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Correlation of Land Surfaces in the Truckee River Valley Between Reno and Verdi, Nevada

A thesis submitted in partial fulfillment of the requirements of the degree of Master of Science in Geology

by

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CORRELATION OF LAND SURFACES IN THE TRUCKEE RIVER VALLEY BETWEEN RENO AND VERDI, NEVADA

By Ralph G. Mock

ABSTRACT

Nine land surface levels occur in the Truckee River valley between Reno and Verdi, Nevada. They consist of a vertical sequence of river terraces and pediments and para-pediments graded to the river terraces. Stable backslopes, actively eroding backslopes, alluvial fans, landslides, and fault scarplets are also present. Remnants of the eight lowest terraces can be correlated throughout the area. Pediments and para-pediments grade to the terraces directly or through bypass notches cut into older land surfaces. Areas of active erosion occur as scattered patches on the piedmonts. Quaternary faulting has been mapped; these faults do not appear to have been active since pre-Wisconsin time. The kinds of soils associated with the vertical sequence of land surfaces appears to be related to duration of weathering, thus landscape stability is implied. The sequence of surfaces indicates that episodic erosion has occurred in the area during the entire Quaternary. Climatic fluctuations and recurrent tectonic uplift are probably the causative factors. The highest land surface is younger than Pliocene-Pleistocene basalts. The Wisconsin-pre-Wisconsin boundary probably lies between land surfaces III and IV based on morphologic differences in the argillic horizons of soils. The lowest surface is tentatively Holocene in age.

INTRODUCTION

Location

The area studied is located in northwestern Nevada along the Truckee River between Reno and Verdi (see Figure 1). This area includes 37 square miles. It is at the western edge of the Basin and Range physiographic province. The Truckee River originates in the Sierra Nevada in the Lake Tahoe basin and flows 90 miles east to Pyramid Lake, a remnant of the former Pleistocene Lake Lahontan. The river flows through several intermontane basins and is antecedent to the mountain ranges which separate these basins. The river has cut narrow valleys and canyons through the mountains, namely the upper Truckee River canyon between Lake Tahoe and Truckee, the Truckee River canyon from below Truckee to Verdi, the Truckee River valley between Reno and Verdi, and the lower Truckee River canyon between Reno and Wadsworth. This report deals only with the valley of the Truckee River between Reno and Verdi.

This reach is in an east-west trending structural valley which is approximately 10 miles long and is bounded on the north by Peavine Mountain, on the south by the northern part of the Carson Range and on the west by the Verdi Range. To the east, the valley opens out into the northern portion of the Truckee Meadows, a north-south trending structural basin in which Reno is located. The valley floor ranges from 5,000 feet elevation at Verdi to 4,500 feet at Reno. Peavine Mountain stands at 8,266 feet, the northern part of the Carson Range is around 8,000 feet elevation, and the Verdi Range has summits at about 7,600 feet elevation.

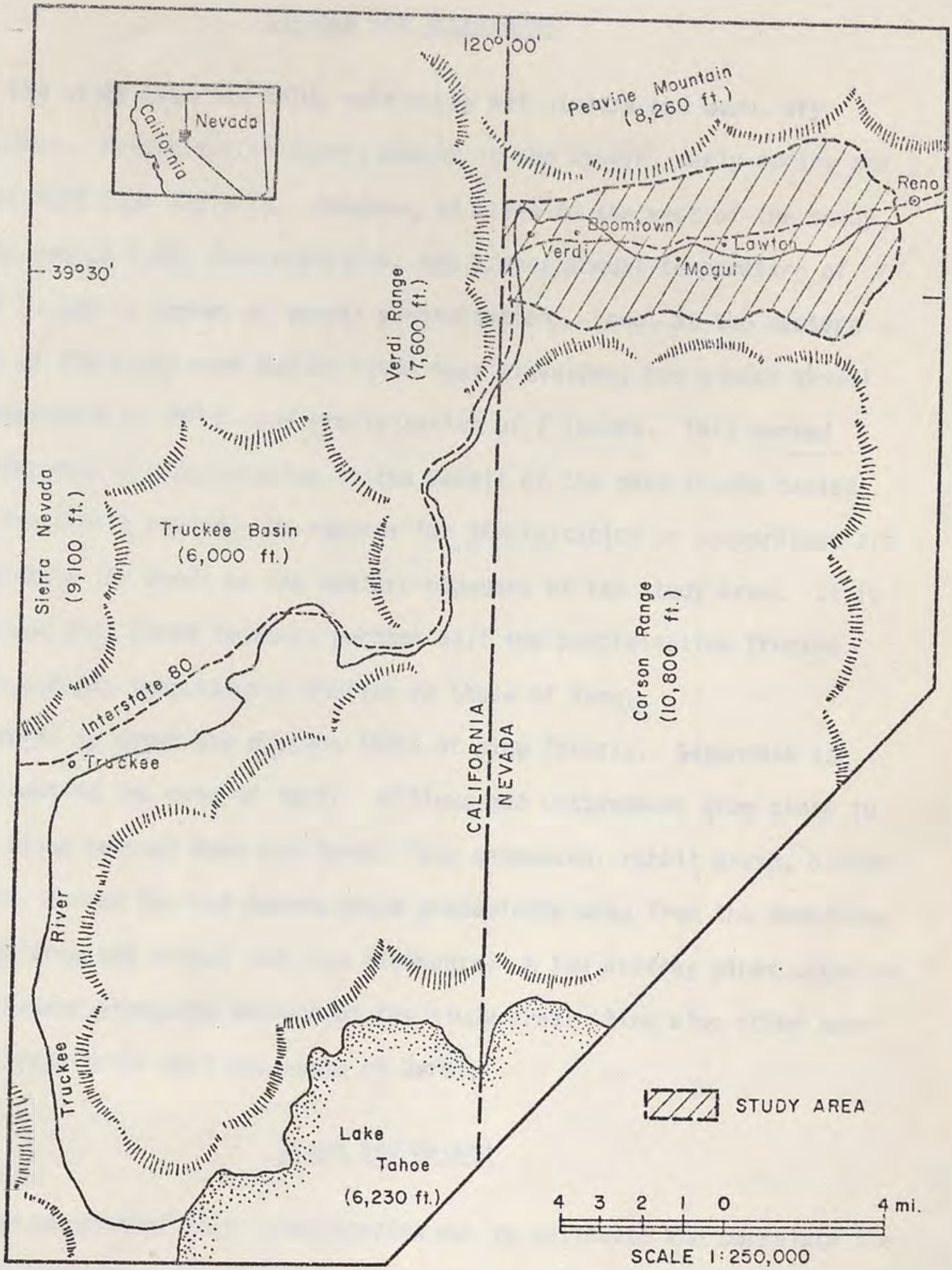


FIGURE 1. LOCATION MAP OF THE STUDY AREA

Climate and Vegetation

The study area has cold, relatively wet winters and warm, dry summers. Precipitation occurs mostly in the winter, early spring and late fall (see Table 1). Truckee, 12 miles to the west of the study area and at 6,000 feet elevation, has a mean annual temperature of 43° F. and 31 inches of annual precipitation. Reno, at the eastern end of the study area and at 4,500 feet elevation, has a mean annual temperature of 49° F. and precipitation of 7 inches. This marked difference in precipitation is the result of the rain shadow caused by the Sierra Nevada. No records for precipitation or temperature are available for Verdi at the western boundary of the study area. It is assumed that Verdi receives perhaps half the precipitation Truckee does and has temperatures similar to those of Reno.

Verdi is about the eastern limit of pine forests. Sagebrush is dominant to the east of Verdi. Willows and cottonwoods grow close to the river between Reno and Verdi. Big sagebrush, rabbit brush, bitterbrush, mormon tea and desert peach predominate away from the immediate river area and extend over the piedmonts. A few Jeffrey pines occur on the higher piedmonts throughout the study area. Pine also occur near the river level west and south of Verdi.

Scope and Method

The purpose of this investigation was to delineate and correlate the river terraces and piedmont land surfaces of the Truckee River valley between Reno and Verdi, Nevada. Relations between land surfaces and their soils were also noted, but the genetic implications of these

Table 1: Precipitation and temperature data for Reno (elevation 4,400 feet) and Truckee (elevation 6,000 feet) from 1931 to 1960 (U.S. Weather Bureau 1962.)

	Average Precipitation		Average Temperature	
	Truckee	Reno	Truckee	Reno
	in.	in.	°F.	°F.
January	6.2	1.2	25.6	31.9
February	5.2	1.0	28.0	36.1
March	4.0	0.7	32.7	41.0
April	2.3	0.5	39.7	47.5
May	1.5	0.5	46.6	53.4
June	0.5	0.4	54.1	60.1
July	0.4	0.3	61.9	68.2
August	0.2	0.2	60.4	66.5
September	0.4	0.2	55.3	60.3
October	1.8	0.5	45.6	50.2
November	3.1	0.6	35.0	39.3
December	5.7	1.1	28.5	33.4
Annual	31.3	7.2	42.8	49.2

observations can only be suggested due to the limited scope of work carried out under this investigation.

Data were collected by intensive field study during spring and fall, 1971. Aerial photographs, scale 1:42,000, were used for field mapping. Soils were examined in stream and road cuts and shovel pits. Descriptions are according to the terminology of the U.S. National Cooperative Soil Survey (U.S. Department of Agriculture, 1951).

The textural descriptions of sediments are in part according to the soil textural classes (U.S. Department of Agriculture, 1951) and in part according to the Wentworth Grade Scale. Textural classes and particle scales for these two systems are given in Appendix I.

Previous Work

Numerous publications deal with the pre-Quaternary geology of the Truckee River valley between Reno and Verdi (Anderson, 1910; Axelrod, 1958; Birkeland, 1963; Bonham and Papke, 1969; Booth, 1960; Gianella, 1948; Godwin, 1958; Heinrichs, 1967; Hill, 1915; Jones and Gianella, 1933; King, 1877; Lindgren, 1897 and 1911; Louderback, 1907; Moore, 1952; Thompson and Sandberg, 1958; and Thompson and White, 1964). The Quaternary geology has been described by several workers. Reid (1911) briefly described river terraces along the Truckee River between Reno and Verdi and commented that these terraces might be of glaciofluvial origin. Blackwelder (1931) discussed river terraces both in the Truckee Basin and in the Verdi area. He tentatively assigned terrace levels in the Verdi area to the Tahoe and Sherwin glacial stades of the Sierra Nevada. Godwin (1958) described gravels in the Verdi area.

The deposits are glaciofluvial according to his interpretation of very large boulders. Axelrod (1958) mapped river terraces in the Verdi area but did not differentiate specific terrace levels. Thompson and White (1964) discussed two pediment levels in the Verdi-Reno area. They interpreted the higher pediment level as older than their Lousetown Formation and describe it as projecting to the high river terrace remnant at Chalk Bluff. They correlated this higher terrace level with the McGee glacial stade of the Sierra Nevada. Their lower pediment surface was correlated with the Sherwin glacial stade. Birkeland (1965, 1966, 1968a, 1968b and 1969) described and mapped glacial outwash deposits in the Verdi-Reno area which he correlated with the Tahoe, Donner Lake, and possibly Hobart glacial stades of the northern Sierra Nevada. Birkeland used soil morphology in his correlations. He also discussed the possibility that some of the terraces in the area could have been initiated by tectonic events.

Although the river terraces and pediment surfaces in the Truckee River valley have been discussed by many writers, to date there has been no detailed delineation of these land surfaces or study of their relation to each other. This is the objective of the present study.

GENERAL GEOLOGY

Pre-Quaternary Rocks

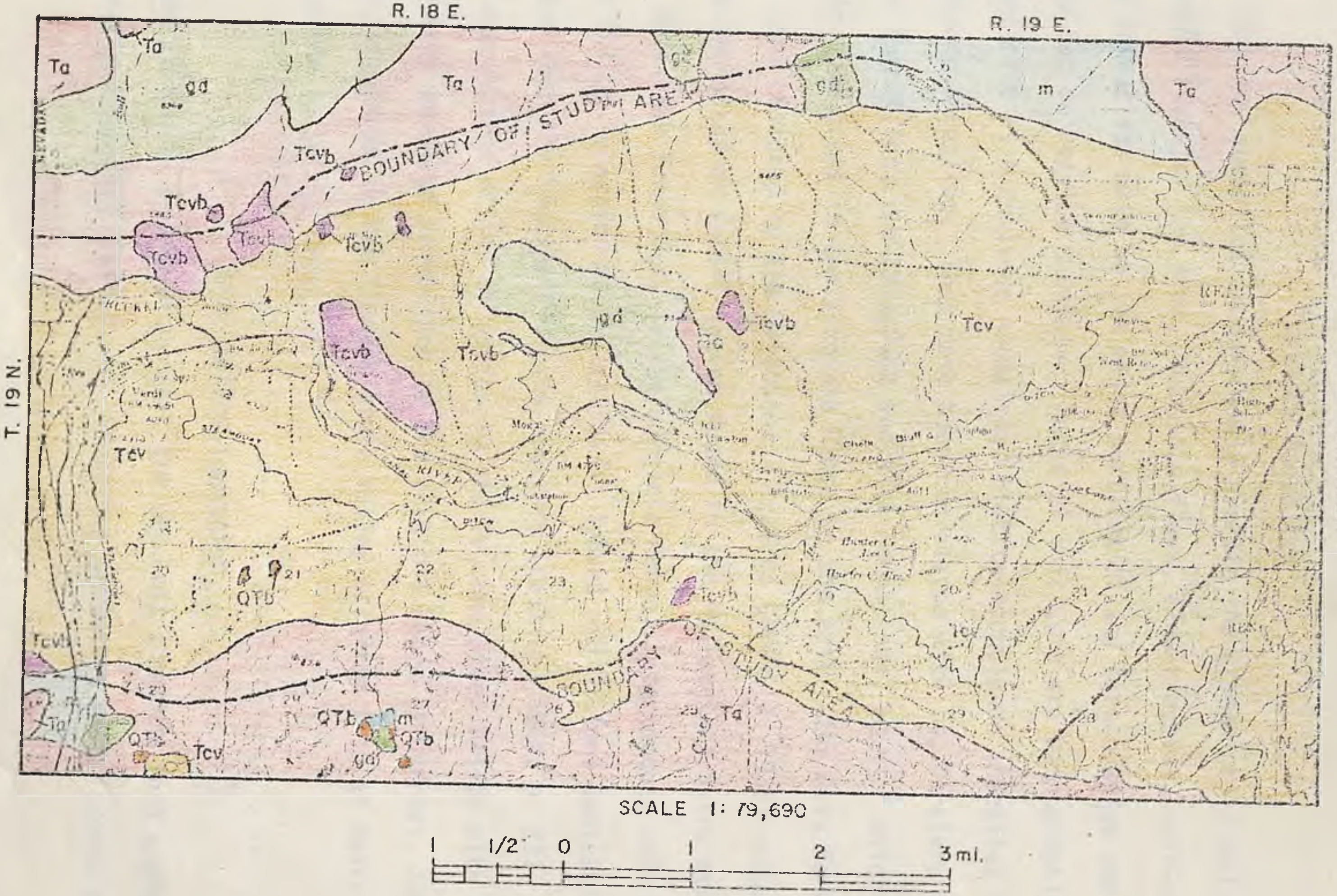
The pre-Quaternary bedrock geology of the Truckee River valley was not studied in detail. Some observations were made in the process of land surface mapping, but the bulk of the information in this section was gathered from the following workers: Anderson (1910), Axelrod (1958), Birkeland (1963), Bonham and Papke (1969), Booth (1960), Gianella (1948), Godwin (1958), Heinrichs (1967), Hill (1915), Jones and Gianella (1933), King (1877), Lindgren (1897 and 1911), Louderback (1907), Moore (1952), Thompson and Sandberg (1958) and Thompson and White (1964).

