb	41-72	5YR 4/5	5YR 5/4	SiC	20	3 vco pr, 2 co abk	sh	s,p	3mkpf,4kgt	II-	es	a,w-i
	3Kb	72-92	7.5YR 5/6, 6YR 4/4	7.5YR 6.5/4, 5YR 5/4	?	40	2 m-co abk	vh,h	?	3nco	III-	ev	s,w
	3Kmb	92-119	7.5YR 7/4	5YR 8/2	?	40	3 m-vco abk	eh	?	2n-mkgt,2mk-kpf	IV	ev	c,w
	3K'b	119-147	7.5YR 7/4,6/4	7.5YR 8/2,6/4	coLS	60	mass	so,sh	so,po	3nco	II+	ev	g,w
	3Bk1b	147-215	7.5YR 5/4	7.5YR 5.5/4, 7.5YR 6.5/4	coLS	70	mass-sg	lo,so	so,po	–	II	es-ev	g,i
	3Bk2b	215-281	7.5YR 4.5/4	7.5YR 6/3	coLS	70	sg	lo	so,po	–	II-	es	a,s
	R	281+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 5-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5e (graded to Durango 2 moraine)						
NM9 32N/10W/33/3	Av	0-6	ND	ND	–	–	–	–	–	–	–
	C	6-16	ND	ND	–	–	–	–	–	–	–
	BAb	16-26	ND	ND	–	sfl	–	–	–	–	–
	Btb	26-41	ND	ND	–	sf pf,sf po	–	–	–	f3fpf	–
	2Btkyb	41-72	ND	ND	4mk mic gb	5-15% 2-3sc cw	1% 1-2sm	–	–	–	–
	3Kb	72-92	ND	ND	4mk mic gb	80% d cm-cs	–	–	–	–	–
	3Kmb	92-119	ND	ND	4mk mic gb	lam + mic cs	–	–	–	–	–
	3K'b	119-147	ND	ND	4n mic gb	50% d cw,50% d	–	–	–	–	–
	3Bk1b	147-215	ND	ND	4n mic gb,0-1 sf gt	30% smi ver cw	–	–	2ngt	–	–
	3Bk2b	215-281	ND	ND	1n mic gb,0-1 sf gt	5% d cvw	–	–	–	–	–
	R	281+	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 5-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t5e (graded to Durango 2 moraine)						
NM9 32N/10W/33/3	Av	0-6	SEr	10YR 4/3	10YR 5/4	fSiL	lo	so,po	–	
	C	6-16	SEr	10YR 4/3	10YR 5/4	fSiL	lo	so,po	–	
	BAb	16-26	SEr	10YR 4/3	10YR 5/4	fSiL	lo	so,po	–	
	Btb	26-41	SEr	10YR 4/3	10YR 5/4	fSiL	lo	so,po	–	
	2Btkyb	41-72	FOu+FCu+ SEr?	10YR 4/3	10YR 5/4	fSiL	lo	so,po	pc	
	3Kb	72-92	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	Top of petrocalcic degrading, Bt tongues. _ Few silica coats on clast bottoms.
	3Kmb	92-119	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	
	3K'b	119-147	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	
	3Bk1b	147-215	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	
	3Bk2b	215-281	FCu	7.5YR 4/3	7.5YR 6/3	coS	lo	so,po	c	
	R	281+	Sandstone	NA	NA	NA	NA	NA	NA	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 6-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t5a (graded to Durango 1 moraine)								
NM10	fill	+26-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	va,s
30N/12W/33/1A	Ap	0-15	7.5YR 4/3.5	7.5YR 5.5/4	fSL+	<1	1 m-co sbk	so	ss,po-ps	--	--	em	c,w
(lab data)	C	15-33	7.5YR 5/3.5	7.5YR 5.5/4	vfSL+	<1	1 m-co sbk	so	so-ss, po-ps	--	--	em	a,s,stl
	Btk1b	33-46	7.5YR 4/4	7.5YR 5.5/4,8/4	L	4	2 co pr,2 m abk	h	s,ps-p	2npf,2npo,2ngt	II	em	c,i
	Btk2b	46-67	7.5YR 5.5/4	6YR 5/4,8/2	L+	0	1 vco pr, 3 m sbk	h	s,p	0-3nco	II+	es	g,w
	Bkb/Kb	67-86	6YR 6/4	6YR 8/2,6/4	fSL	0	1 vco pr, 3 vco pl	h	s,p	0-3nco	II-III	es	g,w
	2Bk1b	86-109	6YR 6/4	6YR 5/4,8/2	fSL	10	2 vco pl	h	s,p	0-1mkco,1ngt	II	em	c,w
	3Bk2b	109-130	6YR 6/4	6YR 6/4,8/3	fSL	65	2 m sbk/ 2 vco pl	h	s,ps-p	0-1mkco,1ngt	II	es	c,w
	3Bk3b	130-167	6YR 6/4	5YR 5/4	fSL	75	mass	vfr	s,p	3vnco	I	em	g,w
	3Bk4b	167-191+	5YR 4/4	5YR 5.5/4	f-mLS	75	mass	vfr	so-ss, po-ps	3vnco	I	e	--
NM11	A	0-12	7.5YR 4/3	7.5YR 5.5/3.5	fLS	<1	1 vf pl	so	so-po	--	--	em	g,s
30N/12W/33/1B	BAt	12-28	7.5YR 4/3.5	7.5YR 6/4	fLS	2	0-1 m-co sbk	so	so-ss, po-ps	1ngt	I	em	c,w
(samples)	2Btk	28-48	7.5YR 5/4	7.5YR 6.5/4	L+	20	2 m sbk	h	ss,ps	1npg,1npo,2ngt	II	es	c,w
	3BCtk	48-68+	?	?	ND	80	mass	sh	ND	1ngt	II+	ev	--

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 6-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t5a (graded to Durango 1 moraine)						
NM10	fill	+26-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
30N/12W/33/1A	Ap	0-15	1mi-f	3mii,1mit	–	sfl	–	–	–	–	–
(lab data)	C	15-33	1mi-f	3mii,1vf-fi	–	–	–	–	–	–	–
	Btk1b	33-46	1mi-f	3mit	4n mic gb	5% 2scr,2smr	–	–	–	–	–
	Btk2b	46-67	1vf	3mit,1ft	–	40% ver smi + sco pf,sf po	–	–	–	–	–
	Bkb/Kb	67-86	1vf	3mit,1ft	–	25-50% 2ss + 2scr pf, 30% ver smi	–	–	–	–	–
	2Bk1b	86-109	–	2mit	4n mic gb	sco pf,5% 3ss pf	–	–	–	–	–
	3Bk2b	109-130	–	2mit	4n mic gb,2 sf gt - 2 mic gt	sf pf,20% 2scr	–	–	–	–	–
	3Bk3b	130-167	–	3mii,2mit	4n mic gb,2 sf gt	–	–	–	–	–	–
	3Bk4b	167-191+	–	3mii	4n mic gb	–	–	–	–	–	–
NM11	A	0-12	2mi-f	2mii,2mit	–	–	–	–	–	–	–
30N/12W/33/1B	BAt	12-28	2mi-f	3mii,3mit	4n mic mam cs gb	sf po	–	–	–	–	–
(samples)	2Btk	28-48	1f	2mit	4n-mk mic cs gb	d,10% 2smr	–	–	–	–	–
	3BCtk	48-68+	vlf	3mit	4n mic gb,0-4n mic gt	50% 3smi	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 6-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
				t5a (graded to Durango 1 moraine)						
NM10	fill	+26-0	NA	NA	NA	NA	NA	NA	NA	
30N/12W/33/1A	Ap	0-15	SEr	7.5YR 5.5/4	7.5YR 6/4	fSL	so	so-ss,po-ps	p	Mechanically compacted on-site?
(lab data)	C	15-33	SEr	7.5YR 5.5/4	7.5YR 6/4	vfSL	so	so-ss,po-ps	p	
	Btk1b	33-46	SEr	7.5YR 5.5/4	7.5YR 6/4	fSL	so	so-ss,po-ps	p	
	Btk2b	46-67	SEr	7.5YR 5.5/4	7.5YR 6/4	fSL	so	so-ss,po-ps	--	
	Bkb/Kb	67-86	SEr	7.5YR 5.5/4	7.5YR 6/4	fSL	so	so-ss,po-ps	--	
	2Bk1b	86-109	CEIr	7.5YR 5.5/4	7.5YR 6/4	fSL	so	so-ss,po-ps	c	
	3Bk2b	109-130	FCu	7.5YR 4/3	7.5YR 5.5/3	fS	lo	so,po	p	
	3Bk3b	130-167	FCu	7.5YR 4/3	7.5YR 5.5/3	fS	lo	so,po	p	
	3Bk4b	167-191+	FCu	7.5YR 4/3	7.5YR 5.5/3	f-mS	lo	so,po	p	
NM11	A	0-12	SEr	7.5YR 5.5/4	7.5YR 6/4	fLS	lo	so,po	p	
30N/12W/33/1B	BAt	12-28	SEr	7.5YR 5.5/4	7.5YR 6/4	fLS	lo	so,po	p	
(samples)	2Btk	28-48	CEIr?	7.5YR 4/3	7.5YR 5.5/3	LS	lo	so,po	cp	Carb. over clay films on clast bottoms.
	3BCtk	48-68+	FCu	7.5YR 4/3	7.5YR 5.5/3	ND	ND	ND	cp	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 7-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
						t4e							
NM12	fill	+13-0	NA	NA	NA	NA	NA	NA	NA	–	NA	NA	NA
30N/12W/21/1	A	0-7	7.5YR 5/4	7.5YR 5.5/4	fSL	0	2 f-m pl	so	so,po	–	I-	ND	a,s
	BA	7-16	7.5YR 5/4	7.5YR 5.5/4	fSL	1	2 m pr,2 co pl	sh	ss,ps	4nco,3npf	I	ND	c,s
	Btk	16-39	7.5YR 4.5/4	7.5YR 5.5/4	fSCL	0	2 co pr, 3 co abk	h	s,ps-p	4nco,1mkpf	II-	ND	c,s
	Btkb	39-48	7.5YR 4/4	7.5YR 5/5	mSC	0	2 co pr, 3 co abk	h	ss,p	–	II	ND	c,s
	Kb	48-92	7.5YR 6.5/4	6YR 8/2	mL	0	1 m-co pl	so	ss,ps	–	III-	ND	c,w
	Bkb	92-109	7.5YR 5/4	7.5YR 6/4	mLS	0	mass	vfr	so,po	–	I	ND	c,s
	2Bky1b	109-148	7.5YR 5/4	7.5YR 6.5/3	mLS	65	mass	lo,sh	so,po	–	II-	ND	g,w
	2Bky2b	148-214	7.5YR 5/4	7.5YR 6/3	mS/LS	60	sg	lo	so,po	–	I	ND	g,w
	2Bkb	214-239+	7.5YR 4.5/4	7.5YR 6/3	mS	60	sg	lo	so,po	–	I-	ND	–
						t4d							
NM13	A	0-10	10YR 4.5/4	9YR 5.5/4	fLS	1	1 vf-m sbk	lo	so,po	–	–	e	a,w
29N/12W/5/3	Bwy	10-36	8YR 5/4	8YR 5.5/4	mSL	0	1 m-co sbk	so	ss,po-ps	–	–	em	a,s
(samples)	Btby	36-61	7.5YR 4.5/3	7.5YR 5.5/3.5	fSL	0	2 vco pr, 2 m-co sbk	sh	so,po-ps	3n-mkco,v1npf	I	em	c,w
	Btkby (b2?)	61-80	7.5YR 4.5/3.5	7.5YR 5.5/3.5	fSL+	1	1 vco pr, 1 vco sbk	sh	ss,ps	3nco	I+	em	c,w
	2Btkby (b2?)	80-102	6YR 5/4	6YR 6/4	mSCL	5	1 vco sbk	fr	s,p	3nco	I	es	c,w
	2BCkbyz (b2?)	102-110	6YR 6/4	6YR 7/4	mSCL	10	mass	fr	s,p	–	II	es	c,w
	2Kby (b2?)	110-129	7.5YR 7/4	7.5YR 9/4	mSCL	1	mass	fr	s,p	–	III	ev	g,i
	2Bk1b (b2?)	129-153	7.5YR 6.5/4	7.5YR 7.5/4	mSL+	5	mass	vfr	ss,p	–	II	es	g,i
	3Bk2b (b2?)	153-182	8YR 5.5/4	8YR 6/4	coLS	25	mass	vfr	so,po	–	II	em	g,i
	3Bk3b (b2?)	182-207+	8YR 5.5/4	10YR 6/4	coS	20	sg	lo	so,po	–	I-	e	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 7-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
						t4e					
NM12	fill	+13-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
30N/12W/21/1	A	0-7	2mi,2vf	ND	–	sf pf	–	–	–	–	–
	BA	7-16	1mi,1vf	ND	–	sf pf,sf po	–	–	–	–	–
	Btk	16-39	–	ND	–	10% 2-3 sci cw	–	–	–	c3fpf	–
	Btkb	39-48	–	ND	–	20% 2-3 sci cw	–	–	–	–	–
	Kb	48-92	–	ND	–	20-50% d + sc hor	–	–	–	–	–
	Bkb	92-109	–	ND	–	d	–	–	–	–	–
	2Bky1b	109-148	–	ND	4n mic gb,0-4n mic gt	d,5% cw	1ng	–	–	–	–
	2Bky2b	148-214	–	ND	4n mic gb,0-1 sf gt	d	–	–	2vngt	–	–
	2Bkb	214-239+	–	ND	2vn mic gb	–	–	–	2vngt	–	–
						t4d					
NM13	A	0-10	1-3mi,0-1f	3mii	–	–	–	–	–	–	–
29N/12W/5/3	Bwy	10-36	2mi-f	3mii,2mit	–	sfl	sf po	–	–	–	–
(samples)	Btby	36-61	2mi,1vf	3mii,2mit	–	d - 1smr	1sc po	–	–	–	–
	Btkby (b2?)	61-80	2mi,2vf	3mii,2mit	4n mic gb	1% 1scr,sf po	1sc po	–	–	–	1vfpo
	2Btkby (b2?)	80-102	1mi	3mii	4n mic gb	sfl	1sc	–	–	–	–
	2BCkbyz (b2?)	102-110	1mi	3mii,1mit	4n mic cs gb	2smi,d	3s gb	1smr	–	–	–
	2Kby (b2?)	110-129	–	2mii,1mit	–	d	1sci	–	–	–	–
	2Bk1b (b2?)	129-153	–	2mii,2mit	4mk mic gb,2n mic gt	20-40% 3smi,d	–	–	–	–	–
	3Bk2b (b2?)	153-182	–	3mii	4mk mic gb	10-20% 1smi	–	–	–	–	–
	3Bk3b (b2?)	182-207+	–	3mii	1n mic gb	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 7-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t4e					
NM12	fill	+13-0	NA	NA	NA	NA	NA	NA	NA	
30N/12W/21/1	A	0-7	SEr	7.5YR 4/4	7.5YR 5/4	fLS	lo	so,po	--	
	BA	7-16	SEr	7.5YR 4/4	7.5YR 5/4	fLS	lo	so,po	p	
	Btk	16-39	SEr	7.5YR 4/4	7.5YR 5/4	fLS	lo	so,po	--	
	Btkb	39-48	Al-SEr?	10YR 5.5/4	9YR 6/4	mLS	lo	so,po	--	
	Kb	48-92	Al-SEr?	10YR 5.5/4	9YR 6/4	mLS?	lo	so,po	--	
	Bkb	92-109	Al-SEr?	10YR 5.5/4	9YR 6/4	mLS	lo	so,po	--	
	2Bky1b	109-148	FCu	7.5YR 4.5/3	7.5YR 6/3	mS	lo	so,po	c	
	2Bky2b	148-214	FCu	7.5YR 4.5/3	7.5YR 6/3	mS	lo	so,po	c	
	2Bkb	214-239+	FCu	7.5YR 4.5/3	7.5YR 6/3	mS	lo	so,po	c	
					t4d					
NM13	A	0-10	SEr	10YR 5/4	9YR 5.5/4	fLS	lo	so,po	p	Thicker under grass, thinner bare.
29N/12W/5/3	Bwy	10-36	SEr	10YR 5/4	9YR 5.5/4	fSL	lo	ss,po-ps	--	
(samples)	Btby	36-61	SEr	10YR 5/4	9YR 5.5/4	fSL	lo	so,po	--	
	Btkby (b2?)	61-80	SEr	10YR 5/4	9YR 5.5/4	fSL	lo	so,po	p	
	2Btkby (b2?)	80-102	Al	10YR 5.5/4	10YR 6/4	mSL	lo	so,po	p	
	2BCkbyz (b2?)	102-110	Al	10YR 5.5/4	10YR 6/4	mSL	lo	so,po	p	
	2Kby (b2?)	110-129	Al	10YR 5.5/4	10YR 6/4	mLS	lo	so,po	p	
	2Bk1b (b2?)	129-153	Al	10YR 5.5/4	10YR 6/4	mLS	lo	so,po	p	
	3Bk2b (b2?)	153-182	Al	10YR 5.5/4	10YR 6/4	coS	lo	so,po	p	
	3Bk3b (b2?)	182-207+	Al	10YR 5.5/4	10YR 6/4	coS	lo	so,po	p	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 8-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t4b								
NM14	A1	0-5	7.5YR 4/3	7.5YR 5.5/3	fSL	0	sg	lo	so,po	–	–	ve	c,s
30N/12W/34/1	A2	5-9	7.5YR 4/3	7.5YR 5.5/3	L	0	2 f gr	so	ss,p	–	–	e	c,s
	BA	9-20	7.5YR 5/4	7.5YR 5.5/4	L	0	1 co pr, 2 co abk	sh	ss,p	–	–	em	c,w
	Btk	20-44	6YR 5/4	6YR 5.5/4	CL	2	1 co pr, 3 f-m abk	h	ss,p	2vnpf,2vnpo, 2vngt	II	em	g,w
	Btkb	44-73	5YR 4.5/4	5YR 5/5	CL+	5	2 vco pr, 3 m-co abk	h	s,p	3npf,3npo,3ngt	II	em	c,w
	K1b/Btkb	73-80	5YR 6/4,4.5/4	5YR 9/2,5/5	SiL,CL	0	2 m pl	h,sh	ss,ps	0-3npf,0-3npo	II-III	es	g,w
	K2b	80-101	5YR 6/4,4.5/4	5YR 9/2,7/3	SiL	0	2 co pl	h	ss,ps	0-3ngt	II-III	es	c,w
	2K3b	101-121	5YR 4.5/4	5YR 9/2,7/3	mSL+	70	mass	sh	s,ps	–	III	es	g,w
	2Bk1b	121-151	5YR 4/4	5YR 6/4	mSL+	70	mass	so	ss,ps	–	I	em	g,w
	2Bk2b	151-161+	?	?	mLS	70	sg	lo	ss,po	–	I	em	–
NM15	A	0-8	7.5YR 4.5/4	7.5YR 6/4	L	<1	1 vf pl,1 vf gr	so	so,ps	–	–	em	c,w
29N/12W/5/2	BAt	8-27	7.5YR 4.5/4	7.5YR 6/4	L	<1	1 m-co sbk	sh	so,ps	3vnco,4ngt	I	em	g,w
(lab data)	Btk	27-52	7.5YR 4.5/4	7.5YR 5/4	L+	<1	1 vco pr, 2 m-vco abk	h	ss,p	3vnco,4vngt	II	em	c,w
	Btkbz	52-77	7.5YR 4.5/4	7.5YR 6/4	L+	<1	1 vco pr, 2 f-vco abk	sh	s,p	2vnco	II	em	c,i
	Btkb	77-92	7.5YR 5/4	7.5YR 6/4,8/2	L+	1	3 m pl	h	ss,ps	–	II+	es	g,i
	Kb	92-112	7.5YR 6/4	6YR 9/2,7/3	vfSCL-	2	3 m-co pl	h	ss,ps	–	III-II	es	g,w
	Kqb	112-129	7.5YR 7/4	5YR 9/2	fSL	2	2 vco pl	h	ss,ps	–	III	es	g,w
	Kqb2 (Bt->K)	129-140	7.5YR 6/4	5YR 8/2,7.5/2	fSCL	2	2 f-m sbk/ 2 f-m pl	h	ss,p	–	III	ev	g,i
	Btkqb2	140-175	7.5YR 5.5/4	5YR 7/4	fSCL-	2	2 co sbk	h	ss,p	2vngt	II	es	c,w
	2Btkb2	175-180	5YR 5/4	5YR 5.5/4	fSCL-	40	2 m-vco abk	h	s,p	2ngt	I	e	c,w
	3BCtkb2	180-203	5YR 4/4	5YR 5.5/4	fSCL-	70	1 f sbk	so	s,p	–	I-	em	d,i
	3Bk1b2	203-238	5YR 4/4	5YR 5.5/3	f-mSL	75	sg	lo	so,po	–	I	e	d,w
	3Bk2b2	238-263+	5YR 4/4	5YR 5/3	fLS	75	sg	lo	so,po	–	–	e	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 8-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t4b						
NM14	A1	0-5	2mi	3mii	–	–	–	–	–	–	–
30N/12W/34/1	A2	5-9	2mi	3mii	–	–	–	–	–	–	–
	BA	9-20	2mi	3mii, 3mi-vft	–	–	–	–	–	–	–
	Btk	20-44	2mi	3mi-vft	4n mic gb	sco pf,5-10% 2scr	–	–	–	–	–
	Btkb	44-73	1mi	3mit	4n mic gb,2 sf gt	sco pf,sf po,5% 2scr	–	–	–	–	–
	K1b/Btkb	73-80	–	1-3mit	–	70% sco pf,d	–	–	–	–	–
	K2b	80-101	–	1-2mit	–	100% sco pf,d	–	–	–	–	–
	2K3b	101-121	–	1mit	4k mic gb,3 sf gt - 3n mic gt	95% d cw,5% d	–	–	3ngt	–	–
	2Bk1b	121-151	–	3mii	4k mic gb	–	–	–	–	–	–
	2Bk2b	151-161+	–	3mii	3-4n mic gb	–	–	–	–	–	–
NM15	A	0-8	2mi,2f	3mii	–	1-2 sc cs	–	–	–	–	–
29N/12W/5/2	BAt	8-27	2mi	2mit,1vft	4n mic gb	sf po	–	–	–	–	–
(lab data)	Btk	27-52	1mi	2mit,2vft	4n mic cs gb	10% 1sci	–	–	–	–	–
	Btkbz	52-77	1mi	3mit,1ft	–	sco pf,2 scr	–	–	–	–	–
	Btkb	77-92	1mi-vf	2mit,2mii	4mk mic cs gb	20-60% sco pf	–	ss ver pf	2ngt	–	–
	Kb	92-112	–	1-2mit, 1-2mii	–	60% d cw,20% sco pf	–	–	2ngt	–	–
	Kqb	112-129	–	2mii	4n mic g	90% 2scr,10% d	–	–	–	–	–
	Kqb2 (Bt->K)	129-140	–	2mit,1mii	4n mic g	d cw	–	–	–	–	–
	Btkqb2	140-175	–	3mit,3mii	4n mic gb,2 sf gt	1scr cs	–	–	–	–	–
	2Btkb2	175-180	–	3mit,1mit	3n mic gb,2 sf gt	–	–	–	–	–	–
	3BCtkb2	180-203	–	3mii,2mit	2n mic gb,2 sf gt	sf po	–	–	2vngt	–	–
	3Bk1b2	203-238	–	3mii	0-4 vn-n mic g	–	–	–	–	–	–
	3Bk2b2	238-263+	–	3mii	0-2 sf g	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 8-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t4b					
NM14	A1	0-5	Er	7.5YR 4/4	7.5YR 5.5/4	L	so	so,ps	--	
30N/12W/34/1	A2	5-9	Er	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	--	
	BA	9-20	Er	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	--	
	Btk	20-44	SEr	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	p	
	Btkb	44-73	SEr	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	p	
	K1b/Btkb	73-80	Er	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	--	
	K2b	80-101	Er	7.5YR 4/4	7.5YR 5.5/4	L	so	ss,ps	--	
	2K3b	101-121	FCu	7.5YR 4/3	7.5YR 6/3	mLS	lo	so,po	pc	
	2Bk1b	121-151	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	pc	
	2Bk2b	151-161+	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	pc	
NM15	A	0-8	SEr	7.5YR 4/4	7.5YR 6/4	fL	so	so,ps	p	Detrital carb. nodules.
29N/12W/5/2	BAt	8-27	SEr	7.5YR 4/4	7.5YR 6/4	fL	so	so,ps	p	
(lab data)	Btk	27-52	SEr	7.5YR 4/4	7.5YR 6/4	fL	so	so,ps	p	
	Btkbz	52-77	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	
	Btkb	77-92	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	
	Kb	92-112	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	Few broken clasts spread by carb.
	Kqb	112-129	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	
	Kqb2 (Bt->K)	129-140	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	
	Btkqb2	140-175	SEr	7.5YR 4/4	7.5YR 6/4	fSL	lo	so-ss,po-ps	p	
	2Btkb2	175-180	CEur	7.5YR 4/3	7.5YR 5/3	fSL	lo	so-ss,po-ps	cp	
	3BCtkb2	180-203	FCu	7.5YR 4/3	7.5YR 5/3	fSL	lo	so-ss,po-ps	cp	
	3Bk1b2	203-238	FCu	7.5YR 4/3	7.5YR 5/3	f-mS	lo	so,po	cp	
	3Bk2b2	238-263+	FCu	7.5YR 4/3	7.5YR 5/3	fLS	lo	so,po	cp	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 9-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
						t4a							
NM16	Ap	0-13	7.5YR 4/3	5YR 5/5	SiL	5	1 vco pl	sh	ss,ps	3nbr	–	–	c,w
31N/10W/10/1 (samples)	Bt	13-24	5YR 3/4	5YR 4/4	SiC	5	1 m pr, 2-3 f-m abk	h-sh	s,p	3mk-npf	–	o-e	c,w
	2BCtk	24-46	7.5YR 4/3	5YR 5/5	SiL	10	1-2 m-co abk	sh	ss,ps	3mkbr,1npo	I+	es	c,w
	2K	46-68	7.5YR 6/4,7/3	5YR 7/3,8/2	SiL?	20	1 m-co abk	sh	ss,po	–	III	ev	c-a,w
	3Km	68-106	5YR 8/2	5YR 8/1	?	40	mass/1 m-vco pl	h-sh	ss,po	–	III+	ev	c,w
	3K	106-132	5YR 7/2	5YR 8/1	?	70	mass/1 m abk	h	ss,po	–	III	ev	c,w
	3Bk1	132-162	7.5YR 4.5/4,7/4	5YR 7/2,8/1	coLS	70	mass	sh	ss,po	–	III	es	c,w
	3Bk2	162-195	7.5YR 6/3,5/3	7.5YR 6/2,6.5/2	coLS	60	mass	so	ss,po	–	III	es	a,w
	4Bk3	195-209	7.5YR 8/2,6/2	5YR 8/1.5,7/2	SiL	5	1-2 f-m abk/ 1 f pl	sh	ss,ps	–	III	ev	c-a,w
	4Bk4	209-269+	10YR 5/3	7.5YR 7/4	coS	5	sg	lo	so,po	–	I-	e	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 9-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t4a						
NM16	Ap	0-13	3vf	ND	–	–	–	–	ND	–	–
31N/10W/10/1 (samples)	Bt	13-24	ND	ND	–	–	–	–	ND	–	–
	2BCtk	24-46	ND	ND	4mk mic gb	d	–	–	ND	–	–
	2K	46-68	ND	ND	–	30% 2scr cs,70% d cw	–	–	ND	–	–
	3Km	68-106	ND	ND	–	d cs	–	–	ND	–	–
	3K	106-132	ND	ND	–	d cw-cs	–	–	ND	–	–
	3Bk1	132-162	ND	ND	4mk mic gb,4n mic gt	20% 2 smr,d	–	–	ND	–	–
	3Bk2	162-195	ND	ND	4n mic g	80% 3smi cw,d	–	–	ND	–	–
	4Bk3	195-209	ND	ND	–	d cw	–	–	ND	–	–
	4Bk4	209-269+	ND	ND	2n mic gb	–	–	–	ND	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 9-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
					t4a					
NM16	Ap	0-13	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	pc	
31N/10W/10/1 (samples)	Bt	13-24	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	pc	
	2BCtk	24-46	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	pc	
	2K	46-68	CEur	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	pc	
	3Km	68-106	Al	9YR 5/3	9YR 6/4	LS	lo	so,po	pc	
	3K	106-132	Al	9YR 5/3	9YR 6/4	S	lo	so,po	pc	
	3Bk1	132-162	Al	9YR 5/3	9YR 6/4	coS	lo	so,po	cp	
	3Bk2	162-195	Al	9YR 5/3	9YR 6/4	coS	lo	so,po	cp	
	4Bk3	195-209	Al	9YR 5/3	9YR 6/4	LS	lo	so,po	p	
	4Bk4	209-269+	Al	10YR 5/3	9YR 6/4	coS	lo	so,po	p	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 10-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
						t3b							
NM17 29N/12W/4/2 (samples)	A	0-8	7.5YR 4.5/4	7.5YR 5.5/4	fSL	0	1 co-vco pl, 1 vf gr	so	so,po-ps	–	–	em	c,s
	BAt	8-20	7.5YR 4/4	7.5YR 5/4	fSL+	0	1 m-co abk	so	ss,ps	–	–	em	c,w
	Btk	20-42	7.5YR 4.5/4	7.5YR 6/4	fSL+/fSCL-	1	1 vco pr, 2-3 m abk	h	ss,p	3πco,1πpf	II	em	c-g,w
	BCtk1	42-53	7.5YR 4.5/4	7.5YR 6/4	fSL+	1	1 co pr, 2 f-m abk	h	ss,p	2πco,1πpf,1πpo	I	em	c,s
	BCtk2	53-65	7.5YR 4.5/4	7.5YR 5.5/4	fSL+	1	2 co pr, 2 f-m abk	sh	ss,ps	2πco,1πpf	I	em	a,s
	2Btk1by	65-83	6YR 4/4	7.5YR 5.5/5	SC/C	15	3 m-co pr	sh	vs,vp	3mkco,4n-mkpf, 4n-mkpo	I+	e	c,i
	2Btk2by	83-94	5YR 4/4	5YR 5/5,9/2	SC	15	2 f-m pl/ 2 f-m sbk	h	vs,vp	3mkco,4n-mkpf, 4n-mkpo	II	em	g,w
	2K1b (Bt->K)	94-101	5YR 6/5	5YR 9/2,7/4	SiC	15	3 f pl/3f sbk	sh	s,p	–	III	es	c-g,w
	2K2b	101-116	5YR 7/4.5,7.5/4	5YR 9/2,7.5/3	SiL	25	3 vf-f sbk	sh,s	ss,ps	–	III	ev	c,w-i
	3Kmb	116-139	5YR 7.5/4	5YR 9/2	SiL	50	mass/1 co pl	vh,sh	ss,ps	–	III+	ev	g,w
	3K1b	139-171	5YR 7.5/4	5YR 9/2	SiL	70	mass	so,sh	ss,po-ps	–	III	es	d,w
	3K2b	171-200	5YR 7/4.5	5YR 8.5/2	SiL	70	mass	so	ss,ps	–	III	es	c-d,w
	3Kyb	200-247	7.5YR 6.5/4	5YR 8.5/2,8/2	SiL	75	mass,sg	so,lo	ss,ps	–	II+	es	c,w-i
	3Bkyb	247-282+	7.5YR 5/4	7.5YR 6.5/4	mLS	75	sg	lo,so	so,po	–	II-	e-em	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 10-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t3b						
NM17 29N/12W/4/2 (samples)	A	0-8	1mi,1vf	3mii,1mit	–	–	–	–	–	–	–
	BAt	8-20	2mi,2vf	3mii,3mit	–	–	–	–	–	–	–
	Btk	20-42	1mi	3mii,3vft	–	25% 2scr	–	–	–	–	–
	BCtk1	42-53	1mi	3mit	–	sf po	–	–	–	–	–
	BCtk2	53-65	1mi	3mit,1vft	–	sf po	–	–	–	–	–
	2Btk1by	65-83	1mi	2mit	4n mic gb	sco pf,sf po	sf po	–	–	–	–
	2Btk2by	83-94	–	3mii,2mit	4n mic gb	10% 3 scr cs	20% 1sc+ sco	–	–	–	–
	2K1b (Bt->K)	94-101	–	v1mit	4k lam+stal cs gb	80% 3sci cs,d,sf po	–	–	–	–	–
	2K2b	101-116	–	1mii	4n-k lam cs gb	85% 3sci cs,d	–	1smr	–	–	–
	3Kmb	116-139	–	1mit,2mii	–	100% d cs-cw	–	1smr	–	–	–
	3K1b	139-171	–	2mit,2mii	4n lam cs gb, 4n mic gt	100% d cw	–	–	–	–	–
	3K2b	171-200	–	2mit,2mii	4n mic g	90% d cw	–	–	–	–	–
	3Kyb	200-247	–	ND	3-4n mic gb, 0-4n mic gt	50% d cw	sm	–	–	–	–
	3Bkyb	247-282+	–	ND	0-v1 sf g	10% d cw	sf po	–	–	–	–

