UNITED STATES DEPARTMENT OF THE INTERIOR

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GUIDEBOOK TO THE LATE CENOZOIC GEOLOGY OF THE BEAVER BASIN, SOUTH-CENTRAL UTAH

by

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INTRODUCTION

The Beaver basin of south-central Utah, a site of prolonged closed-basin deposition during the late Tertiary, has exposures of upper Cenozoic deposits not usually seen in the Basin and Range province. Stream erosion has exposed a nearly continuous section of upper? Miocene to lower? Pleistocene sediments that contain the only Blancan fossils collected in Utah and an assemblage of Pliocene to middle Quaternary volcanic ashes from local and distant sources. Surficial deposits are widespread in the basin and record a sequence of middle Quaternary to Holocene erosional and depositional events that probably are climatically controlled. Both Quaternary and Pliocene sediments are intensely deformed into a broad north-trending antiform resulting from intrusion of a thick, deep diapir of remobilized Jurassic? sediment. These same sediments are displaced by basin-margin faults related to the structural extension of the Basin and Range province and coincident uplift of the adjacent Colorado Plateau. K-Ar age determinations on volcanic ashes and basalt, quantitative analyses of soil development, and uranium-trend soil ages provide time control for Quaternary stratigraphic divisions and for estimates of recency and recurrence intervals of faulting in the basin. Additionally, the physical stratigraphy of the basin-fill sediment, the development of subsurface structure, the concentration of radon gas, and the chemistry of uranium-saturated ground water indicate that uranium mineralization is present in the basin-fill sediments.

Much of the stratigraphy, structural interpretations, and geologic history presented here are the results of recent mapping by M. N. Machette and his colleagues at the U.S. Geological Survey. This mapping is part of a larger effort to understand the development of the Marysvale Volcanic Field and the regional geology of the Richfield $1^{o} \times 2^{o}$ quadrangle. Those interested in the details of the Miocene and older geologic history of the area should consult the recent publications by Cunningham, Rowley, Steven, and others (see reference list).

LATE CENOZOIC GEOLOGY OF THE BEAVER BASIN

The Beaver basin, a sharply defined structural and topographical basin, has been the site of extensive sedimentation, deformation, and potential uranium mineralization since at least late Miocene time. The basin is 25 km long north-to-south and 16 to 22 km wide east-to-west; it is bordered on the east by upper Oligocene to lower Miocene volcanic rocks of the Tushar Mountains (Cunningham and others, 1982a, b) and on the west by the Tertiary? granite-cored Mineral Mountains, Utah's largest exposed pluton (fig. 1). The low hills at the north end of the basin are formed by 8- to 9-m.y.-old rhyolite domes and flows (rhyolite of Gillies Hill, Evans and Steven, 1982) that rest on a platform of volcanic rocks which are distal equivalents to those of the Tushar Mountains (Steven and Morris, 1981; Machette and Steven, 1982). The east and west margins of the basin are fairly abrupt and linear and are controlled by border faults that have been recurrently active during the late Cenozoic.

Sediments exposed in the topographically low parts of the basin are entirely late Miocene or younger with the exception of a southward-projecting horst in the north-central part of the basin. Directly south of this horst, a wildcat oil-and-gas well penetrated 1,400 m of Miocene and younger basin-fill sediment. Unpublished seismic-reflection data along an east-west line through the drilling site show that post-volcanic age sediment (<19 m.y. B.P.) fills

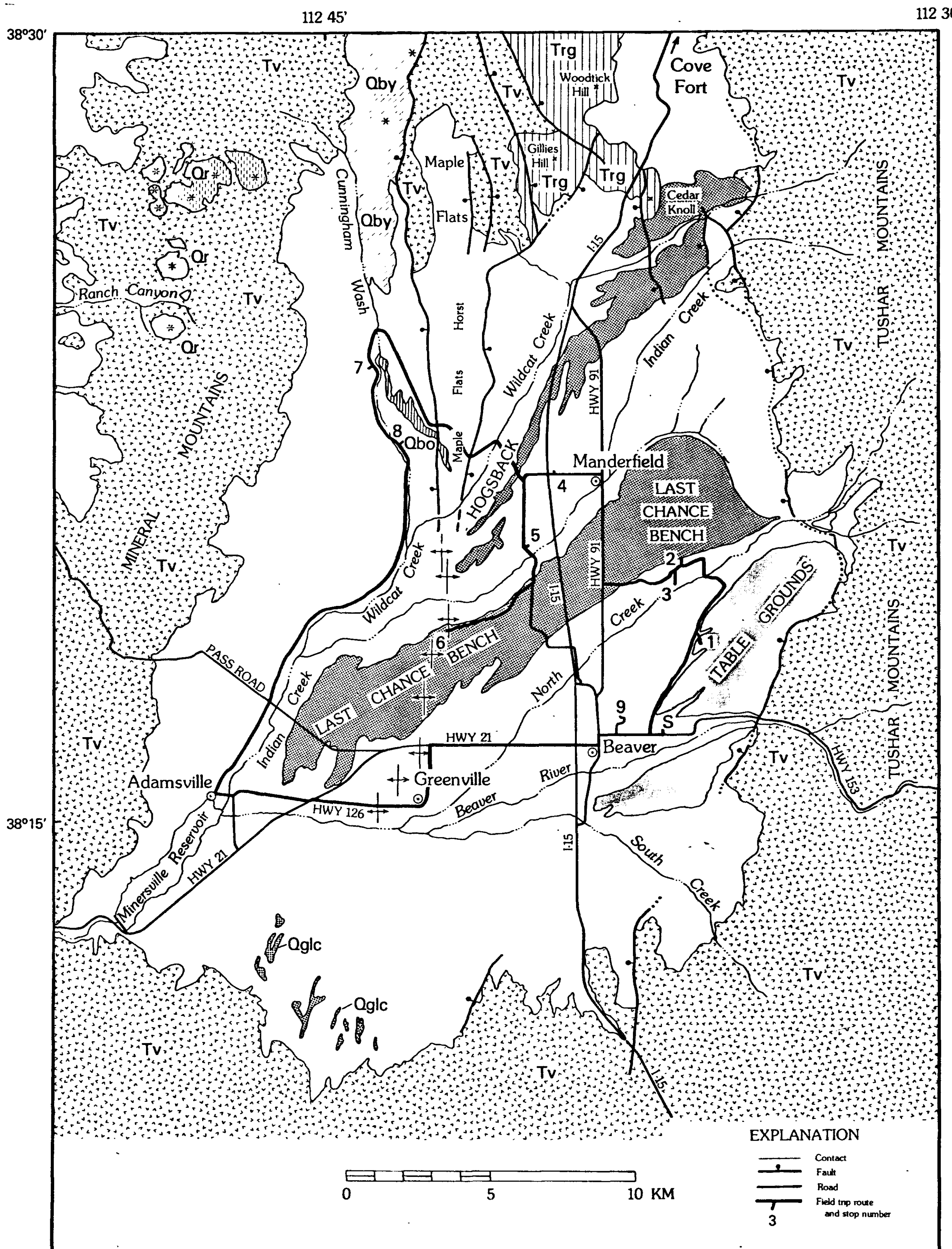


Figure 1. Index map and route of field trip through the Beaver basin, south-central Utah.

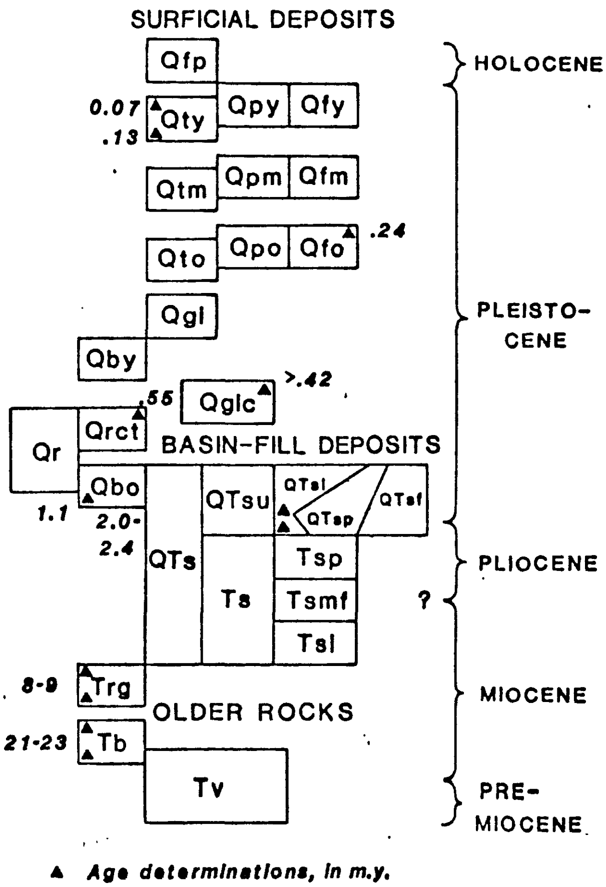
a relatively deep structural trough which is shallower in the center than along the mountain fronts, especially along the east margin of the basin. The east and south-central parts of the Beaver basin probably have the thickest fill; more than 2,000 m may be present in these areas. Because Pliocene and Quaternary deformation probably follows that of the Miocene, mapping of the young basin fill and surficial deposits provides an analog for subsurface exploration of oil and gas and uranium in the Beaver basin (see latter discussion of uranium potential in the basin).

Lower basin-fill deposits and volcanic rocks

The history of early-basin development is obscure because generally only the youngest basin-fill deposits are exposed. Near Cove Fort, about 35 km north of Beaver, a depositional basin of some sort existed in middle Miocene time. In that area and north of Woodtick Hill, poorly exposed gravelly silt and sand underlie the rhyolite of Gillies Hill (figs. 1 and 2, Trg), but exposures of these sediments are sparse and small and provide no information about the thickness of the early basin-fill deposits or the configuration of the basin in which they were deposited. Although the divide area between the Cove Fort and Beaver basins is presently structurally and topographically high, there little evidence that this barrier existed before the eruption of the rhyolite of Gillies Hill, 8-9 m.y. B.P. Upper Miocene and older volcanic rocks, which provide the platform on which the rhyolite rests, were derived from sources to the east, in the Tushar Mountains; this evidence suggests that the present divide area was topographically low in early Miocene time. Therefore, most of the present structural relief in the divide area results from uplift of the Maple Flats horst, whereas the topographic relief is formed by the eruptive pile of upper Miocene rhyolites. The Beaver and Cove Fort basins, and their connecting trough, form a 45-km-long, north-south structural depression named the Cove Fort-Beaver Graben (Cook and others, 1980).

Near the southwest corner of the Beaver basin, pumice-bearing conglomerate and a 7.6-m.y.-old basalt flow (Best and others, 1980) fill a narrow west-flowing channel that drained at least the Beaver basin part of the graben. The pumice fragments and overlying basalt indicate that the conglomerate accumulated during a 9-m.y.-old episode of rhyolitic volcanism documented along the north, east, and south margins of the Beaver basin (Steven and others, 1981; Evans and Steven, 1982). This channel was later closed by uplift along the southwest flank of the Mineral Mountains and the north flank of the Black Mountains (fig. 1) as evidenced by up to 20° of post-depositional rotation of the 7.6-m.y.-old basalt exposed near Minersville Reservior.

The sediments of the Beaver basin form two basic packages, which I refer to as upper and lower basin-fill (see fig. 2, correlation of map units). The lower basin fill has three members; the oldest and most poorly exposed (Tsl) consists of moderately oxidized, slightly gypsiferous, fine-grained bolson deposits of unknown thickness. These rocks crop out only locally at the south end of Maple Flats and, although their relation to the rhyolite of Gillies Hill can not be proven, the exposed part must be younger than the rhyolite. The upper Miocene conglomerates near Minersville Reservior are considered as a coarse-grained facies of the lower member (Tsl). Preliminary interpretation of subsurface drill data suggests that much of this member is coarse grained and could be as much as 1,000 m thick.



SURFICIAL DEPOSITS

Qfp FLOOD-PLAIN ALLUVIUM (HOLOCENE)

YOUNG ALLUVIUM (CA. 12,000-15,000 YR B.P.)

Qfy Alluvial-fan deposits

Qpy Piedmont-slope alluvium

Qty Terrace alluvium

MIDDLE ALLUVIUM (CA. 120,000-140,000 YR B.P.)

Qfm Alluvial-fan deposits

Qpm Piedmont-slope alluvium

Qtm Terrace alluvium

OLD ALLUVIUM (CA. 250,000 YR B.P.)

Qfo Alluvial-fan deposits

Qpo Piedmont-slope alluvium

Qto Terrace alluvium

Qgi GRAVEL OF ANCESTRIAL INDIAN CREEK (CA. 350,000-400,000 YR B.P.)

Qby BASALTS OF RED KNOLL AND CRATER KNOLL (MIDDLE? PLEISTOCENE)

Qglc GRAVEL OF LAST CHANCE BENCH (CA. 500,000 YR B.P.)

Qrct TEPHRA OF RANCH CANYON (550,000 YR B.P.)

Qr RHYOLITE DOMES AND FLOWS (MIDDLE TO LOWER PLEISTOCENE)

BASIN-FILL DEPOSITS

Qbo BASALT OF CUNNINGHAM HILL (CA. 1.1 M.Y. B.P.)

QTs SEDIMENTARY BASIN-FILL DEPOSITS (LOWER? PLEISTOCENE TO UPPER? MIOCENE)--Includes informal units of poorly to moderately consolidated fluvial and lacustrine deposits that comprise two major sedimentary packages

QTsu The upper part consists of a gradational sequence of lacustrine (QTsl), piedmont-slope and fluvial (QTsp), and fanglomeratic (QTsf) basin-fill sediments. The upper basin-fill deposits, early(?) Pleistocene and late Pliocene in age, contain the 1.9-m.y.-old Huckleberry Ridge Ash bed

Ts The lower part is moderately oxidized (in surface exposure), calcalareous and indurated. The upper and lower members (Tsp and Tsl) are relatively fine-grained and are separated by a basinward-thinning(?) coarse-grained conglomeratic member, the conglomerate of Maple Flats (Tsmf). The exposed part of the lower basin fill is Pliocene to late(?) Miocene in age

Trg RHYOLITE AND RHYOLITE TUFF OF GILLIES HILL (UPPER MIOCENE, 8-9 M.Y. B.P.)

OLDER ROCKS

Tb POTASSIUM-RICH MAFIC LAVA FLOWS (MIOCENE)--K-Ar ages are 21.7$\pm$0.8 m.y., 22.1$\pm$0.8 m.y. (H. H. Mehnert, written commun., 1980), and 23.2$\pm$0.2 m.y. (Best and others, 1980)

Tv VOLCANIC ROCKS OF THE TUSHAR MOUNTAINS (EARLY MIOCENE AND LATE OLIGOCENE) AND SEDIMENTARY AND INTRUSIVE ROCKS (MIOCENE TO PALEOZOIC)

Figure 2. Correlation and brief description of major map units in the Beaver basin (see also expanded version in Machette and others, 1981).

Tsl is overlain by a coarse-grained member that consists of interbedded silt, sand, and gravel; these deposits are informally named the conglomerate of Maple Flats (Tsmf). This conglomerate is late Miocene and (or) early Pliocene in age and clearly overlies 9-m.y.-old rhyolite. Boulders in the conglomerate are as much as 2 m in diameter and reflect the vigorous upheaval of the Mineral Range and possibly the Tushar Mountains along the bordering faults of the Beaver-Cove Fort Graben. Because there are no marker beds in the conglomerate member, it is not possible to determine its thickness. However, at least 250 m of these strata are exposed and 500 m or more may be present in the subsurface to the south of Maple Flats. The conglomerate of Maple Flats is exposed mainly in the horst of Maple Flats (fig. 1; Machette and Steven, 1982), in the north-central part of the Beaver basin.

The youngest member of the lower basin fill (Tsp) is a piedmont facies consisting of interbedded fluvial-channel and deltaic(?) sands, calcareous marls, and pebble to cobble gravels. The piedmont facies is moderately oxidized and indurated and contains calcium-carbonate-cemented sandstone lenses and calcium-carbonate nodules. This member is differentiated from younger and older deposits by its moderate amount of oxidation, calcareous marls, and tephra assemblage. Several tephra are present in the upper part of this member, but their sources and ages have not been identified. In the subsurface, the piedmont facies probably intertongues with a playa or lacustrine sequence towards the center of the basin.

