SOIL-GEOMORPHIC RELATIONSHIPS NEAR ROCKY FLATS, BOULDER AND GOLDEN, COLORADO AREA, WITH A STOP AT THE PRE-FOUNTAIN FORMATION PALEOSOL OF WAHLSTROM (1948)

By
Peter W. Birkeland
Department of Geological Sciences
University of Colorado
Boulder, CO 80309-0250

Daniel C. Miller
Parsons Brinckerhoff Energy Services, Inc.
1660 Lincoln Street, Suite 2000
Denver, CO 80264

Penny E. Patterson
Exxon Production Research Company
P.O. Box 2189
Houston, TX 77252

Alan B. Price
Natural Resources Conservation Service
655 Parfet Street, Room E200C
Lakewood, CO 80215

Ralph R. Shroba
U.S. Geological Survey
Box 25046
Federal Center
Denver, CO 80225

INTRODUCTION

The zero mileage for the trip will begin in Boulder (Fig. 1, a and b). On the way to Boulder you will be crossing various drainages and drainage divides, and the geology along the route is taken from compilations by Colton (1978) and Trimble and Machette (1979); they drew on the original work of Hunt (1954), Malde (1955), Scott (1963), Wells (1967), and Machette (1975, 1977).

The Quaternary alluvial deposits form floodplains and flights of terraces, both along the mainstem of the South Platte River, and the numerous tributaries that flow out of the Front Range to eventually join the South Platte River (Fig. 2). Madole (1991) reviews the dating of these deposits. The Holocene deposits (pre-Piney Creek, Piney Creek, post-Piney Creek) have been radiocarbon dated, and the older ones dated either by U-series dating of bone (Szabo, 1980) or association with the Lava Creek ash of 0.64 myr. The Broadway Alluvium is considered to correlate with the Pinedale glaciation (ca. oxygen-isotope stage 2), and the Louviers Alluvium with the Bull Lake glaciation (ca. oxygen-isotope stage 6); two U-series dates on bone in Louviers Alluvium are 129 +/- 10 ka and 86 +/- 6 ka. A U-series date on a horn core in Slocum Alluvium is 190 +/- 50 ka. The Verdos Alluvium is dated by the included Lava Creek ash. Rocky Flats Alluvium is not dated, nor is the next older deposit, the Nussbaum Alluvium (not shown in Fig. 1).

All workers have used soils to some extent in mapping the Quaternary alluvial deposits. However, Machette (1975, 1977, 1985) quantified the soil properties and has presented the latest laboratory data and descriptions (Fig. 3; see also Machette and others, 1976). Soils formed on Holocene deposits generally are A/Cu for the youngest deposit, and A/Bw and/or Bk profiles for the older deposits. Soils on Broadway Alluvium have A/Bw profiles on coarse-grained facies, and A/Bt/Bk on finer-grained facies. Carbonate morphology of soils formed on Broadway and younger alluviums is stage I of Gile and others (1966). Soils formed