TABLE 3.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 10-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t3b					
NM17 29N/12W/4/2 (samples)	A	0-8	SEr	7.5YR 4.5/4	7.5YR 5.5/4	fSL	so	so,po-ps	--	Detrital carb. fragments.
	BAt	8-20	SEr	7.5YR 4.5/4	7.5YR 5.5/4	fSL	so	so,po-ps	--	
	Btk	20-42	SEr	7.5YR 4.5/4	7.5YR 5.5/4	fSL	so	so,po-ps	p	
	BCtk1	42-53	SEr	7.5YR 4.5/4	7.5YR 5.5/4	fSL	so	so,po-ps	p	
	BCtk2	53-65	SEr	7.5YR 4.5/4	7.5YR 5.5/4	fSL	so	so,po-ps	p	
	2Btk1by	65-83	CEr	7.5YR 5.5/4	7.5YR 6/4	LS	lo	so,po	pc	
	2Btk2by	83-94	CEr	7.5YR 5.5/4	7.5YR 6/4	LS	lo	so,po	pc	
	2K1b (Bt->K)	94-101	CEr	7.5YR 5.5/4	7.5YR 6/4	LS	lo	so,po	pc	
	2K2b	101-116	CEr	7.5YR 5.5/4	7.5YR 6/4	LS	lo	so,po	pc	Salts accumulated after pit dug?
	3Kmb	116-139	FCu	7.5YR 4/3	7.5YR 6/3	LS	lo	so,po	c	Salts accumulated after pit dug? Clasts
	3K1b	139-171	FCu	7.5YR 4/3	7.5YR 6/3	S	lo	so,po	c	_ (some broken) spread by carb.
	3K2b	171-200	FCu	7.5YR 4/3	7.5YR 6/3	fS	lo	so,po	c	
	3Kyb	200-247	FCu	7.5YR 4/3	7.5YR 6/3	fS	lo	so,po	c	
	3Bkyb	247-282+	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	c	Few broken clasts spread by sand, gypsum.

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 11-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
						t3a							
NM18	A	0-9	7.5YR 4/4	7.5YR 5/4	L-	3	0-1 f-m pl	so-lo	so,ps	–	–	em	c,s
29N/12W/4/1B	BAt	9-25	7.5YR 4/4.5	7.5YR 5/4.5	L+	3	1 m sbk	vfr	ss,ps-p	1vnpo	–	em-es	c,w
(samples)	Btk	25-43	7.5YR 4/4.5	7.5YR 5.5/4.5	CL	3	2 vco pr, 2 f-co abk	vfi	s,p	2vnpf	II	em-es	c,w
	Btz	43-59	7.5YR 4/4	7.5YR 5.5/4	CL-	3	1 vco pr, 2 m-co abk	vfi	s,ps-p	1vnpf	–	em	c,w-i
	BCkz	59-72	7.5YR 4/4	7.5YR 5.5/4	CL-	3	1 vco pr, 2 m-co abk	vfi	s,ps-p	–	I-	em	c,w
	Btk1b	72-93	6YR 4/4	6YR 5/4	C/CL+	3	2 f-m abk	vfi	vs,vp	2npf,2mkpf	I	es	c,i
	Btk2b	93-109	6YR 4.5/4	6YR 5.5/4	CL+	5	1-2 f-m abk	fr	s,p	3npf,2mkpf	II	es	c,w
	Km1b	109-117	7.5YR 7/4,5/4	7.5YR 9/4,6/4	?	2	3 f-m sbk	eh,lo	?	–	III	ev	c,s
	Km2b	117-140	7.5YR 8/4	7.5YR 9/3	?	2	3 f-m sbk	eh,lo	?	–	IV	ev	a,w
	2Km3b	140-150+	7.5YR 8/4	7.5YR 9/3	?	50	3 co pl	eh	?	–	IV	ev	–
NM19	A	0-9	7.5YR 4/4	7.5YR 5.3/4	fSL-	5	1 f-m pl,1 f gr	so-lo	so,po-ps	–	II-	em	c,s
29N/12W/4/1A	Bwk	9-20	7.5YR 5/4	7.5YR 5.7/4	L	5	1 m sbk	so	so-ss, po-ps	–	II-	em	c,w
(samples)	Bkb/Kmb	20-31	7.5YR 5/4,5.5/4	7.5YR 6/4,7.5/4	L	15	1 m sbk	eh,so	so-ss, po-ps	–	II+	es	va,w
	2Kmb	31-44	7.5YR 6/4,7.5/4	7.5YR 6.5/4,9/2	SiL?	20-40	3 vco pl, 3 m-co abk	eh	so-ss, po-ps	–	IV-	ev	a,w-i
	2Kb	44-50	7.5YR 6/4,9/2	7.5YR 6.5/4,9/2	fSL?	30	1 m sbk	eh,so	ss,ps	–	III+	es-ev	va-c,s-w
	2Km1b	50-60	5YR 7/3	5YR 9/2	?	30	2-3 vco pl, 3 f-co abk	eh	?	–	IV	ev	c-g,w
	3Km2b (b2?)	60-83	5YR 7/3	5YR 9/2	?	50	3 m abk	eh	?	–	III+	ev	c,w
	3Km3b (b2?)	83-110	5YR 7/3	5YR 9/2	?	65	1-2 m abk	h-so	?	–	III	ev	c-g,w
	3Bk1b (b2?)	110-144	5YR 5/3	5YR 6.5/3	mLS-	75	mass/sg	so-lo	so,po	–	II	es	g,w
	3Bk2b (b2?)	144-176+	7.5YR 4/4	7.5YR 6.5/4	mS	75	sg	lo	so,po	–	I	em	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 11-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t3a						
NM18	A	0-9	2mi,2vf	1mit	–	–	–	–	–	–	–
29N/12W/4/1B	BAt	9-25	3mi,3vf	2mit	–	–	–	–	–	–	–
(samples)	Btk	25-43	2mi	3mit	–	10% 1sci	–	–	–	–	–
	Btz	43-59	2mi	3mit	–	–	–	sfl pf	–	–	–
	BCkz	59-72	2mi	3mit	–	sf po	–	sfl pf	–	–	–
	Btk1b	72-93	1mi	3mit	–	sf pf,sf po	–	–	–	–	–
	Btk2b	93-109	–	0-2mit	2n mic g,3 sf g	20% 3sci cs, sf pf,sf po	sf po	–	–	–	–
	Km1b	109-117	–	1mii	–	85% 3sci ci-cs,15% d	–	–	–	–	–
	Km2b	117-140	–	1mii	–	90% 3sci ci-cs, lam/mam,10% d	–	–	–	–	–
	2Km3b	140-150+	–	–	–	95% ci-cs lam,5% d	–	–	–	–	–
NM19	A	0-9	2mi	3mii	–	5% 1sci ci	–	–	–	–	–
29N/12W/4/1A	Bwk	9-20	1mi	3mii,2mit	4n mic gb,2n mic gt	5% 1sci ci,d	–	–	–	–	–
(samples)	Bkb/Kmb	20-31	1mi	3mii,1mit	2k stal ci gb	10% 1sci ci, 30-40% 3sci ci,d	–	–	–	–	–
	2Kmb	31-44	–	0-2mii	4k lam ci gb	90% 3sci hor ci, lam top	–	–	–	–	–
	2Kb	44-50	–	0-2mii	4vk stal ci gb	50% 3sci ci,d	–	–	–	–	–
	2Km1b	50-60	–	1mii	4mk lam ci g	95% 3sci hor ci lam,10% d	–	–	–	–	–
	3Km2b (b2?)	60-83	–	0-2mii	4k-vk stal ci gb	95% 3sci ci	–	–	–	–	–
	3Km3b (b2?)	83-110	–	0-2mii	4vk stal ci gb	80% 3sci cs-cw	–	–	–	–	–
	3Bk1b (b2?)	110-144	–	3mii	4k lam cs gb,1n cs gt	20% 3 sci cw	–	–	–	–	–
	3Bk2b (b2?)	144-176+	–	3mii	4n mic gb,v1 sf gt	–	–	–	–	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 11-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR		TEXTURE	CONSISTENCE		DOMINANT CLAST SIZE	COMMENTS
				MOIST	DRY		DRY/MOIST	WET		
					t3a					
NM18	A	0-9	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
29N/12W/4/1B	BAt	9-25	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
(samples)	Btk	25-43	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	Btz	43-59	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	BCkz	59-72	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	Btk1b	72-93	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	Btk2b	93-109	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	Km1b	109-117	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	Km2b	117-140	SEr	7.5YR 4/4	7.5YR 5/4	L-	so-lo	so,ps	p	
	2Km3b	140-150+	FCu	7.5YR 4/3	7.5YR 6/3	LS	lo	so,po	c	
NM19	A	0-9	SEr	7.5YR 4/4	7.5YR 5/4	fSL-	so-lo	so,po-ps	p	Gravel all petrocalcic frags.
29N/12W/4/1A	Bwk	9-20	SEr	7.5YR 4/4	7.5YR 5/4	SL-	so-lo	so,po-ps	pc	Gravel includes petrocalcic frags.
(samples)	Bkb/Kmb	20-31	SEr	7.5YR 4/4	7.5YR 5/4	SL-	so-lo	so,po-ps	pc	
	2Kmb	31-44	CErl	7.5YR 4/3	7.5YR 6/3	fLS	lo	so,po	cp	Clasts (some broken) spread by carb.
	2Kb	44-50	CErl	7.5YR 4/3	7.5YR 6/3	S	lo	so,po	cp	Clasts (some broken) spread by carb.
	2Km1b	50-60	FDu+CErl	7.5YR 4/3	7.5YR 6/3	S	lo	so,po	c	Clasts (some broken) spread by carb.
	3Km2b (b2?)	60-83	FCu	7.5YR 4/3	7.5YR 6/3	S	lo	so,po	c	Clasts (some broken) spread by carb.
	3Km3b (b2?)	83-110	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	c	
	3Bk1b (b2?)	110-144	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	c	
	3Bk2b (b2?)	144-176+	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	c	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 12-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t2c								
NM20	BAtk→Ak	0-6	5YR 4/5	7.5YR 5/4.5	CL-	<1	1 f-m pl	so	vs,p	–	I-	ve	c,s
32N/10W/23/1	BAtk	6-12	5YR 4/3.5	7.5YR 5/4	CL-	<1	1 f-m sbk	so-sh	vs,p	2br	I	ve	c,w
(lab data)	Btk	12-27	6YR 5/4	5YR 5.5/3.5	CL	<1	2 f-m abk	sh	vs,vp	3br	II-	em	a,i,stl
	Kq	27-43	5YR 7/3.5, 5YR 6/3.5	5YR 8/2,7/2	L	3	1 m pl/2 f sbk	so-sh	s,p	--	III+	ev	c,w
	Kmq1b	43-54	5YR 8/2,6/3	5YR 8/1,8/1.5	L	<1	1 f-co skb	h,lo	s,p	–	III+	ev	c,w
	Kmq2b	54-80	5YR 8/1.5	5YR 9/1	L	<1	2 f-m sbk	h,so	so,po	–	III+	ev	g,w
	Kq1b	80-107	5YR 8/1,7/3	5YR 9/1,8/2	vf-fSL	<1	2 f-m sbk	h,lo	so-ss,po	–	III	ev	g,s
	Kq2b	107-140	5YR 8/2,6/3	5YR 9/1,7.5/3	vf-fSL	1	2 m-co sbk	h,lo	ss,po	–	III	ev	c,w
	2Kq3b	140-177	5YR 5/3	5YR 8/2,8/1	LS	40	mass	fr-fi	so-ss,po	–	III	ev	g,w
	2Bkqb	177-196	5YR 5/3	5YR 7/2	fSCL-	50	mass	fr	so,po	–	II	es	a,s
	3Btkq1b2	196-234	5YR 6/3,5/2.5	5YR 8/2,6.5/2	CL-	0	mass/1 vf abk	vfr	so-ss,po	--	I-II	em	d,w
	3Btkq2b2	234-273+	5YR 7/2,5/3	5YR 8/2, 7.5YR 8/2	C-	0	mass/1 vf abk	vfr	so-ss,po	–	I-II	em	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 12-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t2c						
NM20	BAtk→Ak	0-6	3mi,3vf	3mi	–	sf po	–	–	ND	–	–
32N/10W/23/1	BAtk	6-12	3mi,3vf	3mi	–	1smr	–	–	ND	–	–
(lab data)	Btk	12-27	2mi,2vf	3mit,3vft	–	5% 2 sc cw	–	–	ND	–	–
	Kq	27-43	0-3mi,0-3vf	ND	–	90% d cw,10% dm hor	–	–	ND	–	–
	Kmq1b	43-54	ND	ND	–	95% 2 sc cw,5% d	–	–	ND	–	–
	Kmq2b	54-80	0-3mi,0-3vf	ND	–	95% 2 sc cs,5% d	–	–	ND	–	–
	Kq1b	80-107	ND	ND	–	60% 2sc cs,40% d	–	–	ND	–	–
	Kq2b	107-140	ND	ND	4mk lam cs gb	60% 2sc cs,40% d	–	–	ND	–	–
	2Kq3b	140-177	ND	ND	4mk mic cw gb, 4n mic gt	d	–	–	ND	–	–
	2Bkqb	177-196	ND	ND	4n mic gb,3 sf gt	d	–	–	ND	–	–
	3Btkq1b2	196-234	ND	ND	–	dcvw,3smi	–	–	ND	–	–
	3Btkq2b2	234-273+	ND	ND	–	dcvw,3smi	–	–	ND	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 12-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t2c					
NM20	BAtk→Ak	0-6	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
32N/10W/23/1	BAtk	6-12	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
(lab data)	Btk	12-27	SEr	7.5YR 4/4	7.5YR 5/4	SiL	so	ss,ps	p	
	Kq	27-43	SEr	7.5YR 4/4	7.5YR 5/4	L-	so	ss,ps	p	
	Kmq1b	43-54	SEr	7.5YR 4/4	7.5YR 5/4	L-	so	ss,ps	p	
	Kmq2b	54-80	SEr	7.5YR 5/4	7.5YR 6/4	L-	so	so,po	p	
	Kq1b	80-107	SEr	7.5YR 5/4	7.5YR 6/4	vf-fSL	lo	so,po	p	
	Kq2b	107-140	SEr	7.5YR 5/4	7.5YR 6/4	vf-fSL	lo	so,po	p	
	2Kq3b	140-177	AErl	7.5YR 5/4	7.5YR 6/4	LS	lo	so,po	cp	
	2Bkqb	177-196	AErl	7.5YR 5/4	7.5YR 6/4	fSL	lo	so,po	cp	Clay reworked from lower soil?
	3Btkq1b2	196-234	Er	7.5YR 5/4	7.5YR 6/4	mSL	lo	so,po	--	
	3Btkq2b2	234-273+	Er	7.5YR 5/4	7.5YR 6/4	mSL	lo	so,po	--	