Upper basin-fill deposits

Unlike the lower basin fill, which is characterized by discontinously exposed members that form a vertical assemblage, the upper basin fill is exposed over most of the basin and consists of a complex lateral assemblage. This assemblage contains intertonguing lacustrine (QTsl), fluvial and piedmont-slope (QTsp), and alluvial-fan (QTsf) deposits (fig. 2). The lacustrine deposits consist of light- to medium-green silty clay and silt interbedded with well-bedded, light-gray to light-brown fine sand grading laterally into pebbly sand. The lacustrine sediments are the most widespread and best exposed of the basin-fill deposits in the Beaver basin.

The upper basin fill accumulated in and adjacent to a large perennial-lake basin that persisted through Pliocene and early Pleistocene time. The lake that occupied this basin is here informally called Lake Beaver. At least four and as many as six volcanic ashes (tephra) fell into Lake Beaver during the Pliocene and early Pleistocene; some ashes were erupted locally whereas others were derived from sources thousands of kilometers away.

Blancan fossils collected by G. A. Izett and J. G. Honey from the basal part of intertonguing lacustrine and piedmont-slope deposits include the zebra *Dolichohippus*, the muscrat *Ondatra* cf. *O. idahoensis*, and the microtine rodent *Mimomys meadensis*. The small-mammal taxa suggest a Blancan-5 age of 2.0 to 2.5 m.y. (C. A. Reppening, written commun. to G. A. Izett, 1980). The fossils are from sediments 25 to 50 m below the thickest and most persistent ash in the basin, the Huckleberry Ridge ash bed (previously known as the "Pearlette type B ash"; Izett, 1981; Izett and Wilcox, 1982). This ash is the distal airfall component of a rhyolitic tuff erupted at Yellowstone Park, Wyoming, 2.0 m.y. B.P. Water-laid Huckleberry Ridge ash is found in the western one-half and southern two-thirds of the basin, indicating the minimum extent of Lake Beaver during the late Pliocene and early Pleistocene. About 200-250 m of the lacustrine facies is exposed in the north-center of the basin, but drill-hole data shows that lacustrine deposits must be thicker and have older equivalents in the subsurface, especially near Greenville (fig. 1).

Two other ashes are widely preserved in the 30 m of sediment underlying the Huckleberry Ridge ash bed; they are informally named the "middle ash bed" and the "Indian Creek ash bed." The middle ash bed is correlated, on the basis of its stratigraphic position and mineralogic and chemical properties, with the 2.1-m.y.-old Taylor Canyon-C ash bed of the Long Valley-Glass Mountain area in eastern California (Izett, 1981, 1982). The Indian Creek ash bed, 30 m below the Huckleberry Ridge ash bed, is composed of glassy, gray to black obsidian pellets in a matrix of medium-grained sand. It has chemical and mineralogical affinities with 2.3- to 2.4-m.y.-old rhyolites near the Cudahey Mine and at South Twin Peak (Lipman and others, 1978, table 3; Izett, 1981), both of which are located about 55 km northeast of Beaver. The coarse-grained texture of the Indian Creek ash, indicative of a nearby source area, strengthens its correlation with the local rhyolites.

Another ash, here informally named the Hogsback ash bed, is locally preserved below the Indian Creek ash bed in exposures along the north side of the Hogsback. It is interbedded with varigated light-green silty clays and slightly oxidized, orangish-brown sands. This ash lies about 20 m below the Indian Creek ash and about 50 m below the Huckleberry Ridge ash bed. The Hogsback ash also has chemical and mineralogical affinites that suggest a correlation with the rhyolites of Cudahey Mine and South Twin Peak, although it is much finer grained than the Indian Creek ash.

There are at least 100 m of lacustrine and fluvial sediment overlying the Huckleberry Ridge ash bed. A fifth, locally preserved, thin fine-grained ash (the Last Chance Bench ash bed; Izett, 1981) is found in this part of the Pleistocene section about 40 m above the Huckleberry Ridge. This ash has not been correlated with a source area, but is considered to be about 1.8 m.y. old on the basis of its position relative to the underlying 2.0-m.y.-old Huckleberry Ridge ash bed (Izett, 1981).

Ostracodes and diatoms were collected by R. M. Forester and J. Platt Bradbury from a 35-m-thick interval of sediment underlying the Huckleberry Ridge ash bed and from a 12-m-thick interval containing the Last Chance Bench ash bed; spot collections also were made from sediments of the lower basin fill. Forester and Bradbury's study (1981) suggests that the Beaver basin contained at least four distinctive lacustrine systems and various marginal environments during the Pliocene and the early Pleistocene. These lacustrine systems include an early freshwater lake (Pliocene?), a late Pliocene saline lake (basal QTsl), a late Pliocene to early Pleistocene slightly saline to freshwater lake (middle? QTsl), and an early Pleistocene freshwater lake-pond-stream network (upper? QTsl) similar to some of the modern day environments of the basin.

This data, and the sedimentary structures and stratigraphy of the lacustrine deposits, suggest that Lake Beaver was a shallow, but permanent feature. *Scirpus*, *Chara*, and snails are present in much of the lacustine sequence along with ripple-bedded sands and mudcracks. Diatom and ostracode species suggest that the Pliocene to early Pleistocene lake-water chemistry varied from fresh to slightly saline and was dominated by Na and K cations relative to Ca and Mg cations (Forester and Bradbury, 1981). This interpretation of Lake Beaver's water chemistry is supported by the general lack of carbonate mineralization in much of the lacustrine sediment.

The youngest dated unit contained within the basin fill is the basalt of Cunningham Hill (fig. 2, Qbo), a dark-gray, scoriaceous to massive basaltic lava flow (Machette and others, 1981). This basalt was erupted 1.1±0.3 m.y. B.P. (Best and others, 1980) while the Beaver basin was still closed.

The vent for the basalt may lie beneath younger basalt flows (Qby) in the northwest part of the basin, between the horst of Maple Flats and the Mineral Mountains (fig. 1). The basalt of Cunningham Hill has a weakly reversed natural-remanent magnetic direction with a strong normal (chemical?) overprint (Machette and Steven, 1981); this data shows that the basalt must be older than 0.7 m.y. The basalt flowed south and southeast in an old channel of Cunningham Wash and, because of topographic reversal, it now forms a ridge about 100 m above the level of adjacent, eroded upper basin-fill deposits. The basalt of Cunningham Hill is displaced by a series of north-trending, down-to-the-east normal faults that give the basalt flow a segmented, westward tilt. These faults have a net Quaternary throw of at least 100 m, down towards the basin center, and indicate post-1.1 m.y. uplift along the Maple Flats Horst. This structural interpretation is also supported by discordant relations between the upper and lower basin fill that document sedimentation and contemporaneous growth of an north-trending antiform within the central part of the basin during Pliocene and Pleistocene time.

Unpublished seismic-reflection data and the pattern of faulting along the east margin of the basin show that the youngest basin fill probably underlies the Table Grounds surface (fig. 1, stop 1). Table Grounds is a broad fan-shaped constructional surface that projects to a level of about 45 to 75 m above North Creek and 75 to 100 m above the Beaver River. The southernmost remnant of the Table Grounds surface is preserved as an elogate, west-sloping to flat ridge south of the Beaver River.

Table Grounds is underlain by oxidized sandy pebble to cobble gravels and sparse interbeds of sand (QTsf) Near the Beaver River this sediment buries early Miocene lava flows (Tb; Tmpl of Machette and others, 1981), small remnants of which rise 5-10 m above Table Grounds. The Table Grounds surface is here considered to be about 0.75 m.y. old; this age is based on sedimentation rates of the upper basin fill, the 1.1 m.y. age of the basalt of Cunningham Hill, a 0.55 m.y. age on the post-basin-fill tephra of Ranch Canyon, and an assessment of the relic soil developed in alluvium that forms the Table Grounds surface (see discussion of soil development). Throughout most of the Beaver basin, sediment of 0.75-1.5 m.y. age is either buried by surficial deposits or has been eroded.

Surficial deposits

The time at which the Beaver basin was breached and Lake Beaver drained into the Escalante Desert via Minersville Canyon is evidenced by the fluvial deposition of a locally derived rhyolitic obsidian-lapilli and pumice deposit--the tephra of Ranch Canyon (Lipman and others, 1978; Qrct of Machette and others, 1981). This tephra was erupted from rhyolitic domes in the central Mineral Mountains 0.55±0.01 m.y. B.P. (G. A. Izett, written commun., 1981) and then redeposited in alluvial channels cut in basin-fill sediment. In the Beaver basin, the tephra of Ranch Canyon is exposed mainly along Cunningham Wash (field trip stop 7) and along the southern part of Indian Creek where it is unconformably overlain by surficial deposits. About 3.1 miles north of Manderfield, in the large west-facing road cut of Utah Highway 91, the tephra is interbedded with the basal part of the oldest surficial deposit of the Beaver basin, the gravel of Last Chance Bench. Thus, by about 0.55 m.y. B.P., Lake Beaver had emptied through an outlet at Minersville Canyon, the drainage in the Beaver basin was integrated and had eroded a broad pediment across basin-fill sediment, and the extensive gravel cover of Last Chance Bench was being deposited.

The gravel of Last Chance Bench was completely deposited and its constructional surface was stablized by about 0.5 m.y. B.P. This estimate is constrained by two ages: 1) the underlying tephra of Ranch Canyon (0.55 m.y. B.P.) and 2) a preliminary uranium-trend soil age of 420,000±40,000 yr B.P. (H. M. Steer, 1980; J. N. Rosholt, personal commun., 1981). The later date is from a soil formed in fault scarp colluvium and gravel of Last Chance Bench, and was determined by method described by Rosholt (1980); it is here considered to be a minimum age for the gravel (see discussion at field trip stop 2). Thus, for the purposes of this report, I use an age of 0.5 m.y. B.P. for the Last Chance Bench surface and its underlying gravel. This gravel consists of light-brown to reddish-brown pebbly sand to sandy gravel that generally is coarser grained than the basin-fill sediment on which it lies disconformably near the mountains and unconformably in the center of the basin. Although the gravel is only 2-5 m thick, it forms a protective mantle over the fine-grained basin-fill.

Last Chance Bench is the most extensive geomorphic surface in the Beaver basin; it extends from the east front of the Tushar Mountains, between Indian Creek and North Creek, westward 20 km to near Adamsville (about 5 km northeast of Minersville Reservior). Outliers of this same gravel are preserved as the "Hogsback" between Wildcat Creek and Indian Creek, as high surfaces south and east of Cedar Knoll, and as surfaces mantled by basalt boulders on the north flank of the Black Mountains, south of the Beaver River. Because the gravel of Last Chance Bench is extensively faulted, it occupies a wide range of topographic positions: less than 30 m to more than 100 m above stream level. Most commonly it occurs at levels of about 75 m above stream level. The surface of Last Chance Bench projects 20-50 m above North Creek, a level that is about 25 m below Table Grounds.

Since deposition of the gravel of Last Chance Bench about 0.5 m.y. ago, the history of the basin has been one of periodic downcutting and subsequent deposition of surficial materials related to climatic and tectonic control. These surficial deposits are contained within three major and several minor groups, all of which form widespread gravelly piedmont-slopes, alluvial fans, and terraces (fig. 2). The oldest of these sediments, the ancestral gravel of Indian Creek (Qgi; Machette, 1982a), is inset 5-12 m below the gravel of Last Chance Bench at the south end of the Hogsback and forms a ridge 30-38 m above Indian Creek; a level well above the next younger alluvial unit southwest of the Hogsback. Although the course of ancestral Indian Creek was controlled by fault-induced topography, deposition of the alluvium probably resulted from fluctuations in the climate. Soils data and age control are not available for unit Qgi, but constraints from younger and older surficial deposits suggest an age of 350,000-400,000 yr B.P.

The three major groups of surficial deposits in the Beaver basin are informally designated as "old", "middle", and "young." All three groups consist of locally derived alluvial-fan (Qf), piedmont-slope (Qp), and terrace (Qt) deposits (see fig. 2; Machette and others, 1981; Machette, 1982a; Machette and Steven, 1982). For example, the soils at field trip stops 2 and 4 are formed in old alluvial-fan (Qfo) and piedmont-slope (Qpo) deposits, respectively. The field relations for all three groups of surficial deposits indicate that most fan and piedmont-slope alluvium are slightly younger than the associated terrace alluvium. This same relation has been recognized for alluvial units in central New Mexico (Machette, 1978) and suggests that the slight time-lag between main-stem deposition and local-tributary deposition may be a widespread phenomena in the desert environments of the southwestern United States.

Old alluvium is poorly preserved in small terrace remnants 16-18 m above the Beaver River (near Greenville) and 5-15 m above North Creek, and in small islands of piedmont-slope that are graded to levels 20-25 m above Indian Creek (stop 4). These same terrace deposits are much higher in the northeastern part of the basin; they lie about 60-65 m above Fortuna Canyon west of Wildcat Fields, near the Manderfield exit on I-15. I estimate that the bulk of old aluvium was deposited about 250,000 yr B.P. on the basis of soil development (such as total $CaCO_3$ content, Bt horizon thickness, and clay content) and the correlation of old alluvium with deposits of the last major pre-Bull Lake glaciation in the Rocky Mountains (terminalogy of Colman and Pierce, 1981). An age of 240,000$\pm$40,000 yr B.P. (H. M. Steer, 1980; J. N. Rosholt, personal commun., 1981) was determined from the soil developed in Qfo at stop 2 by the uranium-trend method (Rosholt, 1980).

The middle group of surficial deposits forms terraces along most of the major streams in the Beaver basin and forms extensive piedmont-slopes in and around the basin. Middle alluvial terraces are 2-13 m above the Beaver River near Greenville and 10-13 m above Indian Creek near Manderfield. Most middle alluvium was deposited 120,00-140,000 yr ago. This age range is based on soil development and the correlation of middle alluvium with deposits of the Bull Lake glaciation in the Rocky Mountains (Colman and Pierce, 1981).

Uranium-trend ages between 75,000 and 130,000 yr B.P. (H. M. Steer, 1980; J. N. Rosholt, personal commun., 1981) were determined from soils developed on several faulted middle terraces along South Creek, about 3 km south of Beaver. Soils on the lowest of these "middle terraces" are similar but less developed that those on middle alluvium to the north, and suggests that the group of three South Creek "middle terraces" have a longer age range and their alluvium is slightly younger than most other middle alluvium. The South Creek terraces were formed due to periodic faulting and subsequent downcutting along South Creek, and thus, are considered as a young phase of middle alluvium.

The young group of surficial deposits forms low-level terraces, elevated floodplains, and small alluvial fans throughout most of the Beaver basin. Partly because of their lack of erosion, young deposits have the largest areal distribution and volume of the three groups. Young alluvium forms broad, slightly elevated and coalesced surfaces 3-6 m above the modern floodplain of the Beaver River, between Greenville and Adamsville (13 km west of Beaver), and 3-5 m above Indian Creek, near Manderfield. On the basis of their B and Cca horizon development, young alluvium is correlated with deposits of the most recent major glaciation, the Pinedale, which probably ended about 12,000 to 15,000 yr B.P.

Holocene deposits in the Beaver basin have similar facies as the three alluvial groups, but are restricted mainly to incised and inset channels and small alluvial fans. The Holocene alluvium is generally light-brown to light-gray, medium- to coarse-grained sand and pebbly to bouldery gravel that forms broad, slightly dissected surfaces along the Beaver River and North Creek and, towards the Tushar Mountains, form narrow channels inset into older deposits. Along the lower parts of Wildcat and Indian Creek and their tributaries, the Holocene alluvium includes massive silt and fine sand and abundant organic matter and calcium carbonate deposited in a marsh-like environment. Numerous seeps and springs indicate ground water is near the surface of this unit along the Beaver River and has prevented $CaCO_3$ from accumulating in many of the Holocene soils.

SOIL DEVELOPMENT

The degree of development of soils formed in surficial deposits is used for mapping and correlating these deposits over the basin, and for making estimates of soil age. The discussion of soil development presented here is based on descriptions of about 25 soil profiles and on selected laboratory data for soil characteristics such as texture, $CaCO_3$ content, bulk density, and saturated pH. The laboratory methods used for these analyses are basically the same as those reported in Machette and others (1976) and include clay content by the pipette method (using chemical dispersion) and $CaCO_3$ content by the Chittick gasometric method. Although not reported completely here, these analytical data are the primary basis on which I compare and contrast soil development.