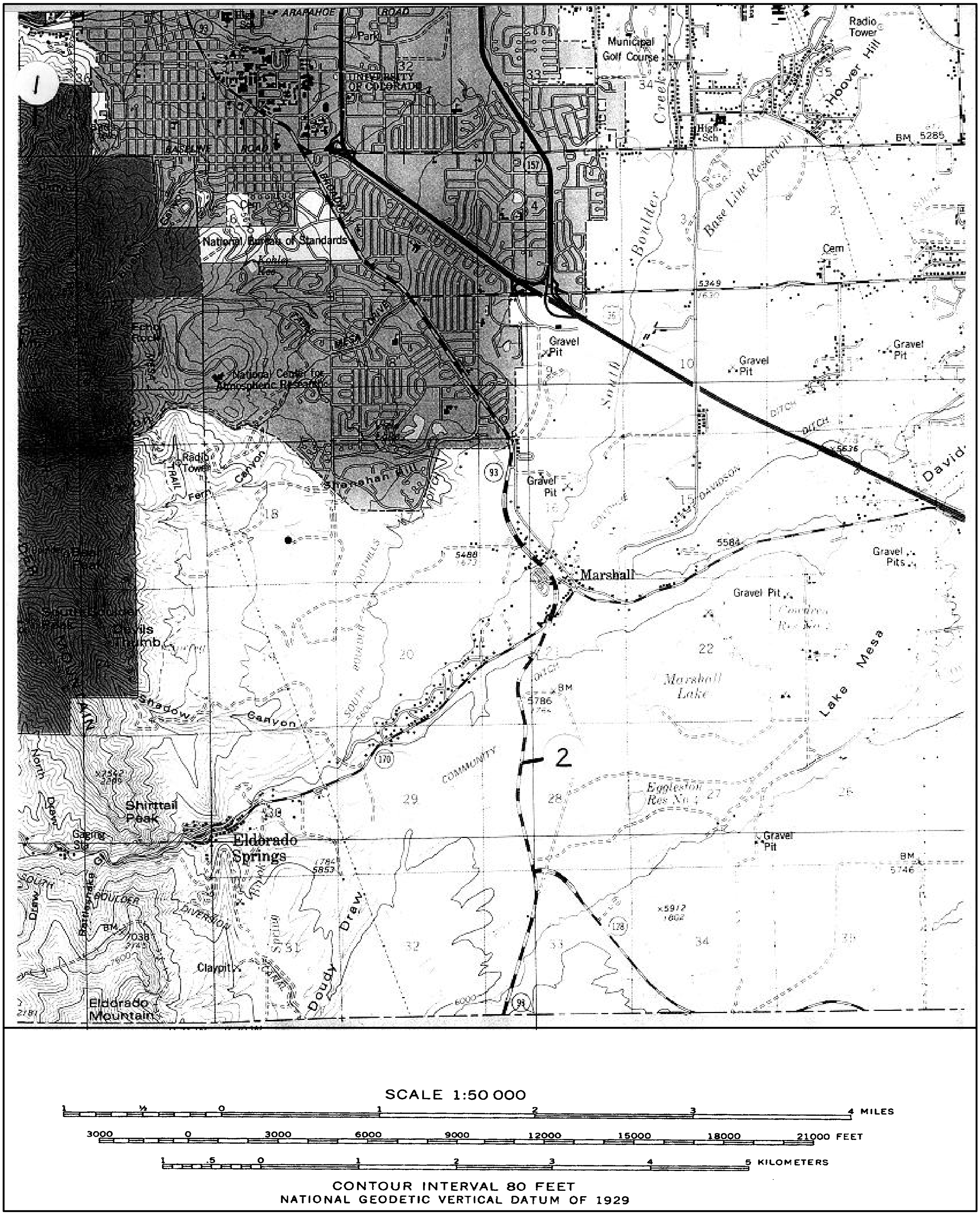

Figure 1a. Map of field trip stops in Boulder County

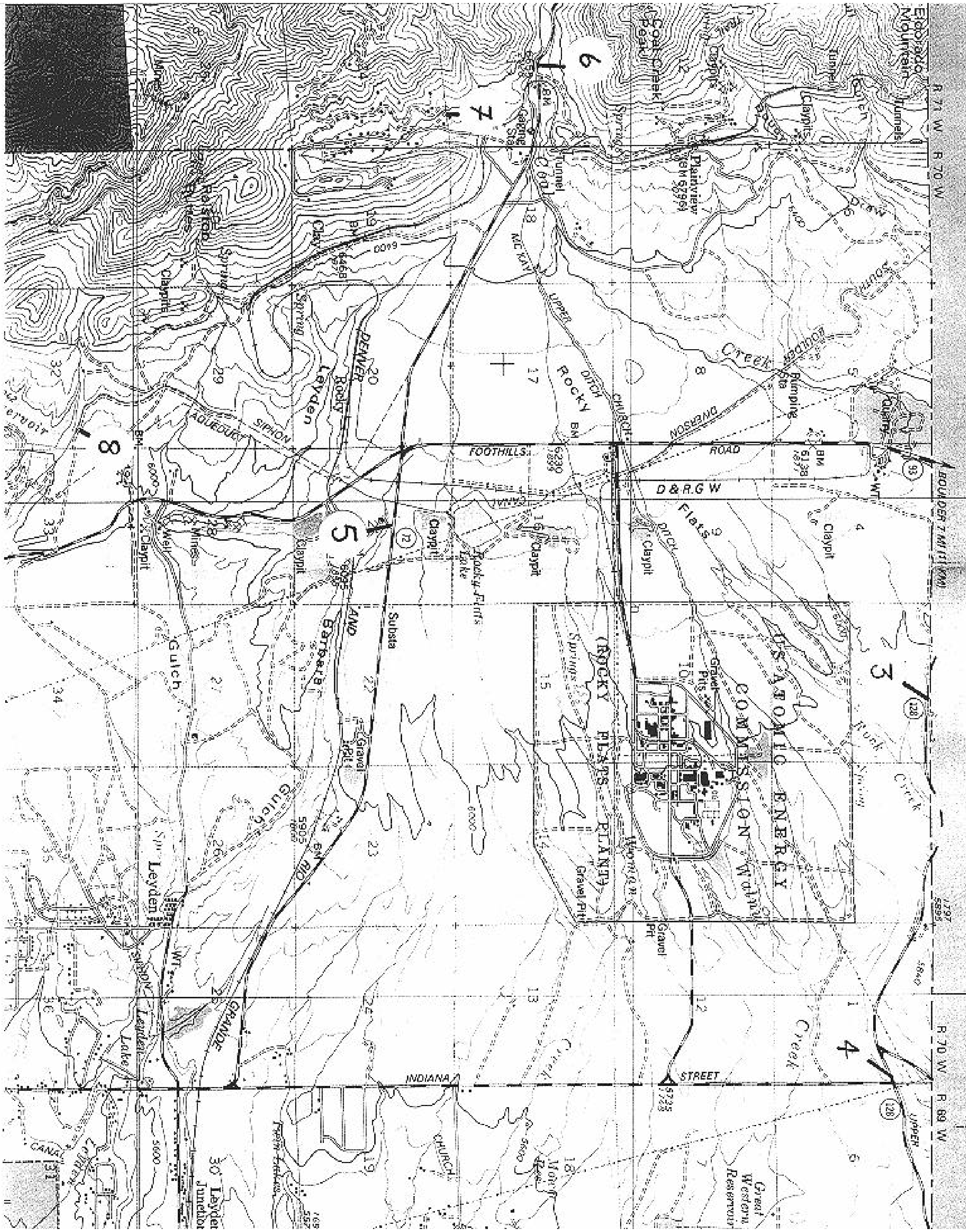

Figure 1b. Map of field trip stops in Jefferson County

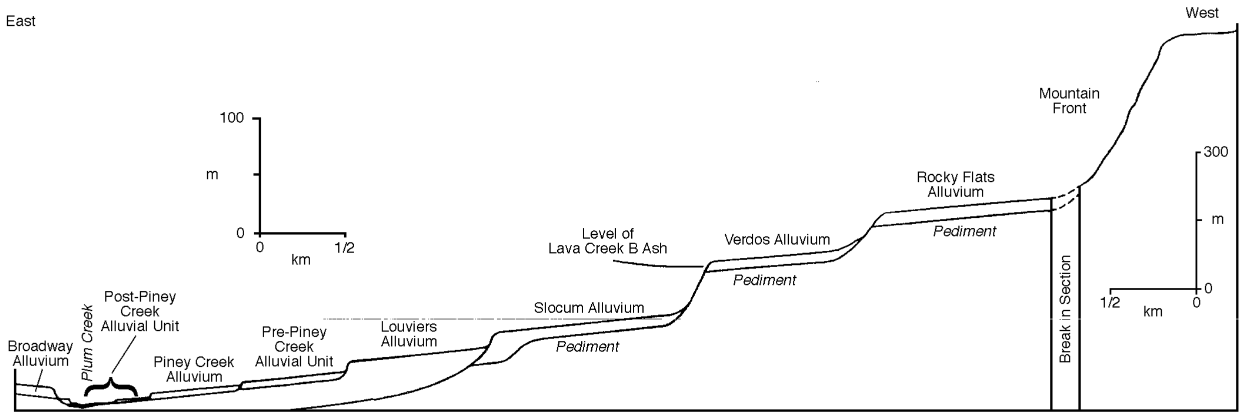

Figure 2. Diagrammatic cross-section showing the Quaternary alluvial units in the Denver area (diagram of Scott, 1963, modified by Madole, 1991)