Metamorphic Rocks

The oldest rocks in the area are metamorphic rocks which crop out in three places. Metavolcanics are found in the Truckee River valley south of Verdi. A small patch of metasediments occurs on the north flank of the Carson Range in section 27, T.19N., R.18E. The southern slope of Peavine Mountain is underlain by a group of metasediments and metavolcanics (see Figure 2). The age of these rocks has not been determined, other than they are older than the granodiorite which locally intrudes them. It has been suggested by many of the workers in this area that these rocks may correlate with metasediments in the Truckee area which Lindgren (1897, p. 1) determined to be middle Mesozoic, based on fossil evidence.

Granodiorite

Biotite-hornblende granodiorite crops out throughout the area (Godwin, 1968, p. 26). This rock is found in the northern part of the



Sources of geologic data used in compiling:

1. Axelrod, (1958)
2. Godwin, (1953)
3. Bonham & Papke (1969)
4. Thompson & White (1964)

Base from U.S. Geological Survey topographic maps of Reno and Mount Rose 15' quadrangles

FIGURE 2. BEDROCK GEOLOGY

Carson Range and on the southwest side of Peavine Mountain. An outcrop also occurs near the axis of the valley, sections 11 and 12, T.19N., R.18E. This intrusive is considered to be part of the Sierra Nevada Batholith, which is generally considered to have been emplaced some time during the Jurassic and Cretaceous periods.

Tertiary Andesites

Tertiary andesites unconformably overlie the granodiorite and metamorphic rocks of the area. Andesite flows, flow-breccias, tuff-breccias and intrusives make up the major portions of the Carson Range and also crop out on Peavine Mountain. Rocks of this unit are petrographically identified as hornblende andesites, biotite-hornblende andesites and pyroxene andesites. They have been correlated with two Tertiary andesite formations, the Kate Peak and Alta Formations, both of which have their type areas in the Virginia Range to the east. The Alta Formation has been assigned to the Oligocene. Axelrod (1949, p. 1935) suggested this age based on fossil leaves found in the sedimentary Sutro member. The Kate Peak Formation, in the Virginia Range, intertongues with the Coal Valley Formation which has fossil leaves and diatoms indicating an age near the Miocene-Pliocene boundary (Calkins, 1944, p. 23). If the correlation of the andesites in the Truckee River valley with the Kate Peak and Alta Formations in the Virginia Range is correct, andesitic eruptions in the Truckee River valley occurred from at least Oligocene up to the Pliocene.

Coal Valley Formation

The pediments in the study area are cut most commonly into a group of weakly indurated fluvial and lacustrine sediments with intercalated basalt flows. These rocks underlie the axial portion of the valley, extend from Reno to Verdi, and are roughly co-extensive with the area of piedmonts. Thompson and White (1964) correlate these sediments with the Truckee Formation whose type area is in the Hot Springs Mountains. Axelrod (1956, p. 100) has pointed out that the sediments in the Verdi area differ from the type Truckee Formation. He correlates them with the Coal Valley Formation. In this report they will also be termed Coal Valley Formation.

These rocks are made up of diatomite, shale, sandstone, conglomerate, coal, tuff-breccia and basalt flows. The majority of the clastic material was derived from the Tertiary andesites. Several estimates of the former maximum thickness of this unit have been given. They range from 1,600 to 3,000 feet thick. Results of a gravity survey (Thompson and Sandberg, 1958, p. 1270) indicate 1,800 feet of sediments in the Hunter Creek area. This thickness decreases to the west. The sediments occur in one to two foot beds which pinch out within 200 feet. The beds form a synclinal structure whose axis parallels the present axis of the valley. Dips of 20° to 30° are found near the flanks of the Carson Range and Peavine Mountain and decrease to less than 10° near the axis of the valley. The sediments are traversed by an intricate system of north-south normal faults downthrown to the west. Displacement on these faults is on the order of a few inches to a few feet.

The stratigraphic relationship of the basalt flows to the Coal Valley Formation has not been agreed upon by previous workers. Louderback (1907, p. 669) described the basalts as being Quaternary lavas which flowed off Peavine Mountain into the Truckee River valley. Gianella (1948, p. 1370) reports an area of baked Coal Valley sediments east of

Verdi which he interpreted as vent areas for post-Truckee Formation (post-Coal Valley Formation) basalt flows. Axelrod (1958, p. 101) described the basalt flows as a discrete middle member of the Coal Valley Formation. Godwin (1958, p. 36) interpreted the lavas as in part conformably overlying the Coal Valley Formation and in part intercalated with the formation. Booth (1960, p. 11) states that basalt flows conformably overlie the Coal Valley Formation.

The lack of good exposures revealing the contacts between the basalt flows in question and the Coal Valley Formation is probably the reason for the wide range of interpretations. It is the opinion of the writer that the basalt flows are contemporaneous with the Coal Valley Formation, or at least pre-date the deformation of the Coal Valley Formation. The following field evidence supports this conclusion: (1) basalt lavas cropping out in the SW¼ of Section 11, T.19N, R.18E. are overlain by Coal Valley sediments, (2) the basalts have angles of dip ranging from 23° to 75° in outcrops on the flanks of Peavine Mountain and basalts near the floor of the valley show dips of less than 10°, thus indicating that the basalts have undergone deformation similar to the sediments, (3) many of the basalt outcrops have pillow lavas in their basal portions, thus indicating a lava which flowed into water, and (4) some of the higher remnants of pediments are cut into basalts and no basalt flows have been found on top of post-Coal Valley erosional surfaces.

The Coal Valley Formation conformably overlies, and in places intertongues with, the upper part of the Tertiary andesites. Axelrod (1958, p. 104) dates the upper part of the formation as middle Pliocene. This date is based on fossil flora and mammal remains.

Pliocene-Pleistocene Basalts

Basalt flows, similar in lithology but stratigraphically above the basalts of the Coal Valley Formation, occur to the south of the study area in the northwest corner of the Carson Range (Sections 21, 27, 28, 32, and 33, T.19N., R.18E.) These outcrops lie at higher elevations than the highest pediments in the valley. In the Fuller Lake area these basalts overlie, with an angular unconformity, sediments of the Coal Valley Formation. These outcrops have been interpreted as remnants of flows which moved down the flank of the Carson Range and out onto the highest pediment. Thompson and White (1964, p. 18) described this situation as follows:

> In the northwestern part of the quadrangle' the low remnants of flows lie on the highest pediment cut on the Truckee and this surface can be projected through several erosion remnants to the highest Truckee River gravels, which form a thin veneer on Chalk Bluff in the Reno Quadrange.

If this stratigraphic relationship is correct, the flows in the northwestern part of the Carson Range are younger than the highest pediment and river terrace in the valley. This point will be discussed further in the following section on age relationships of land surfaces.

These flows have been correlated with similar basalt flows in the Truckee Basin to the west. The correlation was based on the facts that (1) flows in the Truckee Basin can be projected across the Truckee River canyon between Truckee and Verdi to flows in the northern Carson Range, (2) flows in both areas lie with angular unconformity on sediments of the Coal Valley Formation, and (3) flows in both areas have similar lithology (Birkeland, 1963, p. 1457).

Basalts in both these areas have been correlated with the Lousetown basalts in the Virginia Range to the east (Birkeland, 1963, p. 1457;

Thompson and White, 1964, p. 17; Booth, 1960, p. 11; and Godwin, 1958, p. 36). The flows in the Truckee Basin give K-Ar dates ranging from 2.3 to 1.2 million years (Birkeland, 1963, p. 1457)[1]. In addition to K-Ar dates, paleomagnetization is also reported for the basalts in the Truckee Basin. The older (2.3 million years) flows have a normal remnant magnetization, whereas the younger flows (1.9 to 1.2 million years) have a reversed remnant magnetization (Birkeland, 1963, p. 1460). Since all flows in the basin pre-date glaciation in the area, Birkeland places the 1.9 to 1.2 million years flows in the Matuyama reversed polarity epoch as defined by Cox, et al (1964 and 1965), Doell, et al (1966) and Doell and Dalrymple (1966). The older flows have been placed in the Gauss normal polarity epoch.

Heinrichs (1967, p. 3288) found that the flows in the northwestern part of the Carson Range have normal remnant magnetization. Since these flows show a high degree of erosional dissection which would make them older than late Pleistocene, they were correlated with the Gauss normal polarity epoch rather than the Brunhes normal polarity epoch (Thompson and White, 1964, p. 18). This would bracket the flows between 2.4 and 3.35 million years. There is the possibility that the flows could have been extruded during one of the normal events in the Matuyama reversed polarity epoch. This would give an age for these flows of either 0.9 million or 1.9 million years.

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[1]The type area for the Lousetown Formation as defined by Thayer (1937, p. 1648) gives a K-Ar age of 6.8 million years (Heinrichs, 1967, p. 3278). It is apparent that correlation of the basalts in the Truckee Basin with the type Lousetown is in error.

Structure

Louderback (1907, p. 667) described the Truckee River valley between Reno and Verdi as a synclinal structure, with the Truckee River flowing along its axis, and the Tertiary andesites and sediments of the Coal Valley Formation dipping towards this axis from the flanks of the surrounding mountains. Subsequent workers have concurred with and elaborated on this model. Thompson and White (1964, p. 32) concluded that the northern part of the Carson Range originated by flexural uplift forming a domal upwarp. High angle antithetic faulting accompanied this uplift, but was not responsible for the topographic relief. This faulting was the result of tension set up by stretching across the top of the expanding dome. Bonham and Papke (1969, p. 52) described Peavine Mountain as being a similar type of domal upwarp which was faulted on the northeastern side. The Truckee River valley is thus a structural downwarp between these two domes. Thompson and White (1964, p. 34) interpreted the 1,800 feet thickness of the Coal Valley sediments as evidence that this tectonic upwarping was underway during the deposition of these sediments

Summary of Geologic Features

By the close of the Mesozoic era granodiorite had intruded sediments and volcanic rocks which were metamorphosed prior to or during the intrusions. Before the eruption of the Tertiary andesites, which was underway by the Oligocene epoch, uplift and erosion had exposed the granodiorite and metamorphic rocks at the surface. Eruptions of andesite lavas, flow breccias and tuff-breccias took place up to earliest Pliocene. Deposition of Coal Valley sediments commenced just prior to the last stages of andesitic volcanism. Tectonic activity in the form of upwarps and downwarps was active during the deposition of Coal Valley sediments. Eruption of basalt lavas accompanied the deposition of the sediments. Both sediments and basalt flows were deformed to similar degrees. Sediment deposition took place up to at least middle Pliocene. Subsequent to the Coal Valley deposition, a later stage of basaltic volcanism took place. These basalt flows lie with angular unconformity on the Coal Valley Formation. Based on remnant magnetization and correlation with K-Ar dated basalt flows in the Truckee Basin, the age of these basalts is from 3.35 to 2.4 million years; there is also the possibility that they could be as young as 1.9 or 0.9 million years. Tectonic warping within the region was active subsequent to these youngest basalts. Birkeland (1963, p. 1456) determined that the Truckee River was flowing through the area some time before the last basalt eruptions in the Truckee Basin.

GEOMORPHOLOGY

The landforms of the Truckee River valley consist of four major mappable units: (1) mountains, (2) river terraces, (3) pediments and para-pediments, and (4) backslopes. {In the Verdi area there is evidence of nine former river levels. The lower eight of these levels can be traced downstream to the Reno area. All of these terrace levels have piedmont surfaces associated with them which consist in the most part of pediments and their backslopes; there are lesser areas of para-pediments, alluvial fans and fault scarplets.} The major geomorphic areas are shown in Figure 3. Mountains cover 5 square miles or 14 percent of the total study area. Piedmonts, which consist of primarily pediments and their backslopes, cover 19 square miles, or 51 percent of the total study area. The river terrace area, i.e., that area on both sides of the river which is comprised primarily of river terrace remnants, covers 13 square miles, or 35 percent of the study area.

Mountains

Mountainous terrain is located along the south flank of Peavine Mountain, the north flank of the Carson Range, and a mountainous outlier is located to the north of Mogul. These mountain areas have moderately steep to very steep slopes (15^{o} to 35^{o}) in complex patterns. These areas are underlain by erosionally resistant andesites, granodiorites, and metamorphic rocks. Along these mountain fronts, steep to very steep (20^{o} to 35^{o}), V-shaped canyons with narrow bottoms, usually less than 50 feet wide, lead up to ridges which are as narrow as the canyon bottoms.

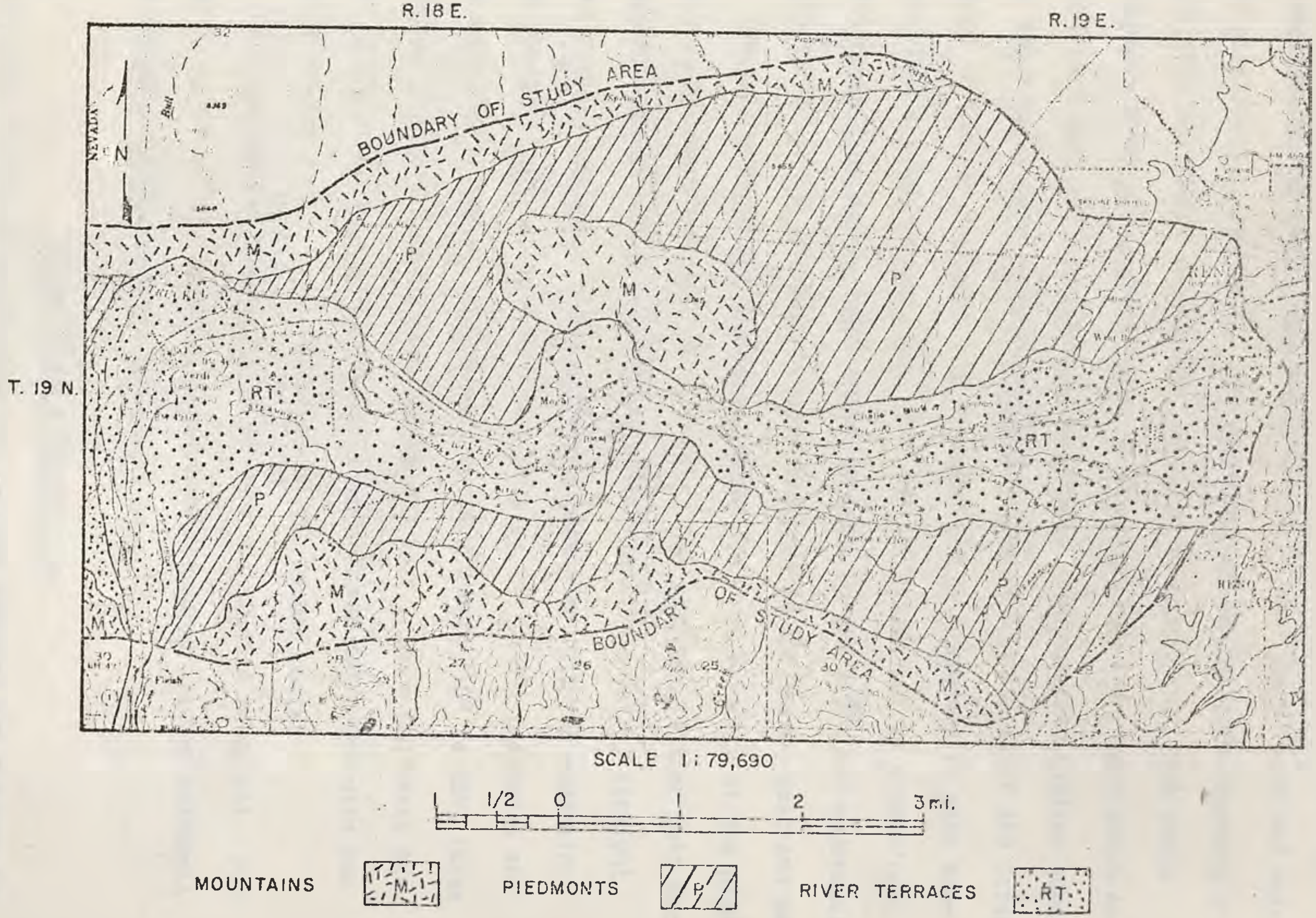

FIGURE 3. MAJOR PHYSIOGRAPHIC AREAS. MOUNTAINS COMPRISE 5 SQUARE MILES, PIEDMONTS 19 SQUARE MILES AND RIVER TERRACES 13 SQUARE MILES OF THE 37 SQUARE MILE STUDY AREA.

