PLEISTOCENE SURFICIAL DEPOSITS OF THE GRAND MESA AREA, COLORADO

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INTRODUCTION

Grand Mesa, with an average surface elevation of about 3050 m, is a basalt-capped plateau that forms one of the most prominent physiographic features in west-central Colorado (fig. 1). Basalt flows capping Grand Mesa have protected the underlying weaker sedimentary rocks from erosion. Progressive erosion of Grand Mesa since the outpouring of basalt 10 million years ago (K/Ar date of 9.7 ± 0.5; Marvin and others, 1966) has produced an impressive array of pediments, alluvial fans, glacial outwash fans, landslides, and colluvial deposits which now flank the mesa on all sides.

The Grand Mesa area has been a topic of study since the Hayden Surveys (Hayden, 1876). Most recent studies have focused on the glacial geology of the area (Henderson, 1923; Nygren, 1935; Retzer, 1954; Yeend, 1969). Sinnock (1978; this guidebook) addressed the geomorphology of the western front of Grand Mesa in his study of the Uncompahgre Plateau and Grand Valley. General treatment of the geology of Grand Mesa is given by Young and Young (1968, 1977). Detailed mapping of parts of the Grand Mesa area has been done by Yeend (1969), Donnell and Yeend (1968a, b, c, d, e), Yeend and Donnell (1968), Hail (1972a, 1972b), and Sinnock (1978).