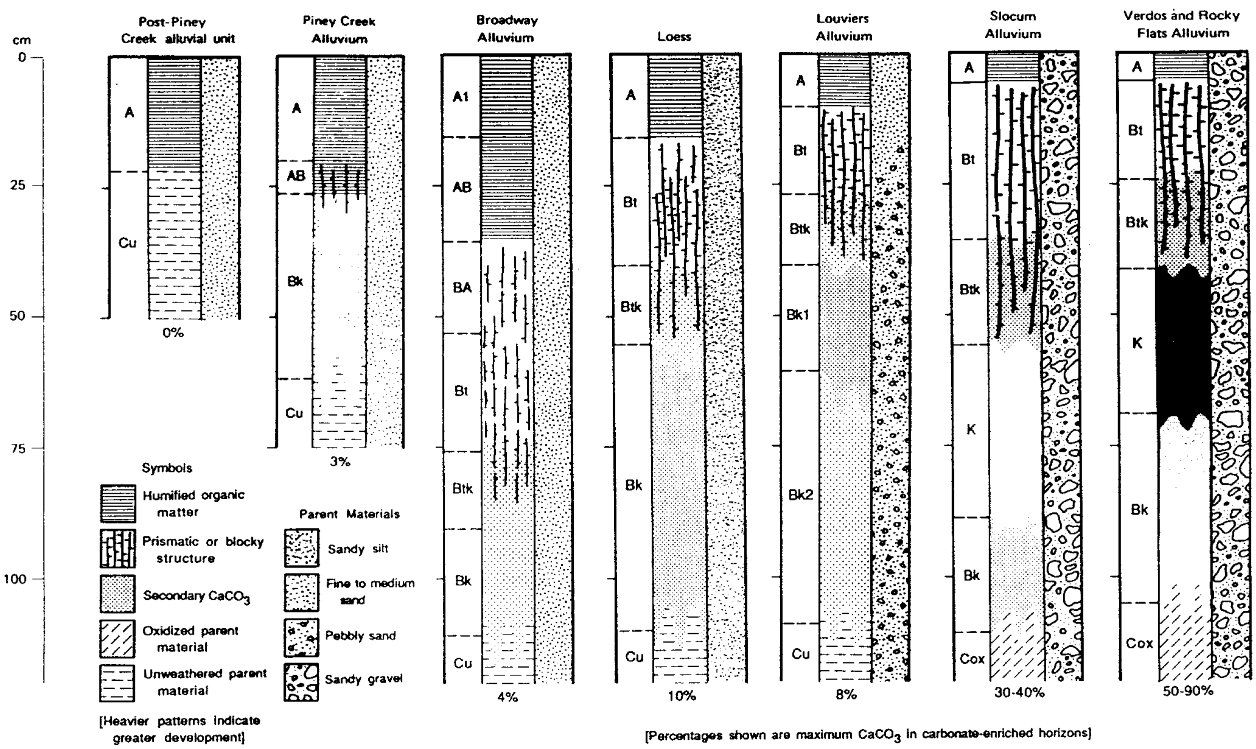

Figure 3. Cross-section of the pre-Fountain weathered zone formed in granodiorite at Contact Corner (from Wahlstrom, 1948)

on loess considered to be of the same age as the Broadway Alluvium also have A/Bt/Bk profile form (Fig. 3; see also Reheis, 1980). Soils formed on Louviers Alluvium have A/Bt/Bk, and stage II or III carbonate morphology. Soils on older deposits have progressively thicker horizons, and redder colors and increasingly greater clay content in the Bt horizons. Slocum Alluvium (ca. 240 ka, Madole, 1991) is the youngest deposit to have a soil with a K horizon (stage III), that on Verdos Alluvium has stage III to IV morphology, and those on Rocky Flats and older deposits have stage IV morphology. The soil on the Rocky Flats Alluvium has maximum development for the area.

DENVER TO BOULDER

The South Platte River flows through downtown Denver and along its banks are Broadway and younger deposits. Downwind of these deposits (to the southeast) are eolian sands, the older ones of which should be laterally contemporaneous with loess farther downwind (Broadway equivalent). As we turn onto the Boulder Turnpike (Highway 36) we cross a high divide capped with Rocky Flats Alluvium, but most of the landscape is mantled with loess. Off to the west you can see the Rocky Flats surface. Next Drainage crossing is Big Dry Creek, flanked by terraces underlain by Slocum and younger alluviums. The route gradually ascends to the next divide at Broomfield and the terrace to the west is underlain with Verdos Alluvium. The next drainage is Rock Creek, and the drainage divide beyond it is underlain by Verdos Alluvium. The route then descends to Coal Creek (Superior and Louisville exit), the first of the creeks we have been crossing that drains from the mountains; the others head in the piedmont. Davidson Mesa is the next divide, underlain by Verdos Alluvium, and it provides excellent views of Boulder Valley, the Flatirons, and the Front Range (including the erosion surface). The next drainage is South Boulder Creek, flanked on the south by terraces underlain with Slocum and Louviers Alluviums, and to the north the southernmost houses in Boulder are on Slocum Alluvium. Just after the high-rise residence halls east of the highway, take the exit to Baseline, turn west toward the mountains staying on Baseline. The junction of

Baseline and Broadway is the zero mileage for the start of the road log.

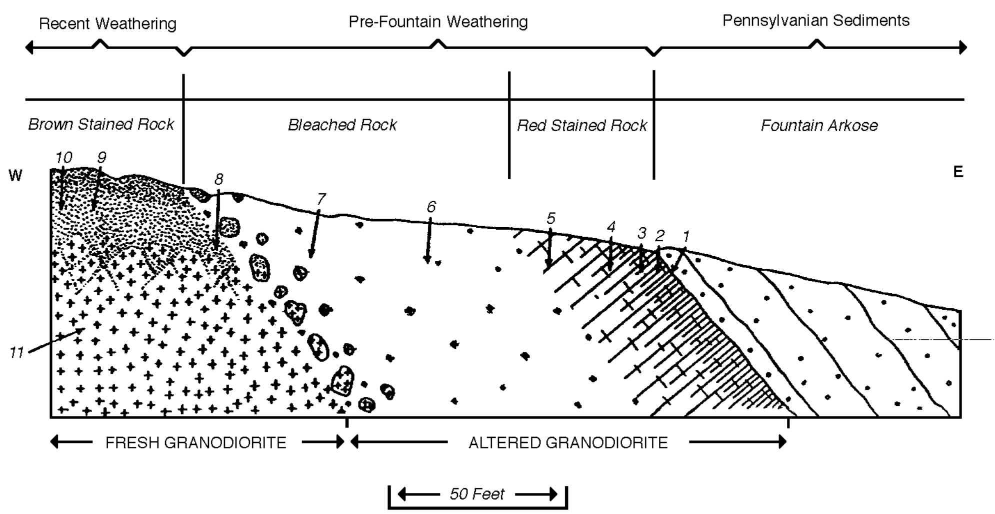

Figure 4. Cross-section of the pre-Fountain weathered zone formed in granodiorite at Contact Corner (from Wahlstrom, 1948)

ROAD LOG

0.0 Junction of Baseline and Broadway in Boulder (Fig. 1a). Proceed west on Baseline. As the road climbs steeply to the right after crossing the mouth of Gregory Canyon, a high angle west-dipping reverse fault is crossed that brings Fountain Formation (to the west) in contact with Niobrara Formation (to the east). To the right can be seen the landslides that moved during the wet spring of 1995, threatened to take out the road, and endangered the houses below. Ahead a park opens up to the left; this is the surface of a large landslide. This is a rotational slide as shown by the relatively flat dip of the Fountain Formation, in contrast to the steep dips of the surrounding in-place Fountain Formation. Huge rocks in the steep front of the slide are of some concern to home owners below. The road winds through many exposures of the Fountain Formation, a haven for rock climbers.