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 13-L BASIC PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	COLOR MOIST	COLOR DRY	TEXTURE (<2 mm)	GRAVEL (vol. pct.)	STRUCTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	CLAY FILMS	CARB. STAGE	EF-FERV.	HORIZ. BOUND., LOWER
					t1u								
NM21	Ak	0-8	7.5YR 4/4	7.5YR 5/4	fSL+	10	0-1 f-m pl	so	ss,ps	–	II-	es	c,w
30N/10W/10/1	BAtk	8-18	7.5YR 4/4	7.5YR 5/4	CL+	10	1 m sbk	fi	s,p	3nco,3n-mkgt	I-	es	c,w
(lab data)	2Btkz	18-51	5YR 4/4	5YR 5/4	C	50	2 m abk	vfi	vs,vp	4mkpf,4mkpo, 4mkgt	I	em	c,w
	3Btk	51-61	5YR 4.5/5	5YR 5/4,7/3	C-	15	2 m abk	fi	s,vp	3mk-kpf,3mk-kpo, 2n-mkgt	II-	es	c,w
	3K1	61-68	7.5YR 6/4	7.5YR 7.5/3	C-	15	2 f-m sbk	fr	s,p	–	III	ev	c,w
	4K2	68-77	7.5YR 6.5/4	7.5YR 8/3,9/2	fSCL	25	2 m pl	vh,lo	ss,ps	–	III+	ev	a,w
	4Kqm1 (Bt→K)	77-103	7.5YR 7.5/4	7.5YR 9/2	fSL-	25	3 vco pl	eh	?	–	IV	ev	c,w
	5Kqm2	103-123	6YR 6.5/4	6YR 8/2	fSL	55	mass/1 co pl	vh	so,po	–	III+	ev	g-c,w
	5Kq	123-141	6YR 6/4	5YR 7.5/2	fSL	55	mass/2 m-co abk	h	ss,po-ps	–	III	ev	c,w
	5K	141-160	5YR 6/3	5YR 7.5/2	fSL	50	mass	so-sh	ss,po-ps	–	III-II	ev	g,w
	5Bk1	160-191	5YR 5.5/3	5YR 7.5/2	f-mSL	55	1 m-co abk	so	ss,po	–	II+	es	a,s
	6Bk2	191-207	5YR 5.5/3	5YR 6.5/3	fSL	20	2 f-m abk	sh	ss,ps	–	II+	es	c,w-i
	7BCk1	207-256	5YR 4.5/3	5YR 6/3	fLS	60	mass/1 m abk	so	so,po	–	II	em	g,w
	7BCk2	256-296	7.5YR 4/4	7.5YR 6/4	mS	60	mass	lo	so,po	–	I	em	c,w
	7BCk3	296-318	5YR 5/3	5YR 7/2	mS	70	mass	so-lo	so,po	–	I-II	em	c,w
	7BCk4	318-353+	6YR 4/3	7.5YR 6/3	mS	65	mass	lo	so,po	–	I-	e	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 13-C OTHER PROPERTIES, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ROOTS	PORES	CARBONATE		GYPSUM	SALTS	SILT CAPS	ORGANS	MnO_2
					COATS ON GRAVEL	FINE EARTH					
					t1u						
NM21	Ak	0-8	2mi-vf	3mii,1mit	2-4n mic gb	5% 1scr cs	–	–	3ngt	–	–
30N/10W/10/1	BAtk	8-18	2mi-vf	3mii,1mit	–	sf po	–	–	–	–	–
(lab data)	2Btkz	18-51	1mi-f	2mit,1mit	4n mic gb,2 sf gt	sf po	–	sfl pf, sfl po, sfl g	–	–	–
	3Btk	51-61	1f	2mit	4k lam cs gb	sf pf,sf po	–	–	–	–	1mipo
	3K1	61-68	–	2mit,2mii	4vk lam cs gb, 4n mic gt	d,sf po	–	–	–	–	–
	4K2	68-77	–	2mii	4vk lam cs gb, 4n mic gt	90% 3sci ci,10% d	–	–	–	–	–
	4Kqm1 (Bt→K)	77-103	–	0-3mit	–	95% 3sci hor ci, lam top	–	–	–	–	–
	5Kqm2	103-123	–	v1mi	–	95% 3sci hor ci	–	–	ND	–	–
	5Kq	123-141	–	3mi	–	80% 3sci cw	–	–	ND	–	–
	5K	141-160	–	3mii,3mit	–	75% 3 sci cw,sf po	–	–	ND	–	–
	5Bk1	160-191	–	3mii	4mk mic cw gb,0-2n gt	50% 3sci cw	–	–	ND	–	–
	6Bk2	191-207	–	3mit	4n mic gb	50% 3sci	–	–	ND	–	–
	7BCk1	207-256	–	3mii	4n mic gb	10% 3sci,sf	–	–	ND	–	–
	7BCk2	256-296	–	3mii	3n mic gb	–	–	–	ND	–	–
	7BCk3	296-318	–	3mii	2n mic g	50% 3smi	–	–	ND	–	–
	7BCk4	318-353+	–	3mii	2n spr gb	–	–	–	ND	–	–

TABLE B.5 DESCRIPTIONS OF SOIL PROFILES IN NEW MEXICO, continued
PART 13-R INFERRED PROPERTIES OF SOIL PARENT MATERIALS AND COMMENTS, continued

PROFILE NO., SITE NO.	HORIZON	DEPTH (cm)	ORIGIN, SOURCE	COLOR MOIST	COLOR DRY	TEXTURE	CONSISTENCE DRY/MOIST	CONSISTENCE WET	DOMINANT CLAST SIZE	COMMENTS
					t1u					
NM21	Ak	0-8	CErl	7.5YR 4/4	7.5YR 5/4	fSL	so	ss,po	cp	
30N/10W/10/1	BAtk	8-18	CErl	7.5YR 4/4	7.5YR 5/4	fSL	so	ss,po	cp	
(lab data)	2Btkz	18-51	CErl	7.5YR 4/4	7.5YR 5/4	fSL	so	ss,po	cp	
	3Btk	51-61	CErl	7.5YR 4/4	7.5YR 5/4	fSL	so	ss,po	cp	
	3K1	61-68	CErl	7.5YR 4/3	7.5YR 6/3	fSL	lo	ss,po	cp	
	4K2	68-77	CErl	7.5YR 4/3	7.5YR 6/3	fSL	lo	so,po	cp	
	4Kqm1 (Bt →K)	77-103	CErl	7.5YR 4/3	7.5YR 6/3	fSL	lo	ss,po	cp	
	5Kqm2	103-123	FCu	7.5YR 4/3	7.5YR 6/3	fSL	lo	ss,po	cp	
	5Kq	123-141	FCu	7.5YR 4/3	7.5YR 6/3	fSL	lo	ss,po	cp	Increase in PM clay.
	5K	141-160	FCu	7.5YR 4/3	7.5YR 6/3	f-mSL	lo	ss,po	cp	
	5Bk1	160-191	FCu	7.5YR 4/3	7.5YR 6/3	f-mSL	lo	ss,po	cp	
	6Bk2	191-207	FCu	7.5YR 4/3	7.5YR 6/3	fSL	lo	ss,ps	cp	Increase in PM clay.
	7BCk1	207-256	FCu	7.5YR 4/3	7.5YR 6/3	fLS	lo	so,po	cp	
	7BCk2	256-296	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	cp	
	7BCk3	296-318	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	cp	
	7BCk4	318-353+	FCu	7.5YR 4/3	7.5YR 6/3	mS	lo	so,po	cp	

TABLE B.6 EXPLANATION FOR SOIL-PROFILE DESCRIPTIONS

HORIZON NOMENCLATURE

After Guthrie and Witty (1982) and Birkeland (1984). K-horizon nomenclature modified from Gile and others (1966). Av denotes vesicular surface horizon (Springer, 1958). → indicates changing morphology (Birkland, 1984). j indicates juvenile or incipient development (National Soil Survey Committee of Canada, 1974).

COLOR

Munsell hue, value, and chroma. If more than one color is given, first is dominant. Intermediate hues (given as 6YR and 9YR) are estimated.

mtl	mottle color

TEXTURE

GRAVEL CONTENT ≥ 2mm (includes granules to boulders)		*SAND SIZE*		*TEXTURAL CLASSES*		*CLASS MODIFIERS**	
		vf	very fine	S	sand (sandy)	+	relatively fine
sg	slightly gravelly (2 - <20%)	f	fine	Si	silt (silty)	-	relatively coarse
g	gravelly (20 - <50%)	m	medium	C	clay (clayey)		
vg	gravelly (≥ 50%)	co	coarse	L	loam (loamy)		
		vco	very coarse				

STRUCTURE

GRADE		*SIZE*		*TYPE*	
mass	massive	vf	very fine (very thin)	gr	granular
sg	single grain	f	fine (thin)	pl	platy
v1	very weak*	m	medium	pr	prismatic
1	weak	co	coarse	cpr	columnar
2	moderate	vco	very coarse (very thick)	abk	angular blocky
3	strong			sbk	subangular blocky

If two structures are separated by comma, first breaks to second.

CONSISTENCE

DRY		*MOIST*		*WET – STICKINESS*		*WET – PLASTICITY*	
lo	loose	lo	loose	so	nonsticky	po	nonplastic
so	soft	vfr	very friable	ss	slightly sticky	ps	slightly plastic
sh	slightly hard	fr	friable	s	sticky	p	plastic
h	hard	fi	firm	vs	very sticky	vp	very plastic
vh	very hard	vfi	very firm				
eh	extremely hard	efi	extremely firm				

TABLE B.6 EXPLANATION FOR SOIL-PROFILE DESCRIPTIONS, cont.

CLAY FILMS AND SILT CAPS*

FREQUENCY		*THICKNESS*		*MORPHOLOGY*			
0	none*	vn	very thin	br	bridging grains	g	on gravel*
v1	very few	n	thin	co	coating grains	gt	on gravel tops*
1	few	mk	moderately thick	pf	coating ped faces	abk:	on blocky peds*
2	common	k	thick	po	lining pores	pr:	on prismatic peds*
3	many	vk	very thick*				
4	continuous						

CARBONATE STAGE

Adapted from Gile and others (1966), Shroba (1977), and Machette (1985).

STAGE	*MORPHOLOGY IN GRAVEL*	*MORPHOLOGY IN FINE EARTH*
I-	discontinuous coats on bottoms or 1-2% nodules 1-2 mm in diameter	few filaments, or 1-2% nodules
I	continuous coats on bottoms	common to abundant filaments
I+	continuous coats on bottoms and tops, or discontinuous coats on bottoms with minor carbonate in matrix	webby carbonate on or within peds
II-	continuous coats on bottoms, with or without coats on tops; disseminated, filamentous, and/or <10% nodular carbonate in matrix	≤10% nodules
II	similar to above, with 10-50% of matrix whitened	10-50% whitened
II+	similar to above, with 50-90% of matrix whitened	50-90% whitened
III-	similar to above, with 90-100% of matrix whitened	90-100% whitened
III	similar to above, with 100% of matrix whitened	100% whitened
III+	similar to above, but strongly cemented	similar to above, but nodular with loose partings
IV-	contains weakly developed or degraded laminar zones on tops and/or bottoms of platy peds	same as in gravel
IV	contains well developed laminar zones	same as in gravel
IV+	similar to above, with variable color and texture within massive parts of platy peds; texture suggests brecciation and recementation but pisolites have not formed	same as in gravel

EFFERVESCENCE

0-ve	none to very slight*	em	moderate
ve	very slight	es	strong
e	slight	ev	violent

TABLE B.6 EXPLANATION FOR SOIL-PROFILE DESCRIPTIONS, cont.

HORIZON BOUNDARY, LOWER

DISTINCTNESS		*TOPOGRAPHY*		*FEATURES*	
va	very abrupt	s	smooth	stl	stone line*
a	abrupt	w	wavy		
c	clear	i	irregular		
g	gradual				
d	diffuse				

ROOTS, PORES AND MnO_2 FLECKS*

ABUNDANCE		*DIAMETER*		*PORE TYPE*		*MnO_2 MORPHOLOGY*	
v1	very few	mi	micro	i	interstitial	pf	on ped faces
1	few	vf	very fine	t	tubular	po	on pores
2	common	f	fine	v	vesicular		
3	many	m	medium				
		co	coarse				

CARBONATE, GYPSUM*, AND SALTS* IN FINE EARTH

FREQUENCY		*THICKNESS*		*CEMENTATION*		*MORPHOLOGY*	
0	none*	vn	very thin*	cw	weak	br	bridges
v1	very few	n	thin, ≤ 1 mm	cs	strong	g	on gravel*
1	few	mk	moderately thick, 1 - 3 mm			gb	on gravel bottoms*
2	common					gt	on gravel tops*
3	many	k	thick, 4 - 9 mm			mam	mammary*
4	continuous	vk	very thick, ≥ 10 mm			mic	micritic*
						sf	filaments
						spr	sparry*
						stal	stalactitic*

CARBONATE, GYPSUM*, AND SALTS* IN FINE EARTH

SIZE		*DISTRIBUTION*		*CEMENTATION*		*MORRPHOLOGY*	
1	fine	d	disseminated	cvw	very weak	hor	horizontal
2	medium	dm	disseminated, in large patches	cw	weak	lam	laminar
3	large			cm	moderate*	pf	on ped faces
		oo	ooids	cs	strong	po	on pores
		sc	hard concretions	ci	indurated	ver	vertical
	SHAPE	sco	coatings*				
		sf	filaments				
r	rounded	sfl	flecks*				
i	irregular	sm	crumbly masses				
		ss	seams				

Percentages indicate outcrop areas with given properties.

TABLE B.6 EXPLANATION FOR SOIL-PROFILE DESCRIPTIONS, cont.

ORGANS*

ABUNDANCE		*AREA*		*CONTRAST*		*MORPHOLOGY*	
f	few	1	fine	f	faint	co	coating grains
c	common	2	medium	d	distinct	g	on gravel
m	many	3	large	p	prominent	pf	on ped faces
						po	on pores

PARENT MATERIAL

ORIGIN		*DOMINANT CLAST SIZE*	
A	side-stream alluvium	p	pebble
BBM	lodgement till (Johnson, 1990)	c	cobble
CD	debris-flow or fluvial (?) sediment in moraines (Johnson, 1990)	b	boulder
CE	colluvium with eolian material		
E	eolian sediment		
FC	main-river fluvial channel	*SOURCE*	
FCP	main-river fluvial channel, less sorted		
FO	fluvial overbank	l	local
MDS	debris-flow sediment in moraines (Johnson, 1990)	r	regional
		u	upstream
SE	sheetwash of reworked eolian sediment		
TD	till or diamicton, undifferentiated		

PUNCTUATION AND GENERAL ABBREVIATIONS

,	and	--	absent
/	or	?	uncertain or indeterminate
-	gradational (first property is dominant)	ND	not determined
+	both (first property is dominant)	NA	not applicable

* Nonstandard term used in this study. Other terms from Soil Survey Staff (1974), except as noted.

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
flood plain	8	<1	39.9	43.4	16.7	0.5	3.1	6.9	19.9	9.5	27.1	10.8	5.5	2.1	3.2	11.5	14.7	0.4	1.54
CO1	23	<1	39.4	40.2	20.3	0.7	3.4	7.2	19.7	8.3	21.4	12.8	6.0	2.6	4.2	13.6	17.7	0.3	1.68
34N/9W-	51	<1	56.5	22.6	21.0	0.5	4.3	10.0	29.7	11.9	7.7	10.1	4.8	2.8	1.8	16.4	20.0	0.9	1.65
/8U/1	95	<1	48.8	35.8	15.4	0.6	3.9	10.8	24.3	9.3	23.1	9.1	3.6	2.4	2.2	10.8	13.0	8.0	1.52
	127	60	57.5	29.0	13.5	3.7	7.7	13.6	25.6	7.0	17.7	8.0	3.3	2.6	2.3	8.5	10.9	9.6	1.64
	169	60	66.4	21.3	12.3	17.0	16.6	14.1	16.0	2.7	10.0	8.0	3.2	3.6	--	--	8.7	4.4	1.59
	179	60	60.7	29.7	9.6	22.6	16.9	7.8	10.6	2.7	13.8	11.5	4.5	2.1	0.9	6.5	7.5	6.5	1.65 *
mAC3	6	35	54.7	30.5	14.8	5.6	10.1	9.7	17.7	11.6	16.6	11.0	2.9	2.1	--	--	12.7	1.6	1.25
CO4	13	70	48.8	27.8	23.4	10.4	8.9	7.4	13.2	8.8	15.3	9.1	3.4	2.9	--	--	20.4	0.2	1.52
35N/9W-	29	75	55.4	19.9	24.7	12.1	12.0	9.3	15.6	6.5	10.5	7.0	2.4	2.4	--	--	22.3	0.3	1.57
/16/3	53	80	69.4	18.7	12.0	14.7	15.4	12.7	19.3	7.3	9.4	6.5	2.8	1.0	--	--	10.9	9.8	1.61
	71	80	78.1	15.5	6.4	18.5	17.4	13.0	21.6	7.6	8.4	5.5	1.7	1.2	--	--	5.2	17.7	1.78
	95	80	81.4	12.9	5.8	19.4	20.3	15.8	19.4	6.4	7.0	5.0	0.8	1.8	--	--	4.0	19.7	1.78
	121	50	83.9	11.6	4.5	21.2	23.4	15.0	18.4	6.0	6.1	4.5	1.0	1.2	--	--	3.3	21.7	1.76
	147	50	83.4	12.4	4.3	22.3	23.9	13.9	17.3	6.0	6.4	5.0	1.0	1.3	--	--	3.0	20.8	1.76
	170	50	84.2	11.8	4.1	21.5	23.2	14.0	18.4	7.1	6.9	4.1	0.8	0.9	--	--	3.2	22.7	1.64
	194	50	82.1	13.9	4.0	23.2	20.7	12.4	18.5	7.3	7.9	5.0	1.0	1.0	--	--	3.0	22.2	1.64
	217	45	85.2	10.7	3.6	24.2	24.6	14.3	17.3	5.3	5.9	4.2	0.6	0.9	--	--	2.7	22.2	1.57
	239	25?	64.8	30.2	5.0	11.5	11.9	8.5	19.6	13.5	17.1	10.4	2.7	1.3	--	--	3.7	20.4	1.85
t7ab	9	5	28.1	58.9	13.0	4.7	5.1	3.8	6.9	7.6	39.8	14.8	4.3	2.9	1.2	8.9	10.1	0.2	1.52
CO11	28	2	26.6	45.6	27.8	4.3	5.3	4.0	6.7	6.3	28.0	12.6	5.1	4.0	2.6	21.2	23.7	0.2	1.59
34N/9W-	59	20	31.6	32.5	36.0	6.5	7.8	5.0	7.1	5.3	16.8	10.6	5.1	3.3	1.9	30.9	32.7	0.3	1.50 *
/8U/3	90	50	40.2	22.6	37.2	12.6	10.2	6.8	7.9	2.7	10.2	8.2	4.3	2.4	0.7	34.0	34.8	0.4	1.50 *
	121	70	66.6	23.2	10.2	28.7	15.9	8.2	10.2	3.7	11.1	8.1	4.0	2.2	0.8	7.2	8.0	23.4	1.60 *
	152	70	70.3	22.1	7.7	27.4	18.2	9.7	11.8	3.2	11.5	6.9	3.7	3.1	--	--	4.6	27.2	1.60 *
	181	90	68.4	24.3	7.3	32.3	15.5	8.3	9.8	2.5	11.9	8.6	3.9	2.0	0.6	4.8	5.4	28.8	1.75
	210	90	66.3	24.0	9.7	35.4	15.9	6.0	6.6	2.5	10.2	9.3	4.6	2.3	1.2	6.2	7.4	30.9	1.75
	238	90	67.9	22.7	9.4	35.0	16.6	6.3	7.2	2.8	10.0	8.8	4.0	2.8	1.1	5.6	6.6	29.5	1.75

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)	
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ			
t6a	6	10	28.5	54.9	16.7	2.8	2.4	2.1	6.2	15.0	35.1	14.8	5.0	4.3	--	--	12.4	0.2	1.39	
CO23	15	10	24.9	54.8	20.3	2.3	1.9	1.7	5.2	13.8	30.8	17.2	6.8	5.8	--	--	14.5	0.0	1.47	
35N/9W-	24	15	22.2	45.0	32.9	3.4	1.9	1.4	5.2	10.3	24.6	14.1	6.3	5.6	--	--	27.3	0.1	1.77	
/17/1	39	35	21.8	27.6	50.5	3.5	2.4	1.9	5.9	8.2	9.6	12.7	5.3	4.6	--	--	46.0	0.3	1.86	
	65	50	35.9	23.2	40.9	8.3	5.5	5.3	9.9	6.9	11.0	7.8	4.4	1.5	--	--	39.4	0.7	1.66	
	87	55	39.4	26.1	34.5	11.5	7.2	6.0	8.7	6.0	13.3	10.4	2.4	1.9	--	--	32.7	2.5	1.65	
	109	25	67.7	19.0	13.4	14.1	24.2	15.1	10.6	3.7	8.0	8.8	2.2	1.9	--	--	11.5	10.7	1.63	
	129	50	59.4	27.4	13.2	19.1	18.7	8.9	7.4	5.3	11.6	12.5	3.3	2.7	--	--	10.5	27.3	1.65	
	145	50	68.8	24.1	7.2	17.4	25.9	12.5	8.5	4.4	10.3	10.9	2.9	2.3	--	--	4.9	22.0	1.69	
	157	70	58.4	32.5	9.1	12.5	15.7	9.5	12.8	7.9	15.7	13.7	3.1	2.7	--	--	6.5	27.2	1.67	*
	182	35	79.2	16.3	4.5	29.0	27.5	12.0	7.8	2.9	7.0	7.7	1.6	1.4	--	--	3.1	22.0	1.67	
t6a	9	5	41.4	49.8	8.8	9.7	8.2	4.6	8.1	10.8	40.1	7.1	2.6	1.9	0.7	6.2	6.9	0.2	1.51	
CO25	24	5	26.8	49.3	23.8	5.5	4.7	2.9	5.8	8.0	34.8	8.7	5.8	1.3	2.6	19.9	22.5	0.3	1.49	
34N/9W-	44	45	26.2	43.8	30.1	6.2	5.0	2.8	5.5	6.6	30.7	8.3	4.8	2.0	2.0	26.0	28.0	0.3	1.60	*
/8U/6	77	45	41.0	30.4	28.6	13.0	9.8	4.2	6.0	8.0	17.6	8.9	3.9	2.3	--	--	26.3	0.2	1.60	*
	117	70	68.8	17.2	14.0	34.4	20.6	5.8	5.6	2.4	8.6	6.1	2.5	1.4	3.5	9.2	12.7	11.9	1.60	
	152	75	77.3	17.4	5.3	34.0	23.8	9.0	8.3	2.2	8.9	6.3	2.2	0.4	0.9	4.0	4.9	21.7	1.56	
	203	75	78.0	15.9	6.1	32.2	27.9	8.7	6.9	2.4	9.3	4.8	1.8	1.5	1.1	3.5	4.6	24.7	1.56	
	250	75	81.4	16.9	1.7	34.0	27.2	9.5	8.2	2.5	8.6	6.2	2.1	0.4	0.9	0.4	1.3	22.9	1.60	*
mD2	8	15	56.0	31.7	12.4	6.0	7.3	7.5	20.3	14.8	22.5	6.9	2.2	2.2	--	--	10.2	0.1	1.37	
CO26	26	25	50.5	32.0	17.5	6.3	6.5	6.0	19.9	11.8	20.4	8.6	3.0	1.4	--	--	16.1	0.7	1.38	
35N/9W-	61	20	47.0	33.2	19.9	5.5	6.6	6.1	18.6	10.1	21.7	8.1	3.4	2.2	--	--	17.7	1.3	1.71	
/15/2	87	35	56.6	30.1	13.3	6.9	8.9	8.1	22.5	10.2	17.7	9.5	3.0	2.5	--	--	10.8	10.1	1.59	
	116	35	65.6	27.9	6.5	6.9	10.4	10.7	24.9	12.6	15.5	9.7	2.7	0.8	--	--	5.7	22.1	1.51	
	146	30	62.1	31.9	6.0	6.2	9.6	9.6	24.5	12.2	18.4	10.8	2.7	1.1	--	--	4.9	17.2	1.63	
	174	25	59.6	33.6	6.9	5.0	7.8	9.2	24.6	12.9	18.4	12.0	3.2	1.6	--	--	5.3	16.3	1.69	
	218	25	56.0	37.4	6.7	2.8	5.9	7.2	26.3	13.7	21.3	12.9	3.2	1.6	--	--	5.0	12.0	1.77	
	262	25	58.8	34.6	6.6	4.8	6.9	7.7	25.6	13.7	20.2	11.7	2.7	1.6	--	--	5.0	13.1	1.63	

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
t5e	9	<1	19.6	53.4	27.0	0.1	0.1	0.3	4.5	14.5	38.2	10.9	4.2	3.1	2.1	22.1	24.1	0.3	1.40 *
CO28	26	<1	10.0	56.1	33.9	0.1	0.0	0.1	2.0	7.7	38.6	12.4	5.2	3.3	1.4	29.2	30.6	0.3	1.60 *
34N/9W-	45	0	10.7	58.9	30.4	0.1	0.1	0.1	2.1	8.3	46.6	7.4	4.8	3.3	2.1	25.0	27.1	0.3	1.70 *
/7U/1	79	0	16.0	57.2	26.9	0.1	0.2	0.2	2.6	12.9	41.3	13.0	3.3	3.2	1.8	21.8	23.6	0.2	1.70 *
	95	<1	15.8	45.3	38.9	0.0	0.1	0.1	2.3	13.3	32.8	8.1	4.3	2.6	0.0	36.3	36.4	0.7	1.70 *
	126	<1	13.6	51.5	35.0	0.1	0.2	0.1	2.0	11.2	37.8	9.0	4.7	2.4	0.7	31.9	32.6	1.2	1.70 *
	161	<1	13.3	54.1	32.7	0.5	0.8	0.6	2.5	8.8	39.3	9.4	5.4	2.3	1.3	29.1	30.4	1.4	1.70 *
	193	1	15.5	46.9	37.6	0.8	1.3	1.0	3.3	9.1	37.1	7.3	2.5	3.0	1.3	33.3	34.6	1.8	1.70 *
	215	25	26.5	34.6	38.9	5.6	4.5	3.7	7.9	4.9	20.9	8.8	4.9	2.1	0.7	36.1	36.7	25.1	1.80 *
	248	30	47.1	28.6	24.3	21.1	10.1	4.9	7.5	3.5	14.2	9.3	5.1	3.5	1.9	18.9	20.8	23.7	1.60 *
	260	50	57.8	25.9	16.4	20.4	18.3	8.2	8.0	2.9	12.7	8.2	5.0	3.2	1.4	11.8	13.2	24.0	1.80 *
t5c	19	0	47.6	32.6	19.8	2.5	4.0	4.9	17.8	18.4	20.9	8.3	3.3	2.8	--	--	17.1	2.4	1.32
CO30	31	0	--	--	23.4 *	--	--	--	--	--	--	--	--	--	--	--	--	2.3 *	1.35
35N/9W-	49	0	36.9	39.7	23.4	0.3	1.4	2.8	12.3	20.2	25.3	10.8	3.6	3.5	--	--	19.9	2.3	1.44
/20/1	60	<1	33.8	40.0	26.2	0.9	1.9	2.5	12.4	16.1	24.9	10.4	4.6	3.6	--	--	22.5	0.6	1.40
	82	<1	--	--	26.5 *	--	--	--	--	--	--	--	--	--	--	--	--	0.6 *	1.50 *
	104	0	25.0	48.3	26.7	0.5	0.8	0.9	4.9	17.8	31.4	12.4	4.6	3.0	--	--	23.8	0.7	1.64
	124	0	22.5	54.3	23.3	0.0	0.2	0.4	4.4	17.4	37.9	13.0	3.4	2.7	--	--	20.6	1.2	1.64
	134	0	--	--	25.0 *	--	--	--	--	--	--	--	--	--	--	--	--	1.0 *	1.67
	156	0	--	--	26.3 *	--	--	--	--	--	--	--	--	--	--	--	--	1.0 *	1.67
	178	0	--	--	26.3 *	--	--	--	--	--	--	--	--	--	--	--	--	1.0 *	1.79
	196	<1	21.6	52.1	26.3	0.5	0.4	0.4	12.3	8.0	32.9	14.0	5.3	3.3	--	--	23.1	0.7	1.77
	220	<1	23.2	53.8	22.9	0.1	0.2	0.3	5.5	17.2	34.5	14.3	5.1	3.0	--	--	20.0	0.5	1.75
	249	0	--	--	22.0 *	--	--	--	--	--	--	--	--	--	--	--	--	0.6 *	1.74
	264	0	27.5	53.6	19.0	0.2	0.3	0.4	8.9	17.7	35.7	13.9	4.0	3.3	--	--	15.7	0.6	1.75
	276	<1	25.8	49.0	25.2	0.7	0.5	0.4	12.9	11.4	32.2	12.5	4.2	2.8	--	--	22.4	0.8	1.79
	300	0	20.2	46.0	33.9	0.1	0.3	0.2	3.7	15.9	32.8	9.1	4.1	2.8	--	--	31.1	0.1	1.72
	325	<1	22.8	46.7	30.5	0.4	0.5	0.4	5.9	15.7	28.3	14.3	4.1	2.3	--	--	28.2	3.6	1.76
	351	<1	19.9	46.8	33.3	0.5	0.8	0.6	10.1	8.1	31.4	11.8	3.7	2.3	--	--	31.0	0.1	1.83