The soils on surficial deposits in the Beaver basin are formed in an alluvial chronosequence that spans the last 0.75 m.y. Because these soils are formed in parent materials of similar lithologies and textures, in similar landscape positions, and in similar biotic, vegetative, and climatic environments, I ascribe their main differences in development to the influence of time, that is, the duration of soil formation. The parent materials consist mainly of pebbly to sandy gravels derived from Tertiary mafic and silicic volcanic rocks. Loess and fine-grained eolian sand, which mantle some of the alluvial deposits in the basin, contribute to the apparent development of B horizons.

Because the soils of the Beaver basin have noncalcareous to very weakly calcareous (<2 percent $CaCO_3$) parent materials, and because there is no evidence of deposition of $CaCO_3$ by shallow ground water, most or all of the $CaCO_3$ in the soils are derived from aerosolic sources such as calcareous eolian sand and dust and from Ca^{++}-enriched rainfall (Bachman and Machette, 1977). Alternately, some soils may have periodically lost $CaCO_3$ from their soil profiles during climatic periods of relatively high-leaching capacity with respect to the rate at which Ca^{++} is supplied to the land surface (Machette, unpublished data, 1982).

The continental climate of the Beaver basin ranges from semiarid with 20-25 cm of rainfall in the low parts of the basin, to dry-subhumid with 25-30 cm of rainfall along the margins of the basin at elevations below 2,100 (6,900 ft) (Stott and Olsen, 1976). The bulk of the annual precipitation occurs during the winter and spring months with about 30 percent falling as rain during the summer months. The mean-annual air temperature ranges from 45° to 49° C at elevations of 1,585 to 2,100 m (5,200 to 6,900 ft) in the basin and the average-monthly maximum (30° C) and average-monthly minimum (-10° C) temperatures occur in January and July, respectively. Under the climatic conditions of the Holocene, calcium carbonate probably accumulates at depths of 50-100 cm and is not leached from the soil because the distribution and amount of annual precipitation is balanced with respect to the airborne influx of Ca^{++} ions to the soil surface (Machette, unpub. data, 1982).

Soils are an important tool in this study because deformation during the Quaternary has left alluvial deposits of many ages at different topographic levels in the basin. I have summarized data for some soil properties of the Beaver chronosequence in table 1, and although this list is not a comprehensive analysis, it shows some time-related soil properties that have proven useful for mapping and differentiating Quaternary alluvial deposits in the Beaver basin. The soil description and laboratory data in this report is presented in tablular form and uses abbreviations for much of the standard soil terminalogy. Readers unfamilar with this terminalogy should consult Soil

Taxonomy (Soil Survey Staff, 1977) or references that deal with soils and geology such as Birkeland (1974).

The two oldest geomorphic surfaces of the basin, Last Chance Bench and Table Grounds (table 1), are significantly different in age, yet have soils that appear similarly developed. One might consider this similarity to indicate a stable or steady state of soil development, but it is an artifact of several factors. Because the Table Grounds surface is only preserved at relatively high altitudes along the moist, eastern side of the basin, its soils have lost more $CaCO_3$ due to periodic leaching than those from Last Chance Bench, which are topographically lower and have formed under a relatively drier environment. This is the reason soils on Table Grounds contain less total $CaCO_3$ (55-70 g/cm^2) than soils on the younger, Last Chance Bench (average of 74 g/cm^2). Compounding this climatic factor is the problem of adequate sampling. The soils of Table Grounds are more eroded than those of Last Chance Bench and my soil pits on Table Grounds did not extend to the base of the Cca horizon; therefore the calculated total $CaCO_3$ contents of Table Grounds soils are minimum values (see table 1).

Combined, these factors result in soils on Table Grounds that appear less developed than those on Last Chance Bench. This is not so. The differentiating criteria lies in the development and the strength of K horizon development (Gile and others, 1965, 1966; Bachman and Machette, 1977). The Last Chance Bench soils have K horizons with advanced forms of stage III $CaCO_3$ morphology, but lack a laminar layer which is typical of the stage IV pedogenic calcretes (indurated calcic soils, Bachman and Machette, 1977) that are developed on Table Grounds. This criteria alone is not compelling evidence for greater soil ages because soil texture can greatly influence the stage of $CaCO_3$ development (Gile and other, 1966). More compelling evidence for greater age is the higher concentration of $CaCO_3$, greater thickness of the zone in which $CaCO_3$ accumulates, and the presence of argillic horizons that have been engulfed by $CaCO_3$. Together, these data suggest that the soils of Table Grounds (0.75 m.y. B.P.) are about 1 1/2 times as old as the soils of Last Chance Bench (0.5 m.y. B.P.).

The next younger group of soils are formed on old alluvium. These soils are markedly less developed than old soils as evidenced by their thinner and less calcareous K horizons, slightly less developed $CaCO_3$ morphology (stage III), and less total $CaCO_3$ content (table 1). The total $CaCO_3$ content of "old soils" ranges from >9 g/cm^2 (a partially leached soil) to a maximum of 38 g/cm^2 (soil profile 8/18/78-1, table 1; field trip stop 3). Although I need more data for these soils, a total $CaCO_3$ content of 35-40 g/cm^2 is probably representative of their maximum calcic development. If one uses this range of values and assumes that the average rate of $CaCO_3$ accumulation during past 0.5 m.y. (0.15 g/cm^2/kyr; Machette, 1982a) is valid, the calcic horizons of old soils could have formed in about 230,000-270,000 yr. This soil-age estimate and the uranium-trend age of 240,000$\pm$40,000 yr strongly suggest that the old alluvium is about 250,000 yr old. It is interesting to note that soils of $\geq$250,000 yr age seem to reach a maximum B-horizon development in terms of clay content, thickness, and color. This observation must be tempered with the probability that B horizons become engulfed by underlying, upwardly migrating calcic horizons and that B horizons are subject to progressive surface erosion with increasing age.

The soils on middle alluvium are much less developed than those on old alluvium, yet show moderately well-developed profile characteristics. Middle soils are differentiated from old soils by Bt horizons that are 1) less red, typically with a maximum color of 7.5YR5/4d, 2) thinner, usually about 30 cm

Table 1. **Comparison of some properties of soils formed in Quaternary surficial deposits of the Beaver basin, south-central Utah.**

(The abbreviated headings are as follows: d, thickness: B horizon values in parentheses are thickness of the clay bulge; *Clay is the difference in clay content between the maximum and the A(↓) or the C (↑) horizon; *$CaCO_3$ is the maximum percent calcium carbonate in the less than 2 mm fraction and the value in parentheses are the maximum percent calcium carbonate in the whole-soil fraction. Tabular abbreviations are as follows: t, thickness; m, moist; d, dry; n.d., no data; -, weak; +, strong.)

Number and location	Deposit	B horizon t, in cm	B horizon Max. color (Munsell)	B horizon *Clay	Cca/K horizon t, in cm	Cca/K horizon Max. Stage	Cca/K horizon *$CaCO_3$	Total $CaCO_3$, in g/cm^2	Remarks
8/8/78-1 Stop 9	Qty	30	5YR 5/3 to 5/4d	3(↓)	100	I	0.4 (0.1)	n.d.	High water table
8/13/78-1 Country Inn	Qty	35	7.5YR 4/4d to 5/4d	3(↓)	20 to 120	II-	0.7 (0.1)	n.d.	High water table
5/14/80-2 Manderfield Church	Qpy	25	7.5YR 4/4m	4(↓)	110	I+	1.9 (0.2)	0.3	
COMMON VALUES, YOUNG ALLUVIUM		30	7.5YR 5/4d	3(↓)	100	I+	<2.0 (0.1)	0-0.3	Age: 12-15 kyr
8/9/78-2 Stop 5	Qtm	17	5YR 5/3d to 5/4d	8(↓) 20(↑)	56	III	32 (30)	11	
5/11/80-2 Greenville dump	Qtm	31	7.5YR 5/4m	18(↓) 29(↑)	53	III-	27 (26)	>8	Thin profile, $CaCO_3$ lost
5/14/80-1 LDS farm	Qpm	45	7.5YR 5/5m	11(↓) 16(↑)	52	III-	16 (10)	>6	Leached, high water table
COMMON VALUES, MIDDLE ALLUVIUM		30	7.5YR 5/4d	12(↓) 22(↑)	54	III-	25 (22)	10-12	Age: 120-140 kyr
8/9/78-1 Stop 4	Qpo	60(85)	5YR 5/6d	7(↓) 25(↑)	118	III	47 (24)	25	Loess over gravel
8/11/78-1 Greenvl. cemetary	Qto	35(68)	5YR 5/6d	25(↓) 32(↑)	85+	III	15 (11)	9	Thin on QTs, $CaCO_3$ lost
8/18/78-1 Stop 3	Qfo	47(88)	5YR 6/6d	18(↓) 25(↑)	115	III	40 (32)	38	Thick, U-trend age: 240kyr
COMMON VALUES, OLD ALLUVIUM		51(80)	5YR 5/6d	17(↓) 27(↑)	106	III	44 (28)	31	Age: 250 kyr
8/8/78-2 Hwy 91 pit	Qglo	35(107)	7.5YR 4/3d	8(↓) 28(↑)	127	III+	59 (59)	78	Max clay in IIK1 horizon
9/27/78-1 Stop 2	Coll/ Qglo	67(132)	5YR 5/6d	23(↓) 32(↑)	133+	III+	53 (38)	49	Base covered
5/10/80-2 Upper BLM pit	Qglo	18(100)	5YR 4/4m	10(↓) 24(↑)	132	III+	68 (67)	70	U-trend age: 420 kyr
COMMON VALUES, GRAVELS OF LAST CHANCE BENCH		40(100)	5YR 5/5d	14(↓) 28(↑)	130	III+	60 (55)	74	Age: 450-500 kyr
9/28/78-1 Stop 1	QTsf	none	n.d.	n.d.	110+	IV	50 (46)	>51	Eroded, cov'd base, min $CaCO_3$
5/10/80-1 BLM pit	QTsf	27	7.5YR 5/4m	n.d.	150+	IV	~65 (~62)	66	High altitude, $CaCO_3$ lost
COMMON VALUES, TABLE GROUNDS SURFACE		strip, consumed	7.5YR 5/4m	n.d.	150?	IV	65 (62)	55-70	Age: 750 kyr, $CaCO_3$ lost

thick, and 3) less clayey, with 12 to 22 percent more clay than the minimum amounts above and below, respectively. Where calcareous, middle soils have K horizons that are 4) thinner and 5) less calcareous, and 6) have less-developed $CaCO_3$ morphology (stage III-) than those of old soils. Middle soils have a maximum calcic development of 10-12 g of $CaCO_3/cm^2$ of soil column. These values require 67,000-80,000 yr to accumulate at a rate of 0.15 g of $CaCO_3/cm^2/kyr$; a period slightly less than the 70,000-130,000 yr age suggested by uranium-trend soil ages on middle alluvium.

My studies of calcic soils in the southwestern United States (Bachman and Machette, 1977; Machette, 1982a, Machette, unpubl. data, 1982) show that soils formed during the last major glacial-interglacial cycle (10,000 to 140,000? yr B.P.) probably yield inaccurate soil-ages when estimated from total-$CaCO_3$ values. This may be explained by climatically induced changes in the rate of accumulation of soil carbonate. During the Holocene, calcic soils in New Mexico have accumulated $CaCO_3$ at rates 2-3 times higher than rates during late Pleistocene time (Machette, 1982a). Climatically induced, cyclic changes in the rate of $CaCO_3$ accumulation have the greatest influence on calcic soils of post-Bull Lake age (that is 100,000-130,000 yr), because $CaCO_3$ may form in these soils during a long pluvial episode (120,000 yr?) marked by a low accumulation rate and a short interpluvial episode (10,000 yr) marked by a higher accumulation rate. Measurements to total $CaCO_3$ content in relict soils of pre-Bull Lake age deposits yield similar average accumulation rates (Bachman and Machette, 1977; Machette, unpub data, 1982) because these soils have formed under multiple cycles which tend to attenuate rate changes. If the $CaCO_3$ in the Beaver soils accumulated at such cyclically variable rates, then the total $CaCO_3$ contents of soils formed over the last 50,000 to 130,000 yr would yield soil-age estimates that are too young. I suggest an age of 120,000-140,000 yr for the middle group of alluvium on the basis of these arguments, the uranium-trend soil ages, strength of soil development, and their probable correlation with deposits of the last major pre-Pinedale glaciation (the Bull Lake glaciation).

The youngest major group of soils in the Beaver chronosequence are weakly developed on latest Pleistocene alluvium. Young soils are characterized by 30-cm-thick, weak argillic B horizons and thick, very weak Cca horizons (table 1). The B horizons are commonly 7.5YR in color, but some of this reddening is caused by ground-water oxidation. Where the water table has remained low, the young soils have weak accumulations of $CaCO_3$, mainly as thin coatings on clasts (stage I), over a thickness of 100 cm. Because most of these soils are developed in fining-upwards stratified deposits, it is difficult to evaluate the amount of secondary clay in their B horizons. For example, the B horizon of soil profile 8/8/78-1 (tables 1 and 7) has 3 percent more clay than its A horizon (18 percent), but has 12-17 percent more than the underlying gravel (a second parent material) Nevertheless, the weak argillic B horizons and lack of substantial accumulations of $CaCO_3$ are the main criteria for differentiating young and middle soils.

Holocene soils in the Beaver area are weakly developed because of the young age and the high level of the water table during the Holocene. Although no detailed soil descriptions were made for Holocene soils of the Beaver basin during this study, these soils are characterized by incipient Bt horizons (usually a cambic or structural B) and oxidized C horizons.

In summary, the soils of the Beaver chronosequence show systematic changes in the developement of argillic and calcic horizons that are related to time. Characteristics of these horizons provide valuable criteria for recognizing and differentiating the surficial and youngest basin-fill deposits of the Beaver basin.

LATE CENOZOIC STRUCTURAL DEVELOPMENT OF THE BEAVER BASIN

The earliest deformation recorded by basin-fill deposits in the Beaver basin involves the north-trending Maple Flats horst which is formed by the conglomerate of Maple Flat and underlying basin-fill deposits and, in the north-central part of the basin, by volcanic rocks. The timing of the horst's uplift is problematical, but the coincidence of its east side with the west margin of the rhyolite of Gillies Hill suggests that the horst existed at least 9 m.y. B.P.

The horst continued to be a positive structural and topographic feature through the subsequent history of basin-fill deposition. Conglomerate along the east side of the Maple Flats horst has been uplifted and is in fault contact with the stratigraphically higher upper-piedmont member (Tsp). The horst has been an uplifted pennisula since Pliocene time as shown by the areal distribution of 2.0-m.y.-old ash found in lacustrine sediment (QTsl) northwest and northeast of the horst, but not on the horst itself. Uplift of the horst continued during the Pleistocene as shown by displacement of the basalt of Cunningham Hill (1.1 m.y.) and by subsidary faults that offset the gravel of Last Chance Bench (0.5 m.y) on the Hogsback.

The Maple Flats horst extends southward as a topographically high block as far as Wildcat Creek and probably extends further southward in the subsurface beneath Last Chance Bench where upper basin-fill sediment is deformed into a broad antiform. This antiform, here named the Last Chance Bench antiform, is cut by as many as 100 closely spaced normal faults trending N. to N. 20° E., and by fewer and more subtle, but clearly contemporaneous, northeast-trending normal faults with down-to-the-northwest displacement.

The axial trace of the Last Chance Bench antiform (fig. 1; Machette and others, 1981) steps 2.4 km east of due north through a series of right-lateral shifts over a distance of 10 km between the Beaver River and Wildcat Creek. Upper basin-fill sediments have attitudes of as much as 20° near the axis of the antiform and horst, but dip less than 5° several kilometers to the east and west of the axis. The 2.0-m.y.-ash is present at roughly concordent elevations, throughout the basin and shows that, although extensively faulted, there has been little net structural displacement across the Last Chance Bench antiform during the Quaternary. However, basin-margin faults east of the Beaver-Manderfield road (Hwy 91) have displaced 0.5-m.y.-old gravels as much as 100 m, down-to-the-west, indicating that extension? and uplift are still active processes in the Beaver basin.