3.6 STOP 1. At a tight turn to the left, pull off to the right into a parking lot. This is “contact corner”, an excellent exposure of the contact between the Boulder Creek Granodiorite and the overlying Fountain Formation (Fig. 4). Wahlstrom (1948) studied the weathering profile in the granodiorite and his abstract is as follows:

“Decomposition of granodiorite underlying basal Fountain (Pennsylvanian) Formation…was the result of pre-Fountain, probably post-Madison weathering. Chemical and mineralogical studies indicate that the weathering took place in a humid, warm or hot climate and that laterization was the dominant process. The results of pre-Fountain and recent weathering are compared and contrasted. The red color of the Fountain Formation is regarded as inherited from a deeply weathered extensive red-stained pre-Fountain regolith.”

Wahlstrom (1948) was one of the first to provide detailed chemical analyses of pre-Quaternary weathering profiles. The recent profile, associated with the present geomorphic surface, is oxidized with brown colors, shows only a slight increase in Al_2O_3 toward the surface, decrease in CaO, and conversion of FeO to Fe_2O_3. In contrast, pre-

Fountain weathering is deep (80 ft) and characterized by red coloration, depletion of SiO_2, Na_2O, CaO, and FeO toward the paleosurface, and the accumulation of Al_2O_3 and Fe_2O_3. Many primary minerals are altered and depleted in the weathering profile, kaolinite is common throughout the profile whereas montmorillonite is common toward the base and illite toward the top. Later, Power (1963) re-studied the clay mineralogy and showed that illite-montmorillonite was dominate throughout, with illite in high amounts at the top of the profile; kaolinite and montmorillonite are present at depth.

Here we will discuss (a) the evidence for a paleosol, (b) the origins of weathering trends and (c), the paleoclimatic implications of the data. We feel that the evidence for a paleosol is weak, that duration of leaching adequately explains the oxide trends, and concur with Power (1963) that laterization (in the context of the formation of an Oxisol-like profile) has not taken place. We will also discuss if the chemical trends require surface exposure.

This is a famous locality and accepted by others as exhibiting evidence of surface weathering prior to burial. Barrientos and Selverstone (1987), for example, used these oxide trends to help demonstrate the presence of metamorphosed paleosols in the Alps, although this has been challenged (Williams, 1988; Barrientos and Selverstone, 1988). Nesbitt and Young (1989) used Wahlstrom's (1948) data to suggest the effects of diagenesis on both the chemical and mineralogical trends in the profile.

The color variation in the overlying Fountain Formation contains relationships important to paleosol research. Here the color is texturally controlled, that is the fine-grained facies is red and the coarse-grained facies is white. Some of us have noticed a similar relation in many areas in the western USA where paleosols are said to be present. Patterson (1990) quantified similar coloration patterns with texture in Eocene strata in Wyoming, and concluded they were diagenetic in origin. The hypothesis is as follows. Following deposition and burial, oxidizing conditions prevailed and the section turned red due to a hematite pigment. At a later time the intrastratal waters became relatively reducing, and this resulted in preferential leaching of the red pigment, but mainly from the coarser-grained strata.

Anyone working on paleosols should be aware of these diagenetically produced color patterns. It goes without saying that at the University of Colorado we have been strongly influenced by the diagenetic origin of redbeds by Walker (1967a). Walker (1967b, 1974) also worked on the problem of inherited red color in redbeds (see last part of Wahlstrom abstract), and has shown that such inheritance is unlikely in many environments.

We end by noting that although some of Wahlstrom's (1948) conclusions have been changed by later work, he was a real pioneer in these kinds of studies. Not bad for one of America's foremost petrologists and optical mineralogists.

Retrace your route down the mountain, heading east on Baseline (40th Parallel).

7.2 Turn right on Broadway, heading south.

9.4 Junction with Table Mesa (Mesa Mesa?) Drive; continue straight ahead on Slocum Alluvium. After leaving the southernmost houses in Boulder, the route drops down to a lower terrace underlain by the Louviers Alluvium. We are heading south on Highway 93. We are in the Louisville 7.5' quadrangle, and the original surficial mapping was done by Malde (1955), another legacy of the presence of the U.S. Geological Survey in Denver.

11.6 South Boulder Creek, flanked by Holocene alluvium.

11.8 Exposure on the right shows Slocum Alluvium overlying Fox Hills Sandstone. Continue south on Highway 93 at the intersection to Eldorado Springs, site of the honeymoon of Mamie and Dwight Eisenhower, and now a premier rock climbing area.

13.2 STOP 2. Before the top of the hill, pull off to the right into a large parking area. This is a good place from which to view the geomorphic surfaces present in the area, in front of the spectacular flatirons. The oldest surface forms the skyline to the right of the flatirons, and is an extensive erosion surface common to the western part of the Front Range (reviewed by Bradley, 1987). Scott and Taylor (1986) have mapped these from the Wyoming border southward to Pueblo. The surface here is considered to be late Eocene and has a patch of bouldery alluvium on it of Miocene age. The boulders are so large that early workers contemplated a glacial origin for the deposit.

Most of the Quaternary deposits of Scott (1963) are present here (see Fig. 3). The red NCAR building rests on the Rocky Flats Alluvium, and several other high remnants of it can be seen to the south. The small canyon north of South Boulder Creek is Shadow Canyon, and Rocky Flats Alluvium caps the high terrace north of the canyon, whereas the lower terrace south of the canyon is underlain by Verdos Alluvium. The widespread fan with the enormous boulders (as high as some pine trees) at the mouth of the canyon, between the terrace remnants just mentioned, is Slocum Alluvium. The large boulders probably were deposited by debris flows. South of South Boulder Creek are widespread terrace remnants also underlain by Slocum Alluvium. All of the alluviums here are sufficiently thin that the terraces can be considered straths.

Discussion here should include (a) timing of alluvial deposition as some streams were glaciated and others were not and (b), method of correlation of the deposits over long distances.

Continue south on Highway 93.