(Profile continued on the following page)

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
t5c, cont.	378	15	32.3	22.4	45.4	4.1	3.5	2.5	11.0	11.2	4.5	10.5	7.3	2.5	–	–	42.8	0.2	1.86
CO30	417	40	24.1	35.5	40.4	9.2	5.8	2.6	4.7	1.8	17.2	12.8	5.5	3.2	–	–	37.2	0.0	1.74
35N/9W-	450	65	42.2	28.5	29.3	10.6	8.8	5.2	9.6	8.0	10.2	12.5	5.7	4.0	–	–	25.3	33.4	1.60 *
/20/1	487	70	31.0	40.7	28.3	7.7	5.7	3.9	7.5	6.2	16.9	16.2	7.6	4.6	–	–	23.7	44.3	1.58
	510	70	44.8	34.0	21.1	10.4	12.1	6.4	9.4	6.5	14.8	13.7	5.6	3.6	–	–	17.6	22.5	1.63
	534	25	–	–	15.0 *	–	–	–	–	–	–	–	–	–	–	–	–	21.0 *	1.58
	570	75	61.2	27.6	11.2	24.6	19.5	6.6	7.4	3.1	11.9	11.2	4.5	3.2	–	–	7.9	23.8	1.68
	605	75	–	–	9.0 *	–	–	–	–	–	–	–	–	–	–	–	–	23.8 *	1.70 *
	645	75	73.8	19.0	7.2	24.0	25.3	12.8	8.4	3.2	8.1	7.9	3.0	2.9	–	–	4.3	19.5	1.80 *
t4b	12	<1	14.1	55.1	30.9	0.3	0.4	0.4	3.4	9.6	41.8	9.2	4.1	2.3	2.9	25.6	28.6	0.2	1.66
CO34	28	<1	13.2	52.5	34.3	0.3	0.3	0.2	2.7	9.8	39.0	9.5	3.9	2.4	1.3	30.6	31.9	0.3	1.67
34N/9W-	43	<1	21.4	42.1	36.5	0.1	0.3	0.2	3.0	17.8	29.9	9.4	2.9	2.3	–	–	34.1	0.3	1.79
/29/1	61	<1	8.7	55.1	36.3	0.1	0.3	0.3	2.0	6.0	41.0	10.3	3.8	2.2	–	–	34.0	0.4	1.80
	73	<1	9.5	52.6	37.9	0.2	0.4	0.3	1.9	6.7	36.6	12.2	3.8	2.8	0.4	34.7	35.1	3.7	1.81
	91	<1	8.7	54.9	36.4	0.4	0.8	0.6	2.0	4.9	38.7	13.3	2.9	2.2	0.0	34.1	34.1	41.6	1.67 *
	126	<1	12.6	60.6	26.8	0.9	1.1	1.1	3.1	6.3	44.7	11.0	5.0	4.2	3.6	18.9	22.5	21.1	1.67
	146	<1	12.6	60.6	26.8	0.9	1.1	1.1	3.1	6.3	44.7	11.0	5.0	4.2	3.6	18.9	22.5	21.1	1.67
	164	<1	13.1	60.7	26.2	1.1	1.3	1.2	3.0	6.5	45.0	11.5	4.2	5.0	5.4	15.8	21.2	12.6	1.67
	186	<1	19.1	63.9	17.0	1.6	3.0	3.0	6.0	5.5	40.8	15.7	7.4	5.3	3.8	7.9	11.7	34.0	1.48
	208	<1	21.2	72.5	6.3	1.3	3.6	3.6	6.7	6.0	44.8	21.4	6.3	3.1	0.9	2.3	3.2	5.0	1.49
	235	1	38.2	57.1	4.8	5.4	8.7	5.2	10.5	8.4	30.6	20.9	5.6	1.8	1.3	1.6	3.0	0.3	1.45 *
	287	15-65	80.4	16.6	3.0	24.6	36.0	9.9	7.6	2.3	9.4	5.0	2.2	1.1	0.0	1.9	1.9	0.6	1.63
	317	60	66.6	24.0	9.4	14.1	19.1	14.4	14.9	4.1	12.7	7.0	4.3	3.4	0.4	5.7	6.0	3.3	1.63 *

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
Bridgetimber	10	2	14.6	61.8	23.6	0.8	0.7	1.1	4.6	7.4	43.4	13.6	4.8	2.4	1.9	19.3	21.2	--	1.27
Gravel	21	4	15.6	54.6	29.8	1.3	1.2	1.4	4.8	7.0	36.3	13.6	4.7	2.3	2.8	24.8	27.5	--	1.55
(La Plata R.)	30	15	16.3	47.6	37.2	1.3	1.5	1.7	5.2	6.6	31.0	11.6	4.9	0.5	--	--	35.7	--	1.70
CO37	55	1	14.7	28.1	57.2	0.8	1.2	1.9	6.1	4.8	15.1	8.8	4.2	1.4	--	--	55.8	--	1.92
34N/11W-	79	5	19.7	25.6	54.7	1.2	1.8	2.4	9.9	4.4	12.2	9.0	4.4	1.0	0.6	53.1	53.7	--	1.92
/25/1	103	15	33.4	21.8	44.8	3.5	6.6	6.2	12.3	4.7	9.9	8.9	3.0	2.8	--	--	42.0	--	1.67
	128	20	40.0	21.8	38.2	7.2	9.1	6.7	12.8	4.2	10.9	7.1	3.8	2.4	0.7	35.1	35.8	0.2	1.70 *
	151	35	40.5	22.8	36.7	6.1	8.9	6.9	14.1	4.6	10.6	8.7	3.5	2.7	1.0	33.0	34.0	0.2 *	1.70
	179	40	56.0	16.6	27.4	16.9	13.6	7.5	14.8	3.2	7.8	5.9	2.9	1.7	1.3	24.4	25.7	0.2 *	1.77
	215	50	53.6	18.1	28.4	11.8	11.0	8.4	17.1	5.3	9.2	5.2	3.7	2.0	1.5	24.8	26.3	0.2	1.78
	260	60	60.6	24.0	15.5	15.8	15.9	10.0	14.5	4.4	12.2	6.9	4.9	2.5	2.3	10.7	13.0	0.2 *	1.76
t7u	7	5	38.7	26.4	34.9	0.8	9.5	7.9	10.0	10.4	10.8	8.4	7.3	5.6	--	--	29.3	2.7	1.88
NM4	26	75	52.2	26.5	21.3	2.2	14.1	11.2	13.0	11.8	14.4	5.8	6.3	1.7	--	--	19.6	6.4	1.68
29N/13W-	48	75	71.6	12.0	16.4	6.5	27.2	17.0	13.6	7.2	6.8	2.8	2.4	1.4	--	--	15.0	7.1	1.54
/21/1B	78	75	87.2	6.2	6.6	3.5	35.1	29.6	16.0	2.9	2.6	2.6	0.9	0.8	--	--	5.8	9.8	1.59
	109	70	89.6	6.0	4.4	3.2	35.1	31.6	17.3	2.4	2.9	2.4	0.7	0.3	--	--	4.1	14.7	1.60
	125	1	83.4	11.1	5.6	0.2	9.6	24.2	40.0	9.4	5.2	2.9	2.9	1.0	--	--	4.6	10.8	1.53
	174	60	93.3	3.7	3.0	5.5	41.1	27.7	16.7	2.5	1.5	1.5	0.7	0.8	--	--	2.2	5.5	1.60
	210	60	94.2	2.6	3.2	3.3	41.6	34.3	13.7	1.5	1.5	0.8	0.3	1.7	--	--	1.5	5.6	1.60 *

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
t6b	7	<1	39.4	34.5	26.1	1.0	2.9	2.2	11.7	21.6	25.7	7.0	1.7	2.0	–	–	24.1	8.8	1.67
NM7	19	<1	32.2	41.8	26.1	0.6	1.9	1.3	8.7	19.8	31.3	9.6	0.9	3.3	–	–	22.8	3.7	1.61
30N/12W-	33	<1	33.9	41.6	24.5	1.0	2.3	1.5	10.5	18.5	30.6	8.3	2.6	2.3	–	–	22.2	3.1	1.43
/27/1B	52	<1	32.7	46.3	21.1	0.4	0.6	0.6	7.9	23.2	34.2	8.3	3.8	2.3	–	–	18.8	3.7	1.52
	78	0	29.1	52.9	18.1	0.1	0.4	0.4	7.9	20.2	39.3	10.0	3.5	2.5	–	–	15.6	10.7	1.58
	102	<1	26.8	55.9	17.3	0.2	0.5	0.4	7.5	18.1	41.4	10.8	3.7	2.4	–	–	14.9	9.4	1.52
	126	<1	29.7	53.2	17.1	0.2	0.4	0.3	6.8	22.0	39.3	10.2	3.7	3.4	–	–	13.8	16.7	1.55
	159	0	34.7	45.9	19.4	0.2	0.6	0.9	9.7	23.3	35.2	7.8	2.9	2.6	–	–	16.8	4.2	1.41
	186	<1	58.1	28.9	13.0	2.3	12.6	8.1	19.3	15.7	22.0	4.9	2.0	1.5	–	–	11.6	0.8	1.52
	215	0	42.0	40.0	18.0	1.1	0.9	0.9	17.3	21.8	28.7	8.0	3.3	1.7	–	–	16.3	1.1	1.49
	235	<1	47.8	34.5	17.8	1.1	2.9	2.2	18.1	23.6	25.8	6.2	2.5	1.9	–	–	15.8	1.3	1.61
	251	<1	48.1	35.5	16.4	0.9	2.0	2.0	22.1	21.1	27.0	5.8	2.6	1.4	–	–	15.0	1.2	1.62
	275	<1	53.1	31.4	15.5	0.8	2.3	2.0	27.1	20.8	23.6	5.0	2.8	1.2	–	–	14.2	1.1	1.77
	300	3	66.6	19.8	13.6	2.8	8.4	8.2	28.0	19.4	15.1	3.1	1.7	1.6	–	–	12.0	0.9	1.72
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	574	<1	43.2	43.0	13.7	0.5	0.4	0.2	12.4	29.8	30.4	9.0	3.6	2.3	–	–	11.4	7.9	1.69
	590	0	24.1	60.0	15.9	0.3	0.8	0.3	7.1	15.6	37.8	16.5	5.7	2.5	–	–	13.4	8.3	1.53
	605	<1	17.6	40.7	41.8	0.1	0.3	0.2	11.3	5.7	17.8	15.7	7.2	4.9	–	–	36.9	4.8	1.85
	624	0	15.6	43.0	41.4	0.2	0.4	0.3	4.1	10.8	16.7	21.8	4.5	5.3	–	–	36.2	5.6	1.80
	643	30	39.6	42.1	18.3	5.4	9.3	4.4	11.7	8.9	23.2	13.8	5.1	3.1	–	–	15.2	5.7	1.73
	673	65	88.6	7.3	4.2	8.3	30.9	25.8	20.2	3.4	3.6	2.8	0.9	0.3	–	–	3.9	1.7	1.73 *
t5a	15	<1	54.2	28.6	17.3	0.8	3.0	3.0	15.6	31.9	20.4	5.0	3.2	1.9	–	–	15.3	5.2	1.72
NM10	33	<1	53.7	29.5	16.8	0.9	2.8	2.9	16.2	31.1	22.4	5.1	2.0	2.3	–	–	14.5	4.4	1.67
30N/12W-	46	4	50.9	27.3	21.8	1.6	5.8	5.9	14.9	22.8	19.1	6.2	2.0	1.8	–	–	20.0	7.4	1.80
/33/1A	67	0	46.2	32.0	21.8	1.4	6.6	8.3	12.8	17.1	23.2	6.1	2.7	1.4	–	–	20.4	22.5	1.79
	86	0	55.7	28.2	16.1	2.2	10.3	13.1	15.0	15.1	20.7	6.3	1.3	1.6	–	–	14.4	18.6	1.92
	109	10	63.2	24.3	12.5	2.6	12.6	15.5	16.9	15.6	18.2	4.9	1.2	1.8	–	–	10.7	17.5	1.92
	130	65	56.7	31.4	11.9	2.1	8.6	10.7	18.2	17.2	21.1	6.5	3.8	2.9	–	–	9.1	15.4	1.73
	167	75	72.6	18.9	8.4	2.7	15.1	21.6	24.2	9.2	11.0	4.5	3.4	2.9	–	–	5.5	3.8	1.73
	191	75	81.8	13.1	4.9	3.5	18.0	25.4	27.5	7.5	6.2	3.9	3.0	1.8	–	–	3.4	3.2	1.73 *

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction															Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm^3)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
t4b	8	<1	51.4	33.5	15.1	0.3	0.7	0.8	15.3	34.3	24.6	5.6	3.3	2.0	--	--	13.1	6.4	1.55
NM16	27	<1	39.8	42.0	18.3	0.4	0.6	0.4	9.2	29.2	30.6	7.9	3.5	1.4	--	--	16.9	11.1	1.43
29N/12W-	52	<1	48.8	33.2	18.0	0.9	2.0	1.4	15.9	28.7	22.6	7.5	3.1	1.3	--	--	16.7	8.4	1.68
/5/2	77	<1	47.9	30.2	21.9	1.3	3.3	2.5	17.7	23.1	20.3	7.2	2.7	2.7	--	--	19.2	16.9	1.55
	92	1	46.8	31.3	21.9	1.3	3.6	2.6	16.1	23.2	19.7	7.6	4.1	2.0	--	--	19.9	21.8	1.72
	112	2	52.8	25.2	22.0	2.0	4.8	3.6	19.1	23.4	15.7	5.6	3.9	2.0	--	--	20.0	34.4	1.62
	129	2	67.5	19.7	12.9	2.4	6.7	4.7	29.4	24.3	12.8	4.5	2.4	1.8	--	--	11.0	49.8	1.40 *
	140	2	59.7	18.9	21.4	2.0	6.1	4.2	26.7	20.7	12.2	5.2	1.5	1.5	--	--	19.9	39.2	1.40
	175	2	57.9	20.0	22.1	1.9	5.3	4.1	26.2	20.4	12.6	5.4	2.0	2.3	--	--	19.8	24.7	1.65
	180	40	51.8	27.2	21.0	3.8	10.2	6.9	16.2	14.8	15.4	8.1	3.7	1.8	--	--	19.1	6.4	1.74
	203	70	65.6	22.1	12.3	7.6	16.4	12.8	18.5	10.3	10.9	6.6	4.6	1.8	--	--	10.5	2.1	1.57
	238	75	85.7	8.7	5.6	14.5	23.9	21.5	21.4	4.5	4.5	2.2	2.0	0.5	--	--	5.1	0.9	1.60 *
	263	75	85.7	8.2	6.1	13.4	21.9	18.8	25.1	6.5	4.7	2.8	0.7	0.7	--	--	5.4	0.7	1.60 *
t2c	6	<1	22.1	48.9	29.0	0.1	0.1	0.2	7.1	14.5	40.0	6.8	2.1	2.2	--	--	26.8	0.5	1.49
NM20	12	<1	26.4	45.3	28.3	0.0	0.1	0.2	7.0	19.0	36.5	6.2	2.6	1.5	0.3	26.6	26.9	3.2	1.44
32N/10W-	27	<1	23.9	42.7	33.4	0.2	0.2	0.2	6.8	16.5	33.3	7.1	2.3	1.5	4.1	27.8	31.9	10.0	1.61
/23/1	43	3	39.0	43.5	17.5	0.2	0.4	0.6	12.5	25.3	30.5	10.1	3.0	1.9	--	--	15.6	51.3	1.64
	54	<1	40.9	43.5	15.6	0.6	0.6	0.8	12.6	26.3	31.2	9.4	2.9	2.1	--	--	13.6	68.0	1.65
	80	<1	45.2	39.3	15.6	1.1	1.4	2.3	13.3	27.1	27.1	8.6	3.5	1.3	--	--	14.3	79.9	1.62
	107	<1	52.6	32.2	15.2	0.0	2.2	4.1	23.9	22.4	21.0	8.4	2.9	1.8	--	--	13.4	70.9	1.51
	140	1	55.3	31.0	13.8	1.1	2.6	5.3	21.2	25.1	16.6	10.9	3.5	0.9	--	--	12.9	58.5	1.60
	177	40	78.2	18.3	3.5	4.2	10.0	16.3	31.1	16.7	10.2	4.7	3.4	1.8	--	--	1.6	37.3	1.50
	196	50	63.0	15.0	22.0	6.5	9.0	12.1	23.0	12.5	7.8	4.0	3.2	2.7	--	--	19.2	22.3	1.48
	234	0	31.7	36.6	31.7	0.1	0.6	1.1	10.0	19.9	24.0	8.2	4.4	3.9	--	--	27.8	8.5	1.56
	273	0	35.5	21.4	43.1	0.1	0.6	2.3	15.8	16.8	13.8	5.2	2.4	****	--	--	17.8	8.8	1.63

TABLE B.7 PARTICLE SIZE, CARBONATE CONTENT, AND BULK DENSITY FOR SELECTED SOIL PROFILES, continued

Surface, Profile No., Site No.	Basal Depth (cm)	Gravel >2 mm (vol %)	Weight Percent of <2 mm Fraction														Carb-onate <2 mm (wt %)	Bulk Density, <2 mm (g/cm³)
			total sand 2000-50 μ	total silt <50-2 μ	total clay <2 μ	vco sand <2000-1000 μ	co sand <1000-500 μ	med sand <500-250 μ	fi sand <250-100 μ	vfi sand <100-50 μ	co silt <50-20 μ	med+fi silt <20-5 μ	vfi silt <5-2 μ	co clay <2-1 μ	med clay <1-0.5 μ	fi clay <.5 μ	med+fi clay <1 μ		
t1u	8	10	37.7	25.6	36.7	1.6	2.6	4.3	15.6	13.6	15.9	6.7	3.1	1.9	–	–	34.8	14.0	1.31
NM21	18	10	44.3	24.6	31.1	1.6	2.7	5.5	19.7	14.8	14.8	7.1	2.8	2.0	–	–	29.1	15.1	1.42
30N/10W-	51	50	28.3	17.9	53.9	1.5	2.3	2.6	9.5	12.4	7.3	7.6	3.0	0.1	–	–	53.8	4.9	1.58
/10/1	61	15	29.1	22.5	48.4	2.0	2.3	2.7	9.6	12.5	12.8	6.9	2.8	1.1	–	–	47.3	6.5	1.58
	68	15	32.0	19.4	48.6	2.7	3.2	3.9	10.5	11.8	11.4	6.1	1.8	0.9	–	–	47.7	40.0	1.60 *
	77	25	46.6	28.0	25.4	3.1	4.3	5.6	21.4	12.2	16.5	8.0	3.5	4.3	–	–	21.1	77.4	1.67
	103	25	51.3	28.2	20.6	3.6	5.1	7.5	20.4	14.7	15.8	8.8	3.6	2.8	–	–	17.8	89.4	1.96
	123	55	77.6	14.5	8.0	7.9	13.7	20.7	27.0	8.3	7.3	4.7	2.4	0.5	–	–	7.5	72.4	1.86
	141	55	74.5	11.1	14.5	5.0	12.8	21.1	28.8	6.7	5.0	3.9	2.1	0.7	–	–	13.8	43.1	1.83
	160	50	74.2	13.7	12.0	2.4	12.6	23.5	26.9	8.8	6.2	5.5	2.1	2.3	–	–	9.7	26.8	1.61
	191	55	75.7	13.3	11.0	3.1	12.1	25.1	27.5	7.8	6.2	4.8	2.4	2.3	–	–	8.8	20.4	1.63
	207	20	57.7	28.3	14.0	0.9	3.9	7.1	29.7	16.1	14.5	10.0	3.8	3.2	–	–	10.8	14.2	1.62
	232	60	74.8	16.1	9.1	1.5	13.5	22.0	28.8	9.0	7.8	5.6	2.8	2.6	–	–	6.5	8.6	1.58
	256	60	81.2	10.9	8.0	2.6	13.8	26.3	31.7	6.9	5.2	3.9	1.8	2.2	–	–	5.8	9.7	1.73
	296	60	90.7	6.0	3.3	3.0	23.2	32.5	27.6	4.4	2.9	1.7	1.4	0.4	–	–	2.8	4.3	1.65
	318	70	91.1	5.3	3.7	5.7	20.8	35.0	26.5	3.1	2.5	2.3	0.4	1.0	–	–	2.8	14.3	1.79
	353	65	91.8	5.0	3.2	5.1	23.9	34.5	24.7	3.7	2.5	1.6	0.9	1.4	–	–	1.8	3.4	1.79 *

* Estimate used to calculate weights of secondary clay and carbonate.
– Not determined or estimated.

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA: CLAY CONTENT (wt. % <2 mm) TOTAL	CLAY CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CLAY CONTENT (g/cm²) TOTAL	CLAY CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (wt. % <2 mm) TOTAL	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 2)	CARBONATE CONTENT (g/cm²) TOTAL	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 2)	PROFILE TOTALS: CLAY CONTENT (g/cm²-profile) TOTAL	CLAY CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) TOTAL	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 2)	COMMENTS, BASAL CARBONATE STAGE
COLORADO PROFILES																	
flood plain	8	16.7	15.4	2.1	0.2	0.4	2.0	--	0.0	-0.2	--	*For actual depth:*					
CO1	23	20.3	15.4	5.1	1.2	0.3	2.0	--	0.1	-0.4	--	32.5	4.0	9.5	6.201	--	
34N/9W/8U/1	51	21.0	15.4	9.6	2.6	0.9	2.0	--	0.4	-0.5	--						
	95	15.4	15.4	9.4	0.0	8.0	2.0	--	5.3	4.0	--	*For 250 cm:*					
	127	13.5	13.5	2.6	0.0	9.6	0.5	--	2.0	1.9	--	36.7	4.0	18.07	9.022	--	
	169	12.3	12.3	3.1	0.0	4.4	0.5	--	1.2	1.0	--						
	179	9.6	9.6	0.6 *	0.0	6.5	0.5	--	0.4 *	0.4 *	--						I-
mAC3	6	14.8	14.8	0.7	0.0	1.6	1.0	8.0	0.1	0.0	-0.3	*For actual depth:*					
CO4	13	23.4	6.4	0.7	0.5	0.2	0.5	15.0	0.0	-0.0	-0.5	9.1	2.1	32.6	29.3	7.2	Primary carbonate content of 15% (parent material estimate 2) is average for deep cuts, and gives about same weight of pedogenic carbonate as in CO1 (younger) and CO11 (older).
35N/9W/16/3	29	24.7	6.4	1.5	1.1	0.3	2.0	15.0	0.0	-0.1	-0.9						
	53	12.0	6.4	0.8	0.4	9.8	2.0	15.0	0.8	0.6	-0.4	*For 250 cm:*					
	71	6.4	6.4	0.3	0.0	17.7	2.0	15.0	1.1	1.0	0.2	9.7	2.1	35.7	32.1	8.0	
	95	5.8	5.8	0.4	0.0	19.7	2.0	15.0	1.7	1.5	0.4						
	121	4.5	4.5	0.8	0.0	21.7	2.0	15.0	5.0	4.5	1.5						
	147	4.3	4.3	0.8	0.0	20.8	2.0	15.0	4.7	4.3	1.3						
	170	4.1	4.1	0.6	0.0	22.7	2.0	15.0	4.3	3.9	1.4						
	194	4.0	4.0	0.6	0.0	22.2	2.0	15.0	4.3	4.0	1.4						
	217	3.6	3.6	0.6	0.0	22.2	2.0	15.0	4.4	4.0	1.4						
	239	5.0	5.0	1.2	0.0	20.4	2.0	15.0	6.2	5.6	1.6						I-

Asterisk (*) in horizon section of table follows single estimated value; in profile section, it follows total that includes more than about 15% of estimated values.
Dashes (--) indicate no measured, interpreted, or calculated values.