Although north-trending faults are predominant in the basin, east- to northeast-trending faults also are present, probably to a greater degree than shown on recent geologic maps (Machette and others, 1981; Machette, 1982a; Machette and Steven, 1982). For example, northeast-trending down-to-the-north faults form lineaments and small scarps in middle and old alluvium north of Indian Creek. The main southwest-trending valley of Indian Creek probably is controlled by a major fault of this same system which would explain the 30-100 m of elevational difference between the levels of Last Chance Bench and the Hogsback.

Many of the faults scarps on Last Chance Bench are 10 to 25 m in height and clearly have a history of recurrent movement. Data on fault scarp morphology and stratigraphic evidence show that many of the faults in the east part of the Beaver basin had late Pleistocene movement (Anderson and Bucknam, 1979; H. M. Steer, 1980). Two major faults displace young alluvium (12,000-15,000 old) in the Beaver area (Machette and others, 1981). The western of the two faults form an arcuate, west-curving, 0.5- to 3-m-high scarp that extends from the Beaver River to North Creek (Anderson and Bucknam, 1979).

Data of R. E. Anderson (written commun., 1982) and H. M. Steer (1980) show that this scarp is slightly less degraded than wave-cut shorelines (data of R. C. Bucknam, written commun., 1979) associated with the 15,000-yr-old shoreline of Lake Bonneville (W. E. Scott, written commun., 1980). These data and the stratigraphic control indicate that the youngest faults in the Beaver area are probably less than 12,000-15,000 yr old.

There are clearly two deformational systems active in the Beaver basin, one related to the progressive growth of the Last Chance Bench antiform that is probably nontectonic, and a second that may be related to recurrent tectonic faulting along the active boundary of the Basin and Range Province and the Colorado Plateau.

POTENTIAL URANIUM MINERALIZATION IN THE BEAVER BASIN

The following discussion of uranium mineralization in upper Cenozoic deposits of the Beaver basin may seem peripheral to the purpose of this report, but is included here to show the potential economic and scientific importance of studying Quaternary stratigraphic and structural problems. Steven and others (1981) argue that the Beaver basin had long been a structural sump for waters draining uranium source areas in the Tushar and Mineral Mountains. The evidence for secondarily deposited uranium in the thick, closed-basin fill of the Beaver basin is largely circumstantial, but apparently convincing enough to promote recent exploration by several companies.

Several stratigraphic, structural, and geomorphic factors are important in a consideration of the potential for uranium concentration in this basin: 1) the basin contains a thick sequence of bolson and lacustrine deposits that date back to the Miocene, and buried parts of this section may contain significant carbonaceous material, 2) rapid lateral-facies changes may provide both chemical and lithological discontinuites favorable for uranium precipitation, 3) the faulted antiform and horst undoubtedly influenced the flow of ground water, and the recurrent nature of the faulting may have caused the flow pattern to change many times; and 4) the basin had a high ground-water table and possibly reducing environment at depth until an outlet was established shortly before 0.5 m.y.

Recent geochemical surveys by Miller and others (1980), a helium survey by Reimer (1979), and radon surveys by McHugh and Miller (1982) and industry (S. M. Hansen, in Steven and others, 1981) strongly suggest that uranium is concentrated in the Pliocene and Miocene basin-fill deposits (see also Miller and McHugh, 1981). Texaco, Phillips, Canyon Resources, and other companies recently have spent considerable time and effort exploring for uranium in the basin. These efforts have concentrated on drilling 150- to 450-m-deep wells in the upper and lower basin-fill deposits between Wildcat Creek, Manderfield, and the Beaver River. The results of these drilling activities is unknown to U.S. Geological Survey personnel at the present time.

ROAD LOG OF THE BEAVER BASIN

Mileage		Observations
Cumul-ative	Between observations	
0.0	0.0	Start of Road Log. Beaver Canyon Campground is located on the north side of Utah State Highway 153 about 1.4 miles east of the juction with Utah Hwy 90 (see fig. 1, field trip route). The campground is built on young (Qfy) and middle (Qfm) alluvial fans of Bone Hollow; these deposits interfinger with and overlap young (Qty) and middle (Qtm) terrace alluvium of the Beaver River that is associated with outwash of the Pinedale and Bull Lake glaciations, respectively. (See fig. 2 for correlation of deposits in the Beaver area.) A soil pit excavated in young fan alluvium on the east side of Beaver Canyon Campground has a profile with A (11 cm), Bt? (33 cm, 10YR5/3d), and weak stage II Cca (50 cm) horizons. A soil pit excavated in middle fan alluvium on the north side of the campground has a much stronger profile consisting of a thin A and thick calcic Bt (stage II) and K/Cca (stage III) horizons. The Bt horizon has 7.5YR 5/4d to 4/4m colors. Turn right (W) onto Hwy 153.
0.2	0.2	Turn right (N) onto North Creek Road, just past the sign for Hi County Estates subdivision. Road climbs up onto small west-sloping remnant of terrace and fan deposits of middle age (correlative with deposits of the Bull Lake glaciation).
0.5	0.3	Broad low surface to the left (W) is the late Pleistocene and Holocene flood plain of North Creek, a major drainage of the Tushar Mountains. Note the west-facing, north-trending fault scarp marked by a line of cottonwood trees about 250 m west of the road.
2.2	1.7	Gravels underlying the Table Grounds surface are displaced by a west-dipping normal fault that is exposed in east face of the gravel pit.
3.4	1.2	Turn left onto access road to De Armitt property. Park at base of hill and walk to top of Table Grounds.

STOP 1. **Table Grounds surface and overview of the Beaver basin**

Overview of the Beaver basin (12:00 is due north):

8-11 Mineral Mountains: Tertiary(?) intrusives, metamorphosed Paleozoic rocks, and Quaternary rhyolites (at the north end).

10-11 Maple Flats horst: Pliocene to Miocene fanglomerate at the south end and Miocene and Oligocene rhyolitic to intermediate volcanic and intrusive rocks at the north end. Middle? Pleistocene cinder cones along the northwest escarpment of the Maple Flats horst.

11:30 8- to 9-m.y.-old rhyolites of Gillies Hill (area of antennas) and Woodtick Hill.

12-4 Tushar Mountains: Intermediate to silic volcanic rocks of 19-27 m.y. age. (For details see Cunningham and others, 1982a.)

4-5 Flat-topped ridges north and south of Beaver Canyon are 22-to 23-m.y.-old potassium-rich mafic lava flows (Machette and others, 1981).

6:00 Ridge south of Beaver River: a remnant of Table Grounds; numerous breaks in slope are scarps formed by middle to late Pleistocene down-to-the-west faults.

6-7:30 Black Mountains: composed of volcanics of the Tushar Mountains, distal ash-flow tuffs from southern Utah, and local rhyolites and basalts.

7:30 Minersville Reservior and Canyon: drainage outlet of the Beaver River and its tributaries.

This stop is on the west edge of the Table Grounds surface, the depositional top and youngest part of the basin-fill. Table Grounds is the highest of the geomorphic surfaces of the Baver basin and is preserved as (1) a narrow remnant of coalesced alluvial fans between North Creek and the Beaver River and (2) as an elongate west-sloping ridge of alluvial-fan and piedmont-slope alluvium just south of the Beaver River. This ridge is cut by north to northeast-trending faults that form scarps 3-15 m high. The eastern end of the ridge is terminated by a down-to-the-west normal fault; the downdropped part of the surface is visible as an $1/2^{o}$ to 1^{o} east-tilted surface at the southern I-15 exit to Beaver. This fault has an estimated throw of 70 m (Anderson and others, 1978) based on the elevations of displaced surfaces.

To the east of us, the frontal fault of the Tushar Mountains places lower Miocene volcanic rocks against lower? Plesitocene fanglomerates (QTsf). The mafic lavas that form high ridges to the east and southeast of here are downdropped about 150 m across this fault zone as evidenced by small outliers of lava which rise slightly above the Table Grounds surface, directly north of the Beaver golf course. Additional, larger-displacement faults, which are basinward of the mountain front, may have a total of several thousands of meters of stratigraphic throw since the early Miocene. These faults form a several-kilometer-wide zone that marks the transition between the Colorado Plateau to the east and the Basin and Range to the west.

Although the soil is not well exposed, fragments of laminated, stage IV calcrete crop out along the margins of Table Grounds. A 1.25-m-deep excavation for the swimming pool on the south side of the DeArmitt home revealed a very strongly developed, thick K horizon, overlain by a Aca and Cca horizons (soil profile 9/28/79-1, table 1 and 2). The maximum clay content of this soil occurs in the K2m horizon, and indicates that the K horizon may have grown upward and engulfed a earlier, deep Bt horizon.

I dug a soil pit on a stable part of Table Grounds, about 1 km to the east of here, that exposed a 27-cm-thick Bt horizon and a stage IV K horizon more than 150 cm thick (table 2, soil profile 5/10/80-1). The thickness of the Bt and K horizons, the advanced stage of $CaCO_3$ morphology in the K horizon, and the surfaces' topographic position above Last Chance Bench, indicate that the Table Grounds surface must date be significantly older than 0.5 m.y. On the basis of this evidence, and stratigraphic and sedimentologic considerations, I estimate that the Table Grounds surface is about 0.75 m.y. old.

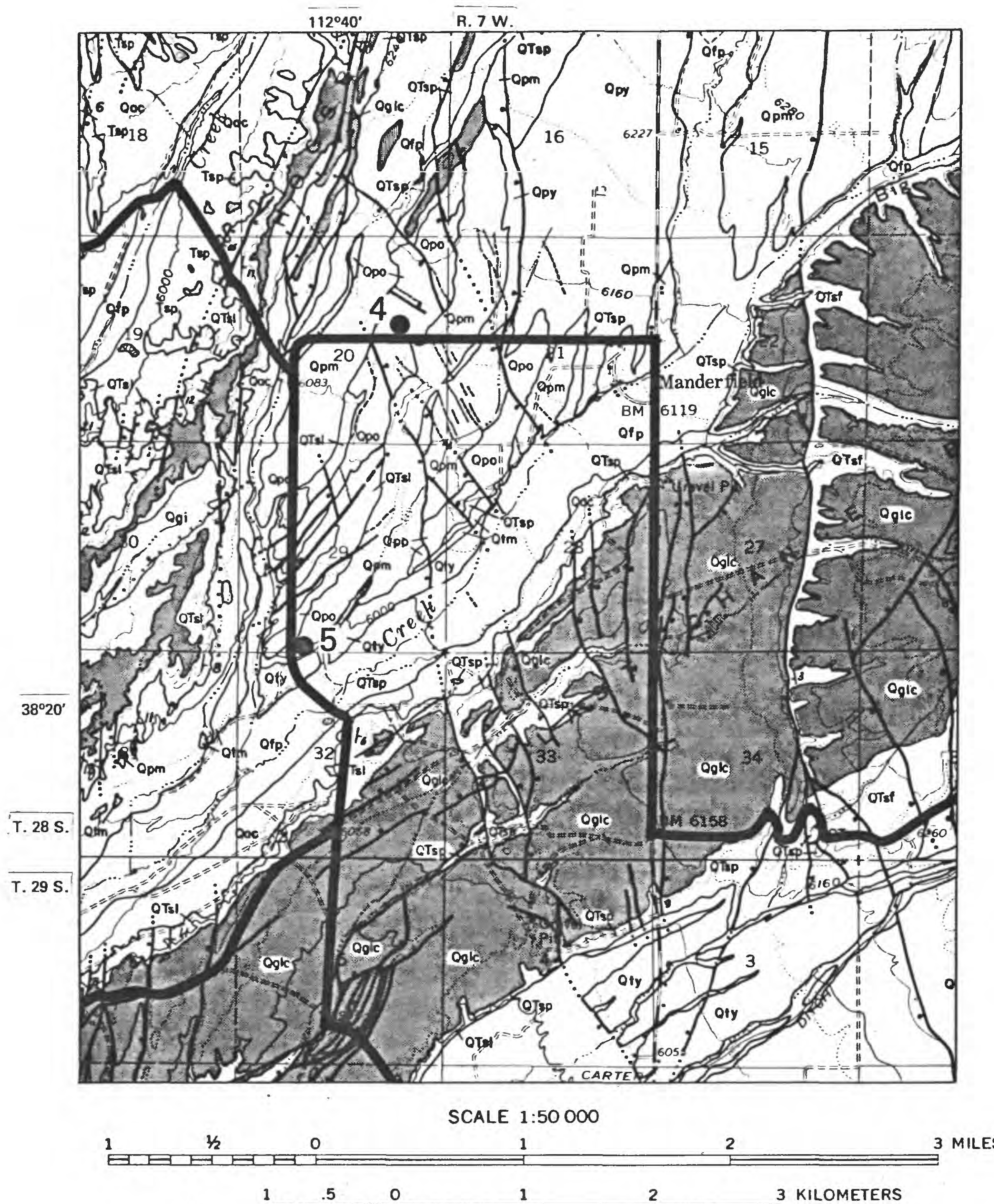


Figure 3. Geologic map of deposits near stops 2 and 3 (from Machette and others, 1981). Map symbols and units are the same as on figures 1 and 2.

Table 2. Soil description and selected laboratory data for soil 9/28/79-1, relict soil on fanglomerate facies of upper basin fill, Table Grounds surface (about 0.75 m.y. old)

Horizon depth, in cm	Color m, moist d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	Percent $CaCO_3$ <2 mm total	Percent gravel total
Aca 0-15	10YR4/4m 10YR5/3d	gL to gSiL	1f-vf gr	ss,ps loose	I	26.8 17.5	16.9 11.1	34.6
Cca 15-25	10YR5/3m 10YR7/2d	gSiL	2cgr to 2fsbk	ss,ps firm	I and IV (frags)	16.8 10.2	38.9 23.7	39.0
K22m 25-55	n.d.(m) white(d)	SiL?	3cpl	s,ps v hard	IV to III+	10.7 10.0	49.7 46.2	7.0
K23m 55-85	10YR5/5m white(d)	SL- to LS+	mass	s,ps v hard	III+	9.5 9.0	41.6 39.5	5.0
K3 55-85	10YR7/3m 10YR8/2d	vgSL+	mass	hard	III- to II	2.0 0.4	25.6? 5.0	80.6
C2ca 85-125+ Base covered	10YR6/6m 10YR7/4d	vgSL-	mass to sg	ss,ps friable	II to I+	4.2 1.6	21.1 8.3	60.9

3.4 0.0 Turn right (N) onto North Creek Road.

4.1 0.7 Turn left (NW) onto narrow paved road. Route crosses flood plain of North Creek which is formed by young alluvium (Qty), minor Holocene floodplain alluvium (Qfp), and sparse remnants of middle terrace alluvium (Qtm). Road parallels North Creek for about 1/4 mile.

4.6 0.5 North Creek. After bridge, road crosses narrow Holocene floodplain, a 50-m-wide remnant of middle terrace alluvium, and levels out on a wide terrace of old alluvium (Qto). About 2.5 km to the west (down grade), a fault displaces Qto and forms an 11-m-high scarp. The upthrown fault block is marked by junipers and the downthrown block is cultivated. Good view of scarp from stop 2, 1 mile ahead.

5.0 0.4 Turn left (W). High surface to the right (N) is the eroded south edge of the Last Chance Bench (LCB) surface.

5.6 0.6 After cattle guard, the road swings to the right (N) as it descends fault scarp. The road then turns to the left (W); park on the right side of road near the irrigation flume. Parking space is limited here, so park close together.

STOP 2. **Buried soil on fault scarp colluvium and gravel of Last Chance Bench.**

Well-developed soils formed on fault scarp colluvium (upper parent material) and gravel of Last Chance Bench (second and third parent materials) are exposed in the arroyo that cuts along the base of this fault scarp (fig. 3). The Bt horizon of this soil is aggradational, having developed while colluvium was washed down the fault scarp. Samples collected by Horst Steer from this soil profile (table 3) yielded a minimum uranium-trend soil age of 420,000±40,000 yr B.P. for the combination of parent materials (J. N. Rosholt, written commun., 1981).