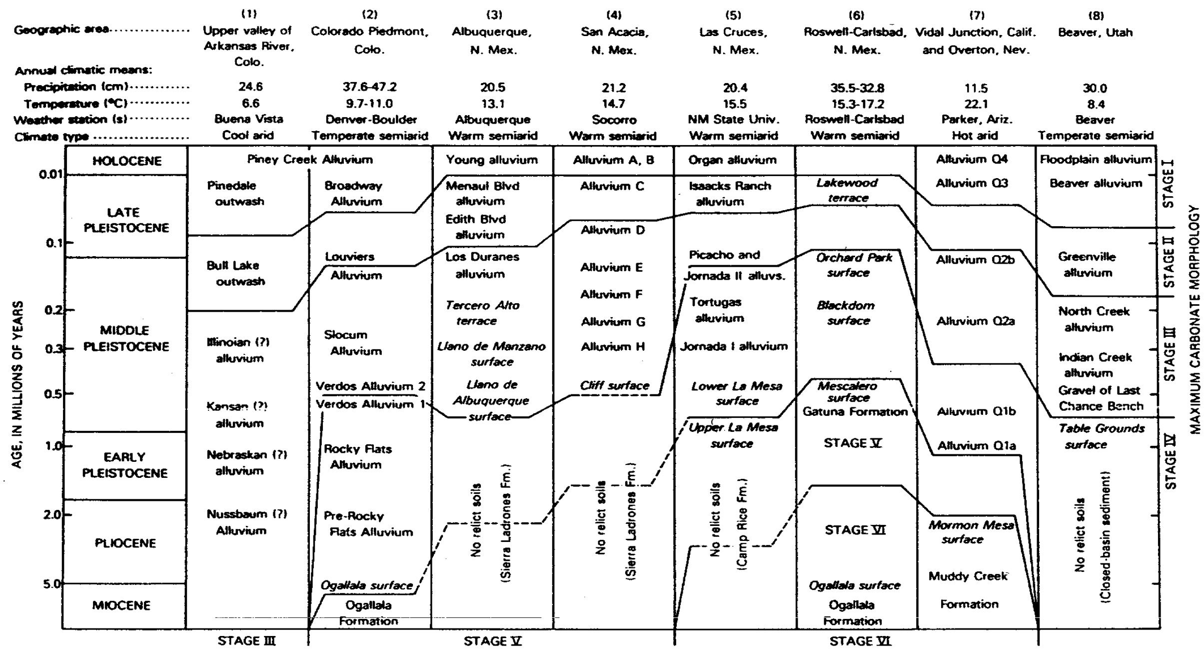

Figure 5. Maximum stages of carbonate morphology in gravelly soils of different ages in the southwestern United States (from Machette, 1985)

13.4 Extensive terrace underlain by Rocky Flats Alluvium. The large surface known as Rocky Flats is in the distance.

13.8 Junction with Highway 128. Turn left onto Highway 128. Route is on Slocum Alluvium and soon the route drops down to the Louviers Alluvium.

14.3 Coal Creek, a creek that was never glaciated and the one that carved the extensive surface that Rocky Flats Alluvium lies on.

15.7 STOP 3. Pull off to the right into a large parking area, 0.3 mi beyond a road that goes off to the right to the “windmill farm”. We are on the north end of the Rocky Flats surface, looking south to the buildings of the Rocky Flats site. Malde (1955) first mapped the area, and Shroba and Carrara (1996) have described and mapped the surficial geology of the site and vicinity at a scale of 1:6,000 using current stratigraphic nomenclature.

The Rocky Flats Alluvium is mainly 1-10 m thick, and locally as much as 30 m or more. It rests on an irregular bedrock surface. The clast composition (see exposure across the road) is dominated by quartzite (70-80%) and granodiorite and gneiss (10-20%). The quartzite crops out for several kilometers in the lower part of Coal Creek Canyon, but the bulk of the drainage is underlain by granodiorite and high-grade metamorphic rocks. Apparently, the quartzite outcrops were the main contributors of clasts to the alluvium. We do not know if the alluvium was deposited during a glacial or an interglacial, although Madole (1991) favors a glacial age. If this is so, we might expect a greater content of granodiorite and gneiss clasts in the alluvium contributed by periglacial activity in the headwaters region, provided that the stream gradients were sufficient to transport the clasts.

Landslides are numerous along the margins of the Rocky Flats surface. From here, landslides are prominent along the south slopes of Rock Creek valley. Flows, slumps, slides, and complex landslides are recognized. Landslide ages range from middle(?) Pleistocene to the present, and most are very young. The latter have crescentic head scarps and lobate toes. Landsliding probably began soon after the streams cut through the Rocky Flats Alluvium and exposed the underlying Upper Cretaceous bedrock. Factors contributing to the extensive landsliding include (a) local saturation by the perched water table at the Rocky Flats alluvium/bedrock contact (note the springs and seeps along the contact) and (b), unstable slopes underlain by bedrock prone to failure because of numerous bedding planes that can serve as slip surfaces, and abundant claystone with expansive clays (Cararra and Shroba, 1994).

Continue eastward along Highway 128.

16.3 Cross Rock Creek. In the roadcut ahead on the right are recent landslides that expose Rocky Flats Alluvium.

17.0 Calcic soil in Rocky Flats alluvium on left. If time

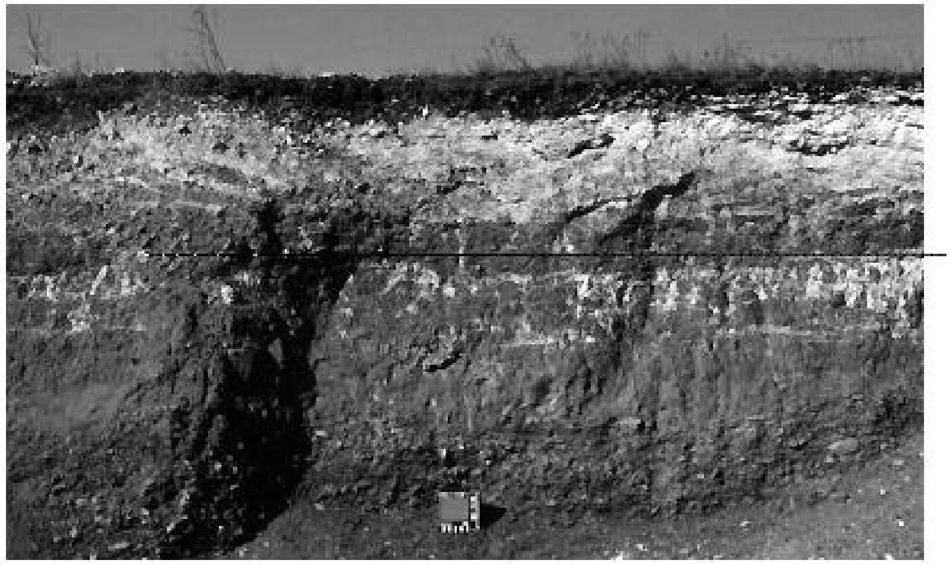

Figure 6. Photograph of the soil at the type locality of the Rocky Flats Alluvium. The vertical arrangement of horizons is: A/KIm/K/Btk/2Btkb (about one-half way below the top; has prominent carbonate accumulation) /3Coxb

allows we may make a brief stop to see the cemented K horizon.