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA										PROFILE TOTALS					COMMENTS, BASAL CARBONATE STAGE
		CLAY CONTENT				CARBONATE CONTENT						CLAY CONTENT		CARBONATE CONTENT			
		(wt. % <2 mm)		(g/cm²)		(wt. % <2 mm)			(g/cm²)			(g/cm²-profile)		(g/cm²-profile)			
		TOTAL	PAR. MATL. (est. 1)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PAR. MATL. (est. 1)	PAR. MATL. (est. 2)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	
t7ab	9	13.0	13.0	1.7	0.0	0.2	1.0	--	0.0	-0.1	--	*For actual depth:*					
CO11	28	27.8	13.0	8.2	4.4	0.2	1.0	--	0.0	-0.3	--	34.8 *	19.9 *	12.3 *	11.0 *	--	
34N/9W/8U/3	59	36.0	11.0	13.3 *	9.3 *	0.3	1.0	--	0.1 *	-0.3 *	--						
	90	37.2	10.2	8.6 *	6.3 *	0.4	1.0	--	0.1 *	-0.1 *	--	*For 250 cm:*					
	121	10.2	10.2	1.2 *	0.0 *	23.4	0.5	--	3.5 *	3.4 *	--	34.9 *	19.9 *	12.9 *	11.6 *	--	
	152	7.7	7.7	0.8 *	0.0 *	27.2	0.5	--	4.1 *	4.0 *	--						
	181	7.3	7.3	0.3	0.0	28.8	0.5	--	1.5	1.4	--						
	210	9.7	9.7	0.3	0.0	30.9	0.5	--	1.6	1.5	--						
	238	9.4	9.4	0.3	0.0	29.5	0.5	--	1.4	1.4	--						I-
t6a	6	16.7	16.0	1.3	0.1	0.2	1.0	--	0.0	-0.1	--	*For actual depth:*					
CO23	15	20.3	16.0	2.4	0.5	0.0	1.0	--	0.0	-0.1	--	38.4	24.0	18.6	17.6	--	
35N/9W/17/1	24	32.9	16.0	4.4	2.3	0.1	1.0	--	0.0	-0.1	--						
	39	50.5	8.0	9.1	7.7	0.3	0.5	--	0.1	-0.0	--	*For 250 cm:*					
	65	40.9	8.0	8.8	7.1	0.7	0.5	--	0.2	0.1	--	41.1	24.0	34.9	33.4	--	
	87	34.5	8.0	5.5	4.2	2.5	0.5	--	0.4	0.3	--						
	109	13.4	7.2	3.2	1.5	10.7	0.5	--	2.9	2.7	--						
	129	13.2	7.2	1.6	0.7	27.3	0.5	--	4.5	4.4	--						
	145	7.2	7.2	0.8	0.0	22.0	0.5	--	3.0	2.9	--						
	157	9.1	9.1	0.4 *	0.0	27.2	0.5	--	1.6 *	1.6 *	--						
	182	4.5	4.5	1.0	0.0	22.0	0.5	--	6.0	5.8	--						I-
t6a	9	8.8	8.8	1.1	0.0	0.2	1.0	--	0.0	-0.1	--	*For actual depth:*					
CO25	24	23.8	8.8	5.0	3.2	0.3	1.0	--	0.1	-0.2	--	23.8 *	15.6 *	14.7 *	13.7 *	--	
34N/9W/8U/6	44	30.1	6.0	5.3 *	4.2 *	0.3	0.5	--	0.0	-0.0 *	--						
	77	28.6	5.3	8.3 *	6.8 *	0.2	0.5	--	0.1 *	-0.1 *	--	*For 250 cm:*					
	117	14.0	5.3	2.4	1.5	11.9	0.5	--	2.3	2.2	--	23.8 *	15.6 *	14.7 *	13.7 *	--	
	152	5.3	5.3	0.6	0.0	21.7	0.5	--	3.0	2.9	--						
	203	6.1	6.1	0.9	0.0	24.7	0.5	--	4.9	4.8	--						
	250	1.7	1.7	0.2 *	0.0 *	22.9	0.5	--	4.3 *	4.2 *	--						I-

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA										PROFILE TOTALS					COMMENTS, BASAL CARBONATE STAGE
		CLAY CONTENT				CARBONATE CONTENT						CLAY CONTENT		CARBONATE CONTENT			
		(wt. % <2 mm)		(g/cm²)		(wt. % <2 mm)			(g/cm²)			(g/cm²-profile)		(g/cm²-profile)			
		TOTAL	PAR. MATL. (est. 1)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PAR. MATL. (est. 1)	PAR. MATL. (est. 2)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	
mD2	8	12.4	6.5	1.2	0.5	0.1	2.0	12.0	0.0	-0.2	-1.1	*For actual depth:*					
CO26	26	17.5	6.5	3.2	2.0	0.7	2.0	12.0	0.1	-0.2	-2.1	28.7 *	10.5 *	35.5 *	29.2 *	-2.1 *	
35N/9W/15/2	61	19.9	6.5	9.4	6.3	1.3	2.0	12.0	0.6	-0.3	-5.1						
	87	13.3	6.5	3.2	1.6	10.1	2.0	12.0	2.7	2.2	-0.5	*For 250 cm:*					
	116	6.5	6.5	1.4 *	0.0	22.1	2.0	12.0	6.3 *	5.7 *	2.9 *	27.8 *	10.5 *	33.6 *	27.6 *	-2.2 *	
	146	6.0	6.0	1.7 *	0.0	17.2	2.0	12.0	5.9 *	5.2 *	1.8 *						
	174	6.9	6.9	2.0	0.0	16.3	2.0	12.0	5.8	5.1	1.5						
	218	6.7	6.7	3.4	0.0	12.0	2.0	12.0	7.0	5.8	0.0						
	262	6.6	6.6	3.1	0.0	13.1	2.0	12.0	7.1	6.0	0.6						I
t5e	9	27.0	16.0	3.4	1.4	0.3	2.0	--	0.0	-0.2	--	*For actual depth:*					Profile doesn't
CO28	26	33.9	16.0	9.2	4.8	0.3	2.0	--	0.1	-0.5	--	122.4	66.8	21.7	14.6	--	reach base of clay.
34N/9W/7U/1	45	30.4	16.0	9.8	4.6	0.3	2.0	--	0.1	-0.6	--						
	79	26.9	16.0	15.5	6.3	0.2	2.0	--	0.1	-1.0	--	*For 250 cm:*					
	95	38.9	16.0	10.5	6.2	0.7	2.0	--	0.2	-0.3	--	121.3	66.1	19.6	12.4	--	
	126	35.0	16.0	18.2	9.8	1.2	2.0	--	0.7	-0.4	--						
	161	32.7	16.0	19.1	9.8	1.4	2.0	--	0.8	-0.4	--						
	193	37.6	16.0	19.9	11.4	1.8	2.0	--	0.9	-0.1	--						
	215	38.9	9.0	8.7	6.6	25.1	1.0	--	7.4	7.1	--						
	248	24.3	7.0	6.9	4.9	23.7	1.0	--	8.8	8.4	--						
	260	16.4	5.0	1.3	0.9	24.0	0.5	--	2.6	2.5	--						I

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA										PROFILE TOTALS					COMMENTS, BASAL CARBONATE STAGE
		CLAY CONTENT				CARBONATE CONTENT						CLAY CONTENT		CARBONATE CONTENT			
		(wt. % <2 mm)		(g/cm^2)		(wt. % <2 mm)			(g/cm^2)			(g/cm^2-profile)		(g/cm^2-profile)			
		TOTAL	PAR. MATL. (est. 1)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PAR. MATL. (est. 1)	PAR. MATL. (est. 2)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	
t5c	19	19.8	19.8	4.9	0.0	2.4	2.0	--	0.6	0.1	--	*For actual depth:*					
CO30	31	23.4	19.8	3.7	0.6	2.3	2.0	--	0.4	0.0	--						
35N/9W/20/1	49	23.4 *	19.8	5.9 *	0.9 *	2.3 *	2.0	--	0.6 *	0.1 *	--	200.8 *	89.2 *	39.4 *	26.3 *	--	
	60	26.2	16.0	4.0	1.6	0.6	2.0	--	0.1	-0.2	--	*For 250 cm:*					
	82	26.5 *	16.0	8.7 *	3.4 *	0.7 *	2.0	--	0.2 *	-0.4 *	--	97.5 *	31.1 *	4.2 *	-3.9	--	
	104	26.7	16.0	9.6	3.8	0.7	2.0	--	0.2	-0.5	--						
	124	23.3	16.0	7.6	2.4	1.2	2.0	--	0.4	-0.3	--						
	134	25.0 *	16.0	4.1 *	1.5 *	1.0 *	2.0	--	0.2 *	-0.2 *	--						
	156	26.3 *	16.0	9.6 *	3.8 *	1.0 *	2.0	--	0.4 *	-0.4 *	--						
	178	26.3 *	16.0	10.3 *	4.0 *	1.0 *	2.0	--	0.4 *	-0.4 *	--						
	196	26.3	16.0	8.3	3.2	0.7	2.0	--	0.2	-0.4	--						
	220	22.9	16.0	9.6	2.9	0.5	2.0	--	0.2	-0.7	--						
	249	22.0 *	16.0	11.0 *	3.0 *	0.6 *	2.0	--	0.3 *	-0.7 *	--						
	264	19.0	16.0	5.0	0.8	0.6	2.0	--	0.2	-0.4	--						
	276	25.2	16.0	5.4	2.0	0.8	2.0	--	0.2	-0.3	--						
	300	33.9	16.0	14.0	7.4	0.1	2.0	--	0.0	-0.8	--						
	325	30.5	16.0	12.9	6.1	3.6	2.0	--	1.6	0.7	--						
	351	33.3	16.0	15.7	8.2	0.1	2.0	--	0.0	-0.9	--						
	378	45.4	13.0	19.3	13.8	0.2	1.0	--	0.1	-0.4	--						
	417	40.4	11.0	16.5	12.0	0.0	1.0	--	0.0	-0.4	--						
	450	29.3	9.0	3.6 *	2.5 *	33.4	0.5	--	6.2 *	6.1 *	--						
	487	28.3	8.0	2.8	2.0	44.3	0.5	--	7.8	7.7	--						
	510	21.1	8.0	1.8	1.1	22.5	0.5	--	2.5	2.5	--						
	534	15.0 *	7.2	3.4 *	1.7 *	21.0 *	0.5	--	6.0 *	5.8 *	--						
	570	11.2	7.2	1.3	0.5	23.8	0.5	--	3.6	3.5	--						
	605	9.0 *	7.2	1.0 *	0.2 *	23.8 *	0.5	--	3.5 *	3.5 *	--						
	645	7.2	7.2	1.0	0.0	19.5	0.5	--	3.5	3.4	--						I

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA: CLAY CONTENT (wt. % <2 mm) TOTAL	CLAY CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CLAY CONTENT (g/cm²) TOTAL	CLAY CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (wt. % <2 mm) TOTAL	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 2)	CARBONATE CONTENT (g/cm²) TOTAL	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 2)	PROFILE TOTALS: CLAY CONTENT (g/cm²-profile) TOTAL	CLAY CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) TOTAL	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 2)	COMMENTS, BASAL CARBONATE STAGE
t4b	12	30.9	16.0	6.1	2.9	0.2	2.0	--	0.0	-0.4	--	*For actual depth:*					
CO34	28	34.3	16.0	9.1	4.9	0.3	2.0	--	0.1	-0.5	--	87.6	39.7	50.5	44.1	--	
34N/9W/29/1	43	36.5	16.0	9.8	5.5	0.3	2.0	--	0.1	-0.4	--						
	61	36.3	16.0	11.7	6.5	0.4	2.0	--	0.1	-0.5	--	*For 250 cm:*					
	73	37.9	16.0	7.9	4.6	3.7	2.0	--	0.8	0.4	--	85.0	39.7	49.7	43.5	--	
	91	36.4	16.0	6.4 *	3.6 *	41.6	2.0	--	12.5 *	11.9 *	--						
	126	26.8	16.0	12.3	5.0	21.1	2.0	--	12.3	11.2	--						
	146	26.8	16.0	7.0	2.8	21.1	2.0	--	7.0	6.4	--						
	164	26.2	16.0	6.9	2.7	12.6	2.0	--	3.8	3.2	--						
	186	17.0	13.0	3.6	0.9	34.0	0.5	--	11.1	10.9	--						
	208	6.3	5.0	2.0	0.4	5.0	0.5	--	1.7	1.5	--						
	235	4.8	4.8	1.8 *	0.0 *	0.3	0.5	--	0.1 *	-0.1 *	--						
	287	3.0	3.0	1.1	0.0	0.6	0.5	--	0.2	0.0	--						
	317	9.4	9.4	1.8	0.0	3.3	0.5	--	0.6	0.5	--						No visible carb.
tbt	10	23.6	16.0	2.9	0.9	0.0 *	1.0	--	0.0 *	-0.1 *	--	*For actual depth:*					Profile depth
(La Plata R.)	21	29.8	16.0	4.9	2.3	0.0 *	1.0	--	0.0 *	-0.2 *	--	123.5	90.8	0.3 *	-2.0 *	--	doesn't reach base
CO37	30	37.2	16.0	4.8	2.8	0.0 *	1.0	--	0.0 *	-0.1 *	--						of clay. Top
34N/11W/25/1	55	57.2	16.0	27.2	19.6	0.0 *	1.0	--	0.0 *	-0.5 *	--	*For 250 cm:*					truncated by
	79	54.7	16.0	24.0	17.0	0.0 *	1.0	--	0.0 *	-0.4 *	--	122.5	90.1	0.3 *	-1.9 *	--	erosion?
	103	44.8	9.0	15.2	12.2	0.0 *	0.5	--	0.0 *	-0.2 *	--						
	128	38.2	7.0	13.0 *	10.6 *	0.2	0.5	--	0.1 *	-0.1 *	--						
	151	36.7	5.0	9.3	8.1	0.2 *	0.5	--	0.1 *	-0.1 *	--						
	179	27.4	5.0	8.1	6.6	0.2 *	0.5	--	0.1 *	-0.1 *	--						
	215	28.4	5.0	9.0	7.4	0.2	0.5	--	0.1	-0.1	--						
	260	15.5	5.0	4.9	3.3	0.2 *	0.5	--	0.1 *	-0.1 *	--						No effervescence.

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA: CLAY CONTENT (wt. % <2 mm) TOTAL	CLAY CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CLAY CONTENT (g/cm²) TOTAL	CLAY CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (wt. % <2 mm) TOTAL	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 1)	CARBONATE CONTENT (wt. % <2 mm) PAR. MATL. (est. 2)	CARBONATE CONTENT (g/cm²) TOTAL	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²) PEDOGENIC (est. 2)	PROFILE TOTALS: CLAY CONTENT (g/cm²-profile) TOTAL	CLAY CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) TOTAL	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 1)	CARBONATE CONTENT (g/cm²-profile) PEDOGENIC (est. 2)	COMMENTS, BASAL CARBONATE STAGE
NEW MEXICO PROFILES																	
t7u	7	34.9	30.0	4.3	0.6	2.7	2.0	--	0.3	0.1	--	*For actual depth:*					
NM4	26	21.3	10.0	1.5	0.8	6.4	0.5	--	0.5	0.4	--	11.1	2.3	10.4	9.6	--	
29N/13W/21/1B	48	16.4	8.0	1.3	0.7	7.1	0.5	--	0.6	0.6	--						
	78	6.6	4.4	0.7	0.2	9.8	0.5	--	1.2	1.1	--	*For 250 cm:*					
	109	4.4	4.4	0.6	0.0	14.7	0.5	--	2.2	2.1	--	11.9	2.3	11.9	10.9	--	
	125	5.6	5.6	1.2	0.0	10.8	0.5	--	2.6	2.5	--						
	174	3.0	3.0	0.9	0.0	5.5	0.5	--	1.7	1.6	--						
	210	3.2	3.2	0.7 *	0.0 *	5.6	0.5	--	1.3 *	1.2 *	--						I-
t6b	7	26.1	18.1	2.8	0.8	8.8	2.0	--	1.0	0.8	--						
NM7	19	26.1	18.1	4.8	1.5	3.7	2.0	--	0.7	0.3	--	*For actual depth:*					
30N/12W/27/1B	33	24.5	18.1	4.7	1.2	3.1	2.0	--	0.6	0.2	--	Upper horizon group (0-300 cm):					
(continued	52	21.1	18.1	5.9	0.8	3.7	2.0	--	1.1	0.5	--	79.5	6.5	21.7	13.2	--	
on next page)	78	18.1	18.1	6.6	0.0	10.7	2.0	--	4.4	3.6	--						
	102	17.3	17.3	5.7	0.0	9.4	2.0	--	3.4	2.7	--	Lower horizon group (555-673 cm):					
	126	17.1	17.1	5.3	0.0	16.7	2.0	--	6.2	5.5	--	36.8	3.3	0.0	6.8	--	
	159	19.4	19.4	8.7	0.0	4.2	2.0	--	1.9	1.0	--						
	186	13.0	13.0	5.3	0.0	0.8	1.0	--	0.3	-0.1	--	Both horizon groups:					
	215	18.0	15.5	7.7	1.1	1.1	2.0	--	0.5	-0.4	--	116.2	9.8	31.1	20.0	--	
	235	17.8	15.5	5.7	0.7	1.3	2.0	--	0.4	-0.2	--						
	251	16.4	15.5	4.2	0.3	1.2	2.0	--	0.3	-0.2	--	*For 250 cm:*					
	275	15.5	15.5	6.5	0.0	1.1	2.0	--	0.5	-0.4	--	67.1	6.5	20.8	13.2	--	
	300	13.6	13.6	5.6	0.0	0.9	1.0	--	0.4	-0.1	--						I-
	--	--	--	--	--	--	--	--	--	--	--						

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA									PROFILE TOTALS					COMMENTS, BASAL CARBONATE STAGE
		CLAY CONTENT				CARBONATE CONTENT					CLAY CONTENT		CARBONATE CONTENT			
		(wt. % <2 mm)		(g/cm²)		(wt. % <2 mm)			(g/cm²)		(g/cm²-profile)		(g/cm²-profile)			
		TOTAL	PAR. MATL. (est. 1)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PAR. MATL. (est. 1)	PAR. MATL. (est. 2)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	
t6b	574	13.7	13.7	4.1	0.0	7.9	2.0	--	2.5	1.9	--						
NM7	590	15.9	15.9	3.6	0.0	8.3	2.0	--	2.0	1.5	--						
30N/12W/27/1B	605	41.8	39.0	11.0	0.7	4.8	2.0	--	1.3	0.8	--						
(continued	624	41.4	39.0	13.4	0.8	5.6	2.0	--	1.9	1.2	--						
from last page)	643	18.3	10.0	4.0	1.8	5.7	0.5	--	1.3	1.2	--						
	673	4.2	4.2	0.8 *	0.0	1.7	0.5	--	0.3 *	0.2 *	--						No visible carb.
t5a	15	17.3	15.0	4.2	0.5	5.2	2.0	--	1.3	0.8	--	*For actual depth:*					
NM10	33	16.8	15.0	4.8	0.5	4.4	2.0	--	1.3	0.7	--	31.8	6.1	29.4	25.8	--	
30N/12W/33/1A	46	21.8	15.0	4.5	1.4	7.4	2.0	--	1.7	1.2	--						
	67	21.8	14.0	6.4	2.3	22.5	2.0	--	8.5	7.7	--	*For 250 cm:*					
	86	16.1	13.0	4.8	0.9	18.6	2.0	--	6.8	6.0	--	33.0	6.1	30.2	26.4	--	
	109	12.5	12.5	4.1	0.0	17.5	1.0	--	7.0	6.6	--						
	130	11.9	10.0	1.3	0.2	15.4	0.5	--	2.0	1.9	--						
	167	8.4	7.0	1.3	0.2	3.8	0.5	--	0.6	0.5	--						
	191	4.9	4.9	0.5 *	0.0 *	3.2	0.5	--	0.3 *	0.3 *	--						I
t4b	8	15.1	15.1	1.7	0.0	6.4	2.0	--	0.8	0.5	--	*For actual depth:*					
NM16	27	18.3	15.1	4.4	0.8	11.1	2.0	--	3.0	2.5	--	45.6	11.5	62.5	56.9	--	
29N/12W/5/2	52	18.0	15.1	6.9	1.1	8.4	2.0	--	3.5	2.6	--						
	77	21.9	15.1	7.0	2.2	16.9	2.0	--	6.5	5.7	--	*For 250 cm:*					
	92	21.9	15.1	4.4	1.3	21.8	2.0	--	5.6	5.0	--	45.2	11.5	62.5	56.9	--	
	112	22.0	15.1	4.6	1.4	34.4	2.0	--	10.9	10.3	--						
	129	12.9	15.1	1.5 *	-0.3 *	49.8	2.0	--	11.6 *	11.1 *	--						
	140	21.4	15.1	2.0	0.6	39.2	2.0	--	5.9	5.6	--						
	175	22.1	15.1	9.4	3.0	24.7	2.0	--	14.0	12.9	--						
	180	21.0	9.0	1.0	0.6	6.4	1.0	--	0.3	0.3	--						
	203	12.3	7.0	1.3	0.6	2.1	0.5	--	0.2	0.2	--						
	238	5.6	5.6	0.8	0.0	0.9	0.5	--	0.1	0.1	--						
	263	6.1	6.1	0.6	0.0	0.7	0.5	--	0.1	0.0	--						No visible carb.