This soil is well developed, but atypical of the Last Chance Bench in that it has a thick, well preserved Bt horizon. The Bt horizon has 23 and 32 percent more clay than the upper and lower soil horizons (table 1), respectively, and has a strong yellowish-red color (5YR 5/6d). The underlying K horizon contains a maximum of 53 percent $CaCO_3$ (<2 mm fraction, stage III+); the $CaCO_3$ in this horizon may be overly concentrated by the change in texture at the horizons's base.

Table 3. Soil description and selected laboratory data for soil 9/27/79-1, buried soil developed in scarp colluvium and gravel of Last Chance Bench (0.5 m.y. B.P.).

Horizon depth, in cm	Color m, moist d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	Percent $CaCO_3$ <2 mm total	Percent gravel total
A1 0-10	10YR3/2m 10YR4/3d	gSL to gL	1f-vf gr	ss,ps firm	none	12.2 7.3	0.3 .2	29.9
B1t 10-20	7.5YR4/3m 7.5YR5/4d	CL	1msb to 1m-fgr	s,p firm	none	31.1 26.0	.3 .3	16.5
B21t 20-38	5YR5/4m 5YR5/5d	gCL	2c-m abk	s,p firm	none	35.0 25.3	.5 .4	27.7
B22tca 38-77	5YR4/6m 5YR5/6d	vgCL	3m-fabk to 3mpr	s,p firm	I to II-	34.5 13.8	2.5 1.0	60.1
K1 77-100	7.5YR7/5m 7.5YR8/2d	gCL	3m-fpl	s,ps hard	III-	33.4 20.3	31.9 19.4	39.1
K2 100-142	7.5YR8/3m white (d)	gCL-	3m-fpl	ss,ps hard	III	27.6 20.2	52.8 38.4	27.3
2K3 142-180	10YR8/3m white (d)	vgSL	mass	ss,ps hard	III-	13.2 5.0	44.4 16.8	62.2
3Cca 180-210+ Base covered	7.5YR7/4m 7.5YR8/2d	LS-	mass to sg	ss,po loose	II- discon- tinous	2.4 2.2	10.3 9.5	7.9

A soil pit dug about 2 km north of here exposed an 18-cm-thick, 5YR Bt horizon, but the laboratory data indicate a clay bulge extends to a depth of about 125 cm, well within the K horizon (table 1). The morphology of $CaCO_3$ in this and other soils on stable sites of Last Chance Bench is an advanced form of stage III (Gile and others, 1966; Bachman and Machette, 1977). The total secondary $CaCO_3$ content of uneroded, relict soils on Last Chance Bench ranges between 70 and 78 g/cm^2 of soil column. Using an age of 0.5 m.y. B.P. for these soils, I calculated an average $CaCO_3$ accumulation rate of 0.15±0.02 g of $CaCO_3$/cm^2/kyr for the Beaver basin (Machette, 1982b).

This long-term accumulation rate is substantially lower than those determined from calcic soils of New Mexico (0.22-0.51 g/cm^2), but is similar to that estimated for the Vidal Junction area of southeast California (Machette, unpubl. data, 1982). Rates determined by R. R. Shroba (in Scott, 1982) for late Pleistocene and Holocene soils in the Salt Lake City area are much higher--0.50 g/cm^2/kyr--than in the Beaver area. It appears that the Salt Lake region has a substantially higher $CaCO_3$ flux rate than Beaver due to the wide exposures of calcareous lake beds and these soils may not have periodically lost $CaCO_3$ due to excessive leaching, as is suspected for many of the soils developed in the relatively wetter climate along the eastern margin of the Beaver basin.

		Continue west on road.
5.9	0.3	Turn left through gate onto private property. Park cars close to road to minimize damage to the field. Walk south about 250 m to the northeast corner of the unfinished house.

STOP 3. **Soil developed on old fan (Qfo) alluvium near North Creek**

Although I initally mapped this alluvial-fan deposit as middle alluvium, the basement excavation for this home revealed a soil far more developed than any I had seen before on middle alluvium. As it turns out, the alluvial fan and terrace are formed by old alluvium that lies at a low topographic position due to offset by down-to-the-west faults. One such fault forms an 11-m-high scarp about 1/2 km to the east of this site (fig. 3)

The soil exposed in the northwest corner of the basement excavation is thick, well developed and contains a full assembleage of subhorizons; it is the most complete and best preserved soil that I have found on old alluvium in the Beaver basin. The argillic B horizon is 35 cm thick and, based on laboratory data, appears to have a clay bulge that extends down into the K horizon (table 4). The maximum clay content in the soil is about 34 percent (<2 mm, B22t horizon), whereas overlying and underlying horizons contain a minimum of 16 and 8 percent clay, respectively. Subhorizons of the B, including the calcareous B3tca, are commonly 5YR6/6d, a strong reddish-yellow color.

The morphologic development of calcic horizons in this soil range from a stage II B3tca (8 percent $CaCO_3$) to a stage III K22 horizon (about 40 percent $CaCO_3$). The calcareous part of the soil is about 75 cm thick (K21-K32 horizons) and represents a significant portion of the soils total $CaCO_3$ content of about 38 g/cm^2. As previously discussed, the time necessary to form this amount of soil carbonate is 230,000-270,000 yr, based on 35-40 g $CaCO_3$ and an average accumulation rate of 0.15 g/cm^2/kyr. This soil-age estimate agrees with the uranium-trend soil age of 240,000±40,000 yr B.P. determined from samples collected at this site.

Table 4. Soil description and selected laboratory data for soil 8/18/78-1, relict soil on old fan alluvium (Qfo) overlying old terrace alluvium (Qto) of North Creek (250,000 yr B.P.).

Horizon depth, in cm	Color m, moist d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	 $CaCO_3$ <2 mm total	 gravel total
A 0-8	7.5YR5/4 to 5/3d	SL	1cpl to 1fsbk	ss,ps	none	16.2 14.5	0.5 .5	 10.8
B1 8-20	7.5YR5/4 to 4/4d	SL	2m-f sbk	ss,ps	none	17.5 15.9	1.0 .9	 9.0
B22t 20-36	n.d.(m) 5YR5/6d	CL	2c-m sbk	ms,ps	none	33.7 28.7	.7 .6	 14.8
B23t 36-49	n.d.(m) 5YR6/6d	L	1m-f sbk	ms,ps	none	18.6 15.8	.7 .6	 15.0
B3tca 49-55	n.d.(m) 5YR6/6d	gL	3m-2f sbk	ms,ps	II	20.3 14.4	8.0 5.7	 29.2
K21 55-70	n.d.(m) 7.5YR7/4d	L	2msbk- 2mabk	ms,ps hard	II+ to II-	18.9 15.6	32.4 26.8	 17.4
K22 70-80	n.d.(m) white(d)	L-	2c-f abk	ms,ps hard	III	13.3 10.8	39.5 32.3	 18.3
K31 90-110	n.d.(m) 5YR8/2-3d	L	2m-fpl	ss,po hard	III-	13.9 13.7	34.3 33.7	 1.7
K32 110-130	n.d.(m) 5YR8/2d	L	2f-1mpl	ss,po firm	III- to II	23.8? 22.5?	26.7 25.2	 5.6
C1ca 130-160	n.d.(m) 7.5YR7-6/4d	SL?	1fsbk	so,po loose	II- to I	n.d.	8.2 6.8	 16.9
C2ca 160+ Base covered	n.d.(m) 5YR5/6d	gSL	sg	so,po loose	II- to I	8.3 5.4	5.8 3.8	 34.9

Turn left (W) onto paved road. Road ascends Last Chance Bench and crosses several down-to-the-west fault scarps.

6.6 0.7 Road descends hill (fault scarp) and turns left (W) along arroyo. Exposures in this arroyo show a soil with a well-developed Bt and calcic horizons (formed in gravels of LCB) in fault contact with piedmont facies (QTsp) of the upper basin-fill that underlie LCB. This site has a geomorphic and structural setting similar to that of stop 2.

7.0	0.4	Gravel pit on right (N) is excavated along the largest fault scarp of LCB, here about 25 m high; this scarp continues to the south, where it intersects a fault that extends south of Beaver. Note the small graben at the base of the main fault scarp.
7.6	0.6	T-intersection with Hwy 91 (Manderfield Road). Turn right (N). Road traverses faulted LCB surface for the next 1.5 miles. Note the numerous 1- to 4-m-high north-trending fault scarps at the north end of Last Chance Bench. Hills to the left (W) are formed by a 1-km-wide northwest-trending horst.
8.0	0.4	Sileage pit on right (E) exposes a well-developed calcic soil typical of LCB.
9.3	0.7	Gravel pit on right (E), field trip stop for Anderson and others (1978, p. 18, mileage 171.0), contains a well developed, stage III calcic soil formed in gravels and a moderately developed Bt horizon formed in a mixture of gravel and loess? (see table 1, soil profile 8/8/78-2). The total $CaCO_3$ content of this soil is 78 g/cm^2, 10 percent greater than the 70 g/cm^2 determined at a wetter site, 80 m higher and 3 km to the east.
9.4	0.1	Cross Indian Creek. Road climbs up onto slightly higher surfaces underlain by young to middle terrace and piedmont alluvium.
10.0	0.6	Manderfield. Turn left (W) at abandoned gas station. Proceed west on dirt 1/4-section-line road. Road descends low swales underlain by thin Qpy and ascends broad interfluves of Qpm and Qpo alluvium. These surficial units overlie sandy piedmont-facies (QTsp) of the upper basin-fill.
10.8	0.8	Road climbs up onto the northern edge of an island of Qpo. Directly past the green cattle-feeder trough, the road drops over a 2- to 3-m-high fault scarp formed in Qpo; the road continues west on dissected surfaces of Qpy and Qpm.
11.2	0.4	Abandoned on-ramp to Interstate Hwy I-15.

STOP 4 (OPTIONAL). **Soil developed in old piedmont-slope alluvium (Qpo) overlying sandy piedmont facies of the basin-fill deposits (QTsp)**

The man-made exposure directly east of the underpass is an uncompleted on-ramp to I-15. These cuts are in an elongate, low south-trending hill that is a isolated remnant of a once-more-extensive piedmont-slope deposit. They expose a well-developed soil formed in loess?, old piedmont-slope alluvium, and sandy piedmont-facies of the upper basin-fill. The east and west edges of this hill are buried by middle and young alluvium, and to the south of here, the old alluvium is displaced by a series of down-to-southeast faults. The detailed division of surficial deposits near here and stop 5 (fig. 4) reveal faulted old and middle age alluvium, but rarely faulted young alluvium (see fig. 4).

The soil at this stop (table 5) is representative of old alluvium, although it is not as well developed as at stop 3. The Bt horizon is 60 cm thick, but the zone of clay accumulation is 85 cm thick; the Bt also has 5YR5/6d colors and weak to moderate subangular blocky structure. A maximum of 29 percent clay (<2 mm; 27 percent, whole soil basis) occurs in the B22t horizon compared to 13 percent in the B3ca and 4 percent in the basal part of the alluvium (3Cn horizon).

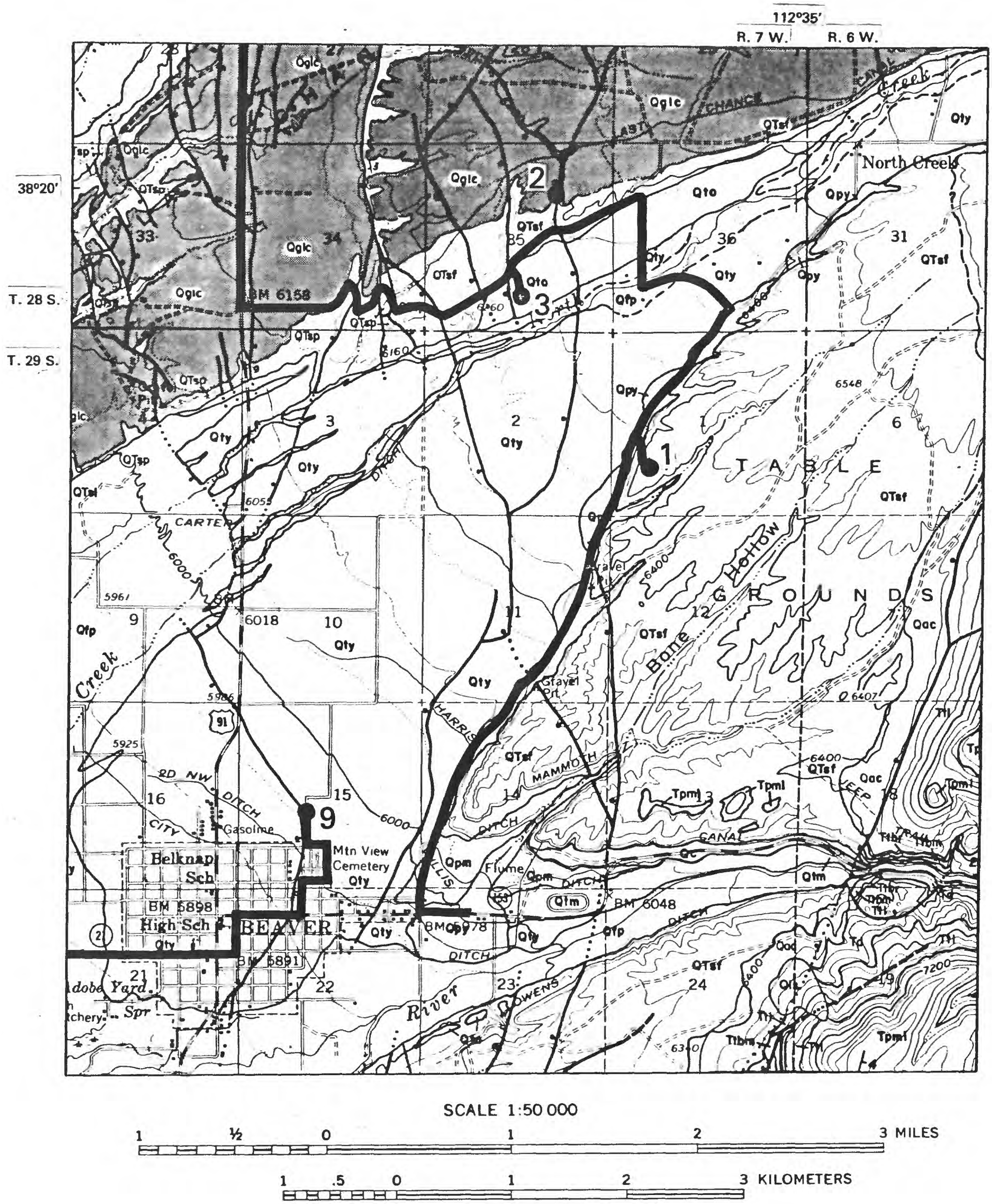


Figure 4. Geologic map of deposits near stops 4 and 5 (from Machette and others, 1981). Map symbols and units are the same as on figures 1 and 2.

Because the B horizon is relatively stone-free (less than 10 percent) and is enriched in silt content (30-40 percent, <2 mm fraction), I think that the parent material for the upper part of this soil may be a sandy loess, partially mixed with the underlying alluvium.

The K horizon, formed mainly in gravelly to very gravelly sands, is thinner (70 cm versus 125 cm) and has $CaCO_3$ more concentrated in thin horizons (47 percent maximum, <2 mm) than at stop 3. $CaCO_3$ is distributed over a total thickness of 118 cm if the calcareous part of the Bt is included. Although the total $CaCO_3$ content for this soil is only 31 g/cm^2, compared to a maximum value of about 38 g (stop 3), the amount is well in the range for old alluvium (table 1).

Table 5. Soil description and selected laboratory data for soil 8/9/78-1, soil on old piedmont alluvium (Qpo, 250,000 yr B.P.), abandoned on-on-ramp to I-15.