18.0 STOP 4. Pull into a large parking lot on the left, after the intersection with McCaslin Boulevard. Walk east to the stop light on Indiana Street, then south along Indiana to a calcic soil exposed in a high roadcut.

This small terrace remnant is Verdos Alluvium. One can see the scarp leading up to the Rocky Flats alluvium northwest of here. Here a thin deposit of gravel rests on the Arapahoe Formation (Upper Cretaceous, nonmarine). A clast-lithology count by Shroba and Carrara (1996) lists 81% quartzite and 9% granite and gneiss. This small drainage, Walnut Creek, heads on Rocky Flats, so the gravel here is reworked Rocky Flats Alluvium. Perhaps weathering and reworking accounts for the slightly greater content of quartzite clasts versus those in the Rocky Flats Alluvium.

The soil here is a A/Bt/K profile with stage III carbonate morphology (compare with Fig. 3). The thickness and color of the Bt are not what we expect for an uneroded soil on the Verdos, so we suspect the A and Bt are formed in younger colluvium derived from the nearby scarp in Rocky Flats Alluvium. The main reason for the stop, however, is to view the K horizon. Machette (1985) has stage III morphology as characteristic of younger Verdos and stage IV as characteristic of older Verdos, in his useful chart of stage = age (Fig. 5). We will use this information at the last stop to help constrain the age of the Rocky Flats Alluvium.

Return to vehicle and proceed south along Indiana Street.

19.4 East entrance to Rocky Flats Environmental Technology Site, the former nuclear processing facility. Verdos Alluvium with calcic soil overlies the Arapaho Formation (Upper Cretaceous). To the south the route crosses Louviers (low terrace) and Slocum (high terrace) Alluviums before ascending to intersect Highway 72 at a stop sign.

22.2 Intersection of Indiana Street with Highway 72. Turn right and head west on Highway 72. Route is on Verdos Alluvium.

24.2 Pit to the left is in the Rocky Flats Alluvium, first described by Malde (1955) and designated the type locality by Scott (1963). The pit walls have been laid back so the site is no longer worth visiting. Where well exposed the soil had a A/Bt/Km (stage IV)/Btk/2Btkb/3Coxb profile (Fig. 6; Machette and others, 1976). This soil will be discussed and compared with another soil on the Rocky Flats at the next stop.

24.9 Turn left into office and manufacturing complex, turn right and go west to the end of a large gravel pit.

25.2 STOP 5. Go south along the west wall of the pit to see the soil formed on Rocky Flats Alluvium. This is the best soil exposure that we have access to on this surface, but shallow ditchcuts on Highway 72, as we turned into here, also display some of the same soil features.

The clasts in the Rocky Flats Alluvium are well exposed here. Quartzite greatly exceeds the other rock types and it is unweathered, whereas the granite and gneiss are highly altered. Hence, if these gravels were reworked (recall stop 4), the resulting gravel would be enriched in quartzite and depleted in the less resistant rock types. We can also ask the question: is this the clast composition we would expect if the gravel were of periglacial origin? For example, quartzite crops out at the canyon mouth, but granodiorite and gneiss higher in the drainage where periglacial processes would be more active during glacial times.

The soils mapped on this alluvium is the Flatirons series, a clayey-skeletal, montmorillonitic, mesic Aridic Paleustoll (Price and Amen, 1984). The morphology of this soil varies from place to place.

The soil profile here is characterized by A/10R Bt/carbonate accumulation horizon that varies from Bk (stage II) to K (stage III). The best expressed clay films (many, prominent) might be off to the right in the E-W oriented cut face. We will compare this soil with that at the type locality, which has 69% clay in a 36-cm-thick Bt/1-m-thick K horizon with a maximum carbonate content of 94%/Btk horizon with 28-33% clay and 3-10% carbonate (Machette and others, 1976). Mapping around the Rocky Flats area (Price and Amen, 1984) indicates that the K-horizon development at the type locality is unusually strong for the surface. To the west, along Highway 93 we described a noncalcic soil of the Flatirons series with a Bt horizon at least 1.2 m thick. Long ago, Malde (1955) drew the contact between the noncalcic and calcic soils on the Rocky Flats surface. Informally here called the “Malde line”, it separates areas to the west that have sufficient soil moisture to flush carbonate from the soil from areas to the east that accumulate soil carbonate. “Malde lines” are common in many regional studies in areas with precipitation gradients, as in the La Sal Mountains of Utah (Richmond, 1962). Commonly, the placement of the line shifts laterally with age of landform. Machette (1985) depicts this on his chart of soil moisture versus Ca influx (Fig. 7). Note that the Boulder area is depicted as being in the area where climatic fluctuation results in carbonate accumulation at relatively dry times and carbonate flushing at relatively wet times. Approximate precipitation zones along this gradient are 51 cm at the mountain front, 46 cm here, and 36 cm in Denver (Machette and others, 1976). So, if soil moisture varies during the Quaternary at a critical place along this gradient, there could be numerous times of carbonate accumulation followed by depletion. Thus, the cumulative amount of carbonate does not always reflect the age of the soil.

Return to Highway 72, heading west.

27.0 Junction Highways 72 and 93; continue west on 72. Here you get a good feel for the expanse of the Rocky Flats surface. D. I. Netoff (written communication, 1970) did an X-ray study of clay minerals in a transect here to see if there were any indicators of paleoclimate. Because all of the soils have a similar montmorillonite-mica-kaolinite clay-mineral assemblage, he concluded that greater soil moisture in the past is not indicated.

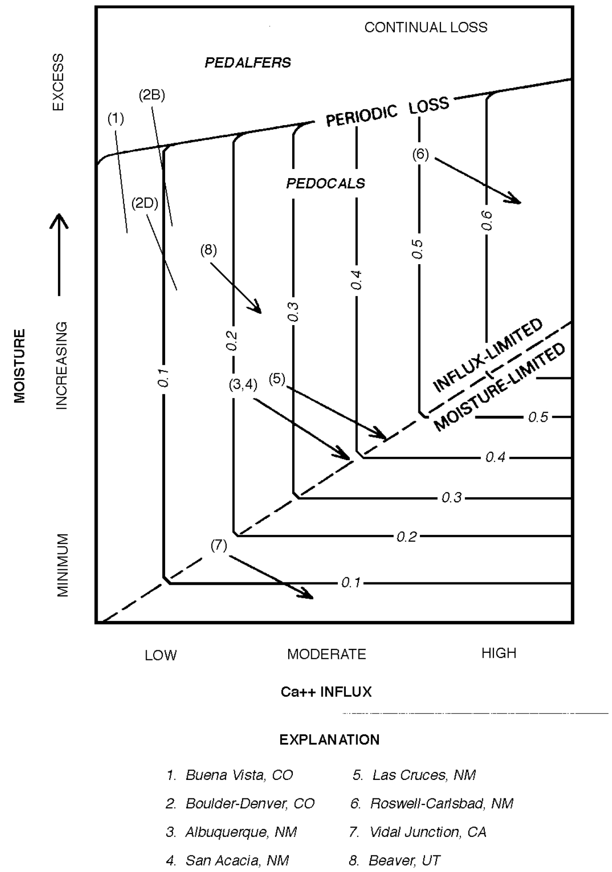

Figure 7. Carbonate accumulation rates (horizontal and vertical lines; values in g of carbonate/cm2/1 ka) under varying conditions of moisture and Ca++ influx (from Machette, 1985). Many of the soil localities are also in Figure 5. Arrows depict inferred values in rates of accumulation during glacials (end of arrow) and interglacials (point of arrow).