The northern portion of the study area, except for the extreme northeastern part, is bordered by mountains which are underlain by andesites on the west, some granodiorite in the central part and metamorphic rocks to the east. The mountains at the southern boundary of the area are almost completely underlain by andesites. Both these mountain areas are characterized by steep valleys and ridges which extend well into the mountain masses proper. The mountain outlier north of Mogul has a more subdued topography than do the flanks of the Carson Range or Peavine Mountain. It is underlain by granodiorite with some andesites on the eastern side. The outlier stands out as a prominent hill bounded by nearly level river terraces on the south and moderately sloping (3^o to 5^o) piedmont erosion surfaces on the north, east and west.

The juncture between pediments, which form the majority of the piedmonts, and mountains occur in two ways. The pediments either join the mountain slopes at the base of mountain fronts in a fairly straight line between canyons, or the pediments extend up into the mountains. The juncture between the moderately sloping (3^o to 5^o) pediments and the moderately steep to very steep mountain fronts (15^o to 35^o) takes place as a smooth curve within 200 to 600 feet. Where pediments extend up canyons, the pediment usually narrows and converges with the narrow canyon floor within 1000 feet of the canyon mouth.

These pediment-mountain junctures were not studied in detail. For mapping purposes, the somewhat gradational boundary between pediments and mountain slopes has been shown as a line.

River Terrace Correlation

All nine levels which comprise the terrace sequence are present in

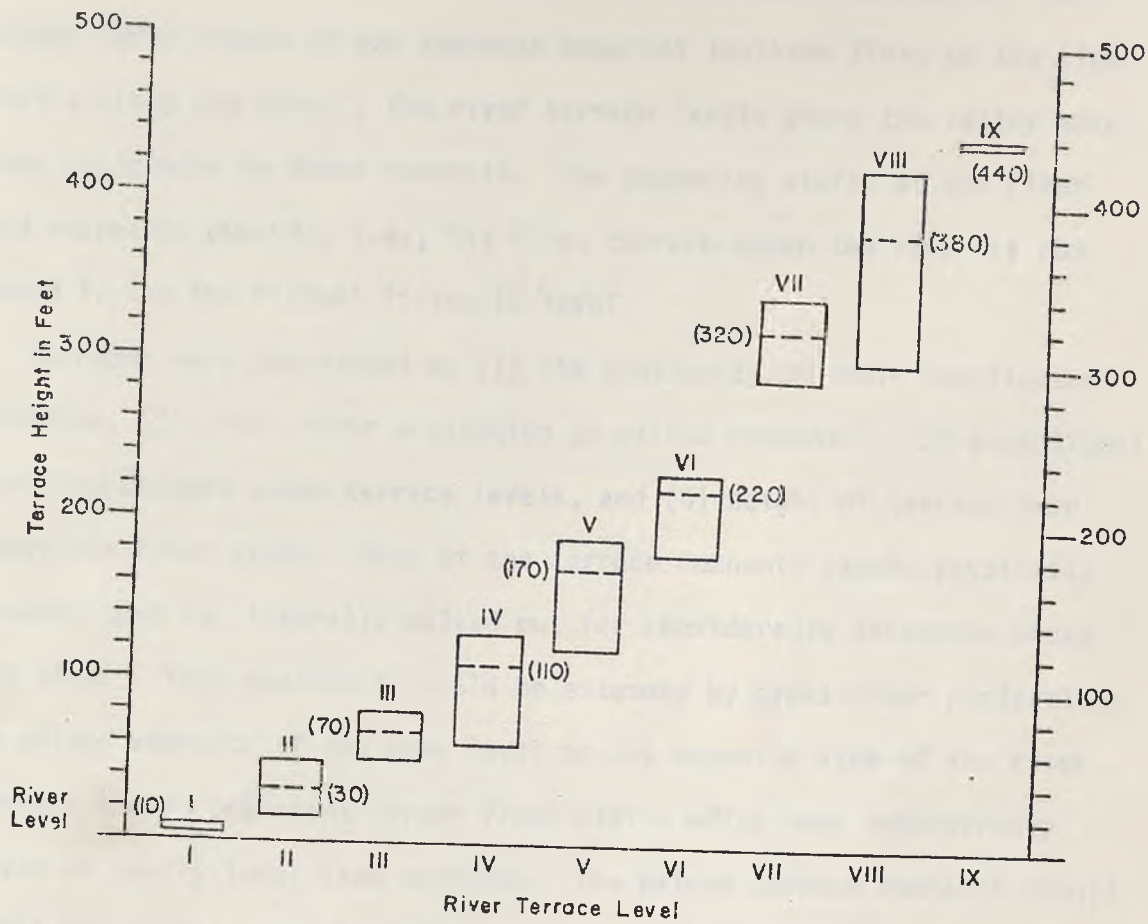

Figure 4. Height of river terrace remnants above the Truckee River. Bars denote the range in terrace height throughout the study area. Broken lines in the bars denote the average terrace height and the numbers in parentheses are the values in feet for the average terrace heights. Data was taken from 7.5 min. topographic maps.

the reach of the valley near Boomtown, Section 16, T.19N., R.18E. (see Plates I, II and III, cross-section A). The terrace remnants in this area, which is considered the type are for the terrace sequence, can be traced laterally to terrace remnants throughout the study area. {For the most part, the lower five terrace levels are continuous throughout the valley except for one major hiatus between Mogul and Lawton. The higher three levels of the sequence occur as isolated flats on the high bluffs along the river.} The river terrace levels along the valley have been designated by Roman numerals. The numbering starts at the river and increases upwards, i.e., the first terrace above the river is numbered I, and the highest is the IX level.

Terraces were correlated by (1) the continuity of their longitudinal profiles, (2) cross-river projection to paired remnants[1], (3) elevational position between known terrace levels, and (4) height of terrace level above the river grade. Many of the terrace remnants can be physically traced, that is, literally walked out for considerable distances along the river. This continuity could be extended by cross-river projections to paired remnants of the same level on the opposite side of the river. Terrace treads represent former flood plains which were transversely level or nearly level land surfaces. The paired terrace remnants should still have this nearly-level cross-river profile if they have not been subsequently modified by erosion or deposition. In most cases, these secondary features could be recognized in the field and avoided when making cross-river correlations. By use of a hand level, the paired

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[1] A <u>paired remnant</u> is a terrace remnant of the same level on the opposite side of the river.

remnant of a particular terrace level could be distinguished from other terrace levels on the opposite side of the river. Many of the discontinuous remnants could be correlated by virtue of their position between identifiable, continuous terrace remnants. Once the general distribution of terrace heights above the present river level has been established (see Figure 4 and Plate II), isolated remnants could be correlated by their height above the river.

Critical Sites for Correlation of Terrace Remnants

All terrace levels can be seen in their relative positions in the Boomtown area (see cross-section A of Plate III). It is the type area for the terrace sequence and terrace levels were traced to the rest of the valley from this locality. In the field, all these terrace levels can best be observed from the top of the basalt bluff north-east of Boomtown (NW¼, NW¼ Section 16, T.19N., R.18E.).

Tracing terrace levels upriver, to the west of the type locality at Boomtown, terrace levels IV and V, lying to the south of the river, can be traced continuously westwards to Verdi. This is the farthest west that these two terrace levels occur. The remnants of terraces VII and VIII on the bluff southwest of Boomtown (SE¼, SE¼ Section 17, T.19N., R.18E.) can be projected to corresponding remnants of these surfaces on the prominent bluff south of Verdi (SW¼ Section 17 and NW¼ Section 20, T.19N., R.18E.). There is a patch of fluvial gravels above terrace VIII on the bluff southwest of Boomtown. These gravels represent a river level IX, but they do not occur outside of the type area. On the bluff south of Verdi there is a terrace level positioned below the level of terrace VII and above the continuous surface of terrace V. This level correlates with terrace level VI. Terraces I, II, and III can be traced continuously, by use of cross-river projections between paired remnants, west from the type area to the boundary of the study area southwest of Verdi.

Tracing east from the type area at Boomtown to the Mogul area (see cross-section B of Plate III): terrace V can be followed continuously, along the south side of the river, to the Belli Ranch and then projected across the river to its paired remnant on the north side of the river. At this point along the north side of the valley, there is one terrace level higher than terrace V and four terrace levels lower than V. The higher level was correlated with terrace level VI and the four lower levels were correlated with terrace levels IV, III, II and I respectively. Terrace III has a paired remnant on the south side of the river at this point.

On the high bluff southeast of Mogul (SE¼, SE¼ Section 14, T.19N., R.18E.) there are two terraces well above the level of terrace VI. These two higher levels are correlated with terraces VII and VIII.

Moving east through the Mogul-Lawton gap, the following terraces occur in the Lawton area (see cross-section C of Plate III). Terrace I and II can be traced through the gap by cross-river projections between paired remnants and occur in the Lawton area as terraces 10 and 20 feet above the river. Other terrace levels which are not traceable through the gap occur at 80, 120, 220, 290, and 340 feet above the river. The 80 foot terrace is correlated with terrace IV, the 120 foot terrace with V, the 220 foot terrace with VI, the 290 foot terrace with VII and the 340 foot terrace with VIII. Ther terrace VI remnant, on the south side of the river, lies below two pediment surfaces. These surfaces were probably graded to terraces VII and VIII which have subsequently been removed by erosion from the south side of the river.

Terraces I, II, and V can be followed continuously from Lawton eastward to West Reno by cross-river projections to paired remnants (see cross-section D of Plate III). Terraces III and IV are discontinuous in this area, but remnants of these levels can be identified by their height above the river and position relative to traceable terrace levels. Terrace VI, on the north side of the river in West Reno, can be traced west to Chalk Bluff where its position below terrace VII and VIII can clearly be seen.

River Terrace Sequence

Nine river terrace levels were recognized and mapped in the Truckee River valley. These surfaces are remnants of abandoned flood plains positioned so that erosion, subsequent to downcutting of the Truckee River, has not been able to remove all traces of them. All the river terrace remnants have down-valley slopes nearly parallel to the present grade of the Truckee River; there are no terrace remnants which have grades greater than the grade of the present river (see Plate II). The grade of the Truckee River averages 30 feet per mile within the study area. The nine terrace levels form a series of strath and fill terraces[2] for the entire length of the river in the study area. Terrace levels range from 10 to 440 feet above the Truckee River. The higher five terraces have had much of their original extent removed by erosion;

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[2] A strath terrace is a river terrace cut on bedrock, whereas a fill terrace is a terrace cut on alluvial fill.

the middle two terrace levels have been partly destroyed by erosion, and the lower two terrace levels are almost untouched by erosion.

River terraces are composed of two physiographic elements: a nearly level tread, and a strongly sloping riser. The tread is the area of the former flood plain. The riser is an erosional scarp which is graded to the tread and was cut by the same river stage that built the tread. Both are mapped as a single terrace unit. Included in this map unit are both relict and younger surface features. Vestiges of old channels and bars can be seen on some of the treads of the lower terrace levels. The tread-riser boundary on all terrace levels has been modified by erosion and the deposition of slope wash and colluvium; these younger deposits have been included in the river terrace map unit without any cartographic distinction. The map boundary between a younger terrace and an older one was drawn where the riser of the younger terrace intersects the tread of the higher and older terrace of some other landform.

For comparative purposes, the present extent of river terraces are given as percentages of the total area of river terraces as delineated in Figure 3. Judging from the extent and position of terrace remnants, the maximum extent of the flood plains associated with each individual terrace level also has been estimated and given as percentages of the total area of river terraces. By comparing the extent of each former flood plain with the present extent of its terrace remnants, the degree of erosional destruction has been estimated. These data for each terrace level are graphically shown in Figure 5.

Longitudinal continuity of the terrace levels is shown in Figure 6 and Plate II. For a terrace to be continuous through a particular reach

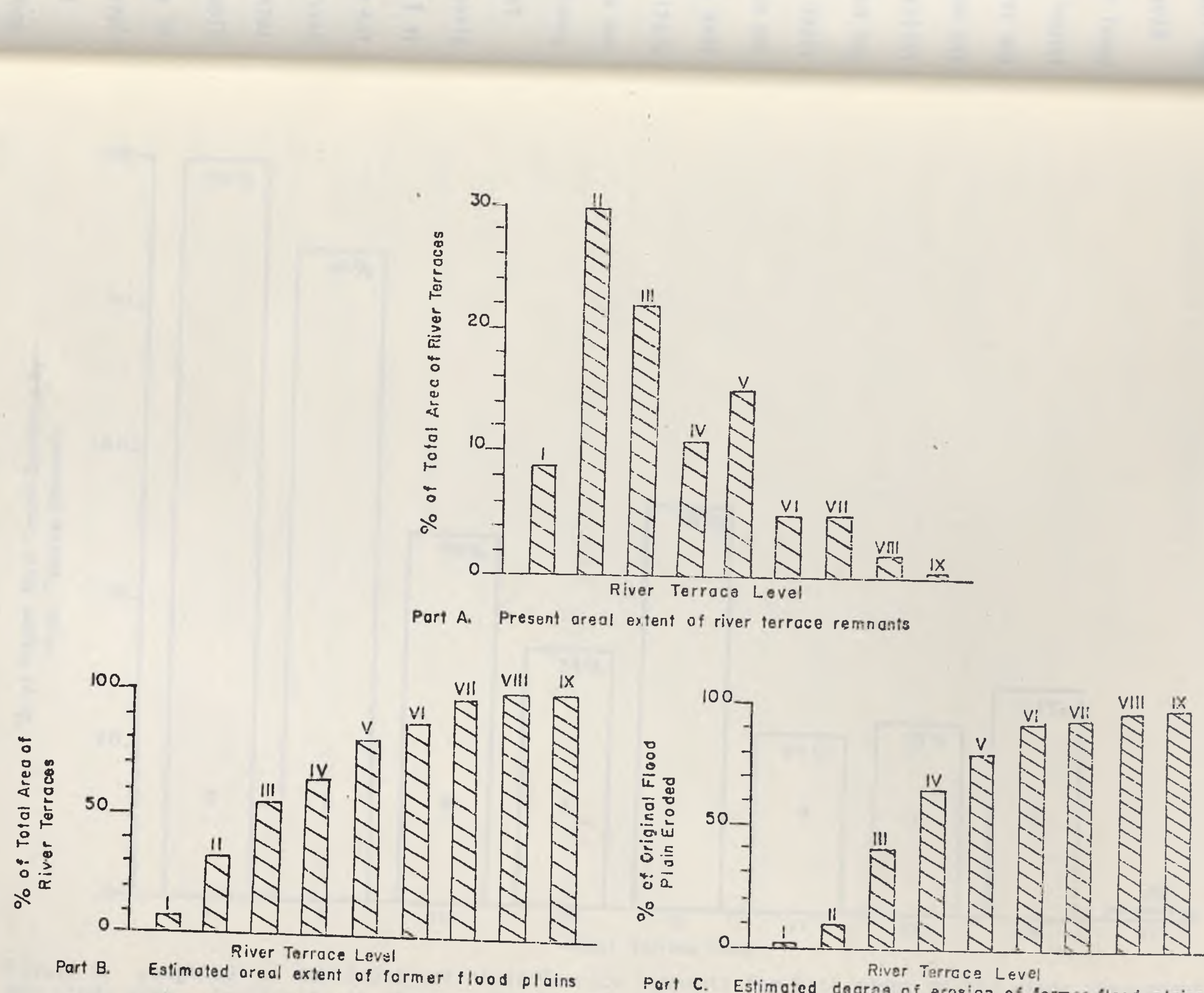

Figure 5. Present areal extent of river terrace remnants, estimated areal extent of former flood plains, and estimated degree of erosion of former flood plains. Total area of river terraces is 13 square miles.