TABLE B.8 CALCULATED WEIGHTS OF SECONDARY CLAY AND CARBONATE, continued

SURFACE, PROFILE NO., SITE NO.	BASAL DEPTH (cm)	HORIZON DATA									PROFILE TOTALS					COMMENTS, BASAL CARBONATE STAGE
		CLAY CONTENT				CARBONATE CONTENT					CLAY CONTENT		CARBONATE CONTENT			
		(wt. % <2 mm)		(g/cm²)		(wt. % <2 mm)			(g/cm²)		(g/cm²-profile)		(g/cm²-profile)			
		TOTAL	PAR. MATL. (est. 1)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PAR. MATL. (est. 1)	PAR. MATL. (est. 2)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	TOTAL	PEDO-GENIC (est. 1)	TOTAL	PEDO-GENIC (est. 1)	PEDO-GENIC (est. 2)	
t2c	6	29.0	16.0	2.6	1.2	0.5	2.0	--	0.0	-0.1	--	*For actual depth:*					
NM20	12	28.3	16.0	2.4	1.0	3.2	2.0	--	0.3	0.1	--	66.7	31.1	147.4	140.1	--	
32N/10W/23/1	27	33.4	16.0	7.2	3.8	10.0	2.0	--	2.4	1.9	--						
	43	17.5	15.0	2.2	0.3	51.3	2.0	--	13.1	12.6	--	*For 250 cm:*					
	54	15.6	15.0	0.9	0.0	68.0	2.0	--	12.4	12.0	--	51.9	22.3	144.2	137.6	--	
	80	15.6	14.0	1.3	0.1	79.9	2.0	--	33.5	32.7	--						
	107	15.2	14.0	1.8	0.1	70.9	2.0	--	28.8	28.0	--						
	140	13.8	13.8	3.0	0.0	58.5	2.0	--	30.6	29.6	--						
	177	3.5	3.5	0.7	0.0	37.3	1.0	--	12.4	12.1	--						
	196	22.0	16.0	2.4	0.7	22.3	1.0	--	3.1	3.0	--						
	234	31.7	16.0	17.2	8.5	8.5	2.0	--	5.1	3.9	--						
	273	43.1	16.0	25.0	15.7	8.8	2.0	--	5.6	4.3	--						I to II
t1u	8	36.7	16.0	3.0	1.7	14.0	1.0	--	1.3	1.2	--	*For actual depth:*					
NM21	18	31.1	16.0	3.4	1.6	15.1	1.0	--	1.9	1.8	--	41.8	19.1	88.8	86.7	--	
30N/10W/10/1	51	53.9	16.0	13.3	9.4	4.9	1.0	--	1.3	1.0	--						
	61	48.4	16.0	6.1	4.1	6.5	1.0	--	0.9	0.7	--	*For 250 cm:*					
	68	48.6	16.0	2.8 *	1.9 *	40.0	1.0	--	3.8 *	3.7 *	--	39.7	19.1	84.9	83.1	--	
	77	25.4	15.0	0.6	0.3	77.4	1.0	--	8.7	8.6	--						
	103	20.6	15.0	0.8	0.2	89.4	1.0	--	34.2	33.8	--						
	123	8.0	8.0	0.4	0.0	72.4	0.5	--	12.1	12.0	--						
	141	14.5	14.5	1.2	0.0	43.1	0.5	--	6.4	6.3	--						
	160	12.0	12.0	1.3	0.0	26.8	0.5	--	4.1	4.0	--						
	191	11.0	11.0	2.0	0.0	20.4	0.5	--	4.6	4.5	--						
	207	14.0	14.0	2.5	0.0	14.2	0.5	--	3.0	2.8	--						
	232	9.1	9.1	1.3	0.0	8.6	0.5	--	1.4	1.3	--						
	256	8.0	8.0	1.2	0.0	9.7	0.5	--	1.6	1.5	--						
	296	3.3	3.3	0.8	0.0	4.3	0.5	--	1.1	1.0	--						
	318	3.7	3.7	0.4	0.0	14.3	0.5	--	1.7	1.6	--						
	353	3.2	3.2	0.6	0.0	3.4	0.5	--	0.7	0.6	--						I-

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS

PART 1-L NORMALIZED HORIZON PROPERTIES AND HORIZON INDEX FOR ACTUAL DEPTH

LAND-FORM	PRO-FILE NO.	SITE NUMBER	PRO-FILE DEPTH (cm)	SOIL AGE, EST. (ka)	REL. HEIGHT AT ST. LINE (m)	MAXIMUM VALUE IN PROFILE (INDEPENDENT OF HORIZON OR PROFILE THICKNESS)											
						NORMALIZED HORIZON PROPERTY										HORIZON INDEX	
						Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
						COLORADO PROFILES											
fp	CO1	34N/9W/8U/1	179	0.2 ?	1.00	0.11	0.33	0.00	0.24	0.33	1.00	0.75	0.10	0.16	0.00	0.29	0.29
mBB	CO2	37N/9W/24/1	52	14	7.01	0.05	0.33	0.00	0.41	0.17	0.00	0.33	0.10	0.18	0.00	0.14	0.14
mAC3	CO3	35N/9W/9/1	296	15.5	9.14	0.16	0.42	0.00	0.29	0.06	0.00	0.33	0.10	0.08	0.00	0.12	0.12
mAC3	CO4	35N/9W/16/3	239	15.5	9.14	0.11	0.17	0.06	0.35	0.67	1.04	0.33	0.20	0.04	0.00	0.26	0.26
t7c	CO5	34N/9W/8U/2	280	14	9.14	0.21	0.33	0.38	0.18	0.78	0.88	0.67	0.20	0.08	0.00	0.27	0.27
mAC2	CO6	35N/9W/16/1A	128	15.5	12.19	0.03	0.42	0.00	0.35	0.17	0.48	0.42	0.05	0.06	0.00	0.13	0.13
mAC2	CO7	35N/9W/16/1B	50	15.5	12.19	0.11	0.42	0.06	0.35	0.17	0.35	0.33	0.20	0.07	0.00	0.16	0.16
t7b	CO8	35N/9W/29/3	146	16	12.19	0.21	0.00	0.00	0.18	1.00	1.15	0.83	0.30	0.03	0.00	0.32	0.32
t7b	CO9	34N/10W/36/3	207	16	12.19	0.16	0.42	0.00	0.18	0.89	1.17	0.58	0.20	0.03	0.00	0.29	0.29
t7b	CO10	33N/9W/31/3	230	16	12.19	0.35	0.17	0.25	0.12	0.56	1.19	0.58	0.10	0.07	0.00	0.28	0.28
t7ab	CO11	34N/9W/8U/3	238	20	13.72	0.21	0.33	0.13	0.24	0.78	1.00	0.75	0.30	0.04	0.00	0.32	0.32
t7ab	CO12	34N/10W/36/2	148	20	13.72	0.21	0.25	0.13	0.18	1.11	1.04	0.92	0.40	0.03	0.00	0.38	0.38
t7ab	CO13	33N/9W/31/5	106	20	13.72	0.24	0.50	0.13	0.24	0.89	1.19	1.08	0.30	0.03	0.00	0.39	0.39
t7ab	CO14	32N/10W/1/1	159	20	13.72	0.24	0.17	0.06	0.12	0.44	0.50	0.67	0.15	0.06	0.00	0.18	0.18
t7ab	CO15	32N/10W/12/1	491	20	13.72	0.13	0.33	0.25	0.06	0.67	0.65	0.92	0.30	0.14	0.00	0.20	0.20
t7a	CO16	35N/9W/16/7	179	25	15.24	0.21	0.67	0.13	0.24	0.78	1.19	0.92	0.30	0.02	0.00	0.35	0.35
t7a	CO17	35N/9W/32/3	420	25	15.24	0.26	0.58	0.06	0.12	1.11	0.96	0.50	0.30	0.04	0.00	0.32	0.32

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 1-C PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND 250 CM

PRO-FILE NO.	PROFILE PROPERTY (profile total of each normalized property multiplied by horizon thickness)																				PROFILE DEVEL. INDEX	
	VALUES FOR ACTUAL THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
COLORADO PROFILES																						
CO1	18.1	48.3	0.0	16.5	15.3	36.2	88.2	12.2	12.2	0.0	25.6	60.2	0.0	16.5	15.3	36.2	88.2	12.2	14.9	0.0	24.7	26.9
CO2	0.5	7.0	0.0	6.5	3.2	0.0	8.7	2.4	5.7	0.0	0.5	7.0	0.0	6.5	3.2	0.0	8.7	22.3	19.4	0.0	3.4	6.8
CO3	3.9	5.3	0.0	6.2	1.6	0.0	12.0	26.0	10.5	0.0	3.9	5.3	0.0	6.2	1.6	0.0	12.0	21.4	9.8	0.0	6.5	6.0
CO4	10.4	1.0	1.4	18.8	25.7	34.1	17.7	27.7	6.2	0.0	11.1	1.0	1.4	18.8	25.7	34.1	17.7	29.9	6.6	0.0	15.2	15.5
CO5	33.0	26.7	24.0	8.6	99.4	64.1	82.3	28.7	8.8	0.0	29.8	26.7	24.0	8.6	99.4	64.1	82.3	28.7	8.1	0.0	37.6	37.2
CO6	2.9	4.3	0.0	6.8	8.6	4.3	28.1	5.3	5.6	0.0	6.2	4.3	0.0	6.8	8.6	4.3	78.9	11.4	10.2	0.0	6.6	13.1
CO7	4.0	8.1	0.4	9.9	6.3	5.2	13.8	3.4	2.7	0.0	12.4	24.8	12.9	9.9	6.3	5.2	63.8	3.4	12.0	0.0	5.8	15.5
CO8	19.8	0.0	0.0	1.6	82.9	90.1	36.0	20.1	3.0	0.0	30.7	0.0	0.0	1.6	123.4	90.1	36.0	25.2	4.3	0.0	26.2	32.0
CO9	29.4	6.6	0.0	13.1	103.0	71.9	25.1	12.5	3.1	0.0	36.2	6.6	0.0	13.1	122.1	71.9	25.1	12.5	3.5	0.0	26.5	29.1
CO10	32.0	1.8	39.3	3.1	30.1	45.4	39.2	4.0	10.5	0.0	39.0	1.8	44.3	3.1	30.1	45.4	39.2	4.0	11.1	0.0	20.5	21.8
CO11	37.0	3.0	14.0	25.8	54.6	69.3	58.6	28.9	4.6	0.0	38.3	3.0	14.8	26.5	54.6	69.3	58.6	29.5	4.6	0.0	29.6	29.9
CO12	18.8	3.8	7.5	6.1	57.8	57.3	43.7	15.2	3.0	0.0	29.5	3.8	13.9	6.1	69.1	57.3	43.7	15.2	5.8	0.0	21.3	24.4
CO13	10.6	8.3	0.9	8.8	39.6	64.9	48.6	10.7	1.2	0.0	10.6	8.3	0.9	8.8	39.6	64.9	48.6	10.7	4.3	0.0	19.4	19.7
CO14	14.5	2.0	1.2	3.9	25.8	15.7	30.6	19.0	5.4	0.0	14.5	2.0	1.2	3.9	25.8	15.7	30.6	32.7	10.6	0.0	11.8	13.7
CO15	35.0	87.4	30.3	0.6	35.9	29.2	114.2	28.5	28.0	0.0	10.4	10.4	15.8	0.1	32.6	22.7	110.9	27.5	11.0	0.0	38.9	25.7
CO16	30.1	7.5	11.3	6.3	54.1	52.2	49.3	18.3	1.5	0.0	45.1	7.5	20.1	6.3	58.1	52.2	49.3	18.3	2.2	0.0	23.1	25.9
CO17	50.9	13.8	9.8	11.4	71.7	67.8	36.0	40.9	6.4	0.0	33.0	13.8	4.2	11.4	67.3	67.8	36.0	23.9	4.0	0.0	30.9	26.1

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 1-R WEIGHTED MEAN PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND

PRO-FILE NO.	WEIGHTED MEAN PROFILE PROPERTY (per cm)																				WTD. MEAN PROF. DEV. IND. (per cm)	
	VALUES FOR DESCRIBED THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
COLORADO PROFILES																						
CO1	0.10	0.27	0.00	0.09	0.09	0.20	0.49	0.07	0.07	0.00	0.10	0.24	0.00	0.07	0.06	0.14	0.35	0.05	0.06	0.00	0.14	0.11
CO2	0.01	0.13	0.00	0.13	0.06	0.00	0.17	0.05	0.11	0.00	0.00	0.03	0.00	0.03	0.01	0.00	0.03	0.09	0.08	0.00	0.07	0.03
CO3	0.01	0.02	0.00	0.02	0.01	0.00	0.04	0.09	0.04	0.00	0.02	0.02	0.00	0.02	0.01	0.00	0.05	0.09	0.04	0.00	0.02	0.02
CO4	0.04	0.00	0.01	0.08	0.11	0.14	0.07	0.12	0.03	0.00	0.04	0.00	0.01	0.08	0.10	0.14	0.07	0.12	0.03	0.00	0.06	0.06
CO5	0.12	0.10	0.09	0.03	0.36	0.23	0.29	0.10	0.03	0.00	0.12	0.11	0.10	0.03	0.40	0.26	0.33	0.11	0.03	0.00	0.13	0.15
CO6	0.02	0.03	0.00	0.05	0.07	0.03	0.22	0.04	0.04	0.00	0.02	0.02	0.00	0.03	0.03	0.02	0.32	0.05	0.04	0.00	0.05	0.05
CO7	0.08	0.16	0.01	0.20	0.13	0.10	0.28	0.07	0.05	0.00	0.05	0.10	0.05	0.04	0.03	0.02	0.26	0.01	0.05	0.00	0.12	0.06
CO8	0.14	0.00	0.00	0.01	0.57	0.62	0.25	0.14	0.02	0.00	0.12	0.00	0.00	0.01	0.49	0.36	0.14	0.10	0.02	0.00	0.18	0.13
CO9	0.14	0.03	0.00	0.06	0.50	0.35	0.12	0.06	0.01	0.00	0.14	0.03	0.00	0.05	0.49	0.29	0.10	0.05	0.01	0.00	0.13	0.12
CO10	0.14	0.01	0.17	0.01	0.13	0.20	0.17	0.02	0.05	0.00	0.16	0.01	0.18	0.01	0.12	0.18	0.16	0.02	0.04	0.00	0.09	0.09
CO11	0.16	0.01	0.06	0.11	0.23	0.29	0.25	0.12	0.02	0.00	0.15	0.01	0.06	0.11	0.22	0.28	0.23	0.12	0.02	0.00	0.10	0.12
CO12	0.13	0.03	0.05	0.04	0.39	0.39	0.30	0.10	0.02	0.00	0.12	0.02	0.06	0.02	0.28	0.23	0.17	0.06	0.02	0.00	0.14	0.10
CO13	0.10	0.08	0.01	0.08	0.37	0.61	0.46	0.10	0.01	0.00	0.04	0.03	0.00	0.04	0.16	0.26	0.19	0.04	0.02	0.00	0.18	0.08
CO14	0.09	0.01	0.01	0.02	0.16	0.10	0.19	0.12	0.03	0.00	0.06	0.01	0.00	0.02	0.10	0.06	0.12	0.13	0.04	0.00	0.07	0.05
CO15	0.07	0.18	0.06	0.00	0.07	0.06	0.23	0.06	0.06	0.00	0.04	0.04	0.06	0.00	0.13	0.09	0.44	0.11	0.04	0.00	0.08	0.10
CO16	0.17	0.04	0.06	0.04	0.30	0.29	0.28	0.10	0.01	0.00	0.18	0.03	0.08	0.03	0.23	0.21	0.20	0.07	0.01	0.00	0.13	0.10
CO17	0.12	0.03	0.02	0.03	0.17	0.16	0.09	0.10	0.02	0.00	0.13	0.06	0.02	0.05	0.27	0.27	0.14	0.10	0.02	0.00	0.07	0.10

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued
PART 2-L NORMALIZED HORIZON PROPERTIES AND HORIZON INDEX FOR ACTUAL DEPTH

LAND-FORM	PRO-FILE NO.	SITE NUMBER	PRO-FILE DEPTH (cm)	SOIL AGE, EST. (ka)	REL. HEIGHT AT ST. LINE (m)	MAXIMUM VALUE IN PROFILE (INDEPENDENT OF HORIZON OR PROFILE THICKNESS)											
						NORMALIZED HORIZON PROPERTY										HORIZON INDEX	
						Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
COLORADO PROFILES, continued																	
t6b	CO18	35N/9W/17/2	256	100	27.43	0.32	0.58	0.06	0.24	1.11	1.00	0.67	0.30	0.03	0.00	0.35	0.35
t6b	CO19	35N/9W/30/1	264	100	27.43	0.34	0.50	0.13	0.18	1.00	1.15	0.67	0.20	0.04	0.00	0.33	0.33
t6b	CO20	35N/9W/8U/4A	146	100	27.43	0.21	0.50	0.13	0.24	0.72	0.77	0.67	0.20	0.12	0.00	0.26	0.26
t6b	CO21	34N/9W/31/1	266	100	27.43	0.21	0.08	0.31	0.18	1.00	1.27	0.67	0.30	0.09	0.00	0.36	0.36
t6b	CO22	33N/9W/31/6	65	100	27.43	0.21	0.17	0.06	0.24	1.11	0.77	0.83	0.20	0.03	0.00	0.29	0.29
t6a	CO23	35N/9W/17/1	182	130	33.53	0.20	0.42	0.31	0.18	1.00	1.00	0.67	0.50	0.10	0.00	0.33	0.33
t6a	CO24	34N/9W/8U/5	254	130	33.53	0.21	0.33	0.06	0.18	0.67	0.69	0.75	0.20	0.09	0.00	0.27	0.27
t6a	CO25	34N/9W/8U/6	250	130	33.53	0.29	0.33	0.06	0.18	0.67	1.08	0.50	0.30	0.04	0.00	0.30	0.30
mD2	CO26	35N/9W/15/2	262	250	60.96	0.16	0.42	0.00	0.35	0.44	0.88	0.67	0.30	0.16	0.00	0.26	0.26
mD2	CO27	35N/9W/15/3	259	250	60.96	0.11	0.33	0.13	0.24	0.67	0.62	0.83	0.30	0.09	0.00	0.25	0.25
t5e	CO28	34N/9W/7U/1	260	240	60.96	0.21	0.17	0.23	0.18	0.67	0.62	1.17	0.25	0.18	0.00	0.30	0.30
t5e	CO29	34N/9W/30/1	384	240	60.96	0.41	0.25	0.06	0.12	1.00	1.35	1.17	0.40	0.07	0.00	0.38	0.38
t5c	CO30	35N/9W/20/1	645	240	60.96	0.36	0.33	0.26	0.24	1.22	1.31	1.00	0.30	0.11	0.67	0.45	0.27
mD1	CO31	35N/9W/21/1	230	345	80.77	0.15	0.33	0.06	0.12	0.56	0.96	0.67	0.30	0.05	0.00	0.25	0.25
mD1 sh	CO32	35N/9W/21/2	378	345	80.77	0.21	0.33	0.38	0.12	1.00	1.35	0.67	0.30	0.15	0.00	0.35	0.35
t5a	CO33	34N/9W/7U/2	486	340	80.77	0.28	0.38	0.23	0.18	0.78	0.81	1.17	0.20	0.39	0.00	0.31	0.39
t4b	CO34	34N/9W/29/1	287	615	118.87	0.26	0.50	0.88	0.18	0.56	0.65	0.75	0.30	0.61	0.00	0.39	0.39
t4a	CO35	34N/8W/7U/2	343	625	124.97	0.13	0.33	0.19	0.12	0.67	0.92	1.17	0.20	0.16	0.00	0.32	0.30
t4a	CO36	34N/9W/20/1	160	625	124.97	0.16	0.50	0.94	0.18	0.67	1.12	0.83	0.30	0.82	0.00	0.37	0.37
tbt	CO37	34N/11W/25/1	260	3000 ?	551.69	0.16	0.67	0.13	0.24	1.22	1.04	0.83	0.40	0.00	0.67	0.35	0.35

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 2-C PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND 250 CM

PRO-FILE NO.	PROFILE PROPERTY (profile total of each normalized property multiplied by horizon thickness)																				PROFILE DEVEL. INDEX	
	VALUES FOR ACTUAL THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
COLORADO PROFILES, continued																						
CO18	59.9	6.7	1.3	19.2	112.8	126.2	89.8	34.5	3.4	0.0	58.6	6.7	1.3	19.2	112.4	126.2	89.3	34.5	3.3	0.0	45.4	45.1
CO19	44.2	9.4	7.8	8.6	100.3	104.2	45.5	28.7	3.9	0.0	42.7	9.4	6.9	8.6	100.3	104.2	45.5	28.0	3.7	0.0	35.3	34.9
CO20	22.2	32.1	1.5	8.8	56.9	47.2	60.2	13.4	6.3	0.0	44.1	32.1	1.5	8.8	103.2	71.2	86.2	13.4	10.0	0.0	24.9	37.0
CO21	35.5	2.6	9.7	11.6	99.9	88.5	48.3	33.4	6.1	0.0	33.8	2.6	9.7	11.6	99.9	88.5	48.3	33.4	5.8	0.0	33.5	33.3
CO22	9.9	1.2	0.4	9.2	39.1	34.0	25.0	5.9	0.7	0.0	9.9	1.2	0.4	31.0	39.1	34.0	25.0	5.9	4.8	0.0	12.6	15.1
CO23	21.7	15.8	7.6	12.9	68.7	72.5	62.2	34.7	5.9	0.0	28.8	15.8	11.8	12.9	68.7	72.5	62.2	34.7	8.9	0.0	30.2	31.6
CO24	31.8	6.7	2.8	29.1	39.1	43.7	49.3	12.8	9.1	0.0	31.4	6.7	2.8	28.6	39.1	43.7	49.3	12.8	8.9	0.0	22.4	22.3
CO25	38.6	17.6	8.3	19.6	43.9	78.0	44.6	16.7	6.9	0.0	38.6	17.6	8.3	19.6	43.9	78.0	44.6	16.7	6.9	0.0	27.4	27.4
CO26	13.3	16.6	0.0	21.0	32.3	54.3	97.0	36.8	22.6	0.0	13.3	16.6	0.0	21.0	31.0	54.3	93.0	35.6	21.9	0.0	29.4	28.7
CO27	20.7	8.3	7.8	6.8	85.4	103.2	187.7	55.6	12.9	0.0	19.7	8.3	7.8	6.8	81.4	99.0	180.2	52.9	12.4	0.0	48.8	46.9
CO28	30.2	10.2	22.6	19.0	110.3	93.5	179.5	46.7	21.5	0.0	28.1	10.2	21.9	19.0	108.1	93.5	179.5	45.7	21.0	0.0	53.3	52.7
CO29	78.9	7.2	2.7	22.1	249.6	278.7	279.8	59.0	4.7	0.0	38.7	7.2	2.7	6.4	154.9	168.9	220.8	44.7	4.7	0.0	98.3	105.2
CO30	70.4	14.0	23.0	15.9	265.1	463.2	367.1	93.7	30.7	31.0	9.0	14.0	4.6	9.8	47.2	170.0	191.7	37.9	16.0	0.0	137.4	53.4
CO31	20.4	12.9	0.6	4.2	66.9	172.2	104.2	44.1	3.0	0.0	21.1	12.9	0.6	4.2	69.1	179.9	104.2	49.1	4.0	0.0	42.8	44.5
CO32	41.7	9.6	21.9	14.2	206.8	262.7	97.3	65.9	16.2	0.0	35.3	8.1	7.1	14.2	204.8	181.9	97.3	63.7	6.5	0.0	73.6	61.9
CO33	63.0	28.8	25.6	16.5	301.8	219.4	302.7	62.9	53.3	0.0	21.1	21.6	10.1	2.2	166.7	114.9	242.5	37.5	28.9	0.0	107.4	188.5
CO34	44.5	52.7	101.3	14.1	56.4	85.6	154.4	44.5	73.3	0.0	34.8	52.7	99.0	9.7	54.4	71.4	142.1	40.8	71.9	0.0	62.7	57.7
CO35	27.0	18.8	10.9	3.8	166.0	252.9	307.6	64.4	22.8	0.0	19.3	18.8	2.1	3.8	124.8	183.6	219.0	45.8	9.6	0.0	87.4	75.6
CO36	15.3	25.2	83.3	3.5	40.8	32.3	69.2	28.9	58.6	0.0	29.5	25.2	94.5	8.8	50.8	32.3	69.2	28.9	60.2	0.0	35.7	39.9
CO37	32.7	18.4	3.5	27.7	190.9	211.4	16.8	71.3	0.0	48.0	31.7	18.4	3.5	27.1	184.8	202.5	16.8	69.3	0.0	48.0	62.1	60.2

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 2-R WEIGHTED MEAN PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND

PRO-FILE NO.	WEIGHTED MEAN PROFILE PROPERTY (per cm)																				WTD. MEAN PROF. DEV. IND. (per cm)	
	VALUES FOR DESCRIBED THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
COLORADO PROFILES, continued																						
CO18	0.23	0.03	0.00	0.07	0.44	0.49	0.35	0.13	0.01	0.00	0.23	0.03	0.01	0.08	0.45	0.50	0.36	0.14	0.01	0.00	0.18	0.18
CO19	0.17	0.04	0.03	0.03	0.38	0.39	0.17	0.11	0.01	0.00	0.17	0.04	0.03	0.03	0.40	0.42	0.18	0.11	0.01	0.00	0.13	0.14
CO20	0.15	0.22	0.01	0.06	0.39	0.32	0.41	0.09	0.04	0.00	0.18	0.13	0.01	0.04	0.41	0.28	0.34	0.05	0.04	0.00	0.16	0.15
CO21	0.13	0.01	0.04	0.04	0.38	0.33	0.18	0.13	0.02	0.00	0.14	0.01	0.04	0.05	0.40	0.35	0.19	0.13	0.02	0.00	0.13	0.13
CO22	0.15	0.02	0.01	0.14	0.60	0.52	0.38	0.09	0.01	0.00	0.04	0.00	0.00	0.12	0.16	0.14	0.10	0.02	0.02	0.00	0.19	0.06
CO23	0.12	0.09	0.04	0.07	0.38	0.40	0.34	0.19	0.03	0.00	0.12	0.06	0.05	0.05	0.27	0.29	0.25	0.14	0.04	0.00	0.17	0.13
CO24	0.13	0.03	0.01	0.11	0.15	0.17	0.19	0.05	0.04	0.00	0.13	0.03	0.01	0.11	0.16	0.17	0.20	0.05	0.04	0.00	0.09	0.09
CO25	0.15	0.07	0.03	0.08	0.18	0.31	0.18	0.07	0.03	0.00	0.15	0.07	0.03	0.08	0.18	0.31	0.18	0.07	0.03	0.00	0.11	0.11
CO26	0.05	0.06	0.00	0.08	0.12	0.21	0.37	0.14	0.09	0.00	0.05	0.07	0.00	0.08	0.12	0.22	0.37	0.14	0.09	0.00	0.11	0.11
CO27	0.08	0.03	0.03	0.03	0.33	0.40	0.72	0.21	0.05	0.00	0.08	0.03	0.03	0.03	0.33	0.40	0.72	0.21	0.05	0.00	0.19	0.19
CO28	0.12	0.04	0.09	0.07	0.42	0.36	0.69	0.18	0.08	0.00	0.11	0.04	0.09	0.08	0.43	0.37	0.72	0.18	0.08	0.00	0.21	0.21
CO29	0.21	0.02	0.01	0.06	0.65	0.73	0.73	0.15	0.01	0.00	0.15	0.03	0.01	0.03	0.62	0.68	0.88	0.18	0.02	0.00	0.26	0.42
CO30	0.11	0.02	0.04	0.02	0.41	0.72	0.57	0.15	0.05	0.05	0.04	0.06	0.02	0.04	0.19	0.68	0.77	0.15	0.06	0.00	0.21	0.21
CO31	0.09	0.06	0.00	0.02	0.29	0.75	0.45	0.19	0.01	0.00	0.08	0.05	0.00	0.02	0.28	0.72	0.42	0.20	0.02	0.00	0.19	0.18
CO32	0.11	0.03	0.06	0.04	0.55	0.69	0.26	0.17	0.04	0.00	0.14	0.03	0.03	0.06	0.82	0.73	0.39	0.25	0.03	0.00	0.19	0.25
CO33	0.13	0.06	0.05	0.03	0.62	0.45	0.62	0.13	0.11	0.00	0.08	0.09	0.04	0.01	0.67	0.46	0.97	0.15	0.12	0.00	0.22	0.75
CO34	0.16	0.18	0.35	0.05	0.20	0.30	0.54	0.16	0.26	0.00	0.14	0.21	0.40	0.04	0.22	0.29	0.57	0.16	0.29	0.00	0.20	0.23
CO35	0.08	0.05	0.03	0.01	0.48	0.74	0.90	0.19	0.07	0.00	0.08	0.08	0.01	0.02	0.50	0.73	0.88	0.18	0.04	0.00	0.25	0.30
CO36	0.10	0.16	0.52	0.02	0.25	0.20	0.43	0.18	0.37	0.00	0.12	0.10	0.38	0.04	0.20	0.13	0.28	0.12	0.24	0.00	0.22	0.16
CO37	0.13	0.07	0.01	0.11	0.73	0.81	0.06	0.27	0.00	0.18	0.13	0.07	0.01	0.11	0.74	0.81	0.07	0.28	0.00	0.19	0.24	0.24