29.6 Go under the railroad tracks.

29.8 STOP 6. Pull off to the right just beyond a large roadcut on the right. Go back to the roadcut.

The soil here represents the youngest soil of the chronosequence we will show you. Like the Rocky Flats Alluvium, the parent gravel is dominantly quartzite, derived from the slopes to the north, and also perhaps from Coal Creek. Price and Amen (1984) map the soil as the Curecanti series, a loamy-skeletal, mixed Typic Argiboroll. The soil here has an A/Bt/BC/C profile with sandy loam to sandy clay loam texture and moderately thick grain-coating clay films in the 10-7.5YR Bt. Soils with this profile form are common to Bull Lake and Louviers deposits (see Fig. 3) where the parent material clay is low in content, but they can form in younger deposits with higher parent material clay.

The estimated age of this deposit and its height above Coal Creek help constrain the incision rate of this stream. The surface here is about 12 m above the stream, and this would be close to the maximum amount of mainstem incision here. This is close to the amount of incision below the surface of the Rocky Flats Alluvium at the mouth of the canyon, and the amount of this incision increases downvalley. These data indicate a low rate of incision by Coal Creek, perhaps the reason that the Rocky Flats surface is so well preserved.

The low incision rate helps explain the old landscape here, as shown by well-developed soils on bedrock. For example, 0.3 mile west of here at the same elevation is a high roadcut exposing a strongly developed soil in colluvium. The soil has a thick 2.5YR 5/8 Bt horizon with prominent clay films on grains. This development surely indicates several hundreds of thousands of years of landscape stability.

Turn around and go east on Highway 72.

30.7 Turn right onto Blue Mountain Road and head south. We are on the Rocky Flats Alluvium, and ahead and to the left is an alluvial fan derived mainly from the Fountain Formation. A well-developed Flatirons soil is mapped on the fan deposit.

31.0 Cross the railroad tracks.

31.4 STOP 7. Park at the junction of Blue Mountain Road and Ute Drive, and walk west on Ute drive to the west end of the first long roadcut.

The soil here is strongly developed and formed on gneiss. The morphology best matches the Lininger series, a fine-loamy, mixed, Typic Argiboroll (Price and Amen, 1984). The profile is A/Bt/Crt with a sandy clay loam 2.5YR Bt, characterized by moderately thick clay films on ped surfaces. We will discuss whether or not an E horizon is present, and if so what it might mean in terms of paleoclimate or soil-forming process. Ej horizons are present in the easternmost forested soils along the mountain front north of here. Quartz clasts are common in the soil, demonstrating a concentration due to a combination of weathering and colluviation.

This morphology surely demonstrates landscape stability here of several hundreds of thousands of years. Also, because this soil is not buried, any young sediment eroded from the bedrock in the catchment must be routed around this surface.

Turn around and retrace route.

32.1 Turn right at junction with Highway 72.

This view gives one an appreciation of the expanse of the Rocky Flats surface. Coal Creek runs along the north edge of the surface, and along it are mapped both Nussbaum and Verdos Alluviums.

South of Rocky Flats is a valley called Leyden Gulch. The small stream in Leyden Gulch heads on the Rocky Flats surface about 0.5 mile from Coal Creek, near the mouth of Coal Creek Canyon. We suspect that the gulch will erode headward upstream and eventually capture Coal Creek into a course along the south side of Rocky Flats, leaving the present route of Coal Creek high and dry. This might even produce a thick gravel deposit in Leyden Gulch that could confuse future geologists who may wish to correlate valley-filling episodes with climate cycles. Such a scenario is well described by Ritter (1967).

33.9 Turn right onto Highway 93, heading south.

34.5 On the left is an exposure of near-vertical dipping Fox Hills Sandstone. Beyond it we cross Leyden Creek, then ascend to an extensive terrace underlain by Verdos Alluvium.

35.5 The route descends from the Verdos Alluvium and the contact between the alluvium and the bedrock (Laramie Formation) is well exposed. The original road was east of here, cut into the valley wall, but repeated landsliding convinced people to move it to the present alignment. The flat-topped mountain in the distance is North Table Mountain, underlain by three flows of potassic basalts, dated at 65 myr. Quickly we cross Ralston Creek, a low terrace underlain by Broadway Alluvium, and a slightly higher terrace underlain by Louviers Alluvium.

40.0 Turn right onto the Denver Water Board road to Ralston Reservoir, and drive west along the terrace underlain by Louviers Alluvium.

40.7. STOP 8. Sign in at the office. Walk west along the road on the south side of Ralston Creek (past a buried soil in colluvium derived from potassic basalt), cross the dam, trend northwest across the spillway, climb up to a road and descend into a large gravel borrow pit. This pit changes over the years, but enough remains that we still have a good story in trying to constrain the ages of the Verdos and Rocky Flats Alluviums. The work discussed here represents mostly unpublished reports of three students in partial fulfillment of their course work in Soils and Quaternary Stratigraphy at the University of Colorado.

Van Horn (1972, 1976) first described the Verdos Alluvium of Ralston Creek to the east of here, along the south side of the pit (exposure now has material dumped on it). He described a reworked volcanic ash in the northwest part of the pit. The ash was considered to be equivalent to the Pearlette Ash Member of the Sappa Formation in Nebraska. Other ashes associated with Verdos Alluvium are considered to be equivalent to the Lava Creek ash derived from the Yellowstone Caldera. Hence, Verdos Alluvium is considered to be close to 0.64 myr old (Fig. 2; age estimate from John Obradovich, personal communication, 1994). The outcrops of the ash and enclosing alluvium are poor and we can not demonstrate its relationship to the Verdos Alluvium of Ralston Creek just east of the ash locality.

Price and Amen (1984) map the Veldkamp and Nederland series on the Verdos Alluvium; both are skeletal, mixed, mesic Aridic Argiustolls. Machette and others (1976) described both noncalcic and calcic soils on the Verdos Alluvium west of here. The noncalcic soil has a ca.