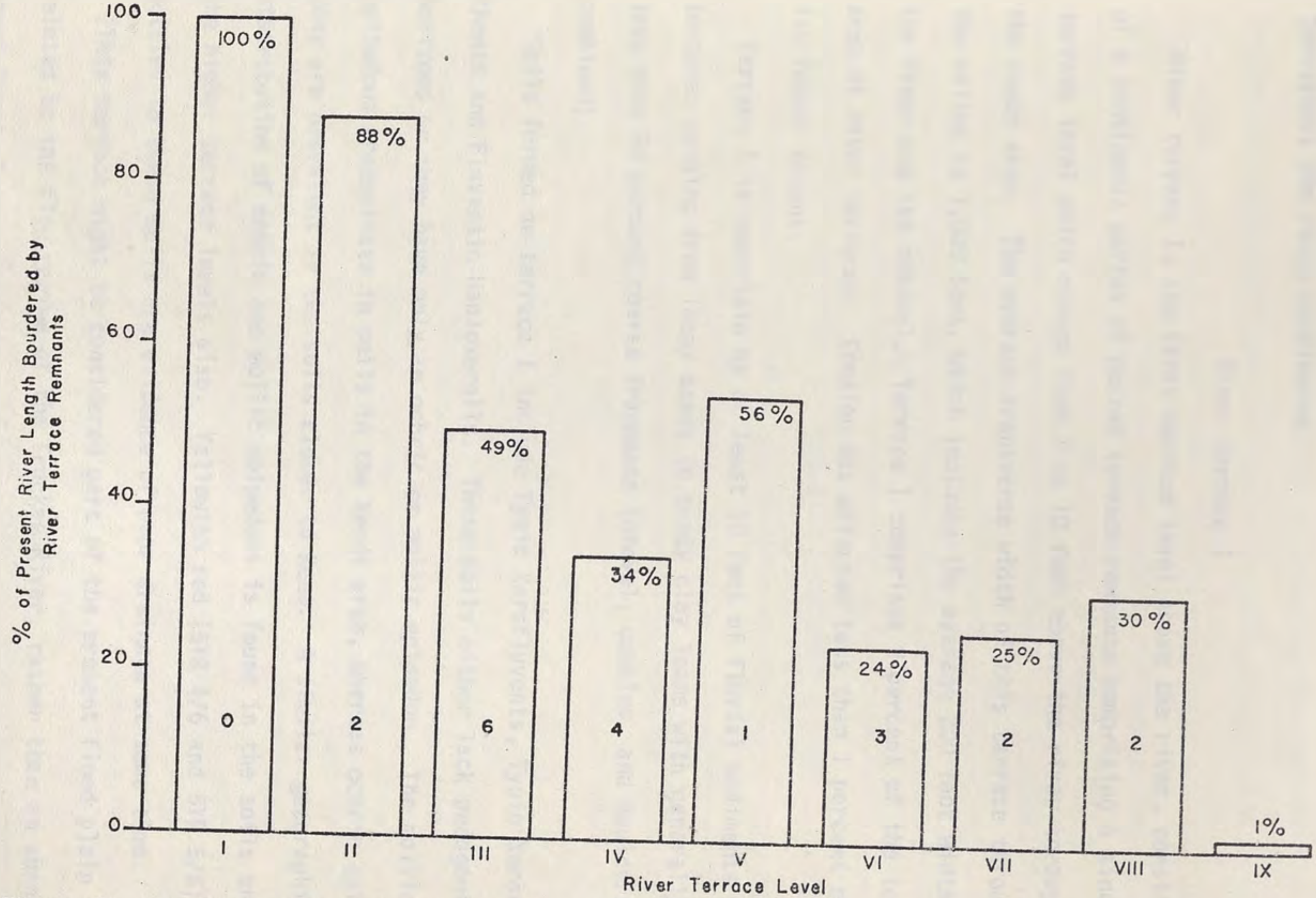

Figure 6. Longitudinal continuity of river terrace remnants for both sides of the river throughout the study area. Continuity is given as percent of present river length, which is 14 miles. Numbers at the bottom of the bars indicate the number of hiatuses in terrace continuity.

of the valley it must be present at least on one side of the river throughout the reach considered.

River Terrace I

River terrace I, the first terrace level above the river, consists of a continuous series of paired terrace remnants comprising a single terrace level which ranges from 7 to 10 feet above the river throughout the study area. The average transverse width of this terrace throughout the valley is 1,000 feet, which includes the average 200 foot width of the river and its channel. Terrace I comprises 9 percent of the total area of river terraces. Erosion has affected less than 1 percent of its former extent.

Terrace I is underlain by at least 10 feet of fluvial sediments with textures ranging from loamy sands to sandy clay loams with generally less than 30 percent coarse fragments (gravel, cobbles, and boulders combined).

Soils formed on terrace I include Typic Xerofluvents, Typic Xerorthents and Fluventic Haploxerolls. These soils either lack pedogenic horizons or they have only an ochric or mollic epipedon. The mollic epipedons predominate in soils in the Verdi area, whereas ochric epipedons are prevalent in the soils closer to Reno. A similar geographic distribution of ochric and mollic epipedons is found in the soils on the higher terrace levels also. Yellowish red (5YR 4/6 and 5YR 5/6) mottles in these soils are evidence of poor drainage at some time.

This terrace might be considered part of the present flood plain related to the flow regime of the Truckee River, rather than an abandoned flood plain related to a previous higher stage of the river. Terrace I has flooded in historic time (November 1950; December 1955; February 1963). Floods large enough to overflow onto terrace I are called intermediate regional floods and have calculated reoccurrence intervals of 1 in 100 years (U.S. Army Corps of Engineers, 1970, p. 51). The active flood plain of a river has been defined by Leopold, Wolman and Miller (1964, p. 468) as that surface which is attained or just overtopped by floods with a reoccurrence interval of 1 to 2 years. Their definition is based on recorded reoccurrences of full bank stages for a variety of rivers in diverse climatic settings. The formation of a flood plain is dependent on a stable river regime, that is a river which is neither aggrading nor degrading. Leopold chooses the 1 to 2 year flood interval to define a stable river and the flood plain which is the product of this stable river. According to Leopold's definition, terrace I is well above the full bank flow level of the river, and is therefore a relict feature and not part of the present flow regime flood plain.

River Terrace II

Eighty-eight percent of the present river length, on one side or the other, is bounded by remnants of river terrace II. This terrace level is almost continuous throughout the study area, ranges from 17 to 50 feet above the river, and is comprised of many paired remnants. Remnants comprise 30 percent of the total area of river terraces. Width of remnants range from 500 to 1,000 feet throughout most of the study area. Near Reno, at the eastern boundary of the study area, remnants of this terrace flare out to widths of 3,200 feet. Vestiges of former channels and bars can be seen on some remnants. Channels and bars are particularly well-preserved south of the basalt bluff in the NE¼ Section

16, T.19N., R.18E.

The former flood plain associated with terrace II comprised 32 percent of the total area of river terraces and had an average width of 1,600 feet. Erosion has destroyed only about 10 percent of the former flood plain.

[Remnants of the river terrace II occur primarily as strath terraces with 10 to 15 feet of coarse fluvial sediments over a laterally planed surface cut into the Coal Valley Formation.] The terrace remnant on which the settlement of Mogul is located (Center Section 14, T.19N., R.18E.) and the terrace remnant between Hunter Creek Reservoir and Keystone Avenue (N½ Section 15, T.19N., R.18E.) are underlain by coarse fluvial sedimentary fills which extend at least 20 feet to the present river level. The texture of these sediments, under both strath and fill terraces, are bouldery, cobbly, gravelly loamy sands. Boulders with diameters ranging from 1 to 4 feet are most common, but there are also very large boulders with diameters greater than 7 feet.[3] The boulders and cobbles in these sediments average 61 percent andesite, 6 percent basalt, 32 percent granitic material and less than 1 percent metamorphic material.

Soils developed on terrace II include Typic Haplargids and Typic Argixerolls. They have ochric or mollic epipedons and argillic horizons. The argillic horizons are bouldery, cobbly, and gravelly throughout with fine earth fractions ranging from sandy clay loam to clay textures. Structure in the argillic horizon, if present, is usually weak angular blocky.

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3 Birkeland (1968, p. 139) has demonstrated that boulders of this size were probably transported by cataclysmic floods related to ice dam breachings at Lake Tahoe during the Pleistocene. Present day analogs to these floods have been observed in Iceland and are termed <u>jokulhaups</u>.

The sola are about 30 inches thick. No accumulations of calcium carbonate or opal were noted in these soils.

River Terrace III

Remnants of the third terrace above the Truckee River are less continuous than the lower terraces. Only 49 percent of the present river length is bounded by remnants of terrace III. There are six hiatuses in this terrace through the study area. Remnants of terrace III make up approximately 22 percent of the total area of river terraces. This terrace ranges from 50 to 80 feet above the river and has paired remnants west of Mogul. East of Mogul there is one unpaired remnant south of the river near Swope Jr. High School (SE¼, SE¼ Section 16, T.19N., R.18E.).

The average width of the terrace III flood plain was 2,600 feet. The areal extent of this flood plain was approximately 54 percent of the total area river terraces, nearly 40 percent of the original flood plain has been removed by erosion.

Remnants of terrace III occur as both strath and fill terraces. Strath terraces with approximately 20 feet of coarse fluvial sediments over a bedrock floor cut into the Coal Valley Formation are found at the following localities: two small remnants occur on the east side of the river south of Verdi (SE¼ Section 18, T.19N., R.18E.); a remnant occurs below the basalt bluff east of Verdi (West Center Section 15, T.19N., R.18E.); and a remnant occurs south of the Mogul Power Station (NW¼, NW¼ Section 28, T.19N., R.18E.). Fill terraces with at least 50 to 80 feet of fill to the present river level occur along the western boundary of the study area, in the Verdi area (SW¼ Section

14, T.19N., R.18E.); on the north side of the river between Verdi and the basalt bluff (S½ Section 9, T.19N., R.18E.); and on the north side of the river across from the Mogul Power Station (SW¼ Section 14, T.19N., R.18E.). The structure of the river terrace remnant south of Swope Jr. High School (SE¼, SE¼ Section 16, T.19N., R.18E.) cannot be determined due to lack of exposure. The textures of the fluvial sediments under both strath and fill terraces are bouldery, cobbly, gravelly loamy sands. The boulders in these sediments are similar to the boulders of river terrace II., i.e., boulders are commonly 1 to 4 feet in diameter with some greater than 7 feet in diameter. Lithology of the boulders and cobbles averages 79 percent andesite, 4 percent basalt, 15 percent granitic and 1 percent metamorphic.

Soils developed on terrace III include Typic Haplargids and Typic Argixerolls. They have ochric and mollic epipedons and argillic horizons. The argillic horizons are bouldery, cobbly and gravelly throughout, with fine earth fractions ranging from sandy clay loams to clays. Structure of the argillic horizons is moderate to strong angular blocky. The sola on the order of 60 inches thick are thicker than the sola of soils developed on terrace II. These soils do not have accumulations of calcium carbonate or opal.

River Terrace IV

Treads of river terrace IV range from 60 to 130 feet above the grade of the river. About 34 percent of the total river length is bounded by remnants of this terrace. Four hiatuses in the continuity of this terrace occur within the study area. Remnants of terrace IV comprise approximately 11 percent of the total area of river terraces. Only one instance of paired terrace remnants occurs within the study area: a remnant of terrace IV south of Roy Gomm School (SW¼, SW¼ Section 16, T.19N., R.19E.) has a paired remnant across the river (Center Section 16, T.19N., R.19E.). Unpaired remnants of this terrace occur northwest of Mogul (NW¼ Section 14, T.19N., R.18E.), east of Verdi (NW¼ Section 15, T.19N, R.18E.), and in the southwest part of Reno (S½ Section 15, T.19N., R.19E.). Terrace IV remnants have tread widths from 1,000 to 1,500 feet in the western portion of the study area and narrow to widths of about 400 to 500 feet in the eastern part of the area. A relict gravel bar with very large boulders occurs just to the north of Boomtown (NW¼ Section 16, T.19N., R.18E.).

The flood plain associated with terrace IV comprised 64 percent of the total area of river terraces. The average width of this flood plain was approximately 3,100 feet. Erosion has removed about 82 percent of this original flood plain.

The remnant of terrace IV east of Verdi (NW¼ Section 16, T.19N, R.18E.) is a strath terrace with about 23 feet of coarse fluvial sediments over a laterally planed floor cut into the Coal Valley sediments. The other remnants of terrace IV are fill terraces. The depth of this fill is at least to the present level of the river, or about 100 feet. The coarse fluvial sediments which underlie the strath and fill terraces of this level are similar to texture of fluvial sediments of the lower terraces, a bouldery, cobbly, gravelly loamy sand with very large boulders is common for all the terrace levels. Lithologically terrace IV boulders and cobbles average 73 percent andesite, 10 percent basalt, 15 percent granitic and 1 percent metamorphic.

Soils developed on terrace IV include Typic Paleargids, Duric Paleargids and Typic Argixerolls. They have ochric or mollic epipedons over argillic horizons. The argillic horizons have two subhorizons: (1) an upper boulder-, cobble-, gravel-free horizon with a clay texture, and (2) a lower bouldery, cobbly, gravelly subhorizon of somewhat coarser fine earth texture ranging from sandy clay loams to sandy loams. The coarse fragments in the lower subhorizon are coated with clay. Structure in the upper subhorizon is commonly strong prismatic. Sola thicknesses are greater than 144 inches. Accumulations of calcium carbonate or opal may or may not be present with depths of 40 inches in these soils. Opal cemented pans (duripans) have not been seen in these soils.

River Terrace V

Remnants of river terrace V comprise approximately 15 percent of the total area of river terraces. Remnants of this surface range from 120 to 190 feet above the present river grade and their continuity is broken only by one hiatus between Lawton and Mogul. Paired terraces are common throughout the study area. Treads range in width from 1,200 to 1,500 feet, except for the terrace on which the settlement of Lawton is located which has a tread width of 800 feet. Terrace V occurs along 56 percent of the present river length.

The maximum extent of the flood plain associated with terrace V was about 80 percent of the total area of river terraces and had an average cross-valley width of 3,700 feet. Erosion has destroyed about 80 percent of the former flood plain.

The prominent terrace V remnant on which Boomtown is located (Center

Section 16, T.19N., R.18E.) is a strath terrace with approximately 25 feet of coarse fluvial sediments under it. The remainder of the terrace V remnants are fill terraces with approximately 150 feet of fill extending to at least the present river level. An exception to this is the terrace just to the southeast of Chalk Bluff (Center Section 17, T.19N., R.19E.). This terrace is underlain by about 40 feet of fill which in turn overlies the Coal Valley Formation. These sediments are generally bouldery, cobbly, gravelly loamy sands with 1 to 4 foot boulders. Boulders greater than 7 feet are also found in these sediments. Lithologically the boulders and cobbles average 81 percent andesite, 13 percent basalt, 5 percent granitic and 1 percent metamorphic.

Soils developed on terrace V include Typic Paleargids, Mollic Paleargids, Duric Paleargids, Typic Durargids, Haplic Durargids, Typic Argixerolls, and Duric Argixerolls. They have ochric or mollic epipedons over argillic horizons; some have duripans. The argillic horizons have morphologies similar to the argillic horizons of soils of terrace IV; that is, they have two subhorizons: an upper clay-textured horizon which is almost completely free of coarse fragments (particles greater than 2mm.), and a lower, somewhat coarser-textured horizon with 40 to 50 percent coarse particles. This is the youngest terrace on which duripans occur, but they are not always present here.

River Terrace VI

Remnants of river terrace VI range from 180 to 230 feet above the present river level. These remnants comprise about 5 percent of the total river area. Remnants of this level occur as a series of isolated terraces on both the north and the south side of the river. Tread widths on these remnants are between 500 to 700 feet. Twenty-four percent of the present river length is bordered by remnants of this level.