Horizon depth, in cm	Color m, moist d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	Percent $CaCO_3$ <2 mm total	Percent gravel total
A/B 0-10	7.5YR3/5m 7.5YR4/4d	L	2fpl	ms,ps	none	21.4 20.0	0.2 .2	6.4
B22t 10-38	7.5YR4/4m 5YR4/5d	CL-	2fsbk	s,pm	none	28.5 27.4	.2 .2	3.9
B23tca 38-52	7.5YR4/5m 5YR5/6d	SCL-	1msbk	ms,ps	I	21.5 19.5	1.7 1.6	9.5
B3ca 52-70	7.5YR6/4m 7.5YR7/4d	SCL	2msbk	ms,ps	II+	13.3 12.8	28.2 27.2	3.7
K22 70-95	n.d.(m) 5YR8/3-2d	gSL+	2mpl	ss,po	III	15.7 8.1	47.3 24.4	48.4
K23 95-115	n.d.(m) 5YR8/3d	vgSL-	1mpl to mass	so,po firm	III	7.7 2.5	36.6 12.0	67.2
C1ca 115-170	n.d.(m) 7.5YR8/2d	vgLS-	mass to sg	so,po loose	III-	3.7 .8	11.0 2.4	77.8
2C2ca 170-230	n.d.(m) 7.5YR7/3d	vgS	sg	so,po loose	I+	4.0 .6	3.8 .6	85.4
3Cn(QTsp) 230+ Base covered	n.d.(m) 10YR5/4d	SiL+	mass	ss,po firm	I vienlets	19.2 19.2	.4 .4	.0

11.5	0.1	I-15 underpass. Proceed west; high juniper-covered surface, named the "Hogsback," is a northern extension of LCB. The gravel that forms the Hogback is 2-5 m thick and contains the same calcic soil as seen on LCB.
11.6	0.5	Turn left on south fork of road.
12.2	0.6	Small patented claim at 3:00 (W) is in the Huckleberry Ridge ash bed (2.0 m.y. B.P.). Although the airfall component is only 5-10 cm thick, the ash is as much as 1.5 m thick in the lacustrine facies due to reworking from adjacent terrain.
12.4	0.2	Road crosses intermittent drainage and climbs up on Qpo. This alluvium is displaced by a series of NE-trending faults that are part of a large, but poorly preserved fault system which controls the course of the ancestral and the modern Indian Creek.
13.1	0.7	Road descends onto terraces along north bank of Indian Creek. Notice small fluvial scarps as we drop from Qpo to Qtm and to Qty. Turn left into parking area, west (upwind we hope) of pig feeding lot.

STOP 5. **Soils developed on middle and young terrace alluvium of Indian Creek**

The parking area for this stop is located on the lower of two rather continuous alluvial terraces that are preserved mainly along the north side of Indian Creek. The lower terrace is 5-6 m above stream level and is underlain by about 3 m of sandy gravel that lies on light-green silty clays of the upper basin fill (QTsl). The upper of the two terraces is 10-13 m above stream level and here is formed by interfingering middle terrace alluvium of Indian Creek and middle piedmont-slope alluvium derived from basin-fill and older surficial deposits to the north. The middle alluvium is displaced by a series of parallel north- to northeast-trending, down-to-the-southwest faults (fig. 4).

The gravel pit in middle terrace alluvium exposes an eroded, yet representative profile of a middle-age soil. The soil has a partially eroded 17-cm-thick Bt horizon with a maximum of 22 percent clay, 8 percent and 20 percent more than the minimum contents of the respective overlying and underlying horizons (table 6). Laboratory data show 15-20 percent clay in the K horizons, indicating the possibility of a deep, engulfed Bt horizon. The Bt has a maximum color of 5YR5/3d, slightly less chroma than old soils.

$CaCO_3$ is concentrated at a shallow depth in this soil, with a maximum content of 32 percent in the K3 horizon (44-60 cm). $CaCO_3$ forms a continuous medium within the soil (stage III), coating and engulfing all clasts and giving the soil matrix a white color. The total $CaCO_3$ content for this soil is 11.6 g/cm^2, about one-third that of old soils and one-sixth that of soils formed in gravels of Last Chance Bench (table 1).

In contrast to the moderately well-developed soil on middle alluvium, the young alluvium exposed near the road, contains a weakly developed stage I calcic horizon and 7.5YR colors in the B and Cox horizons. Data for several other young soils are summarized in table 1 and we will see a noncalareous soil in young alluvium at stop 9.

Table 6. Soil description and selected laboratory data for soil 8/9/78-2, relict soil on middle terrace alluvium of Indian Creek (120,000-140,000 yr B.P.)

Horizon depth, in cm	Color d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	Percent $CaCO_3$ <2 mm total	Percent gravel total
A 0-7	10YR5/2 to 6/2d	L-	2f-1f sbk	ss,ps	none	12.1 11.4	0.2 .2	5.4
B2t 7-13	7.5YR5/3 to 6/3d	L+	1f-wf sbk	ms,pm	none	22.8 19.0	.2 .2	16.5
B3 13-24	5YR5/4 to 7.5YR5/2d	gL	2msbk	ms,ps	none	20.0 15.1	.6 .5	24.6
K2 24-44	white to 7.5YR8/3d	gL	1mpl	ss,ps	III	15.6 10.9	18.9 13.2	30.2
K3 44-60	white to 7.5YR8/2d	SiL	2msbk	n.d.	III	19.1 18.4	31.6 30.4	3.9
2Cca 60-80	7.5YR8/3d	vgSL-	1fsbk to sg	n.d. loose	II to I	5.0 1.5	9.0 2.6	70.6
2Cn 80-100+ Base covered	n.d.	vgS	sg	so,po loose	I-	2.2 .4	3.3 .5	83.3

Continue south across Indian Creek.

14.0 0.9 Road climbs steep, short grade cut on interfingering piedmont and lacustrine facies of the upper basin fill.

14.2 0.2 Crest of hill, turn right (W). Road parallels north edge of LCB from here to our next stop (6), a distance of about 1.8 miles. Most of the surface south of this road junction consists of faulted sections of LCB with scarps of 2-10 m height. Note that most of these surfaces are back-tilted to the southeast, whereas the predominant fault trend is N. to N. 10° E. with down-to-the-west movement. The spacing between faults decreases westward, towards the axis of the LCB antiform.

15.1 0.9 Continue straight (W), past ranch road. This road is one of the few good accesses into the cental part of Indian Creek.

15.7 0.6 Intersection with road to the left (S); continue straight (W) through unlocked gate in section-line fence.

16.4 0.7 Pull off of the road and park among the juniper tress. We should now be at the highest elevation on the central part of Last Chance Bench, on the surface axis of the antiform.

STOP 6. **Last Chance Bench, overview of upper Cenozoic deposits and structure**

This stop provides a convenient point to view and discuss some of the stratigraphic and sedimentary aspects of the upper Cenozic basin-fill deposits. Stop 6 is located on the surface axis of the Last Chance Bench antiform and we can see both east- and west-tilted beds below the gravel mantle (fig. 5). Near the axis, these beds dip as much as 20°, but several kilometers away these beds become nearly conformably with the overlying gravels, indicating a narrow, but intensive, zone of deformation.

The numerous scarps we crossed in route from stop 5 to 6 are produced by the episodic? or continual growth of the antiform. These scarps range from 1- to 2-m-high gentle slopes to 10- to 20-m-high steep escarpments. Drainage from the bench is through a system of ephemeral streams and arroyos which are almost entirely structurally controlled by a combination of west- and east-tilted surfaces, and subparallel fault scarps; these structures tend to concentrate runoff into the south-central part of the bench.

Faulted gravels are exposed along the north rim of Last Chance Bench. In several places, the gravels are downdropped in fault contact with much older basin-fill sediment: the presence of well-developed soils in the gravel indicates that displacement must be fairly recent (post-soil formation). Along the Beaver River, these same faults offset middle alluvium, indicating late Pleistocene movement.

The axis of the antiform was mapped from the pattern of east- and west-tilted surfaces, from the dip of underlying sediments, and from the orientation of the fault scarps (Machette, 1982a). From its southernmost exposure, directly north of the Beaver River, to Wildcat Creek on the north, the axis of the antiform trends about 15° E. of N., and steps to the east, en echelon, through a series of northeast-trending faults (figs. 1 and 5). To the north of stop 6, the axis is located at the west end of the Hogsback and projects northward to the low ridge formed by conglomerate of Maple Flats. This ridge is a the southern extension of the Maple Flats horst.

The upper Cenozoic sediments exposed below the gravel here, and in exposures on the south side of the Hogsback, provide a nearly continuous record of more than 1 m.y. of lacustrine silts, clays, and finely bedded sands deposited in a shallow, but permanent lake. Sandstones with ripple marks and mudcracked claystones also show the lake was shallow during deposition of the upper basin fill.

Five discrete volcanic ashes are preserved in the lacustrine facies of the upper basin fill. The uppermost ash, named the Last Chance Bench ash (Izett, 1981), is white, fine-grained, and about 5 cm thick. The Last Chance Bench ash bed is estimated to be 1.8 m.y. old (Izett, 1982, p. 21) on the basis of its stratigraphic position with respect to other dated units and its chemical and mineralogic similarities with Bishop-type ashes from the Glass Mountain-Long Valley area of California (Izett, 1981). This ash is well exposed about 10-20 m below the gravel of Last Chance Bench on west of the limb of the antiform (fig. 6).

A medium- to coarse-grained, ripple-bedded sandstone crops out 20-25? m below the Last Chance Bench ash, and this sandstone lies about 12-15 m above a second ash in the section, the 2.0-m.y.-old Huckleberry Ridge ash bed (Izett, 1981, 1982; Izett and Wilcox, 1982). The basal Huckleberry Ridge is composed of 5-10 cm of coarse, water-laid airfall ash; it is overlain by 0.8-1.5 m of reworked, finer grained ash with abundant sedimentary and deformational load structures. The Huckleberry Ridge ash bed, interbedded in lacustrine sediment, has been found in 40-50 outcrops in the southern and western parts of the Beaver basin.

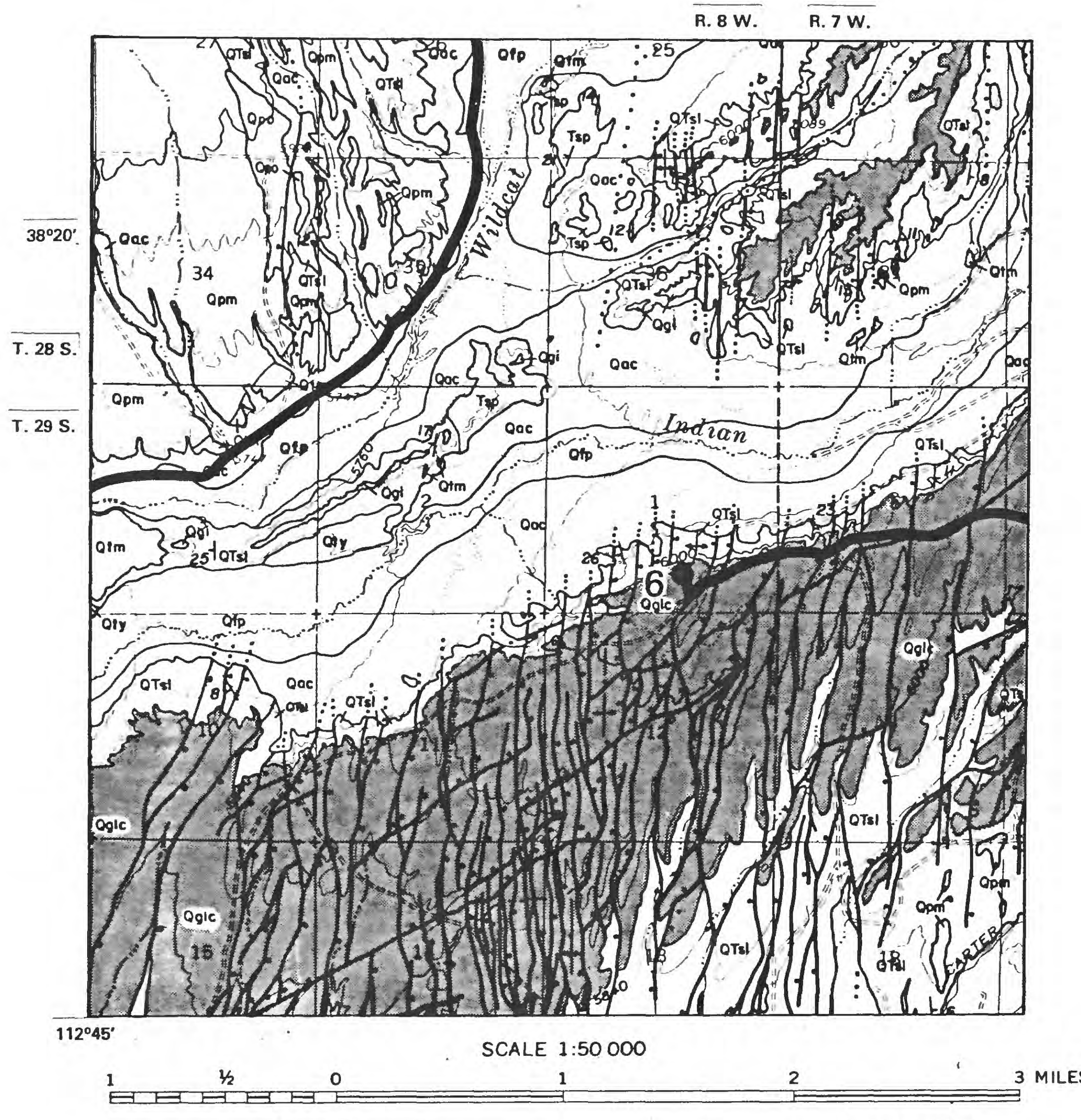


Figure 5. Geologic map of the central part of Last Chance Bench near the antiform crest, stop 6 (from Machette and others, 1981). Map symbols and units are the same as on figures 1 and 2.

An outcrop area known informally as the "triple ash locality", located about 1 km north of Indian Creek (N. 25° E of stop 6), is one of the most important localities in the Beaver basin in that it permits the physical correlation of beds south and north of Indian Creek. In this area, the Huckleberry Ridge ash bed caps a 30-m-thick section that contains a very fine-grained white ash informally named the middle ash bed and, 4 m lower at the base of the section, a coarse-grained obsidian-rich lapilli bed informally named the Indian Creek ash bed (Izett, 1981). These ashes are correlated with the tuff of Taylor Canyon (type-C, 2.1 m.y. B.P., Glass Mountain-Long Valley area; Izett, 1981) and with tephra from the rhyolite of Cudahey Mine? (2.3-2.4 m.y., near Black Rock, Utah; Izett, 1981), respectively.

Another ash, here informally named the Hogsback ash bed, is locally preserved below the Indian Creek ash bed in exposures along the north side of the Hogsback. It is interbedded with varigated light-green silty clays and slightly oxidized, orangish-brown sands. This ash lies about 20 m below the Indian Creek ash and about 50 m below the Huckleberry Ridge ash bed. The Hogsback ash also has chemical and mineralogical affinites that suggest a correlation with the rhyolites of Cudahey Mine and South Twin Peak, although it is much finer grained than the Indian Creek ash. Although the correlation of these ashes are tentative, the suggested ages agree well with other stratigraphic and sedimentalogic evidence.