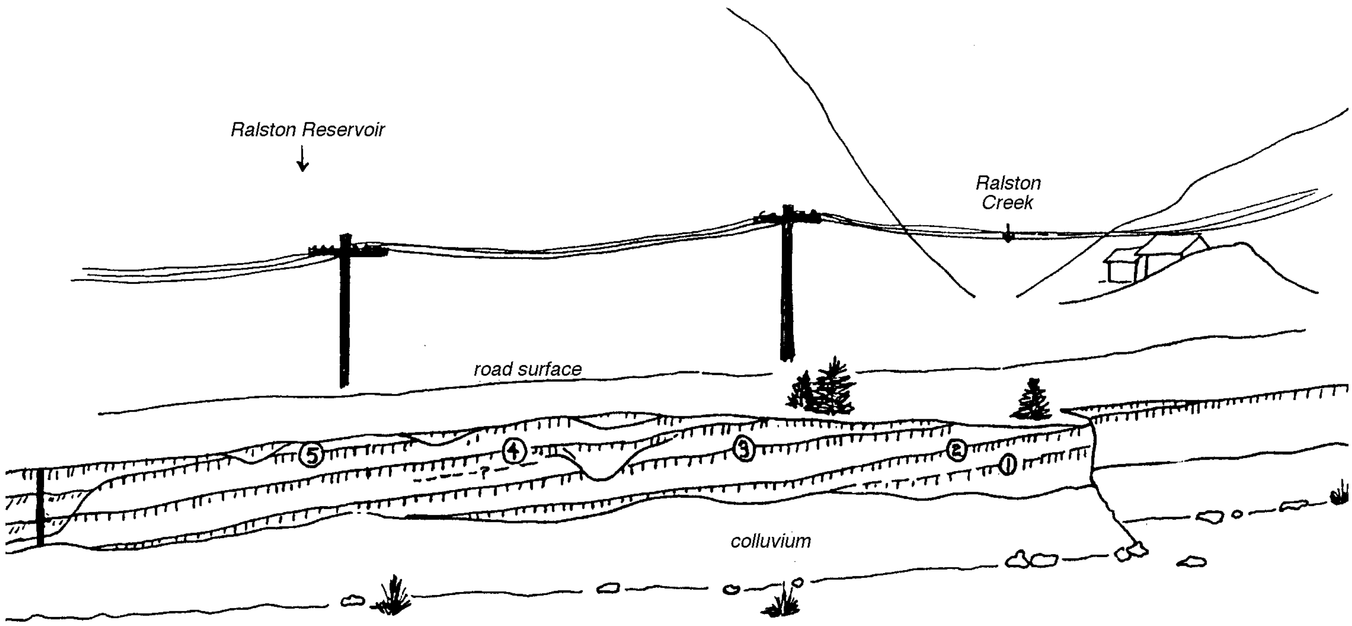

Figure 8. Sketch of soils (tick marks, buried soils in the high cut are numbered) and deposits in the Ralston Reservoir borrow pit (diagram by Julie Brigham-Grette, modified by Penny Patterson)

1-m-thick 5YR Bt horizon with a maximum of 29% clay. In addition to a Bt horizon, the calcic soil has a 0.6-m-thick K horizon, with stage IV carbonate morphology at the top and stage III at the bottom, and carbonate content maxima that varies from 93% at the top to 26% at the bottom. The presence and absence of pedogenic carbonate in soils so close to one another probably is explained by proximity to the “Malde line” and the accumulation and depletion of carbonate with time, depicted in the Machette chart (Fig. 7).

Julie Brigham-Grette was the first student to study the soils exposed in the southwest wall of the pit, as part of an amino acid study (unpublished report, 1980; Fig. 8). The deposits are local fan deposits derived from the west and their relation with either the ash to the north or the Verdos alluvium to the east is not known. She recognized at least five buried calcic soils in the high cut, and found that the deposits and soils were not offset along the northward projection of the Golden fault. The common morphology of the buried soils is a 5YR Bt horizon overlying either a Bk with stage II carbonate morphology or a K horizon with stage III morphology.

In time we realized that these soils occupy the space (provided by erosion) between the existing Rocky Flats and Verdos Alluviums, and by estimating the ages of the buried soils, we can estimate the duration of the hiatus between the two alluviums. In a simple way, soils with stage II-III morphology in the area require about 150,000 yr to form (Fig. 5). Hence, the five such soils in the high cut would require 0.75 myr to form. If these soils formed before the Verdos Alluvium was deposited, and the latter is 0.6 myr old, the estimated minimum age of the Rocky Flats Alluvium is about 1.35 myr.

Penny Patterson (unpublished report, 1984; Patterson and others, 1984) was the second student to study the soil sequence. To the five buried soils in the high cut, she added two buried soils in a cut-and-fill sequence at the east end of the exposure (Fig. 8; now poorly exposed). The focus of her work was a paleomagnetic study of the buried Bt horizons. Results of the study reveal both normal and reversed magnetic components. Natural remanent magnetism directions are poorly clustered, with a mean that is close to the expected axial dipole field direction. Stepwise thermal demagnetization to 650 degrees C, however, brought about a continued removal of a dominantly normal component, with a progressive shift of the sample directions toward a reversed polarity. The reversed remanence in all seven buried soils appears to have been acquired between 1.75 and 0.78 myr ago (latter age for the Brunhes/Matuyama boundary from Tauxe and others, 1992); it most likely represents in part depositional remanent magnetism acquired at the time of deposition, and in part chemical remanent magnetism (CRM) associated with pedogenesis.

The normal component represents CRM acquired over the last 0.78 myr. The latter is the minimum age of the youngest buried soil, and we assume that the two youngest buried soils took 0.1 myr to form and the five older buried soils took about 0.75 myr to form. Hence, a minimum age estimate for the Rocky Flats Alluvium is the sum of the last two ages plus 0.78, or 1.63 myr.

Dan Miller (unpublished report, 1988) undertook a laboratory study to quantify the clay and carbonate contents of the soils exposed in the high cut. Maximum clay contents in the Bt horizons vary from 34-43% (versus 18-23% in the underlying horizons), and maximum carbonate contents vary from 25 to 36%, with 57% in the uppermost K horizon. He made various assumptions on bulk density and accumulation rates of both pedogenic clay and carbonate in the area, and estimated 0.8-0.9 myr to form the buried soils in the high cut, but no estimate was made on the ages of the two youngest buried soils at the east end of the cut. If we add the above age of 0.9 myr to the age of the Verdos Alluvium, the estimated minimum age of the Rocky Flats Alluvium comes out to be about 1.5 myr.

We conclude that the evidence from this pit is that the hiatus between the two alluvial units is long and the Rocky Flats Alluvium is older than the 1 myr age estimated by the study on the degree of magnetite oxidation (Mabee, 1978).

This is the end of the field trip; return to Denver.

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