The maximum extent of the flood plain associated with terrace VI was 88 percent of the total area of river terraces; it had a cross-valley width of 4,200 feet. Erosion has removed 94 percent of the original surface.

Most remnants of river terrace VI are fill terraces with at least 180 feet of fill extending to the present river grade. One strath terrace is preserved east of Chalk Bluff (SW¼, NE¼ Section 17, T.19N., R.19E.). It has approximately 30 feet of coarse sediments over a floor cut into the Coal Valley Formation. Both strath and fill terraces are underlain by coarse-textured sediments similar to those of lower terraces. Very large boulders are also present in these sediments. Lithologically, the boulders and cobbles are 79 percent andesite, 6 percent basalt, 16 percent granitic and less than 1 percent metamorphic.

Soils of this terrace are similar to the soils of terrace V. They include Typic Paleargids, Mollic Paleargids, Duric Paleargids, Typic Durargids, Halpla Durargids, Typic Argixerolls, and Duric Argixerolls. They have ochric or mollic epipedons over argillic horizons and the upper subhorizon of the argillic horizon is free of coarse fragments and overlies a subhorizon with coarse fragments. Duripans and calcic horizons are present in some, but not all of these soils.

River Terrace VII

Remnants of river terrace VII range from 290 to 340 feet above the grade of the river. This terrace, like the terrace VI, occurs as scattered remnants on both sides of the river throughout the valley.

Remnants of terrace VII comprise about 2 percent of the total area of river terraces. The remnant of this terrace which is located on the northern part of the prominent bluff south of Verdi (SW¼ Section 17, T.19N., R.18E.) has a tread width of 4,000 feet. Other remnants are less extensive and occur on the bluff southwest of Boomtown (SE¼, SE¼ Section 14, T.19N., R.18E.), the bluff southeast of Mogul (NW¼, SE¼ Section 14, T.19N., R.18E.) and the bluff east of Lawton (SE¼, NW¼ Section 18, T.19N., R.18E.).

The maximum extent of the flood plain associated with terrace VII was 99 percent of the total river terraces and had an average cross-valley width of 4,800 feet. Erosion has removed 95 percent of the original flood plain.

Remnants of terrace VII occur only as strath terraces cut into the Coal Valley sediments. About 25 feet of coarse sediments (bouldery, cobbly, gravelly loamy sands) underlies the terraces of this level. Very large boulders--one measures 10 by 8 by 15 feet--occur in the sediments under terrace VII on the bluff southeast of Mogul. Lithologically the boulders and cobbles average 50 percent andesite, 11 percent basalt, 38 percent granitic and 2 percent metamorphic.

Soils of this terrace are similar to soils of terraces V and VI. They include Typic Paleargids, Mollic Paleargids, Duric Paleargids, Typic Durargids, Haplic Durargids, Typic Argixerolls, and Duric Argixerolls. Ochrich or mollic epipedons overlie argillic horizons which have an upper clay-textured boulder-, cobble-, gravel-free subhorizon and a lower subhorizon with coarse fragments. Duripans and calcic horizons are present in some, but not all of these soils.

River Terrace VIII

Remnants of river terrace VIII comprise approximately 2 percent of the total area of river terraces. About 30 percent of the present river length is bounded by remnants of this terrace which range from 300 to 420 feet above the river grade. Though remnants of this terrace are not extensive, they stand out as prominent bluffs along the river. The large bluff south of Verdi (Center Section 20, T.19N., R.18E.) is composed in part of terrace VIII, the top of the bluff southeast of Mogul (SE¼, SE¼ Section 14, T.19N., R.18E.) is part of the tread of terrace VIII and the prominent flat surface of Chalk Bluff (Center Section 17, T.19N., R.18E.) is part of the tread of terrace VIII. Tread widths on these remnants are about 700 feet.

The former flood plain associated with terrace VIII composed about 100 percent of the total area of river terraces and had an average cross-valley width of 4,800 feet. Erosion has destroyed all but 2 percent of the former flood plain.

At least 60 feet of coarse sediments lie between terrace VIII and the Coal Valley Formation at the bluff southeast of Mogul. These sediments are too thick to be considered the lateral accretion sediments of a strath terrace, thus terrace VIII is a fill terrace. Structural relationships of the other remnants are not exposed. Sediments under terrace VIII are similar to sediments under the lower terraces. Very large boulders are also present in these sediments. Lithologically they average 59 percent andesite, 10 percent basalt and 30 percent granitic.

Soils of terrace VIII are similar to the soils of terrace V and older terrace levels. They include the subgroups Typic Paleargids, Mollic

Paleargids, Duric Paleargids, Typic Durargids, Hapla Durargids, Typic Argixerolls, and Duric Argixerolls. Ochric and mollic epipedons overlie argillic horizons which have an upper clay-textured boulder-, cobble-, and gravel-free subhorizon. Duripans, calcic horizons, and petrocalcic horizons are present in some, but not all these soils.

River Terrace IX

A patch of coarse fluvial sediments 300 by 600 feet wide occurs as a knoll above river terrace VIII on the bluff just southwest of Boomtown (SE¼, SE¼ Section 17, T.19N., R.18E.). This is the lone evidence of terrace IX within the study area. The lithology of the boulders and cobbles averages 84 percent andesite, 2 percent basalt, 13 percent granitic and 1 percent metamorphic. The largest boulders in this deposit are from 2 to 3 feet in diameter. Although no remnants of river terraces older than terrace VIII were found elsewhere, there are pediments which are above the pediments which grade to terrace VIII. These higher pediments might have graded to terrace IX.

The remnant of terrace IX has been so modified by erosion that none of the original terrace surface is left, and therefore the soils on the remnant cannot be associated with terrace IX.

Piedmont Land Surfaces

The piedmont areas, those areas between the river terraces and the mountain fronts, form two broad linear zones to either side of the Truckee River throughout the study area (see Figure 3). The piedmonts in this valley are composed of (1) pediments, (2) para-pediments, and (3) backslopes. There are also a few scattered alluvial fans which are not very extensive. As a general rule, alluvial fans are usually extensive features on most piedmonts in the Western Nevada region.

The episodic erosion which has taken place along the river, as evidenced by the river terraces, is also manifest on the piedmonts. The piedmont analog to the river terrace sequence is composed of a series of pediments and para-pediments stacked one above the other. Many of these surface levels are graded to the terraces in the river terrace sequence, thus providing a direct link for correlation of fluvial and piedmont land surfaces.

Pediments

The pediments are erosional surfaces cut into the sediments of the Coal Valley Formation. The relief of these cut surfaces is low, but the exact configuration of these surfaces cannot be continuously observed because they are almost always covered by a mantle of alluvial sediments termed pedi-sediments. The pedi-sediments were derived from rocks in the upslope mountain areas and are bouldery, cobbly, gravelly loamy sands to sandy clay loams with boulders up to 3 to 4 feet in diameter. Material from the Coal Valley Formation is probably present in the fine earth fraction of these sediments. The pedi-sediment mantle, which ranges from less than 1 foot to 20 feet thick, determines the surface shape of the pediments, which are simple, smooth, planate surfaces with a concave-upwards longitudinal profile. These surfaces are gently to moderately sloping, some strongly sloping curves (2^{o} to 6^{o}) extending from the mountain fronts to the river terraces. The pediment surfaces are graded to the moderately steep to very steep (15^{o} to 30^{o}) mountain fronts. This transition takes place over relatively short lateral distances, on the order of 200 to 600 feet.

Where younger, lower pediments are cut into older, higher pediments, the younger pediments have backslopes with moderately steep to very steep (15^o to 30^o) slopes. These steep backslopes contrast markedly with the moderately sloping pediments and occur at the head, the elevationally higher portions, of the pediments. These backslopes only comprise a small area compared to the area of their pediments.

During a pediment erosion episode the actively eroding backslopes encroach on the higher, older land surfaces and a younger land surface, a pediment, is formed below the older land surface. This process continues until the erosion consumes the higher land surface or until erosion is stabilized (see Figure 8).

The pediment map units include both the pediments and their backslopes. Both these landforms are most commonly stable in this area, since soils have formed on them.[4] Also included within the pediment map unit are ephemeral stream channels cut below the pediment surface and minor alluvial fan deposits. The map boundary between a younger pediment and an older pediment was drawn where the backslope to the younger sediment intersects the higher, older pediment.

The pediments occur as vertical sequences of discrete land surfaces in areal groupings which closely correspond to individual drainage areas on the piedmonts. Each of these areas is herein termed a system of pediments. There are 13 systems of pediments within the study area (see Figure 7). Within each system, the higher, older pediments have been modified considerably by erosion. Remnants of these older levels occurs

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[4] Soil formation requires the condition of stability in a landscape. A stable landscape is one where neither erosionof nor deposition on the land surface is proceeding faster than the rate of soil formation.

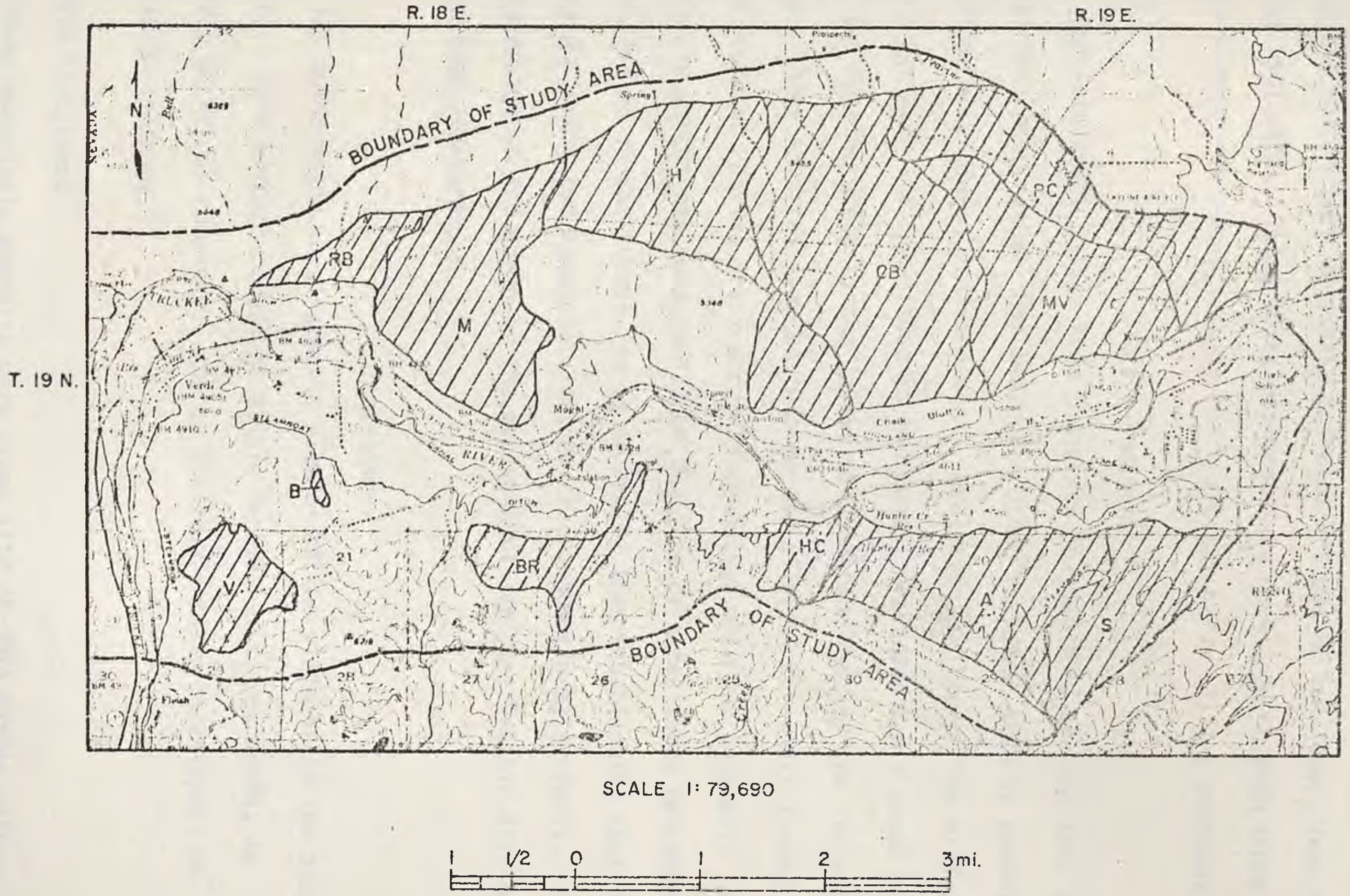

FIGURE 7. MAJOR SYSTEMS OF PEDIMENTS

as isolated mesas and round-shouldered ridges. Below these isolated features, there is usually a relatively extensive, continuous pediment. Incised within this extensive pediment are one or two lower, less extensive pediments. These lower pediments are developed on both sides of the present drainage channels which are cut below all the pediment levels.

Para-Pediments

Para-pediments differ from pediments in that they are cut into alluvial sediments rather than bedrock. Other features, such as general surface morphology, pedi-sediments, evolution and boundaries with other land surfaces are like those of pediments. Para-pediments occur mainly in the Peavine Creek system in the northeastern part of the study area. There these surfaces are cut into an old alluvial fan which formed at the mouth of Peavine Creek where it debouched onto the piedmont. Exposures in stream and road cuts show that the para-pediments cut across the bedding of the former fan at an angle, thus establishing that the para-pediments are erosional, rather than depositional surfaces. The para-pediments are shown on the map without any cartographic distinction from pediments.

Backslopes

The third major physiographic element of the piedmont is the backslope. This element occurs as stable backslopes to pediments, as stable backslope complexes, and as actively eroding backslopes, or "erosion balloons."

Stable Backslopes

These moderately steep to very steep (15^o to 30^o) slopes either stand above and are graded to pediments or they occur as areal complexes of steep slopes which lead down to a dendritic network of channels. These slopes were sites of formerly active erosion, but are presently characterized by soils with argillic horizons which imply that these land surfaces have been stable with respect to erosion and deposition long enough for an argillic horizon to form.

Backslopes which are graded to pediments were included in the map unit. Stable backslopes which do not grade to pediments, or if pediments are present at their base the pediments are relatively small in extent compared to the adjacent backslope, were mapped as stable backslope complexes. Also included in this map unit were deep linear channels and their steep walls which are cut into and below the systems of pediments. The soils on these channel walls have argillic horizons.

Actively Eroding Backslopes

The term "erosion balloons" is used to identify those prominent backslope areas which are presently eroding, or have recently been eroded. They commonly have an ovate outline and prominent dendritic rills which join at the base of the area; the outline of the area and the rill system frequently resemble an ovate leaf with a prominent vein system (See Figure 8). The "erosion balloons" are relatively light-colored, in comparison with adjacent areas of stable backslopes, since the light-colored Coal Valley Formation is extensively exposed within the balloon; one concludes that a soil like that of the adjacent stable backslopes has been stripped away. These features occur either as a single balloon or as a complex of several coalescing balloons.