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued
PART 3-L NORMALIZED HORIZON PROPERTIES AND HORIZON INDEX FOR ACTUAL DEPTH

LAND-FORM	PRO-FILE NO.	SITE NUMBER	PRO-FILE DEPTH (cm)	SOIL AGE, EST. (ka)	REL. HEIGHT AT ST. LINE (m)	MAXIMUM VALUE IN PROFILE (INDEPENDENT OF HORIZON OR PROFILE THICKNESS)											
						NORMALIZED HORIZON PROPERTY										HORIZON INDEX	
						Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
NEW MEXICO PROFILES																	
fp	NM1	29N/13W/17/1	82	0	0.91	0.05	0.25	0.06	0.00	0.17	0.81	1.17	0.10	0.01	0.00	0.23	0.23
t8u	NM2	29N/13W/21/1A	136	5	3.05	0.05	0.50	0.06	0.24	0.06	0.31	0.83	0.10	0.10	0.00	0.15	0.15
t7u	NM3	29N/13W/16/1	123	10	6.10	0.16	0.17	0.35	0.12	0.11	0.35	0.67	0.20	0.21	0.00	0.16	0.16
t7u	NM4	29N/13W/21/1B	210	10	9.14	0.14	0.25	0.08	0.06	0.56	1.15	0.81	0.30	0.11	0.00	0.29	0.29
t7u	NM5	32N/10W/33/2	99	10	12.19	0.18	0.17	0.19	0.12	0.56	1.00	0.83	0.20	0.07	0.00	0.26	0.26
t6b	NM6	32N/10W/22/1	131	100	27.43	0.16	0.08	0.06	0.06	0.22	0.31	0.50	0.20	0.04	0.00	0.13	0.13
t6b	NM7	30N/12W/27/1B	673	100	27.43	0.16	0.07	0.25	0.06	0.22	0.88	0.75	0.20	0.18	0.00	0.19	0.16
t6a	NM8	30N/11W/5/1	200	130	33.53	0.17	0.08	0.06	0.12	0.78	0.98	0.42	0.20	0.05	0.00	0.27	0.27
t5e	NM9	32N/10W/33/3	281	240	60.96	0.32	0.17	0.63	0.04	0.78	0.92	1.00	0.50	0.38	0.00	0.29	0.29
t5a	NM10	30N/12W/33/1A	191	340	80.77	0.21	0.25	0.50	0.29	0.44	0.73	0.92	0.30	0.37	0.00	0.27	0.27
t4e	NM12	30N/12W/21/1	239	430	89.92	0.14	0.33	0.38	0.29	0.67	0.73	1.00	0.30	0.44	0.00	0.29	0.29
t4d sh	NM13	29N/12W/5/3	207	520	99.06	0.17	0.25	0.56	0.06	0.67	0.58	0.92	0.20	0.46	0.00	0.23	0.23
t4b	NM14	30N/12W/34/1	161	615	118.87	0.21	0.33	0.56	0.06	0.44	0.88	1.00	0.20	0.49	0.00	0.28	0.28
t4b	NM15	29N/12W/5/2	263	615	118.87	0.21	0.33	0.63	0.35	0.67	0.71	0.83	0.30	0.57	0.00	0.29	0.29
t4a	NM16	31N/10W/10/1	269	625	118.87	0.19	0.67	0.75	0.24	0.44	0.62	0.79	0.30	0.71	0.00	0.29	0.29
t3b	NM17	29N/12W/4/2	282	740	138.68	0.18	0.33	0.81	0.24	1.06	1.10	0.92	0.30	0.48	0.00	0.40	0.40
t3a	NM18	29N/12W/4/1B	150	800	146.30	0.06	0.17	1.00	0.00	0.78	0.65	0.92	0.50	0.78	0.00	0.34	0.34
t3a sh	NM19	29N/12W/4/1A	176	800	146.30	0.11	0.33	1.00	0.00	0.33	0.00	1.17	0.50	0.43	0.00	0.34	0.34
t2c	NM20	32N/10W/23/1	273	1950	329.18	0.13	1.00	0.88	0.47	0.78	0.31	0.50	0.25	0.97	0.00	0.36	0.36
t1u	NM21	30N/10W/10/1	353	2430	441.96	0.16	0.17	0.81	0.00	0.78	1.19	0.83	0.50	0.54	0.00	0.34	0.34

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 3-C PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND 250 CM

PRO-FILE NO.	PROFILE PROPERTY (profile total of each normalized property multiplied by horizon thickness)																				PROFILE DEVEL. INDEX	
	VALUES FOR ACTUAL THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
NEW MEXICO PROFILES																						
NM1	1.6	1.0	2.6	0.0	2.5	31.0	49.7	1.5	0.4	0.0	1.6	1.0	2.6	0.0	2.5	95.7	49.7	1.5	0.4	0.0	9.0	15.5
NM2	0.8	41.7	1.9	5.9	1.4	3.4	75.3	5.0	4.9	0.0	0.8	98.7	1.9	5.9	1.4	3.4	75.3	5.0	7.8	0.0	14.0	6.3
NM3	6.7	5.6	17.0	1.8	9.8	5.2	42.2	7.7	13.4	0.0	13.4	5.6	32.9	1.8	23.9	5.2	42.2	7.7	26.0	0.0	10.9	15.9
NM4	10.0	10.9	8.1	2.4	26.1	59.9	35.4	19.9	8.5	0.0	10.8	17.6	10.6	2.4	26.1	59.9	35.4	19.9	9.9	0.0	18.1	19.3
NM5	11.4	4.7	6.0	1.8	38.7	38.6	39.5	9.3	4.1	0.0	27.3	17.3	34.3	1.8	89.0	38.6	77.3	16.9	15.3	0.0	15.4	31.8
NM6	6.5	1.9	2.8	0.7	10.5	3.7	20.4	9.5	3.1	0.0	6.5	1.9	2.8	0.7	10.5	3.7	20.4	9.5	4.9	0.0	5.9	6.1
NM7	59.7	0.5	44.4	3.2	40.6	83.3	312.1	42.2	50.1	0.0	22.9	0.5	29.0	0.0	24.9	22.7	144.4	16.7	25.9	0.0	63.6	48.7
NM8	9.4	1.1	1.7	7.4	34.6	35.7	25.1	10.0	4.4	0.0	9.4	1.1	1.7	7.4	34.6	35.7	25.1	10.0	4.4	0.0	12.9	12.9
NM9	34.4	7.8	50.2	2.8	78.1	74.5	57.5	37.4	30.5	0.0	32.8	7.8	48.2	2.8	74.7	74.5	57.5	37.4	29.1	0.0	37.3	36.5
NM10	18.4	16.4	45.4	17.3	52.3	55.4	85.4	29.9	25.1	0.0	30.8	16.4	74.9	17.3	58.8	75.8	85.4	35.8	27.5	0.0	34.6	42.3
NM12	14.6	14.7	32.8	3.6	51.4	20.7	53.8	22.1	32.4	0.0	15.2	14.7	32.8	3.6	51.4	20.7	53.8	22.1	32.6	0.0	24.6	24.7
NM13	18.4	9.4	19.7	4.5	48.8	30.2	54.9	26.5	28.2	0.0	20.2	9.4	19.7	4.5	48.8	30.2	54.9	26.5	30.0	0.0	24.1	24.4
NM14	19.2	15.0	30.1	1.8	38.2	45.4	77.9	24.1	26.1	0.0	37.9	15.0	30.1	1.8	57.9	45.4	77.9	24.1	28.1	0.0	27.8	31.8
NM15	19.3	19.5	49.2	8.9	94.4	42.3	121.8	50.3	49.9	0.0	17.3	19.5	49.2	8.9	94.4	42.3	121.8	50.3	49.9	0.0	45.6	45.4
NM16	30.4	91.5	90.7	2.6	18.3	23.2	48.7	36.8	64.7	0.0	29.8	91.5	88.3	2.6	18.3	23.2	48.7	36.8	63.4	0.0	40.7	40.3
NM17	28.9	33.2	116.5	8.0	103.8	57.7	86.4	35.1	43.6	0.0	25.6	33.2	110.5	8.0	100.3	57.7	86.4	34.7	42.3	0.0	51.3	49.9
NM18	4.7	3.8	43.7	0.0	51.7	37.8	91.2	34.8	34.3	0.0	9.9	3.8	131.2	0.0	73.9	37.8	174.6	84.8	67.8	0.0	30.2	58.4
NM19	13.9	14.2	75.4	0.0	23.4	0.0	65.7	35.0	31.8	0.0	21.7	14.2	80.0	0.0	23.4	0.0	65.7	35.0	33.7	0.0	25.9	27.4
NM20	28.1	172.1	114.9	17.4	50.6	6.0	78.5	37.1	146.6	0.0	25.8	160.2	108.5	17.4	44.2	6.0	74.7	34.8	139.4	0.0	65.1	61.1
NM21	31.8	25.8	85.6	0.0	49.7	56.7	93.3	58.7	53.4	0.0	23.5	22.2	79.7	0.0	49.7	56.7	92.3	57.0	49.7	0.0	45.5	63.7

TABLE B.9 SUMMARY OF HARDEN INDEX CALCULATIONS, continued

PART 3-R WEIGHTED MEAN PROFILE PROPERTIES AND PROFILE DEVELOPMENT INDEX FOR ACTUAL DEPTH AND

PRO-FILE NO.	WEIGHTED MEAN PROFILE PROPERTY (per cm)																				WTD. MEAN PROF. DEV. IND. (per cm)	
	VALUES FOR DESCRIBED THICKNESS OF PROFILE										VALUES FOR THICKNESS EXTRAPOLATED OR LIMITED TO 250 cm											
	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	Rubifi-cation	Color Paling	Color Light-ening	Melani-zation	Total Texture	Clay Films	Struc-ture	Consis-tence	Carb-onate	Sapro-lization	For Actual Depth	For 250 cm
NEW MEXICO PROFILES																						
NM1	0.02	0.01	0.03	0.00	0.03	0.38	0.61	0.02	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.38	0.20	0.01	0.00	0.00	0.11	0.06
NM2	0.01	0.31	0.01	0.04	0.01	0.02	0.55	0.04	0.04	0.00	0.00	0.39	0.01	0.02	0.01	0.01	0.30	0.02	0.03	0.00	0.10	0.03
NM3	0.05	0.05	0.14	0.01	0.08	0.04	0.34	0.06	0.11	0.00	0.05	0.02	0.13	0.01	0.10	0.02	0.17	0.03	0.10	0.00	0.09	0.06
NM4	0.05	0.05	0.04	0.01	0.12	0.29	0.17	0.09	0.04	0.00	0.04	0.07	0.04	0.01	0.10	0.24	0.14	0.08	0.04	0.00	0.09	0.08
NM5	0.11	0.05	0.06	0.02	0.39	0.39	0.40	0.09	0.04	0.00	0.11	0.07	0.14	0.01	0.36	0.15	0.31	0.07	0.06	0.00	0.16	0.13
NM6	0.05	0.01	0.02	0.01	0.08	0.03	0.16	0.07	0.02	0.00	0.03	0.01	0.01	0.00	0.04	0.01	0.08	0.04	0.02	0.00	0.05	0.02
NM7	0.09	0.00	0.07	0.00	0.06	0.12	0.46	0.06	0.07	0.00	0.09	0.00	0.12	0.00	0.10	0.09	0.58	0.07	0.10	0.00	0.09	0.19
NM8	0.05	0.01	0.01	0.04	0.17	0.18	0.13	0.05	0.02	0.00	0.04	0.00	0.01	0.03	0.14	0.14	0.10	0.04	0.02	0.00	0.06	0.05
NM9	0.12	0.03	0.18	0.01	0.28	0.27	0.20	0.13	0.11	0.00	0.13	0.03	0.19	0.01	0.30	0.30	0.23	0.15	0.12	0.00	0.13	0.15
NM10	0.10	0.09	0.24	0.09	0.27	0.29	0.45	0.16	0.13	0.00	0.12	0.07	0.30	0.07	0.24	0.30	0.34	0.14	0.11	0.00	0.18	0.17
NM12	0.06	0.06	0.14	0.02	0.22	0.09	0.23	0.09	0.14	0.00	0.06	0.06	0.13	0.01	0.21	0.08	0.22	0.09	0.13	0.00	0.10	0.10
NM13	0.09	0.05	0.10	0.02	0.24	0.15	0.27	0.13	0.14	0.00	0.08	0.04	0.08	0.02	0.20	0.12	0.22	0.11	0.12	0.00	0.12	0.10
NM14	0.12	0.09	0.19	0.01	0.24	0.28	0.48	0.15	0.16	0.00	0.15	0.06	0.12	0.01	0.23	0.18	0.31	0.10	0.11	0.00	0.17	0.13
NM15	0.07	0.07	0.19	0.03	0.36	0.16	0.46	0.19	0.19	0.00	0.07	0.08	0.20	0.04	0.38	0.17	0.49	0.20	0.20	0.00	0.17	0.18
NM16	0.11	0.34	0.34	0.01	0.07	0.09	0.18	0.14	0.24	0.00	0.12	0.37	0.35	0.01	0.07	0.09	0.19	0.15	0.25	0.00	0.15	0.16
NM17	0.10	0.12	0.41	0.03	0.37	0.20	0.31	0.12	0.15	0.00	0.10	0.13	0.44	0.03	0.40	0.23	0.35	0.14	0.17	0.00	0.18	0.20
NM18	0.03	0.03	0.29	0.00	0.34	0.25	0.61	0.23	0.23	0.00	0.04	0.02	0.52	0.00	0.30	0.15	0.70	0.34	0.27	0.00	0.20	0.23
NM19	0.08	0.08	0.43	0.00	0.13	0.00	0.37	0.20	0.18	0.00	0.09	0.06	0.32	0.00	0.09	0.00	0.26	0.14	0.13	0.00	0.15	0.11
NM20	0.10	0.63	0.42	0.06	0.19	0.02	0.29	0.14	0.54	0.00	0.10	0.64	0.43	0.07	0.18	0.02	0.30	0.14	0.56	0.00	0.24	0.24
NM21	0.09	0.07	0.24	0.00	0.14	0.16	0.26	0.17	0.15	0.00	0.09	0.09	0.32	0.00	0.20	0.23	0.37	0.23	0.20	0.00	0.13	0.25

APPENDIX C

VOLCANIC ASH SITES AND IDENTIFICATION

Lenses of volcanic ash have been confirmed at 17 sites in the Animas valley (Table C.1; Plates 1 and 2). Two additional sites (Table C.2) were reported previously but could not be relocated. Other sites, useful for comparing development of the Animas and adjacent river valleys, are in the La Plata drainage west of Bridge Timber Mountain (Scott and Moore, 1981; Izett and Wilcox, 1982) and in the Los Pinos drainage north of Ignacio (G.R. Scott, U.S. Geological Survey, oral communication, 1981).

Of 17 sites in the Animas valley, only eight have been reported recently (Izett and Wilcox, 1982; Moore and Gillam, 1984; Gillam and others, 1985). Eight, including all four in northwestern New Mexico, were located for this study and one, described by Woolsey (1906) but lost for several decades, was relocated. Four were found by G.R. Scott and D.W. Moore (U.S. Geological Survey, oral communication, 1981 and 1982).

Geomorphic and Stratigraphic Position of Ash Beds

Ash beds occur in several settings. Most beds lie above fluvial gravels of terraces t4a and t4b, where they form lenses within overlying alluvial fan deposits (less often, ash rests on the gravel and is covered with alluvial fan or eolian deposits). Ash also overlies alluvium in channels that were probably graded to t4a and t4b and gentle bedrock slopes above t4a and t4b. In such settings, the ash is within or buried by younger alluvial or eolian

TABLE C.1 VOLCANIC ASH LOCALITIES

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
N/2 NE/4 sec. 5, T35N, R9W	Durango East (1963)	A1 35N/9W/5/1 (this study)	probably Lava Creek B (this study, shard shape)	private	35N/9W/5/1 (A), (B)
SETTING AND STRATIGRAPHY	North of Animas City Mtn., in southeast edge of large, south-facing dipslope. Ash up to 15 m (50 ft) thick (Woolsey, 1906) and at least 500 m (1600 ft) wide; thinly laminated; fills depressions in erosion surface that truncates Morrison Formation and Junction Creek Sandstone; locally associated with stream gravels from La Plata Mountains (possibly deposits of Junction Creek), but stratigraphic relations unclear due to poor exposures; overlain by landslide or debris-flow deposits. Laminations, fossil aquatic snail (Gyraulus spp.), large volume of ash, and common mass movements in area suggest possible accumulation in a landslide-dammed lake that trapped runoff from a large area.				
ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2240-2260 m (7340-7400 ft); top of deposit slopes gently down to east. About 120 m (400 ft) above floor of dry valley between large dipslope and Animas City Mountain. Because site drained toward Animas River, minimum elevation of ash is upper limit for elevation of river at this time.				
COMMENTS	Mine first reported by Woolsey (1906); mentioned by Larsen and Cross (1956); approximate location mapped by USGS (1971). Relocated by M. L. Gillam.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite (examined bulk sample); coarse to very fine silt, <1 % clastics.				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SE/4 NW/4 NW/4 sec. 7, T35N, R9W	Durango West (1963)	A2 20 (Izett and Wilcox, 1982)	Lava Creek B (Izett and Wilcox, 1982, samples 77W1 and 77G1)	private and Colorado Division of Wildlife	none
SETTING AND STRATIGRAPHY	On spur southwest of Junction Creek. Ash about 4.5 m (15 ft) thick and 45 m (150 ft) wide; unstratified; overlies Mancos Shale; overlain by stream gravel from La Plata Mountains, probably deposited by Junction Creek. Gravel capping main part of spur to south is a lower terrace of Junction Creek. Common landslides in area suggest ash may have accumulated in a landslide depression; however, similarity in height above base level to previous site suggests little if any subsequent movement. Reversed magnetic polarity (E. M. Shoemaker, unpublished data).				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2270 m (7450 ft), ≈ 120 m (400 ft) above Junction Creek.				
COMMENTS	First reported by Woolsey (1906); mentioned by Larsen and Cross (1956); approximate location mapped by USGS (1971) and Schwochow (1981); incorrectly mapped farther west by Aurand (1920). Izett and Wilcox (1982) give elevation as 7200 ft, inconsistent with Woolsey's (1906) 400-ft height above Junction Creek. Relocated by R. W. Blair.				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
NW/4 SE/4 SW/4 sec. 36, T35N, R9W	Durango East (1963)	A3 35N/9W/36/1 (this study)	none [too fine to see clearly with binocular microscope]	State of Colorado	35N/9W/36/1 (A)
SETTING AND STRATIGRAPHY	On west edge of bluff, exposed in bulldozer scrapes next to pipeline. Ashy sediments are about 0.6 m (2 ft) thick and at least 9 m (30 ft) wide; overlie Animas Formation, west and above gravels of Florida River (terrace 4a or 4b); overlain by locally-derived alluvium and sandy loess; cannot be traced laterally along undisturbed slopes.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2190 m (7180 ft), ≈ 95 m (280 ft) above Florida River.				
COMMENTS	Located by M.L. Gillam. May be near site on Spencer Ranch first reported by Woolsey (1906; see Table C.2).				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; some detrital biotite?; mostly fine to very fine silt, 5-10 % clastics (examined bulk sample).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SE/4 SW/4 NW/4 sec. 3, T34N, R9W	Loma Linda (1968)	A4	none	Bureau of Land Management	none
SETTING AND STRATIGRAPHY	South of Big Canyon, at top of northwest-facing slope. Ash thickness unknown; ash underlain by gravel of Animas River (terrace t4b); overlain by sandy loess?				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash and gravel top at ≈ 2110 m (6920 ft), ≈ 165 m (540 ft) above Animas River and ≈ 50 m (160 ft) above nearby streambed.				
COMMENTS	Located by G. R. Scott or D. W. Moore.				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SE/4 NW/4 SE/4 sec. 3, T34N, R9W	Loma Linda (1968)	A5 34N/9W/3/4 (this study); 19[a] (Izett and Wilcox, 1982)	Lava Creek B (Izett and Wilcox, 1982, sample 77W28; this study, sample MM5)	private	34N/9W/3/4A (A), (B)
SETTING AND STRATIGRAPHY	North of Highway 160, on east side of large, south-facing amphitheater; ≈ 0.6-2 m (2-6 ft) of fairly pure and impure ash, fining upward; within fine-grained to pebbly, locally-derived fan alluvium that overlies gravel of Animas River (terrace t4b).				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2110 m (6920 ft). Gravel top at ≈ 2100 m (6900 ft), ≈ 165 m (540 ft) above Animas River and ≈ 80-85 m (260-280 ft) above Wilson Gulch.				
COMMENTS	Located by G. R. Scott. Izett and Wilcox (1982) give elevation of ash as 6880 ft.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; basal part is coarse to very fine silt, 1-2 % clastics; top part is medium to very fine silt, 10 % clastics (examined bulk sample).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
NW/4 NW/4 NE/4 sec. 12, T34N, R9W	Loma Linda (1968)	A6 34N/9W/12/1 (this study); 19[c] (Izett and Wilcox, 1982)	Lava Creek B (Izett and Wilcox, 1982, sample 77W2)	private	34N/9W/12/1 (A)
SETTING AND STRATIGRAPHY	North and south of Highway 160, at west end of roadcut, 0.16 km (0.1 mi) west of entrance to KOA campground. In southern exposure, fairly pure ash and ashy sediments 0.2-1.2 m (0.5-4 ft) thick, fining upward, not traced laterally; deposits overlie thin gravel of Florida River (terrace t4a or t4b); overlain by sandy loess. Ash north of highway is thinner and apparently is within loess overlying gravel.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2115 m (6940 ft), near top of low drainage divide; slightly higher than top of Florida River gravel (terrace t4a) to west.				
COMMENTS	Located by G. R. Scott or D. A. Coates. Izett and Wilcox (1982) give elevation of ash as ≈ 6950 ft.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; very fine sand to medium silt, about 20 % clastics (examined bulk sample).				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
NW/4 SW/4 NW/4 sec. 11, T34N, R9W	Loma Linda (1968)	A7 34N/9W/11/1 (this study); 19[b] (Izett and Wilcox, 1982)	Lava Creek B (Izett and Wilcox, 1982, sample 77W27)	private	34N/9W/11/1
SETTING AND STRATIGRAPHY	South of Highway 160, in driveway cut off County Road 232. Ash ≈ 0.6 m (2 ft) thick; underlain by gravel of Animas River (terrace t4b); overlain by sandy loess.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash and gravel top at ≈ 2125 m (6880 ft), ≈ 165 m (540 ft) above Animas River and ≈ 55-80 m (180-260 ft) above Wilson Gulch, depending on projection angle.				
COMMENTS	Located by G. R. Scott. Izett and Wilcox (1982) inferred that this could be the Florida Mesa locality of Woolsey (1906), but site doesn't fit Woolsey's description.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; coarse to very fine silt, about 5 % clastics (examined bulk sample).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SE/4 SE/4 NW/4 sec. 11, T34N, R9W	Loma Linda (1968)	A8	none	private	none
SETTING AND STRATIGRAPHY	South of Highway 160, near top of north-facing slope. Ash ≈ 0.3-0.6 m (1-2 ft) thick and at least 150 m (500 ft) wide; overlies Animas Formation, surface of which slopes gently down to west toward gravel of Animas River (terrace t4a); overlain by sandy loess.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2115 m (6940 ft). Top of nearby gravel at ≈ 2105 m (6910 ft), ≈ 175 m (580 ft) above Animas River and ≈ 65 m (220 ft) above Wilson Gulch.				
COMMENTS	Located by G.R. Scott. Izett and Wilcox (1982) give elevation of ash as ≈ 6875 ft.				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
S/2 SW/4 SE/4 sec. 29, T34N, R9W (at CO34)	Loma Linda (1968)	A9 34N/9W/29/1 (this study)	probably Lava Creek B (this study, shard shape, no biotite)	private	34N/9W/29/1, 208-235 cm depth
SETTING AND STRATIGRAPHY	In gravel pit at east end of County Road 214. Ashy alluvium ≈ 0.9 m (3 ft) thick and at least 30 m (100 ft) wide; most ash in basal 0.4 m (1.3 ft), extensively bioturbated; upper part thinly bedded. Alluvium fills swale in top of Animas River gravel (terrace t4b); overlain by sandy loess.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash and top of gravel at ≈ 2040 m (6690 ft), ≈ 155 m (500 ft) above Animas River.				
COMMENTS	Located by G. R. Scott or D. W. Moore. No longer exposed, due to pit restoration.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite (examined bulk sample).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SE/4 SE/4 SW/4 Sec. 32, T34N, R9W	Loma Linda (1968)	A10 34N/9W/32/1 (this study)	none	private	34N/9W/32/1 (A)
SETTING AND STRATIGRAPHY	Near west edge of highest bench of Florida Mesa, exposed briefly in shallow excavation for house at 135 Gambel Circle, in Juniper Heights subdivision. Ashy sediments of unknown thickness, several meters above underlying gravel (probably of terrace t4b, near intersection with t4a).				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2030 m (6660 ft), ≈ 150 m (500 ft) above Animas River.				
COMMENTS	Located by M.L. Gillam.				
MICROSCOPE APPEARANCE	Shards coated with carbonate; about 5% ash and 95% clastics; few phenocrysts but no biotite; mostly very fine and fine sand (examined bulk sample).				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
E/2 SE/4 NW/4 sec. 10, T33N, R10W	Long Mountain (1968)	A11 33N/10W/10/1 (this study)	Lava Creek B (this study, sample MM1)	private	33N/10W/10/1
SETTING AND STRATIGRAPHY	Near west summit of ridge, on isolated remnant of highest piedmont surface. Ash 0.1-0.6 m (0.3-2 ft) thick, fairly pure, unstratified; fills depression in upper part of fine-grained, alluvial-eolian cap. Piedmont surface probably was graded to terrace t4b on opposite side of Animas River, before subsequent lateral erosion of t4b.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2060 m (6760 ft), ≈ 120 m (400 ft) above nearby streambeds and ≈ 195 m (640 ft) above Animas River.				
COMMENTS	Located by E. Evanoff and M. L. Gillam.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; coarse to very fine silt, 1-2 % clastics (examined bulk sample, heavy mineral and light mineral separates).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
center SW/4 NE/4 sec. 10, T33N, R10W	Long Mountain (1968)	A12 33N/10W/10/2 (this study)	none	private	none
SETTING AND STRATIGRAPHY	At east summit of ridge described for previous site. Fairly pure ash 0.2-0.5 m (0.5-1.5 ft) thick, not traced laterally; overlies fine-grained alluvium that fills depression in underlying gravelly alluvium; overlain by sandy loess.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2040 m (6700 ft), ≈ 105-110 m (340-360 ft) above nearby streams and 185 m (600 ft) above Animas River.				
COMMENTS	Located by E. Evanoff and M. L. Gillam.				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
center NW/4 SE/4 sec. 23, T33N, R10W	Long Mountain (1968)	A13 33N/10W/23/1 (this study)	probably Lava Creek B (this study, shard shape, no biotite)	private (Southern Ute Indian Reservation)	33N/10W/23/1
SETTING AND STRATIGRAPHY	At west edge of small mesa, in pipeline trench now covered by road. At least 1.1 m (3.6 ft) of ashy deposits; basal part fairly pure, with ripple laminations; upward increase in clastics, including thin beds of locally-derived sheetwash and small lenses of alluvium filling shallow scours; partly bioturbated; fills depression in surface of sandy loess, which overlies gravel of Animas River (terrace t4b or t4bx); overlain by sheetwash and sandy loess.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Top of gravel at ≈ 1970 m (6460 ft), ≈ 60-75 m (200-250 ft) above nearby streams and ≈ 120 m (400 ft) above Animas River. Top of ash ≈ 1.5 m (5 ft) above top of gravel.				
COMMENTS	Located by D. W. Moore.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; mostly medium to very fine silt, 1-2 % clastics (examined bulk sample).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
Sec. 4, T31N, R10W	Cedar Hill (1985)	A14 31N/10W/4/3 (this study)	none	private	31N/10W/4/3 (A)
SETTING AND STRATIGRAPHY	In shallow cut into hillside, behind house at 7 Road 2403 in Dutchman Hill subdivision. Ashy alluvium from surface to depth of 1.3 m (4 ft); extent unknown; overlies terrace t4b.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 1910 m (6270 ft), ≈ 145 m (470 ft) above Animas River.				
COMMENTS	Located by M.L. Gillam.				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
E/2 SE/4 NE/4 sec. 9, T31N, R10W	Cedar Hill (1985)	A15 31N/10W/9/1 (this study)	Lava Creek B (this study, sample MM2)	Bureau of Land Management	31N/10W/9/1
SETTING AND STRATIGRAPHY	North of Miller Canyon, at head and on east side of south-draining gully; 0.1 m (0.4 ft) of fairly pure ash, cross-bedded, grading upward into 1.2-2 m (4-6.5 ft) of ashy sand, structureless. Within basal part of thick, locally-derived, sandy fan alluvium, which overlies gravel of Animas River (terrace t4b).				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 1876 m (6150 ft). Top of gravel at ≈ 1873 m (6140 ft), ≈ 50 m (170 ft) above nearby stream and ≈ 110 m (360 ft) above Animas River.				
COMMENTS	Located by M. L. Gillam.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; mostly very fine sand to fine silt, about 5 % clastics (examined bulk sample, heavy mineral and light mineral separates).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
NW/4 NE/4 SE/4 sec. 16, T31N, R10W	Cedar Hill (1985)	A16 31N/10W/16/1 (this study)	Lava Creek B (this study, sample MM3)	State of Colorado	31N/10W/16/1
SETTING AND STRATIGRAPHY	At head of Arch Rock Canyon, in south bank of arroyo; 0.5 m (1.5 ft) fairly pure ash, overlain by 0.6 m (2 ft) impure ash; resting on Animas River gravel (terrace t4b); overlain by eolian silty sand.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash and gravel top at ≈ 1865 m (6110 ft), ≈ 3 m (10 ft) above adjacent stream and ≈ 100 m (330-340 ft) above Animas River.				
COMMENTS	Located by M. L. Gillam.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; mostly medium to very fine silt, about 15-20 % clastics (examined bulk sample, heavy mineral and light mineral separates).				