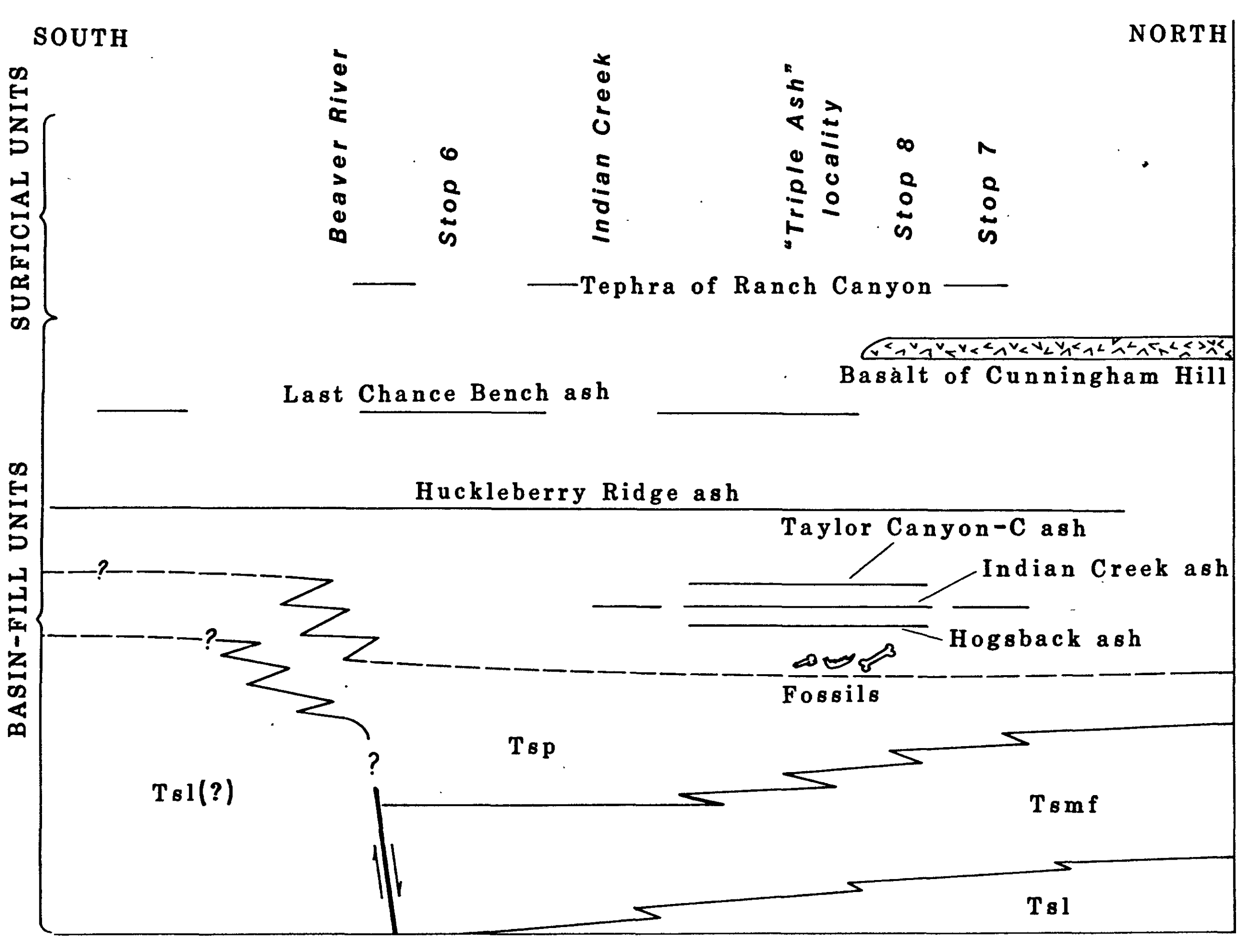


Figure 6. Schematic cross section of sedimentary deposits of the Beaver basin showing position of volcanic ashes. Map symbols and units are the same as on figures 1 and 2.

Fossils collected below the Huckleberry Ridge ash bed, and probably below the Hogsback ash, indicate a late Pliocene age for the enclosing sediments. These fossils, the first Blancan mammalian assembleage collected in Utah, provide more evidence of the Pliocene and Pleistocene history of basin sedimentation. Additional data, in the form of subsurface information, may allow a more complete analysis of Miocene sedimentation and deformation in the basin. For example, the Beaver Lulu Federal No. 1--a 11,400-ft-deep wildcat oil-and-gas test--was drilled at a site 1 1/2 km northeast of stop 6. This well was spudded in Pliocene sediments, about 20 m below the Huckleberry Ridge ash bed, and penetrated about 1,400 m (4,600 ft) of unconsolidated bolson deposits, including thick sections of coarse-grained conglomerates and alternating beds of oxidized and reduced playa? sediments.

To the south of Last Chance Bench, Texaco Minerals has recently completed a uranium exploration program: they had anticipated drilling about 300 wells, 150-500 m deep, to evaluate the potential for in-situ recovery of uranium. Geophysical logs of these drill holes contain a wealth of information from which one could interpretate the subsurface configuration, structure, and facies relations of Pliocene and Miocene sediment in the Beaver basin.

21.1	4.7	Retrace route along north edge of LCB, across Indian Creek and north to Y in road. This route provides a better view of the patented claim in the Huckleberry Ridge ash bed. Take left fork (NW) at Y intersection.
21.4	0.3	Crest of the "Hogsback." Road cuts expose gravel of Last Chance Bench unconformably overlying ostracode and gastropod bearing light-green siltly-clays and light-brown to orangish-brown sands of the lacrustrine facies of the upper basin-fill (QTsl).
21.8	0.4	Road descends the Hogsback. Small knob directly to the left (W) has Huckleberry Ridge ash in fault contact with uplifted older piedmont facies of the upper basin fill (Tsp). The piedmont facies is characterized by reddish-brown, thin-bedded conglomerates and sands, white to very light-brown calcareous marls, and light-brown silty clays.
22.1	0.3	Road makes a sharp left turn and crosses Wildcat Creek. Hills to the west are formed by the basalt of Cunningham Hill (1.1 m.y.) and QTsl and Tsp facies of the upper basin fill. Maple Flats, the high ridge to the north, is a horst formed by conglomerates and the underlying oxidized bolson sediment that comprise the two lowest exposed members of the lower basin fill. The east and west margins of Maple Flats are fault controlled.
23.0	0.9	Continue on road as it turns to the right (NW). Road ascends valley cut in lower basin-fill deposits. Graded dirt road to the left (S) goes around the south end of the southern extension of Maple Flats and affords a good view of deformed sediment between here and the south end of the Hogsback.
24.0	1.0	Road cuts to the right are in west-dipping conglomerate of Maple Flats that is in fault contact with lacustrine (QTsl) and piedmont (QTsp) sediments. The fault extends from south of the basalt of Cunningham Hill (at 9:00) to the drainage divide between the Cove Fort and Beaver basins, 10 km to the north.

24.4	0.4	Road climbs out of arroyo and crests hill. Proceeds northwest to first graded road to the left. Middle? Pleistocene basalt of Crater Knoll (cinder cone at 1:00) is preserved on the eastern flank of this valley. The vents for Crater Knoll and Red Knoll are coincident with the major west-bounding fault of the Maple Flats horst.
26.6	1.8	Turn left (W) and cross Cunningham Wash. The 1.1-m.y.-basalt of Cunningham Hill is poorly exposed in this arroyo. The source vent for the basalt has not been found.
27.0	0.4	Most of the piedmont slope along this portion of the road is formed by a thin mantle of middle alluvium that overlies fluvially deposited tephra of Ranch Canyon.
27.5	0.5	Pull off road at top of hill. As the road turns to the left it will descend into a tributary canyon of Cunningham Wash.

STOP 7. **Cunningham Hill area: Relation between the basalt of Cunningham Hill (1.1 m.y.) and the tephra (pumice) of Ranch Canyon (0.55 m.y.)**

This road cut and exposures to the northwest in a tributary to Cunningham Wash show the relations between middle piedmont alluvium (Qpm), the tephra of Ranch Canyon (Qrct), and the basalt of Cunningham Hill (fig. 7).

The tephra of Ranch Canyon, here a water-laid obsidian pellet and pumice deposit, fills a channel cut below the level of the topographically higher basalt. Locally derived boulders of basalt in the basal part of the channel fill show that the basalt is older than the tephra. Also, the pumice deposit clearly laps up against the valley wall cut adjacent to the basalt, indicating that the pumice does not lie beneath the basalt.

The pumice deposit is at least 10 m thick, as measured in the road cut. Exposures of the pumice in quarries upstream are even thicker, indicating the deep level of stream incision during deposition of the pumice, 0.55 m.y. B.P. Scattered outcrops of the pumice are found near stream level along Cunningham Wash, Wildcat Creek, and Indian Creek as far south as Adamsville. The basalt of Cunningham Hill, erupted 1.1±0.3 m.y. B.P., flowed along an ancestral, southeast-trending channel of Cunningham Wash and projects to a much higher base level than the pumice-filled channel. These relations strongly suggest that middle Pleistocene streams (in this part of the basin) were incised below the early Pleistocene depositional level of the basin and that these streams were flowing towards an outlet at Minersville Canyon, not towards the central part of the basin as they were during the early Pleistocene. The widespead planation of basin-fill deposits, some of which were structurally elevated by the Last Chance Bench antiform, was accomplished soon after 0.55 m.y. B.P., as evidenced by reworked pumice in the basal part of the gravel of Last Chance Bench. Thus, I argue that sediment deposition continued in a closed-basin environment until after 1.1 m.y., but ceased well before 0.55 m.y.

Using these constraints, and the degree of soil development on Last Chance Bench and Table Grounds, I estimate that basin-fill sediments were deposited until about 0.75 m.y. B.P. in the Beaver basin (see discussion at stop 1 and in text). Since 0.75 m.y. B.P. the history of basin sedimentation has been one of drainage integration and base level lowering, extensive lateral planation (Last Chance Bench), and periodic downcutting and subsequent depostion of the old, middle, and young alluvial- fan, piedmont-slope, and terrace deposits.

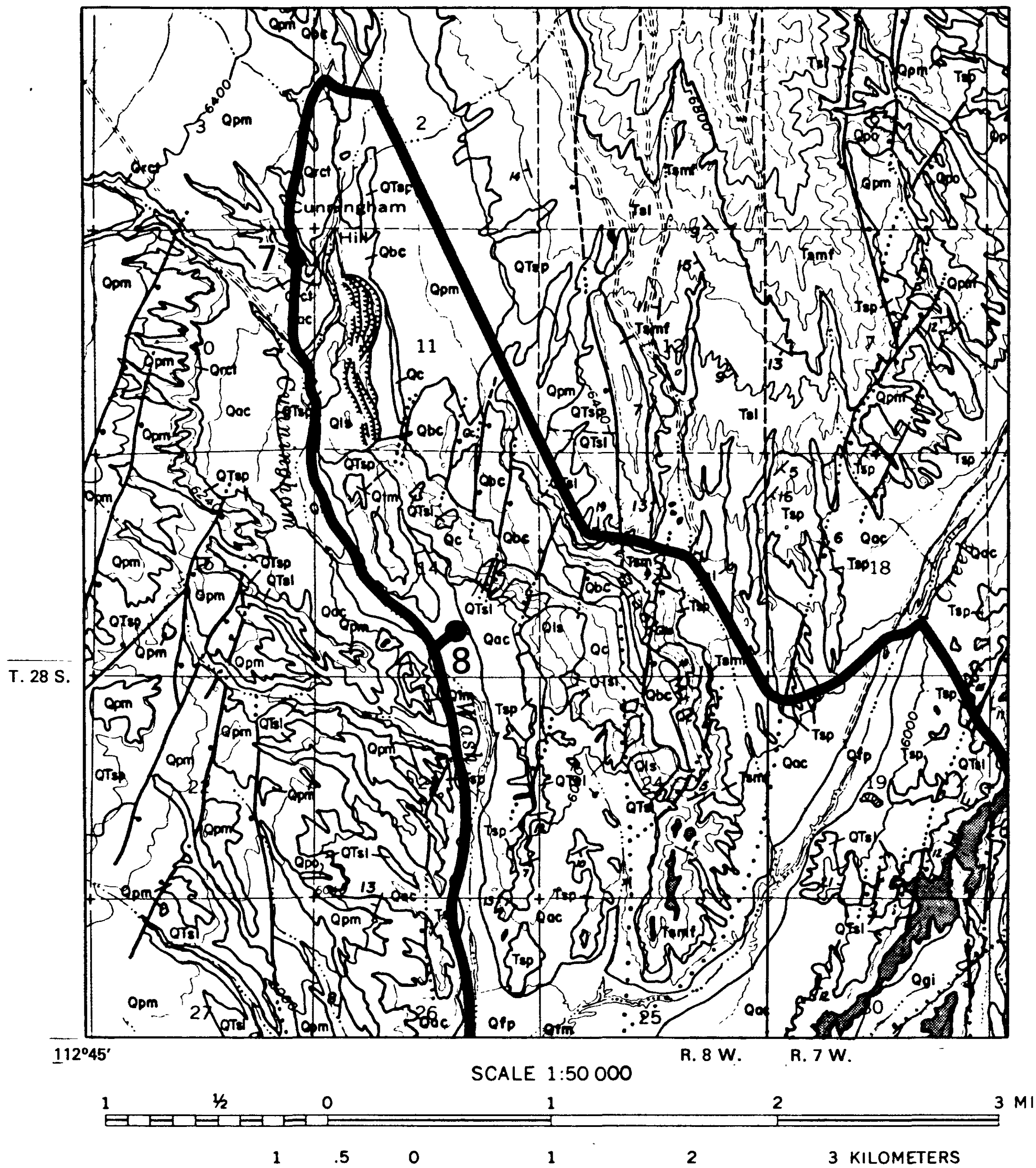


Figure 7. Geologic map of deposits near stops 7 and 8 (from Machette and others, 1981). Map symbols and units are the same as on figures 1 and 2.

27.9	0.4	Note the large landslide mass of toreva blocks. The heavy basalt that forms the high ridge to the left (E) rests on incompetent beds of the upper basin fill. The slide mass is about 1/2 km long and 250 m wide, and has a relief of about 40 m. Old remnants of landslide basalt are present along the east side of the road.
29.3	1.6	Break out into open valley of Cunningham Wash. High remnants of middle and old terrace and piemont-slope alluvium to the east and west indicate the deep incision of Cunningham Wash since middle Pleistocene time. Watch carefully on the left (10:00) for the road that leads to the south end of the basalt of Cunningham Hill. Exit and park on this road. Walk north of the parking area to large bulldozer cut below the basalt.

STOP 8. **Faulted Huckleberry Ridge ash bed and lacustrine facies of basin-fill deposits**

The Huckleberry Ridge ash bed and enclosing lacustrine deposits are well exposed in a bulldozer cut on the southwest side of Black Mountain (the ridge formed by the basalt of Cunningham Hill). The ash bed, exposed intermittently for a distance of 1-2 km along the south side of the ridge, is cut by numerous north-trending, down-to-the-east normal faults (fig. 7). One such fault (N. 50° E., 65° S.), exposed in the west end of the cut, has about 4 m of displacement. Of interest here are the basal airfall part of the ash bed, the overlying horizontally bedded ash, and the flame-like and contorted structures caused by penecontemporaneous loading of the ash bed.

The Huckleberry Ridge ash bed is about 2.2 m thick and is enclosed by lacustrine deposits that dip between about 8° and 12° to the west. These attitudes are consistent with the general dip of beds on the west limb of the antiform and horst. The overlying basalt flow has fault-induced dips of 0-5°, indicating a 5-10° angular unconformity between these two units. Because the lacustrine beds between the ash and the basalt flow must be 1.1-2.0 m.y. in age, uplift of the horst and antiform must have continued into the early Pleistocene. Likewise, the deformation of the basalt flow shows continued post-1.1 m.y. B.P. uplift of the horst and rotation of outlying beds.

From this site we can look due south about 1 1/2 km to the area in which G. A. Izett and J. G. Honey collected the first Blancan land mammals in Utah. The fossils include the zebra Dolichohippus, the muscrat Ondatra cf. O. idahoensis, and the microtine rodent Mimomys meadensis. The small-mammal taxa suggest a Blancan-5 age of 2.0 to 2.5 m.y. B.P. (C. A. Reppening, written commun. to G. A. Izett, 1980). They also collected less diagnostic bones of frog and fish, and teeth and bones of Pliocene horse and mastodon. To date, all of the fossils collected in the Beaver basin are from interbedded lacustrine and piedmont-slope sediments 25 to 50 m below the Huckleberry Ridge ash bed.