Backslopes and channels cut below pediments with greater than 50

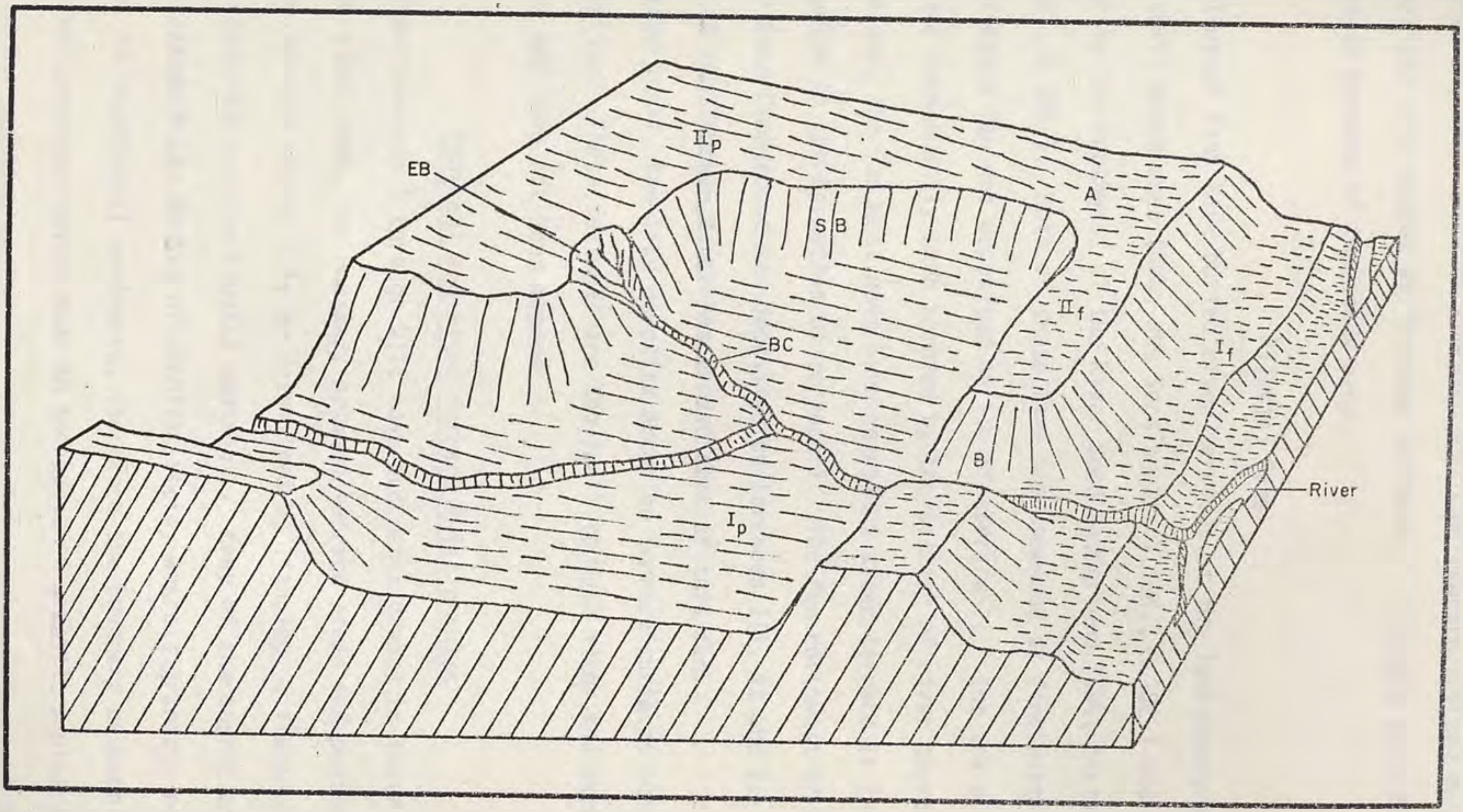

Figure 8. Diagrammetric display of river terrace and pediment relationships. FP - Flood plain, I_f - First river terrace, II_f - second river terrace, I_p - pediment graded to the first river terrace, II_p - pediment graded to the second river terrace, SB - stable backslope to pediment I, EB - eroding backslope "erosion baloon," BC - bypass channel connecting "erosion balloon" to river, A - pediment graded directly to river terrace, and B - pediment graded to river terrace through bypass notch.

percent of their surfaces composed of exposed bedrock (Coal Valley Formation) were mapped as "erosion balloons." This map unit comprises about 10 percent of the study area.

Alluvial Fans

Alluvial fans have buried river terraces at two locations; one in the Belli Ranch area (NW¼, NW¼ Section 22, T.19N., R.18E.) and the other to the northwest of the River Bend Campground (SW¼, Section 9, T.19N., R.18E.). Both of these fans are composed of fine earth. The Belli Ranch fan was deposited on top of terrace II. The toe of this fan has subsequently been removed by the cutting of river terrace I. Therefore, the fan must have been deposited after terrace II formed, but prior to the formation of terrace I. The fan northwest of the River Bend Campground was deposited on terraces III, II and I. A cut bank of the Truckee River has eroded some of this fan.

Other small, fan-like deposits occur on terrace surfaces throughout the valley. These features are too small to much alter the terrace treads and have not been mapped.

Pediment and River Terrace Relationships

River terraces I through VIII have pediments graded to their treads. In the study area, the boundary between terrace tread and pediment graded to the terrace can usually be determined by lithology differences in the pedi-sediments and the fluvial sediments. Many of the source areas for pedi-sediments are devoid of granitic rocks, whereas granitic rocks are common in the fluvial sediments, therefore the boundary between pediments and river terraces can be made on the basis of granitic boulders and cobbles in the mantling sediments. If granitic rocks are present in the source areas for the pedi-sediments, the boundary is then based on the occurrence of granodiorite with phenocrysts of hornblende, since hornblende granodiorite occurs only in the Sierra Nevada to the west and could have only been transported into the study area by the river. In addition to direct grading of pediments to river terraces along broad reaches of the valley, some pediments are graded to river terraces through bypass notches in older terraces and pediments (see Figure 8). When erosion takes place in this manner, it is possible to have material eroding from high on the piedmont and still maintain stable, older land surfaces between the eroding and the river.

Pediment Correlations

Those pediments which are graded to river terraces are correlated with the river terrace it grades to and they are denoted by the same roman numeral as their correlative river terrace. These two land form elements comprise a specific land surface level which is designated with the same roman numeral as the river terrace. Although there are many graded relationships between pediments and river terraces, not all of the pediment surfaces can be physically traced to their corresponding river terrace. Other methods were used to correlate these isolated pediments. These correlation techniques included: (1) comparison of the elevation of the lowest remnant of a pediment with the local elevation of the river terrace sequence, (2) relative position of an unknown pediment to a known pediment, and (3) morphology of soils on the pediments (a suggestive criterion, only). If the elevation of the lowest remnant of a pediment is lower than the elevation of an adjacent river terrace, i.e., pediments which have remnants at elevations below a river terrace are younger than the river terrace. The relative position of a pediment can be used to determine its relative age if the pediment is compared with the other pediments in the same system. Certain soil stratigraphic criteria have been determined for this study area and these criteria were used to suggest the relative stratigraphic position of some pediment remnants.[1] The correlation of the pediments was carried out using the above techniques for each of the major pediment systems shown in Figure 7. The pediments within a particular system are denoted by the first letter or letters in the name of the system and the relative position of a particular pediment is denoted by a subscript number. For example, the second pediment level above the present drainage channel in the Chalk Bluff system is designated CB_2. If a particular pediment level can be correlated with a river terrace then the system notation is dropped and the pediment is designated by the roman numeral of its correlative river terrace. Pediment correlations are summarized in Table 2.

Peavine Creek System

This system of piedmont land surfaces, which are para-pediments, lies in the extreme northeast part of the study area. The system covers that area which drains into Peavine Creek and is comprised of four para-pediments. The third para-pediment is graded to river terrace V at the Mountain View Cemetery. The next level above this was correlated with terrace VI because this surface is at the same apparent elevation

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[1] The soil stratigraphic criteria are detailed and discussed in a subsequent section of this report, LAND SURFACES AND DISTRIBUTION OF SOILS.

SYSTEM	LEVEL	MAP SYMBOL	SPECULATIVE CORRELATION
Peavine Creek System	PC_1	PC_1	II or III
	PC_2	V	
	PC_3	VI	
	PC_4	PC_4	$>$ VI
Mountain View System	MV_1	MV_1	II or III
	MV_2	V	
	MV_3	VI	
	MV_4	MV_4	$>$ VI
	MV_5	MV_5	$>MV_4$
Chalk Bluff System	CB_1	CB_1	II or III
	CB_2	IV	
	CB_3	V	
	CB_4	CB_4	$>$ VI
Lawton System	L_1	V	
	L_2	VII	
	L_3	VIII	
Highland System	H_1	I	
	H_2	H_2	$<$ VII
	H_3	H_3	$<$ VIII
	H_4	H_4	$>H_3$
	H_5	H_5	$>H_4$

Table 2. Correlation of pediments for each major pediment system as delineated in Figure 7. If a definite correlation with a river terrace was established then the pediment was denoted by the same Roman numeral as its correlative river terrace. If a pediment was not definitely correlated with a river terrace then it was denoted by its relative position within its particular system. Speculative correlations are given for these latter pediments.

SYSTEM	LEVEL	MAP SYMBOL	SPECULATIVE CORRELATION
Mogul System	M_1	M_1	II or III
	M_2	M_2	IV
	M_3	V	
	M_4	VI	
	M_5	VII	
River Bend System	RB_1	III	
	RB_2	V	
	RB_3	VI	
Verdi System	V_1	VIII	
Boomtown System	B_1	VI	
Belli Ranch System	BR_1	BR_1	>III & <IX
	BR_2	V	
	BR_3	VI	
	BR_4	VII	
	BR_5	VIII	
	BR_6	IX	
Hunter Creek System	HC_1	V	
	HC_2	VI	
	HC_3	HC_3	>VI
	HC_4	HC_4	>HC_3
Alum Creek System	AC_1	III	
	AC_2	IV	
	AC_3	AC_3	IV or V
	AC_4	VI	

Table 2. Continued

SYSTEM	LEVEL	MAP SYMBOL	SPECULATIVE CORRELATION
Skyline System	S_1	V	
	S_2	S_2	$>V$
	S_3	S_3	$>S_2$
	S_4	S_4	$>S_4$

Table 2. Continued

as the VI pediment in the Mountain View system to the west. At the time this VI pediment was being cut, the Peavine Creek system and the Mountain View system were part of the same control system which was subsequently divided into the present two separate systems. The highest para-pediment, PC_4, is older than terrace VI based on its position above VI. The lowest para-pediment level, PC_1, is incised below the level of pediment V. PC_1 bears a soil with an argillic horizon, but no pedogenic calcium carbonate or opal is present in the soil. The higher pediments have calcium carbonate or opal in their profiles, therefore this level is probably a II or III surface.

Mountain View System

This system covers a small drainage area to the southwest of the Peavine Creek system. There are five pediment levels in this system. The lowest level, MV_1, has a soil with an argillic horizon but no pedogenic calcium carbonate or opal which is present in soils on higher pediments in the system. This level was therefore correlated with terrace level II or III. The next two higher pediments can be traced to terrace V and VI. The highest two pediments, MV_4 and MV_5, which are mesa-like remnants, are older than level VI based on their positions above this level.

Chalk Bluff System

The Chalk Bluff system is the largest system within the study area. This system covers the large drainage area to the north of Chalk Bluff. Four pediments occur in this system. The highest pediment remnant forms an isolated mesa above a broad, rather continuous pediment. Incised into this broad pediment is a lower pediment and higher up on the piedmont is still a lower pediment. The broad pediment grades to terrace V through a bypass notch to the east of Chalk Bluff. The next lower pediment, which is cut into the V pediment, has a soil with a clay-textured argillic horizon and pedogenic calcium carbonate and opal accumulations. Based on its position below V and its soil characteristics, this level is correlated with terrace IV. The lowest pediment within the system, CB_1, has a soil with an argillic horizon (sandy clay loam texture) but no pedogenic calcium carbonate or opal. This level was correlated with level II or III. The highest pediment ia above V and projects laterally to the greater than VI pediments in the systems to the east. It is therefore considered to be greater than terrace VI.

Lawton System

The Lawton system covers a small drainage area to the north of the settlement of Lawton. This system has three pediments. The lowest level grades to river terrace V, the intermediate level is graded to river terrace VII and the highest level can be projected over a short distance to the top of Chalk Bluff which correlates with terrace VIII.

Highland System

The Highland system consists of five pediments which lie to the north of the island-like mountain area northeast of Mogul. This system has always been isolated from the river. Erosional materials removed from this sytem were transported to the river through a narrow bypass channel in the mountain area to the south. None of these pediments are directly graded to river terraces. All of the pediments except the lowest have soils with argillic horizons. Pedogenic calcium carbonate occurs in the third pediment's soil, H_3. The lack of an argillic horizon indicates that the lowest pediment is younger than terrace II, and it was therefore correlated with terrace I. By comparing the lowest elevation of the higher remnants it was determined that the second level, H_2, is younger than terrace VII and that the third level, H_3, is younger than terrace VIII.

Mogul System

To the northwest of the settlement of Mogul is a pediment system with five levels. The higher two levels occur as remnant mesas which stand above a relatively broad, continuous pediment level which has two lower pediments incised into it. The lower of the two high mesa remnants is graded to river terrace VI. The higher has a remnant whose elevation is below the elevation of river terrace VIII. This pediment was correlated with river terrace VII. The broad, intermediate pediment is graded to terrace level V. The higher of the incised pediments has pedigenetic calcium carbonate in the soil, whereas the lower pediment does not. Both soils have argillic horizons. On this basis, the higher incised pediment is correlated with terrace IV and the lower with terrace II or III.

River Bend System

The westernmost system on the north side of the river is the River Bend system. This system is located north of the River Bend Campground and is composed of three pediments. The highest level forms an isolated mesa above an extensive pediment which as a lower pediment cut into it. The lower and middle pediments are graded to river terrace III and V respectively. The highest level has remnants at elevations lower than remnants of terrace VII, and was therefore correlated with terrace VI.

Verdi System

The Verdi system is located south of the town of Verdi. This system has one pediment graded to terrace VIII.

Boomtown System

A small isolated pediment remnant forms a mass to the south of Boomtown. This remnant is well above the surface of terrace V and lies below the level of river terrace VII on the bluff to the west, therefore it was correlated with terrace VI.

Belli Ranch System

A complex system of pediment remnants are located in the area to the south and east of the Belli Ranch. Four pediments occur on the prominent hill to the southeast of the ranch. The lowest of these four pediments is above the level of river terrace V and below the elevation of terrace VII. Therefore, it was correlated with terrace VI. The remaining three higher pediments were correlated with terraces VII, VIII and IX. This is the only system where there is evidence of a pediment older than terrace VIII. There are two pediments west of this hill. The higher projects across a narrow stream channel to the VI pediment on the hill to the east. The lower of these two pediments was correlated with terrace V because of its position below VI and projection through a bypass notch to terrace V. To the east of the hill is another pediment, BR_1. The lower end of this pediment is well above the level of terrace III and its upper portion is cut into pediment IX. At the extreme eastern boundary of this system there are two pediments occurring as isolated mesas. The lower of these two is graded to river terrace VIII. The higher was correlated with terrace IX.

Hunter Creek System

The pediment system in the Hunter Creek area is made up of four pediments. The lower two levels are graded to river terraces V and VI. The two higher remnants, HC_3 and HC_4, which form fairly extensive broad pediments probably correlate with terraces VII and VIII, but their exact correlation cannot be determined.

Alum Creek System

Within the Alum Creek system there are four pediments. The lower two levels, in the northern part of the system, are graded to river terraces II and IV. There is also a pediment in the northern part of the system which is cut by river terrace V and lies below the longitufinal projection of river terrace VII; this pediment was correlated with terrace VI. This VI pediment can be traced to the southern part of the system by one cross-stream projection. In the southern part of the system there is a pediment below this VI level and above the southern extension of pediment III. This pediment was correlated with terrace IV or V.

Skyline System

The Skyline system is located in the southeastern part of the study area. This area includes the most western portion of the city of Reno in the Skyline Boulevard area. This system consists of four pediments; the lowest of these is graded to river terrace V. The upper three pediments are older than V, but their exact correlation cannot be determined.