TABLE C.1 VOLCANIC ASH LOCALITIES, continued

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
SW/4 NE/4 SW/4 sec. 34, T30N, R12W	Flora Vista (1963)	A17 30N/12W/34/2 (this study)	probably Lava Creek B (this study, shard shape, no biotite)	Bureau of Land Management or private (close to boundary)	30N/12W/34/2
SETTING AND STRATIGRAPHY	South of Hargis Arroyo, in north bank of small tributary arroyo; ≈ 2 m (6 ft) of impure ash and ashy sediment, thinly bedded; within basal part of locally -derived, sandy fan alluvium; underlain by Animas River gravel (terrace t4b); overlain by eolian silty sand.				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 1750 m (5760 ft). Gravel top at ≈ 1750 m (5730 ft), ≈ 85-90 m (280-290 ft) above Animas River.				
COMMENTS	Located by M. L. Gillam.				
MICROSCOPE APPEARANCE	Shards mostly bubble-wall and bubble-junction, but few pumiceous with tubular vesicles; no biotite; mostly very fine sand to fine silt, few % clastics (examined bulk sample, heavy mineral and light mineral separates).				

TABLE C.2 VOLCANIC ASH LOCALITIES (REPORTED BUT UNCOMFIRMED)

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
NE/4 NW/4 sec. 4, T35N, R35W; E/2 NW/4 & E/2 SW/4 sec. 33, T36N, R9W	Durango East (1963)	none	none (no ash present)	Forest Service and private	none
SETTING AND STRATIGRAPHY	On narrow ridge north of Animas City Mountain, between unnamed dry valley and Animas River valley; ridge underlain by Dolores Formation and Entrada Sandstone. No ash here now.				
ELEVATION AND RELATION TO BASE LEVEL	Ridge crest at 2210-2252 m (7240-7385 ft), 75-140 m (250- 450 ft) above stream to west and 215-260 m (700-850 ft) above Animas River.				
COMMENTS	General location mapped by Aurand (1920), USGS (1971), and Schwochow (1981), probably based on misinterpretation of Woolsey's (1906) description for site A1. R. W. Blair found no evidence of ash, but a small deposit could have been mined out (Gillam and others, 1984).				

LOCATION	7 1/2' QUADRANGLE	SITE NUMBER	IDENTIFICATION AND BASIS	PROPERTY OWNER	SAMPLE NUMBER
sec. 25, 26, or 35? T35N, R9W	Durango East (1963)	none	none (not relocated)	private	none
SETTING AND STRATIGRAPHY	On northeastern Florida Mesa; ash at least 1m (3 ft) thick and covers at least 0.8 hectare (2 acres); overlies coal-bearing formations (presumably the Fruitland Formation and/or lower Kirtland Formation); overlain by gravelly and fine-grained deposits (probably locally-derived fan alluvium and loess. Description adapted from Woolsey (1906).				
ASH ELEVATION AND RELATION TO BASE LEVEL	Ash at ≈ 2210-2220 m (7240- 7280 ft)? About 75 m (250 ft) above Florida River.				
COMMENTS	First reported by Woolsey (1906) on Spencer Ranch about 6 km (4 mi) east of Durango; mentioned by Larsen and Cross (1956). Most of sec. 35 but no nearby areas owned by Spencers in 1909 (date of first records at county assessor's office). Aurand (1920) and Schwochow (1981) placed site in sec. 25 (?); USGS (1971) placed it in sec. 26 (?). No ash has been found in these sections, although it is present in section 36 (site A3).				

deposits. The relative heights of t4a and t4b, which project above the oldest preserved moraines (Plates 1 and 2), suggest that the ashes are middle to early Pleistocene.

Ash Identification

The position of the ash deposits shows that they are either beds of Lava Creek B ash from the Yellowstone caldera complex, 800 to 920 km north-northwest of the Animas valley on the Idaho-Wyoming border (e.g. Izett and Wilcox, 1982), or beds of the Bishop ash from the Long Valley caldera, about 940 to 970 km west-southwest of this area in east-central California (e.g. Izett and others, 1988; Sarna-Wojcicki and Davis, 1991). However, preliminary data suggested that the deposits were more likely to be Lava Creek B.

Izett and Wilcox (1982) identified ash at four sites in the Animas valley as Lava Creek B from unspecified features possibly including shard shape, refractive index of glass, and mineralogy of phenocrysts. However, no beds of Bishop ash have been identified in the San Juan Mountains or San Juan Basin. Petrographic examination of samples from 12 sites showed that the shards have bubble-wall and bubble-junction shapes with large radii of curvature, as typical for type G ashes from the Yellowstone caldera compex. The absence of phenocrystic biotite, which occurs in the Bishop ash (Izett, 1981; Sarna-Wojcicki and Davis, 1991), also suggested Lava Creek B. Normal magnetic polarity in ash at the Junction Creek site (Table C.1, site A2; Strobell, unpublished data) is not diagnostic, as both ashes are normally polarized.

Methods

Since the ashes were most likely either Lava Creek B or Bishop, typical samples were analyzed by energy-dispersive X-ray fluorescence spectrometer (XES) to distinguish

these alternatives at minimum cost. Five samples were analyzed (Table C.3), including three unknowns from the Animas valley, one control from Animas valley which Izett and Wilcox (1982) had identified as Lava Creek B, and one control of Lava Creek B from Lake Tecopa, California. The second control, which was collected by E.E. Larson from the quarry at Shoshone, is from tuff A of Sheppard and Gude (1968) as mapped by Hillhouse (1987). Other samples from this bed have been identified from trace-element concentrations as Lava Creek B (Izett and others, 1972; Sarna-Wojcicki and others, 1984, sample 38). Although the composition of ash changes downwind from the source area (Sarna-Wojcicki and Davis, 1991), relatively long distances to Lake Tecopa and the Animas valley suggest that Lava Creek B ash in both areas should be chemically similar. A sample of Bishop ash was not available, but the analytical data would be compared with published data for both ashes.

Before analysis, samples from the Animas valley were treated with HCl to remove secondary carbonate and sieved through brass screens to isolate the 74-125 μ fraction. Most minerals (phenocrysts or local contaminants) were removed with a mixture of acetylene tetrabromide and acetone (specific gravity 2.40), to yield glass concentrates. In contrast, the control sample from Lake Tecopa was not pretreated. It appeared to consist of clean glass, but may have contained a few phenocrysts or detrital grains.

Powdered splits from the samples were analyzed by XES (Kevex model 0700) for three major elements (Ti, Mn, and Fe) and seventeen trace elements (V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Mo, Sn, Ba, La, and Ce). Elemental concentrations, in percent or parts per million, were calculated from count rates by calibration with four rock standards (MAG-1, QLO-1, STM-1, and W-2) from the U.S. Geological Survey (Stevens and others, 1960; Flanagan, 1976). Fred Luiszer performed the analyses at the University of Colorado under the direction of John Drexler.

TABLE C.3 ASH SAMPLES USED TO MEASURE ELEMENTAL CONCENTRATIONS

SITE NO.	LAB NO.	SAMPLE NO.	LOCATION	FRACTION ANALYZED	EVIDENCE OF ALTERATION
A11	MM1	33N/10W/10/1	piedmont surface, La Posta Cyn., CO	glass	thin coatings on some shards (relatively clean)
A15	MM2	31N/10W/9/1	t4b, Miller Cyn., NM	glass	partial coatings on most shards
A16	MM3	31N/10W/16/1	t4b, Arch Rock Cyn., NM	glass	heavy coatings on shards
A5-LCB [1]	MM5	34N/9W/3/4A	t4b, Wilson Gulch, CO	glass	most shards very clean
LCB-LT [2]	LCB	NA	Lake Tecopa, CA	whole	none; shards very clean

1. A5-LCB was previously identified as Lava Creek B ash, probably from petrographic features (Izett and Wilcox, 1982, site 19[a]).
2. LCB-LT was previously identified as Lava Creek B ash from trace-element concentrations (Izett and others, 1972; Sarna-Wojcicki and others, 1984).

Results and Interpretation

Unknowns were evaluated by comparison with controls and with published data for the Lava Creek B and Bishop ashes. Elemental concentrations in the three unknowns and two controls are roughly comparable (Table C.4 and Figure C.1). Coefficients of variation for individual elements are low to moderate, ranging from 7 to 67 percent. However, the resemblance between sample pairs, as expressed by similarity indices (Borchardt and others, 1972), ranges from 0.70 to 0.87 if computed for all 20 elements (Table C.5) and increases to 0.82 to 0.96 if computed for 11 elements with relatively low coefficients of variation ($\leq$ 20.7 percent).

These similarity indices are generally lower than Sarna-Wojcicki and others (1984) obtained for samples of the same ash from different sites, or 0.93 to 0.99. However, the differing ranges may be attributed to variables such as sample preparation, chemical weathering, secondary cements, instrument calibration, measurement precision, and elements used. Samples for this study were not prepared as carefully as in laboratories of the U.S. Geological Survey. Also, Sarna-Wojcicki and others (1984) measured a different set of elements by instrumental neutron activation (INA), which is more precise than XES. Therefore, the lower similarity values obtained here are considered sufficient to match the three unknowns with the two controls, and to identify them as Lava Creek B.

Comparison with published data for the Lava Creek B and Bishop ashes is not useful for identifying the Animas valley samples because the data sets are not comparable, and because concentrations from this study may be poorly calibrated. Most of the published data (e.g. Hildreth, 1977; Sarna-Wojcicki and others, 1984, 1987; Izett, 1988; Izett and others, 1988) were obtained by INA, but some are from atomic absorption spectrophotometry, microprobe, or colorimetry. Published data from x-ray fluorescence spectrometry (XRF), potentially the most comparable to data in this study, are in the form

TABLE C.4 ELEMENTAL CONCENTRATIONS MEASURED BY XES

SITE (Table C.1, Table C.3)	CONCENTRATION						
	Ti [1] (%)	V [6] (ppm)	Cr [3,6] (ppm)	Mn [1,4] (ppm)	Fe [1,4] (%)	Co [3,6] (ppm)	Ni [3] (ppm)
A11	0.14	21.2	26.9	231	2.01	11.8	9.12
A15	0.09	12.6	6.4	234	1.69	7.2	4.07
A16	0.16	17.4	11.8	281	2.17	11.4	5.44
A5-LCB	0.12	53.7	27.0	245	1.85	19.0	0.00
LCB-LT	0.12	22.1	29.1	274	1.90	9.0	7.46
avg.	0.13	25.4	20.2	253	1.92	11.7	5.218
std. dev.	0.03	16.2	10.3	23	0.18	4.5	3.495
coeff. var.	20.7	64.0	51.2	9.2	9.3	38.5	67.0
	Cu [3] (ppm)	Zn [3,4] (ppm)	Rb [1,4] (ppm)	Sr [1] (ppm)	Y [1] (ppm)	Zr [1,5] (ppm)	Nb [1] (ppm)
A11	68.9	124	213	19.4	115	264	45.72
A15	30.3	122	259	2.9	143	229	51.61
A16	47.4	121	214	17.8	118	252	42.11
A5-LCB	21.0	92	204	14.1	126	302	46.87
LCB-LT	18.3	113	201	29.4	143	270	45.81
avg.	37.2	114	218	16.7	129	263	46.424
std. dev.	21.1	13	23	9.6	13	27	3.412
coeff. var.	56.7	11.5	10.7	57.4	10.4	10.1	7.4
	Mo [5] (ppm)	Sn [7] (ppm)	Sb [5] (ppm)	Ba [2,4] (ppm)	La [2,4] (ppm)	Ce [2,4] (ppm)	
A11	2.88	9.44	1.35	217	106	83.9	
A15	2.60	6.03	1.23	88	104	79.6	
A16	2.37	5.01	0.95	148	82	69.3	
A5-LCB	2.71	15.22	0.55	202	136	99.5	
LCB-LT	2.74	6.29	0.00	184	115	96.7	
avg.	2.66	8.40	0.82	168	109	85.8	
std. dev.	0.19	4.16	0.55	51	19	12.5	
coeff. var.	7.2	49.5	67.4	30.6	17.9	14.5	

Typical uses for comparing volcanic ash samples (Sarna-Wojcicki and Davis, 1991):

1. XRF, most useful.
2. XRF, useful.
3. XRF, useful for mafic tephra.
4. INA, most useful.
5. INA, marginally useful.
6. INA, useful for mafic tephra.
7. Not usually analyzed.

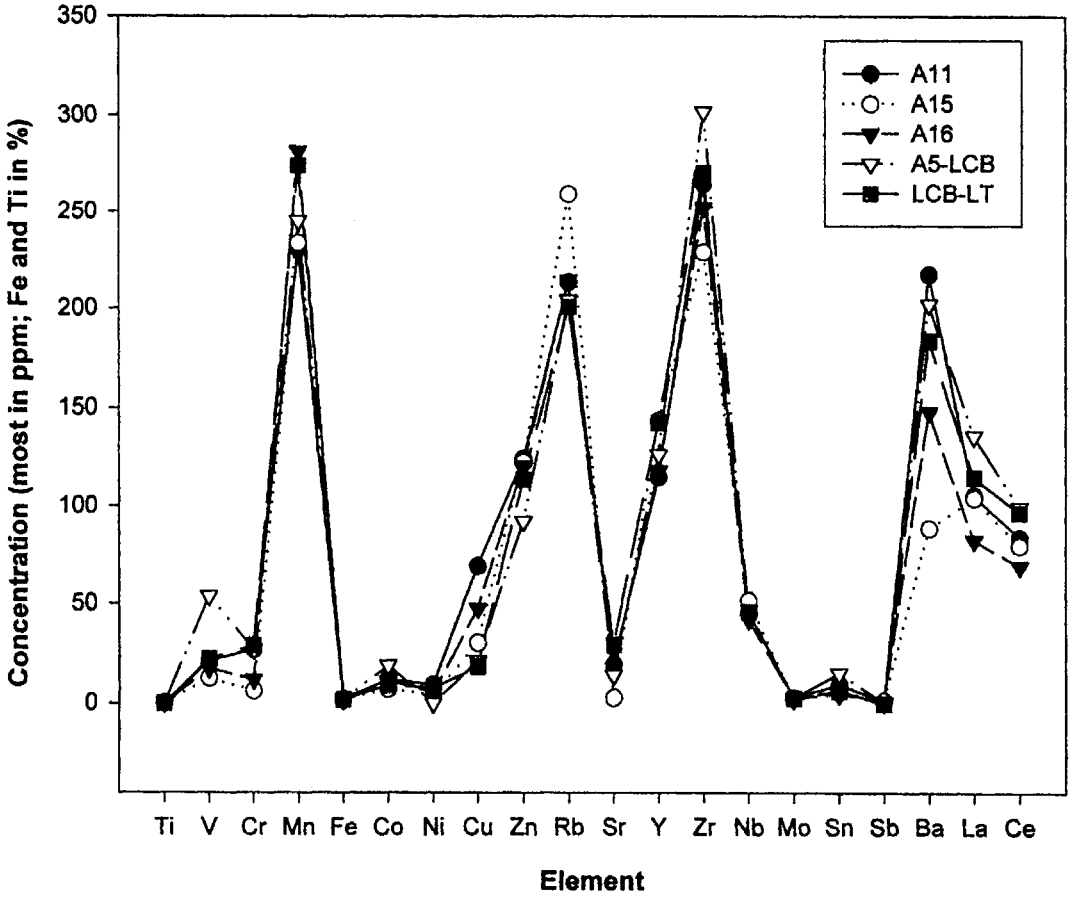

FIGURE C.1 Elemental concentrations measured by XES in three unknowns (A12, A16, and A17) and two samples of Lava Creek B ash (A5-LCB and LCB-LT).

TABLE C.5 SIMILARITY INDICES FOR SAMPLE PAIRS

SAMPLES	SIMILARITY INDEX VALUES		
	all 20 elements	14 elements [1]	11 elements [2]
A11, A15	0.70	0.75	0.88
A11, A16	0.81	0.87	0.90
A11, A5-LCB	0.74	0.83	0.89
A11, LCB-LT	0.80	0.83	0.91
A15, A16	0.74	0.74	0.83
A15, A5-LCB	0.61	0.74	0.84
A15, LCB-LT	0.69	0.76	0.87
A16, A5-LCB	0.66	0.78	0.82
A16, LCB-LT	0.74	0.80	0.86
A5-LCB, LCB-LT	0.87	0.94	0.96

1. Includes elements used by Sarna-Wojcicki and others (1984), i.e. Ti, Mn, Fe, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba, La, Ce (V, Cr, Co, Ni, Mo, Sn, Sb excluded)
2. Includes elements with coefficients of variation of approximately 20% or less.

of count rates (Sarna-Wojcicki and others, 1984, 1987) that cannot be compared directly with concentrations. Also, published data include only 12 of the elements in this study (Ti, Cr, Mn, Fe, Co, Zn, Rb, Sr, Zr, Ba, La, and Ce).

Among elements previously measured in the Lava Creek B and Bishop ashes, the most diagnostic are Fe, Ti, La, Zn, and Rb, in roughly decreasing order. Concentrations of Fe, Ti, La, and Zn are lowest in published data for the Bishop ash, higher in published data for the Lava Creek B ash, but highest in samples from this study. These anomalous values and other differences suggest systematic errors in data from this study. For example, in the case of Rb, the three unknowns (A11, A15, and A16) are more like Lava Creek B, the control LCB-LT (known to be Lava Creek B) is more like Bishop, and the control A5-LCB is between the ranges for both ashes. With respect to Ce, all samples from this study fall between the ranges for both ashes as determined by Izett and others (1988) and Sarna-Wojcicki and others (1987), but four samples are within the higher end of the range for Bishop ash as measured by Hildreth (1977). Concentrations of Cr, Co, Zn, and Zr in samples from this study are very different from those in Bishop ash, but data for these elements in Lava Creek B ash have not been published. Mn and Sr have broadly overlapping ranges in both ashes and are not diagnostic.

In summary, the four Animas valley samples appear to match the Lake Tecopa control, and to be Lava Creek B ash, based on similar elemental concentrations. Similarity between the Lake Tecopa control and the Animas valley control, which Izett and Wilcox (1982) identified as Lava Creek B, validates their identifications of three more sites by non-chemical methods. Four other sites are interpreted as Lava Creek B from their petrographic similarity to the sites of Izett and Wilcox (1982). Six sites have not been identified, but are assumed to be Lava Creek B because they occupy similar stratigraphic positions and because no other ashes have been identified in the region.