		Return to graded dirt road along Cunningham Wash and proceed south.
30.1	0.8	Low ridge at 9:00 (E) is composed of piedmont facies of the lower basin fill (Tsp) and overlying lacustrine facies of the upper basin fill (QTsl). These two units are placed in contact by a north-trending, west-dipping normal fault. Late Pliocene

		fossils were collected from the varigated orangish-brown and light-green sands and silty-clays near the south end of this ridge. The high ridge to the east is formed by the conglomerate of Maple Flats and small remnants of the gravel of Last Chance Bench.
31.3	1.2	Continue straight (S) past junction with road around south end of high ridge. Sediments below the gravel cap of the Hogsback (10:00) contain, in descending order, the Huckleberry Ridge ash bed (2.0 m.y.), the Taylor Canyon-C ash bed (the middle ash, 2.1 m.y.), and the Indian Creek (lower obsidian pellet bed, 2.3-2.4 m.y.?) and the Hogsback ash beds from the Cudahey Mine area (2.3-2.4 m.y.?, Izett, 1981).
32.0	0.7	The low ridge at 12:00 is formed by gravel of ancestral Indian Creek (Qgi) that lies well below Last Chance Bench, but above old terrace alluvium (Qto). The irregular topography of the ridge top is caused by north-trending faults that form the Last Chance Bench antiform to the south.
33.1	1.1	The road cutting off sharply to the left (8:00) was constructed for the Beaver Lulu Federal No. 1, a wildcat oil-and-gas well drilled by Bagder Oil Company in the spring of 1981. The well site lies about 200 m south of Indian Creek and was spudded near the top of the Pliocene, slightly west of the surficial axis of the antiform. The well penetrated 4,600 ft (1,400 m) of Pliocene and Miocene basin fill; unofficial sources said that the well then penetrated thin Cretaceous(?) with a trace of coal, about 4,050 ft of overthickened Middle Jurassic Arapien Formation, about 1,050 ft of Navajo Sandstone, about 1,000 ft of quartzite, about 600 ft of red beds (Moenkopi? Formation), and entered the Kaibab Limestone at about 11,400 ft. The well was reported as dry.
33.7	0.6	Road bends to the right (SW). The Huckleberry Ridge ash crops out as a 15°-west-dipping resistant bed on the west face of the low saddle at 10:00. The Indian Creek ash bed is in base of the saddle, about 30 m lower than the Huckleberry Ridge ash bed. The wide surface to the west of the ridge is formed by middle terrace alluvium (Qtm).
34.9	1.2	Road makes a sharp bend to the left (S). Note the stream-cut embankments along Wildcat Creek on the left (E). These cuts expose the tephra of Ranch Canyon disconformably overlain by middle terrace alluvium. The broad piedmont surfaces to the right (W) are formed mainly by granitic piedmont-slope alluvium (Qpy and Qpm) derived from the Mineral Mountains.
35.5	0.6	On the left (E) the well preserved Indian Creek terraces are formed by young, middle, and old alluvium. The old terrace alluvium forms the highest ridge directly east of the creek and buries west-dipping gravel of Last Chance Bench.
36.8	1.3	Four-way intersection with the Pass Road; continue south to Adamsville. The Pass Road extends northwest across the Mineral Mountains to the Milford Valley.
38.2	1.4	Road passes under powerlines; turn left and continue under powerlines. Merge with road from northwest and cross cattle guard. Directly ahead is the small town of Adamsville.
39.3	1.1	Turn left onto Main Street, Adamsville, Utah. Continue east on this road to intersect Hwy 21.

39.8 0.5 Road cuts on left (N) are in middle and old terrace alluvium of Indian Creek. The Beaver River forms a wide Holocene and late Pleistocene flood plain directly south of the road.

41.4 1.6 Intersection with Hwy 21 (Beaver-Milford). Turn left, proceed about 100 m, and turn right onto Hwy 26 (to Greenville). For the next 2 miles, Hwy 26 lies on old terrace alluvium (Qto) of the Beaver River. Middle alluvium forms a terrace 2-6 m below the old terrace and is present mainly south of the highway. The small north-trending ridges and swales on this road are scarps formed by southward extensions of the same faults that form the Last Chance Bench antiform; they have predominantly down-to-the-east movement in this area (see figure 8 for local geology).

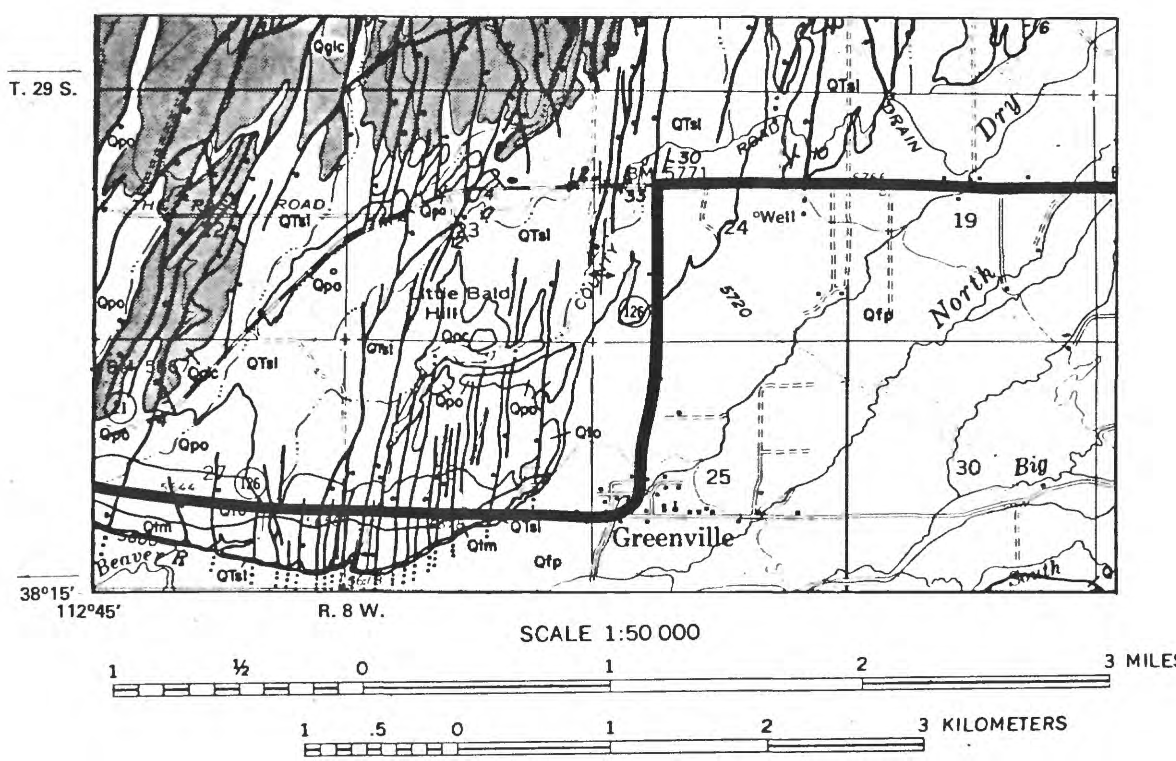


Figure 8. Geologic map of deposits north of the Beaver River showing deformation of surficial units (from Machette and others, 1981). Map symbols and units are the same as on figures 1 and 2.

43.7	2.3	As we drop off the old terrace and onto the Holocene floodplain of North Creek, note the narrow remnant of a southwest-trending middle terrace on which the blue barn is built. A gravel pit directly south of the highway exposes the lower 2 m of middle alluvium (with a Cca horizon) and fluvial sand and overbank? silts and clay of the upper basin fill (QTsl). The basin-fill sediments dip to the east (east limb of antiform) and are displaced by west-dipping normal faults.
44.2	0.5	Greenville, multiple intersection, bear left (NNE). Proceed past the post office (barely noticable on the left).
45.0	0.8	The road crosses the Holocene floodplain of North Creek and local alluvium derived from basin-fill sediment (QTsl) and surfical deposits. The small knolls on both sides of the road are underlain by QTsl.
45.6	0.6	Intersection with Hwy 21, turn right (E). Sileage and barrow pits north of the road have east-dipping fluvial sand, silt, and gravel of early(?) Pleistocene age that are probably some of the youngest basin-fill preserved in the central part of the Beaver basin. The road stays on flood-plain alluvium of North Creek for the next 3 miles.
48.9	3.3	Pass under I-15. At 2:00, the west end of the Table Grounds surface (south of Beaver River) is downdropped to the west about 70 m by a fault that displaces upper Pleistocene alluvium in the town of Beaver (stop 9). The southern of two I-15 exits to Beaver (with gas stations and a restaurant) is built on a downdropped, east-tilted part of Table Grounds. Further to the west, this surface is faulted and downdropped again, probably below stream level. Together, these faults have displaced the Table Grounds surface (0.75 m.y. old) at least 100 m.
49.4	0.5	Main Street, Beaver. Turn left (N) and proceed past Beaver High School, then turn right on Hwy 153.
49.7	0.3	The road rises onto the upthrown surface of faulted young alluvium (Qty) as we pass a blue and white hospital sign on right. The scarp can be traced from the south edge of Beaver, north through Beaver, to North Creek.
50.0	0.3	Turn left on 500 E, proceed north past swimming pool on left and ball field on right. Turn right (E) on 400 N. After crossing the irrigation canal, turn left at the southeast corner of the cemetary. Go one block north, turn left, then turn right, into the Beaver Ready Mix plant. Stop 9 is about 250 m north of the entrance to the plant.

STOP 9. **Morphology of upper Pleistocene faults near Beaver and soil in faulted young alluvium**

Almost the entire area between the Beaver River, on the south, and North Creek, on the north, is underlain by uppermost Pleistocene gravel that is time equivalent to glacial deposits of the Pinedale glaciation in the Rocky Mountains (terminology of Colman and Pierce, 1981). These gravels form an extensive, largely featureless plain which is broken by several faults with 1- to 3-m-high scarps. The most basinward of these faults, here informally named the Beaver fault (fault No. 48 of Steer, 1980), extends from well south of the Beaver River to North Creek where it splays into two branches (fig. 3).

The Beaver fault forms a well-defined scarp in the town of Beaver and north to the KOA campground. During an informal field trip to this stop in 1979, the proprietor of the Ready Mix Plant dug a pit at base of a pre-existing trench across the fault scarp. This pit exposed faulted gravels that are buried by a thin wedge of scarp colluvium, indicating that the total throw in the gravels is slightly more than the 2.5 m height of the fault scarp.

Scarps profiles were measured by H. M. Steer (1980) and R. E. anderson (written commun., 1982) along the Beaver fault and a similar fault (no. 49) about 1 km to the east of Stop 9. These fault scarps have maximum scarp-slope angle (θ) and height (H) values (fig. 9) that are similar to, but slightly less degraded than, the highest wave-cut shoreline of Lake Bonneville (Bucknam and Anderson, 1979) which was formed 14,000-15,000 yr B.P. (W. E. Scott, written commun., 1981). These fault scarps are more degraded than the scarps of the Drum Mountains, which are probably of Holocene age. These data indicate that the low scarps along the Beaver fault (less than 3 m high) must have been formed during the late Pleistocene or early Holocene. Recurrent movement of the Beaver fault and other faults in this part of the basin is shown by the large range of scarp heights (10-70 m) formed in deposits of late to early Pleistocene age.

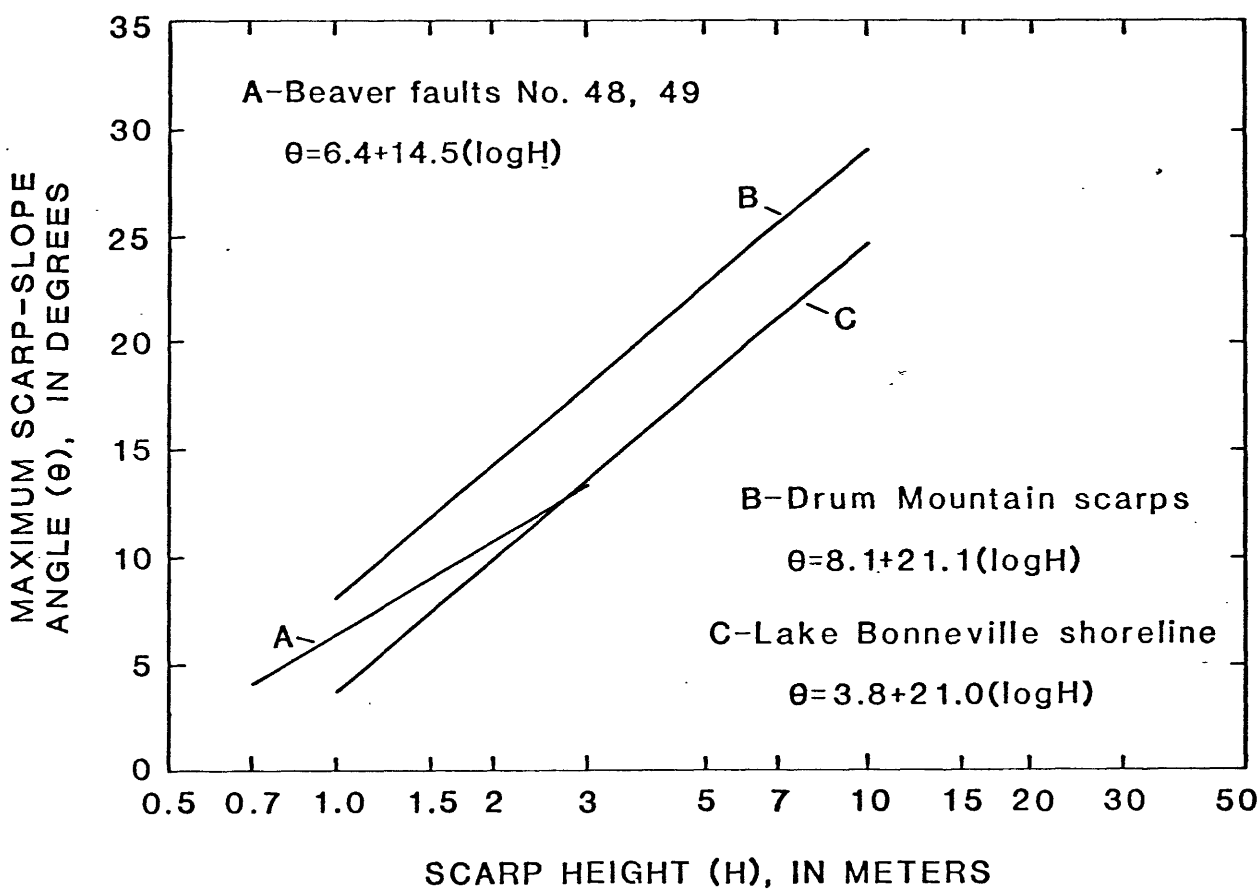


Figure 9. Morphometric data for two late Pleistocene fault scarps near Beaver.

The soil exposed on the upthrown side of the Beaver fault is typical of those formed on young gravelly alluvium of the Beaver basin (tables 1 and 6). These soils usually have A and B1 horizons formed in fine-grained deposits that overlie a weak argillic B2 and oxidized C horizon in loose sandy gravels. This B horizon has a clay content of 18 to 22 percent which, although about 15 percent more than the underlying gravels, is not proof of pedogenic clay accumulation. The colors of the B horizon (7.5YR) are significantly redder than its parent materials at the time of deposition, but are less red than those of the Cox and Cca horizons, indicating probable groundwater oxidation of the soil parent materials.

Near-surface water levels in the floodplain between the Beaver River and North Creek have prevented significant accumulation of $CaCO_3$ in the soil. $CaCO_3$ is present in these soils, but commonly forms only thin discontinuous coatings on clasts to a depth of more than a meter, whereas the soils formed in young alluvium along Indian Creek have as much as 2 percent $CaCO_3$ that forms continuous stage I coatings on gravel clasts and on the sandy matrix.

Table 7. Soil description and selected laboratory data of soil 8/8/78-1, relict soil on young alluvium of North Creek, Beaver Ready Mix Plant.

Horizon depth, in cm	Color m, moist d, dry	Texture	Structure	Consistence wet dry	$CaCO_3$ stage	Percent clay <2 mm total	Percent $CaCO_3$ <2 mm total	Percent gravel total
Spoil								
A 0-7	7.5YR3/3m 7.5YR5/3d	gL	1mpl	ss,ps friable	none	18.3 12.6	tr 0.0	30.9
B1 7-18	7.5YR3/4m 7.5YR5/3d	L+	2m-1f sbk	ss,ps firm	none	21.6 18.7	tr .0	13.4
2B2 18-37	5YR3/4m 5YR3.5/5d	vgSL+	1msbk to sg	ss,po loose	none	18.3 4.2	tr .0	76.9
2Cox 37-66	n.d.(m) 5YR4.5/6d	vgS	sg	so,po loose	I-	4.8 1.1	tr .0	76.6
2Cca 66-107	n.d.(m) 5YR5/4 to 5YR6/2.5d	vgLS	sg	ss,po loose	I	9.3 1.8	0.4 .3	80.2
Base covered								

End of field-trip road log. Retrace route to Hwy 153; turn left (E) to Beaver Canyon Campground or right (W) to Beaver.

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