QUATERNARY FAULTS

There are three areas where post-Coal Valley faulting was mapped: (1) along Peavine Creek (NW¼, NW¼ Section 5, T.19N., R.19E.), (2) east of Chalk Bluff (NE¼ Section 17, T.19N., R.19E.) and (3) northwest of Lawton (SW¼, NE¼ Section 13, T.19N., R.18E.). There could be other Quaternary faults not noted during the field survey. Faults are obscure features and usually are missed unless the fault planes have been exposed. Faults were mapped only when the fault planes could be seen clearly in stream or road cuts. The faults east of Chalk Bluff are the only faults observed which have expression in surface scarplets. The scarplets visible in the field are erosional scarplets which have migrated approximately 50 feet upslope from the fault plane which initiated them. None of the faults mapped offset land surfaces younger than level VI. Faults are dip-slip and downthrown to the west or towards flanking mountain fronts. All fault planes are overlain by soils containing argillic horizons which have developed since fault displacement. Most of the scarplets associated with these faults have been totally removed by erosion. This field evidence indicates that the faults mapped have not had any displacement subsequent to the pre-Wisconsin time, i.e., subsequent to formation of land surface level V.

LAND SURFACES AND DISTRIBUTION OF SOILS

Observations of soils were not extensive enough to establish conclusive relations, nonetheless, certain general morphological characteristics and geographic associations could be determined. Illustrative pedon descriptions for the land surface levels are given in Appendix II.

For the most part, some soils are formed in coarse textured bouldery, cobbly and gravelly sandy loam parent materials; some soils formed in finer textured, silt loam and sandy clay loam, alluvial sediments. None of these parent materials had limestone or calcareous rocks as source rocks. Glassy volcanic materials were supplied to all these parent materials from the tuffaceous Coal Valley sediments and the tuff breccias of the Tertiary andesites.

Apparent Age Sequence of Soils

The vertical sequence of land surfaces is the basis for establishing an age sequence of soils. Land surface I bears soils which lack pedogenic horizons except for an ochric or mollic epipedon. Soils on river terrace I have yellowish red (5YR 4/6 and 5YR 5/6) mottles indicating poor drainage at some time. Soils on this land surface include Typic Xerorthants, Typic Xerofluvents, and Fluventic Haplaxerolls.

All soils on land surfaces above land surface I have an argillic horizon below a mollic or ochric epipedon. Argillic horizons in soils on land surfaces II and III have coarse fragments throughout their thickness, if coarse fragments were present in their apparent parent material. Textures in these argillic horizons range from sandy clay loam to clay. Sola on surface III are thicker and finer textured than sola on land surface II. Sola on land surface III are on the order of 60 inches thick. Structure of the argillic horizon of soils on both these land surfaces is weak to moderate prismatic or blocky. No calcium carbonate or opal accumulations were found within 40 inches of the surface in these soils. Soils on land surfaces II and III include Typic Haplargids, and Typic Argixerolls.

Soils on land surfaces above III commonly have an upper subhorizon in the argillic horizon which is free of coarse particles. These upper subhorizons have clay textures and overlie a lower subhorizon which has coarse fragments and fine earth textures of sandy clay loam to loamy sand. The coarse fragments in this lower subhorizon have clay coatings to depths greater than 144 inches in some exposures. The boulder-, cobble- and gravel-free upper subhorizon of the argillic horizon, which is common in soils older than those developed on land surface III, might be the result of additions of fine textured sediments or airborne volcanic ash, since weathered. All soils above land surface III have enough clay in their argillic horizons to be in the great group of Paleargids.

Land surface IV is the lowest, youngest land surface to have soils with calcium carbonate or opal accumulations within 40 inches of the surface, although these accumulations are not always present. None of the calcium carbonate or opal accumulations are cemented enough to be duripans or calcareous duripans, whereas strongly cemented duripans and calcareous duripans up to 30 inches thick are found in soils on land surfaces V and older (pans are not always present on these older surfaces, either). Soils on land surface IV include Typic Paleargids, Duric Paleargids, Typic Argixerolls and Mollic Paleargids. Soils on land surfaces V and older include Typic Paleargids, Mollic Paleargids, Duric Paleargids, Typic Durargids, Hapla Durargids, Duric Argixerolls and Typic Argixerolls.

Areal Soil Distribution

In addition to a difference in soil morphology, apparently due to age, there is also a geographic variation of soil morphology. Mollic epipedons occur in soils in the western part of the study area and on the higher pediments along the flank of the Carson Range. Soil with ochric epipedons occur in the eastern part of the study area and high on the flanks of Peavine Mountain. Mollic epipedons appear to occur in areas which have relatively higher precipitation than the areas with ochric epipedons.

Duripans and calcareous duripans occur in soils of the higher river terraces east of Hunter Creek. Duripans and calcareous duripans are common in soils on pediments in the Verdi system, Chalk Bluff system, Mountain View system, Peavine Creek system and Skyline system. Duripans and calcareous duripans are commonly absent from soils on pediments in the Hunter Creek system, Belli Ranch system, River Bend system, Mogul system, Highland system and Lawton system.

Land Surface Stratigraphic Boundaries Based on Soil Morphology

Certain stratigraphic boundaries were distinguished within the study area based on differences in soils morphology. These criterion are considered valid for the study area but should not be considered applicable to regional correlations.

The soil stratigraphic criteria are: (1) land surfaces with soils lacking an argillic horizon are younger than land surface II, (2) land surfaces bearing soils with calcium carbonate accumulations within their upper 40 inches are older than land surface III, (3) land surfaces which bear soils with cemented duripans are older than land surface IV, (4) land surfaces bearing soils with an argillic horizon which has an upper subhorizon which is free of coarse fragments overlying a lower subhorizon with coarse fragments is older than land surface III, (5) land surfaces with soils which have argillic horizons with high clay contents relative to the clay content of their parent material and having strong structural grades are older than land surface III, and (6) land surfaces bearing soils with duripans are older than land surface IV.

Soil Morphology as Related to Age

The formation of argillic horizons and the accumulation of calcium carbonate and opal is related to the weathering of primary silicate minerals over a period of time. This can be demonstrated by considering the following. Argillic horizons have not developed on the younger land surfaces, i.e., land surface I and the erosion balloons. Land surface II and III have argillic horizons which are less clayey than the argillic horizons of the higher, older soils. They also have a more weakly developed structure in their argillic horizons than the older soils. The depth of clay translocation, as attested by clay coatings on coarse fragments, becomes progressively greater going from the younger land surface II to the older land surface IV. These morphologic changes in the argillic horizons imply an increasing degree of weathering of primary silicate minerals to clays and an increasing depth of translocation of some of these clays in progressively older soils.

The occurrence of accumulations of calcium carbonate and opal also are related to weathering over a period of time. There is no calcium carbonate in the parent material of the soils, thus the calcium carbonate must come from the weathering of silicate minerals which release calcium ions which combine with carbonic acid from atmospheric water and precipitate as calcium carbonate. The silica which comprises the opal accumulations also must be derived from the weathering of silicate minerals. These processes must take considerable time because these materials are only found on land surfaces older than land surface III.

The similarities in soil morphology on land surfaces older than IV implies that given enough time these morphology characteristics will go towards a limit.

EPISODIC EROSION IN THE TRUCKEE RIVER VALLEY

Episodic erosion has occurred in the Truckee River Valley throughout the Quaternary as evidenced by the river terrace sequence and the system of stacked pediments graded to the river terraces. In part, the nature of this episodic erosion can be inferred from the present landscape. Butler (1959) discussed periodic phenomena in landscapes. He described two phases in a landscape cycle, the unstable phase and the stable phase. In the unstable phase, erosion and deposition create new land surfaces. The unstable phase terminates at the time of relative cessation of erosion and deposition, which is followed by a stable phase at which time soils develop on the newly formed land surfaces. A landscape may experience numerous cycles, and if the soil of a former stable phase is not eroded in succeeding unstable phases, that former stable phase will be recorded in the landscape. Butler's concept readily applies to the river terraces, pediments and the soils of the surfaces in the Truckee River Valley.

Stable and Unstable Phases in the Landscape

Unstable phases are represented in the valley by the sequence of river terraces and pediments. At the outset of an unstable phase, the river dissected its former flood plain and formed a new flood plain at a lower elevation. Dissection on the piedmonts also occurred and new pediments were cut by erosion and graded to the new flood plain. Very little deposition occurred in the study area during the unstable phases. Most of the erosional materials were carried out of the area by the river and deposited elsewhere. There are some alluvial fans which represent deposition during the unstable phase of younger cycles.

The stable phases are evidenced in the valley by the vertical sequence of increasingly weathered soils on the river terraces and pediments.

During unstable phases the river first downcut and then lateral erosion, flood plain formation, began to dominate over degradation as evidenced by the strath terrace remnants. It cannot be demonstrated from field evidence if the fill terraces represent a single aggradation period, or multiaggradational periods associated with each terrace level, or some combination of the two.

Erosion on the pediments is apparently controlled by a stationary local base level of erosion, in this case, the position of the river when it was laterally cutting a flood plain. The facts that pediments are graded to terrace level, that there is a pediment level associated with each terrace level and that the pediments have smooth, planar surfaces all support the concept of a stationary local base level of erosion controlling the process of pediment formation. The pediments must establish themselves by erosion during a flood plain forming period in the river's history. When the river cuts below its flood plain, the local base level for piedmont erosion changes. Erosion on the pediments, subsequent to such a river incision, will be adjusted to the new base level. In the case of the Truckee River valley, the change in local base level through time was always in the direction of a new lowering.

Characteristics Formes of Land Surface Levels

Nine land surface levels produced by episodic erosion in the valley can still be found in the present landscape. These land surface levels are primarily river terraces and pediments. Although the components of the surface levels are genetically the same, erosion has affected the older levels more than the younger, and some levels did not develop to the extent that others did; the result being that each level has its own characteristic morphology.

The highest, oldest land surface, land surface IX, occurs as small, isolated and localized pediments and a single terrace remnant in the southwestern part of the study area. The original land surface of the terrace remnant has been destroyed by erosion; it presently occurs as a gravel knoll above terrace VIII.

Land surfaces VI, VII and VIII occur as discontinuous, isolated flats on, or on top of, the bluffs along the river and as isolated mesas and round-shouldered ridges on the piedmonts throughout the area. Judging from the distribution of their remnants, these surfaces probably were relatively extensive flood plains and pediments in the past. Surface VI still has extensive pediment and para-pediment remnants in the north-eastern part of the study area.

Land surface V occurs as a prominent terrace which is relatively continuous and has many paired remnants throughout the length of the river. Surface V pediments are broad, continuous surfaces cut into and below the higher, isolated mesas and round-shouldered ridges. These pediments occur extensively throughout the area and their formation was responsible for removing much of the higher, older surfaces.

Land surface IV is represented by a discontinuous terrace level below the prominent terrace V. Pediments of level IV are incised below the broad surface of pediment V. Erosion associated with the formation of land surface IV was not nearly as extensive as erosion associated with the formation of land surface V.

Land surface III occurs as discontinuous terrace remnants below terrace IV throughout the length of the river and as scattered, small pediments high on the piedmont. These pediments are incised below the level of pediments IV and V and are connected to the river by bypass channels.

Land surface II has a relatively continuous terrace below the remnants of terrace III. It occurs on the piedmont as pediments similar to the pediments of surface III and as stable backslope complexes. Erosion associated with the formation of land surface II primarily took place along the river in the form of flood plain formation.

Land surface I is represented by a continuous paired river terrace and two local pediments north of Mogul.

Currently, erosion is probably active in the piedmont, as attested by "erosion balloons" which occur on backslopes throughout the area. This erosion episode is represented in the river area as the dissection of terrace I by the river and side streams.

Causative Phenomena

There are two possible events which might have been responsible for the episodic erosion and stability in the valley. They are climatic change and tectonic uplift. Both events have been active within the region during the Quaternary. Birkeland (1964, p. 822) described the terrace sequence in the Truckee Basin to the west of the study area, as being a nested set of fill terraces underlain by glacial outwash. This sequence was interpreted to have had its origin totally in climatic fluctuations. Aggradation was active during the glacial periods with degradation, to near the present river level, occurring during the interglacials. Each successive younger glaciation had a less extensive aggradation phase; thus outwash did not fill the valley to the level of the former terrace. The net result is a nested set of three fill terrace levels in the Truckee Basin. These terrace levels interfinger and do not extend above morainal material upstream and were therefore interpreted by Birkeland to be contemporaneous with glaciation.

The eastern front of the Carson Range, the north side of Peavine Mountain, and in general, the entire northwestern Nevada region has been active tectonically throughout the Quaternary. This is substantiated by fault scarplets in Quaternary alluvial deposits, historic earthquakes and current active seismicity. Tectonic activity in the form of faulting or warping could alter the river regime significantly enough to instigate erosion events along the river.

(The occurrence of very large boulders in the fluvial sediments under the terraces is evidence that, at least, some of the terraces were flood plains during the times of glaciation in the Sierra Nevada Mountains. The necessary transporting forces to carry these boulders was generated during glacial dam collapse at Lake Tahoe (Birkeland, 1968, p. 139). Because these very large boulders can be found under all terrace levels does not necessarily mean that all terraces were flood plains during glacial stades. Boulders could have been let down from a higher terrace onto a lower flood plain as a lag when the lower flood plain was cut out of the higher terrace.)

There are three terraces in the Truckee Basin; nine terraces occur in the study area, (i.e. the river valley below the Truckee Basin), and they all presumably formed in the same time period as those of the Truckee Basin. All terrace levels in the study area have evidence of a stationary base level during their erosion stage, *i.e.* strath terrace remnants and pediments graded to the terraces. No such stationary base level for the erosion stage has been reported in the Truckee Basin where the terraces were presumably controlled by climatic changes. Based on this, it appears that the terrace sequence and related pediments in the Truckee River valley are genetically a complex system of landforms related probably both to tectonic and climatic influences.

AGE RELATIONSHIPS OF LAND SURFACES

Maximum Age of Land Surfaces

All of the river terrace levels and related piedmont erosion surfaces are Quaternary in age. A maximum age limit can be established by the presence of basalt clasts in the sediments forming the highest and oldest land surfaces. The remnant of river terrace IX, on the bluff southwest of Boomtown, contains basalt cobbles and boulders. These basalt cobbles could have been supplied to the river from two source areas. They could have come from the basalts in the Truckee Basin farther to the west or they could be from the basalts in the northern part of the Carson Range. The Truckee Basin basalts range from 1.3 to 2.3 million years B.P. (Birkeland, 1963, p. 1457), whereas the basalts from the northern part of the Carson Range are from 2.4 to 3.35 million years B.P. (Thompson and White, 1964, p. 18). The remnant of pediment VIII, in the Verdi system, has pedi-sediments with basalt boulders and cobbles. These sediments were derived locally from drainage areas in the northern part of the Carson Range. The presence of basalt cobbles and boulders in these sediments means that these two surfaces must be younger than the flows which produced the basalts, i.e. the surfaces are younger than rocks which range from 1.3 to 3.35 million years B.P.

Terrace VIII is the highest, oldest terrace which has fluvial sediments with very large boulders (boulders with diameters greater than 7 feet). Jokulhaups, floods resulting from the collapse of unstable glacier dams at Lake Tahoe during the Pleistocene, have been postulated (Birkeland, 1968, p. 137) to have provided the rapid discharges necessary to transport these very large boulders. Therefore, it is inferred that sediments with clasts of this very large size were deposited during glacial stades in the Sierra Nevada Mountains. From this evidence, terrace IX is younger than the basalts of the region and terrace VIII was a flood plain during a glacial stade, which implies that the higher terrace levels are Pleistocene in age.

Thompson and White (1964) described and mapped gravel in the northern part of the Carson Range which they considered to be older than the basalt flows in the area. This age relationship was based on the lack of basalt clasts in the gravel. They described this gravel (Thompson and White, 1964, p. 18) as being under a pediment (i.e., part of the pedi-sediment) which is, in turn, overlain by a basalt flow. This pediment surface is said to project to the level of Chalk Bluff. The present study disputes this correlation. All terrace levels mapped in this report have basalt clasts in their sediments or correlate with remnants which have basalt clasts in their sediments. The down valley extension of Thompson and White's pre-basalt pediments must have been removed by erosion, if they occurred.

Minimum Age of Land Surfaces

The lowest terrace level, terrace I, has a calculated flood frequency of, on an average, 1 in 100 years and has a history of three floods in the last 20 years. This flood frequency indicates that this surface is not part of the present flood plain of the Truckee River, but is related to some former flow regime. The history of flooding might indicate that this terrace has just recently been removed from flood plain status. Terrace I has been tentatively assigned to the Holocene.

Intermediate Ages of Land Surfaces

The exact time stratigraphic position of the terrace levels above the Holocene terrace I is difficult to establish. The terrace sequence is probably in part glaciofluvial and in part tectofluvial. None of the terrace levels can be traced physically upstream in the glaciofluvial terraces of the Truckee Basin. Birkeland (1968) has differentiated and mapped two ages of glacial outwash and possibly a third in the Truckee River valley. He assigned these deposits to the Tahoe, Donner Lake and possibly Hobart glacial stades of the northern Sierra Nevada Mountains. His criteria for these correlations were based on soil profile morphology, lithology of sediments and size of boulders in the sediments. No specific reference to terrace levels were made in his report, although in an earlier publication (Birkeland, 1965, p. 58) terrace relationships in the Verdi area were shown on a schematic diagram. Birkeland's interpretation of outwash distribution and terrace levels, and the findings of this study are presented in Table 3.

Several workers in the Central Valley of California, the Sierra Nevada Mountains and the Western Great Basin have reported that soil morphology differs between soils formed on Wisconsin and pre-Wisconsin aged deposits (Birkeland, 1964, 1967 and 1968; Birkeland and Janda, 1971; Janda and Croft, 1967; Morrison, 1964; and Morrison and Frye, 1965). The pre-Wisconsin deposits have soils with argillic horizons with high clay contents relative to their parent material. These argillic horizons have strong prismatic or blocky structure. The Wisconsin deposits bear soils which either lack argillic horizons or if the argillic horizons are present, they are less clayey than the adjacent pre-Wisconsin argillic horizons. The Wisconsin argillic horizons have weak to moderate prismatic

Age	Terrace Level (This Report)	Glacial Outwash (Birkeland-1965 & 1968)
Holocene	Terrace I (10 Ft.)	Recent Alluvium
Wisconsin	Terrace II (30 Ft.)	Tahoe Outwash (Two terrace levels the higher is 80 ft.)
	Terrace III (70 Ft.)	
Pre-Wisconsin	Terrace IV (100 Ft.)	Donner Lake Outwash (One terrace level 120 ft.)
	Terrace V (150 Ft.)	
	Terrace VI (210 Ft.)	Pre-Donner Lake Mainstream Gravel & Hobart Outwash (?) (Three terrace levels 250, 320 and 400 ft.)
	Terrace VII (310 Ft.)	
	Terrace VIII (350 Ft.)	
	Terrace IX (440 Ft.)	

Table 3: Birkeland's (1965 and 1968) interpretation of glacial outwash deposits and river terrace levels as they compare to the river terrace levels identified in this report. Height of terraces above the river for the Revdi area are indicated in parentheses. Ages are speculative.

or blocky structure.

Similar morphological differences in the clayeyness and structure of soils were observed in the Truckee River valley between soils on terrace III and IV. It is possible that these differences might also reflect the time stratigraphic boundary between the Wisconsin and pre-Wisconsin.

SUMMARY

There are nine land surface levels, primarily cut into the weakly indurated sediments of the Coal Valley Formation, in the present landscape of the Truckee River valley between Reno and Veri, Nevada. These land surface levels form a stratigraphic sequence; that is, each successive higher level is older than the level below. All levels were formed during the Quaternary. They consist primarily of river terraces and pediments graded to the river terraces. In addition, there are also para-pediments, alluvial fans, erosion balloons (eroding backslopes), stable backslope complexes and fault scarplets.

In the Boomtown area there is evidence of nine river terraces, the lower eight terraces can be correlated with their respective remnants throughout the study area. The terrace remnants consist of both strath and fill remnants. The straths represent times in the river history when the river was laterally cutting a flood plain in the local bedrock and a time when the river was a stationary local base level of erosion.

The piedmonts are primarily made up of a stacked series of pediments which are graded to the river terraces. In addition to pediments, there are areas which are primarily stable backslopes and scattered patches of active erosion, or "erosion balloons," which are located on the stable backslopes to erosionally stable pediments. The vertical sequence of pediments occur in areal groupings, or systems of pediments, which closely correspond to individual drainage areas on the piedmonts. There are 13 such systems of pediments within the study area. The pediments are either graded to the river terraces directly along broad reaches of the river, or they grade to the river terraces through bypass notches

cut into higher, older pediments and river terraces.

Several Quaternary faults were mapped; they are high angle normal faults and have not had any displacement since the pre-Wisconsin.

There is a vertical, or age sequence of soils, on the vertical sequence of land surfaces. The differences in these soils are apparently reflections of duration of weathering and are manifest in their argillic horizons and accumulations of pedogenetic calcium carbonate and opal. Land surface I bears soils without argillic horizons. Argillic horizons increase in clayeyness, depth of clay illuviation and structural grade going from land surface II up to land surface IV. Argillic horizons have similar morphology in soils older than the fourth land surface. Pedogenetic calcium carbonate or opal first appears on land surface IV and is found as cemented pans on land surfaces above IV, although pedogenetic calcium carbonate and opal is not always present in soils on these older surfaces.

The land surface sequence and their soils are evidence of episodic erosion and stability within the valley throughout the Quaternary. The river has periodically downcut and formed a new flood plains at lower elevations. This downcutting also lowered the local base level of erosion and new pediments were cut into and below older pediments. The abandoned land surfaces stabilized with respect to erosion and deposition to the degree that soils developed on them. The mechanism behind this periodicity in the landscape was probably related to both climatic fluctuations and tectonic uplift.

The land surfaces are Quarternary in age; that is, they are younger than the 1.3 to 3.35 million years B.P. basalts of the region as evidenced by clasts of these rocks in their mantling sediments. The lowest terrace is tentatively assigned to the Holocene. It has flooded three times in the last 20 years, but does not have a sufficiently high flood reoccurrence interval to be defined as the active flood plain of the river. Very large boulders (greater than 7 feet in diameter) occur on all terrace levels which indicates that some or all of these terraces were flood plains during glacial stades in the Sierra Nevada Mountains. These boulders were carried by floods resulting from glacial dam collapses, jokulhaups, at Lake Tahoe. Differences in argillic horizon morphology between soils on land surface III and IV suggest that the stratigraphic boundary between the Wisconsin and pre-Wisconsin occurs between these two ages of land surfaces.

APPENDIX I

TEXTURAL CRITERIA USED IN DESCRIBING SOILS AND SEDIMENTS

APPENDIX I

TEXTURAL CRITERIA USED IN DESCRIBING SOILS AND SEDIMENTS

Particle Size Scale

	mm.	in.	ft.
Very large boulders	...	>84	>7
boulders	...	12 - 84	1 - 7
cobbles	...	3 - 12	.25 - 1
gravel	...	.08 - 3	...
sand	.05 - 2	...	...
silt	.002 - .05	...	...
clay	<.002	...	...

APPENDIX II

ILLUSTRATIVE PEDON DESCRIPTIONS

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE I

Taxonomic Identity: Typic Xerorthent
Physiographic Position: River Terrace
Parent Material: Fluvial sediments
Vegetation: Grass and Willows
Location: East of Mogul (NE 1/4 section 14, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 4,660 feet

A1	0 - 16"	Grayish brown (10YR 5/2) sandy clay loam, dark grayish brown (10YR 4/2) moist; weak coarse prismatic and strong coarse prismatic and strong coarse angular blocky structure; very hard firm, sticky and plastic; noneffervescent; gradual smooth boundary. (16 inches thick.)
A2	16 - 31"	Grayish brown (10YR 5/2) sandy clay loam, dark grayish brown (10YR 4/2) moist; massive; very hard, firm, sticky and plastic; many fine to medium distinct mottles of yellowish red (5YR 5/6); noneffervescent; gradual smooth boundary. (15 inches thick.)
C1	31 - 52+"	Very pale brown (10YR 7/4) sandy clay loam, dark brown (10YR 4/3) moist; massive; very hard, firm, sticky and plastic; noneffervescent.

ILLUSTRATIVE PEDON DESCRIPTION
FOR
LAND SURFACE II

Taxonomic Identity: Typic Haplargid
Pshysiographic Position: River Terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush and rabbitbrush
Location: Road cut west of freeway bridge (NW1/4, SW 1/4 section 15, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 4,760 feet

A1	0 - 4"	Light brownish gray (10YR 6/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate very fine to fine granular structure; weakly coherent, friable, non-sticky and non-plastic; noneffervescent; clear wavy boundary. (4 inches thick.)
B21t	4 - 16"	Brown (10YR 5/3) gravelly, cobbly silty clay loam, very dark grayish brown (10YR 3/2) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; noneffervescent; clear smooth boundary. (12 inches thick.)
B22t	16 - 34"	Dark grayish brown (10YR 4/2) cobbly, gravelly clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; hard to very hard, friable, sticky and plastic; noneffervescent; gradual irregular boundary. (18 inches thick.)
C1	34 - 99"+	Light gray (10YR 6/1) cobbly, gravelly silt, dark grayish brown (10YR 4/2) moist; massive; weakly coherent, friable, slightly sticky and slightly plastic; noneffervescent.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE III

Taxonomic Identity: Typic Argixerall
Physiographic Position: River Terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush
Location: Gravel pit north of River Bend Campground (NW 1/4, SE 1/4 section 9, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 5,080 feet

A1	0 - 9"	Dark grayish brown (10YR 4/2) cobbly, gravelly sandy clay loam, very dark grayish brown (10YR 3/2) moist; moderate very fine to fine granular structure; slightly hard; friable, slightly sticky and slightly plastic; noneffervescent; clear smooth boundary. (9 inches thick.)
B2t	9 - 52"	Dark brown (10YR 4/3) very cobbly, very gravelly sandy clay, dark brown (10YR 3/3) moist; moderate fine angular blocky structure, slightly hard, friable, sticky and plastic; noneffervescent; gradual irregular boundary. (43 inches thick.)
C1	52 - 152+"	Dark yellowish brown (10YR 4/4) very cobbly, very gravelly sandy loam, dark brown (10YR 3/4) moist; massive; slightly hard, friable, non-sticky and nonplastic; noneffervescent.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE IV

Taxonomic Identity: Duric Paleargid
Physiographic Position: River terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush
Location: Freeway cut at Mogul road side rest (NE 1/4, SE 1/4 section 15, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 4,880 feet

A1	0 - 18"	Light brownish gray (10YR 6/2) clay, dark grayish brown (10YR 4/2) moist; massive; very hard, firm, sticky and plastic; noneffervescent; clear smooth boundary. (18 inches thick.)
B21t	18 - 38"	Brown (10YR 5/3) clay, dark brown (10YR 4/3) moist; strong coarse prismatic and strong medium angular blocky structure; very hard, very firm, very sticky and very plastic; noneffervescent; clear smooth boundary. (20 inches thick.)
IIB22tcasi	38 -51"	Brownish yellow (10YR 6/6) cobbly, gravelly sandy loam, yellowish brown (10YR 5/4) moist; moderate coarse platy structure; hard firm, nonsticky and nonplastic; clay coatings on coarse fragments; violently effervescent; clear smooth boundary. (13 inches thick.)
IIB23t	51 144"+	Yellowish brown (10YR 5/4) cobbly, gravelly sandy loam, brown (10YR 4/3) moist; massive; hard, firm, slightly sticky and slightly plastic; noneffervescent; clay coatings on coarse fragments.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE V

Taxonomic Identity: Typic Paleargid
Physiographic Position: River terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush
Location: Freeway cut at Mogul road side rest (NE 1/4, SE 1/4 section 15, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 4,880 feet

B21t	0 - 31"	Dark brown (10YR 4/3) clay, dark brown (10YR 3/3) moist; strong medium angular blocky structure; hard, firm, sticky and plastic; noneffervescent; gradual smooth boundary. (31 inches thick.)
IIB22t	31 -100+"	Yellowish brown (10YR 5/4) cobbly, gravelly sandy loam, dark brown (10YR 4/3) moist; massive; hard, firm, slightly sticky and slightly plastic; clay coating on coarse fragments; noneffervescent.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE VI

Taxonomic Identity: Typic Paleargid
Physiographic Position: River terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush, rabbitbrush and desert peach
Location: Shovel pit north of Mogul (NE 1/4, SE 1/4 section 15, T. 19 N., R. 18 E.)
Slope: Near level
Elevation: 4,920 feet

A1	0 - 11"	Grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; strong coarse angular blocky structure; slightly hard, friable, sticky and plastic; noneffervescent; clear smooth boundary. (11 inches thick.)
B21t	11 - 23"	Dark brown (10YR 4/3) clay, dark yellowish brown (10YR 3/4) moist; strong coarse prismatic structure; very hard, firm, sticky and plastic; noneffervescent; gradual smooth boundary. (12 inches thick.)
IIB22t	23 - 50+"	Dark yellowish brown (10YR 4/4) cobbly, gravelly sandy clay, very dark grayish brown (10YR 3/2) moist; massive; very hard, firm, sticky and plastic; noneffervescent.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE VII

Taxonomic Identity: Typic Paleargid
Physiographic Position: Pediment
Parent Material: Pedi-sédiments
Vegetation: Sagebrush
Location: Shovel pit west of Hunter Creek (NW¼, SW¼ Section 19, T. 19 N., R. 19 E.)
Slope: 10% (6°) strongly sloping
Elevation: 5,120

A1	0 - 11"	Light brownish gray (10YR 6/2) cobbly, gravelly clay, dark grayish brown (10YR 4/2) moist; strong coarse prismatic and strong medium angular blocky; very hard, very firm, very sticky and very plastic; non-effervescent; gradual smooth boundary. (11 inches thick.)
B21t	11 - 21"	Brown (7.5YR 5/4) cobbly, gravelly clay, dark brown (7.5YR 4/4) moist; strong coarse prismatic and strong medium angular blocky structure; very hard, very firm, very sticky and very plastic; noneffervescent; gradual smooth boundary. (10 inches thick.)
B22tca	21 -60+"	Light brown (7.5YR 6/4) cobbly, gravelly clay, dark brown (7.5YR 4/4) moist; strong medium angular blocky structure; very hard, very firm, very sticky and very plastic; violently effervescent; calcium carbonate coatings on peds and coarse fragments.

ILLUSTRATIVE PEDON DESCRIPTION

FOR

LAND SURFACE VIII

Taxonomic Identity: Typic Durargid
Physiographic Position: River terrace
Parent Material: Fluvial sediments
Vegetation: Sagebrush
Location: Shovel pit on top of Chalk Bluff (SW 1/4, NW 1/4 section 17, T. 19 N., R. 19 E.)
Slope: Near level
Elevation: 5,020 feet

A11	0	4"	Light brownish gray (10YR 6/2) clay loam, very dark grayish brown (10YR 3/2) moist; weak medium angular blocky structure; weakly coherent to slightly hard, friable, slightly sticky and slightly plastic; noneffervescent; clear smooth boundary. (4 inches thick.)
A12	4	9"	Light brownish gray (10YR 6/2) clay loam, very dark grayish brown (10YR 3/2) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; noneffervescent; clear smooth boundary. (5 inches thick.)
B21t	9	21"	Dark brown (10YR 4/3) clay, dark yellowish brown (10YR 4/4) moist; strong coarse prismatic and strong medium angular blocky structure; extremely hard, firm, sticky and plastic; noneffervescent; clear smooth boundary. (13 inches thick.)
IIB22t	21	29"	Light yellowish brown (10YR 6/4) cobbly, gravelly sandy clay loam, yellowish brown (10YR 5/4) moist; massive; hard, friable, slightly sticky and slightly plastic; noneffervescent; clear smooth boundary. (8 inches thick.)
IIC1sim	29	32"+	Light yellowish brown (10YR 6/4) cobbly, gravelly sandy clay loam, yellowish brown (10YR 5/4) moist; massive; strongly cemented; noneffervescent.

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