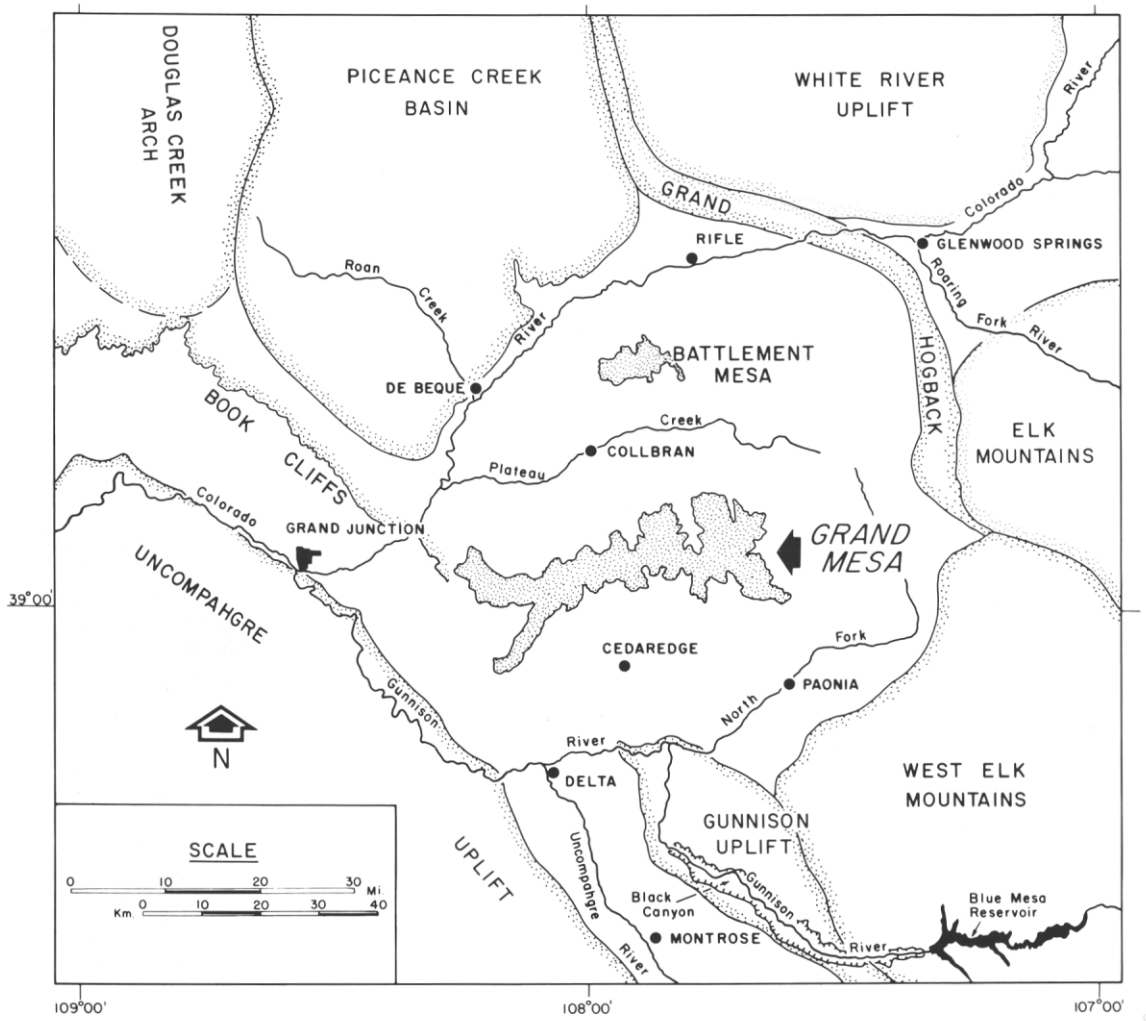

Figure 1. Index map of western Colorado showing positions of Grand Mesa and other physiographic features.

In this paper we briefly address the general geology of the Grand Mesa area, and then we provide a more detailed description of the Pleistocene surficial deposits. Our intent is to illustrate the complexity and diversity of the surficial deposits, and to bring together for the first time an overview of the depositional processes that were active during their formation.

GEOLOGIC SUMMARY

Grand Mesa is a conspicuous landform visible from many parts of western Colorado. It is separated from adjacent landforms, such as the Book Cliffs, Uncompahgre uplift, Gunnison uplift, West Elk Mountains, Huntsman Hills and Battlement Mesa by the Colorado River, the Gunnison River, North Fork of the Gunnison River, Muddy Creek and Plateau Creek (fig. 1). The Mesa is situated in the southern Piceance Creek basin. Several smaller structural flexures, such as the Montrose syncline, the axial extension of the Gunnison uplift, and the West Elk Mountain uplift, are also present in the area. Several small-displacement normal faults are also present. The oldest rocks in the area (fig. 2) are the sandstones and variegated shales of the Morrison Formation (Jurassic). The Morrison is overlain by 1,500 to 2,500 m of drab-colored Upper Cretaceous shale, sandstone and coal that comprise the Dakota Sandstone, Mancos Shale and Mesaverde Formation (and equivalents). The Mesaverde and Mancos make up most of the stratigraphic section visible on the west and south slopes of Grand Mesa. Cretaceous rocks are overlain by a variable thickness of Tertiary sandstone, shale, marlstone, lean oil shale and claystone that make up the Wasatch Formation (Paleocene-Eocene), Green River Formation (Eocene), Uinta Formation (Eocene) and the North Park Formation (Miocene).

Tertiary sedimentary rocks are overlain by up to 240 m of basalt flows and intercalated tuff, baked soil horizons, and volcanic conglomerate. The Grand Mesa basalt is part of the bimodal suite of late Cenozoic alkali basalts that are scattered throughout northwestern Colorado (Larson and others, 1975). The area of basalt extrusion was probably near the east end of the Grand Mesa in an area of dikes and small plugs. As many as 20 basalt layers may be present; individual flows range in thickness from 15 to 60 m. The quantity of basalt that was released is unknown. Yeend (1969) speculates that the flood lavas extended from the vent area outward over much of southern Piceance Creek basin and over the northern part of the Uncompahgre uplift. Young and Young (1968) contend, however, that the original area of basalt coverage was limited, more or less, to the basalt's present-day extent. Their hypothesis is that basalt eruption occurred near or within Miocene stream valleys with the subsequent flows being confined to the

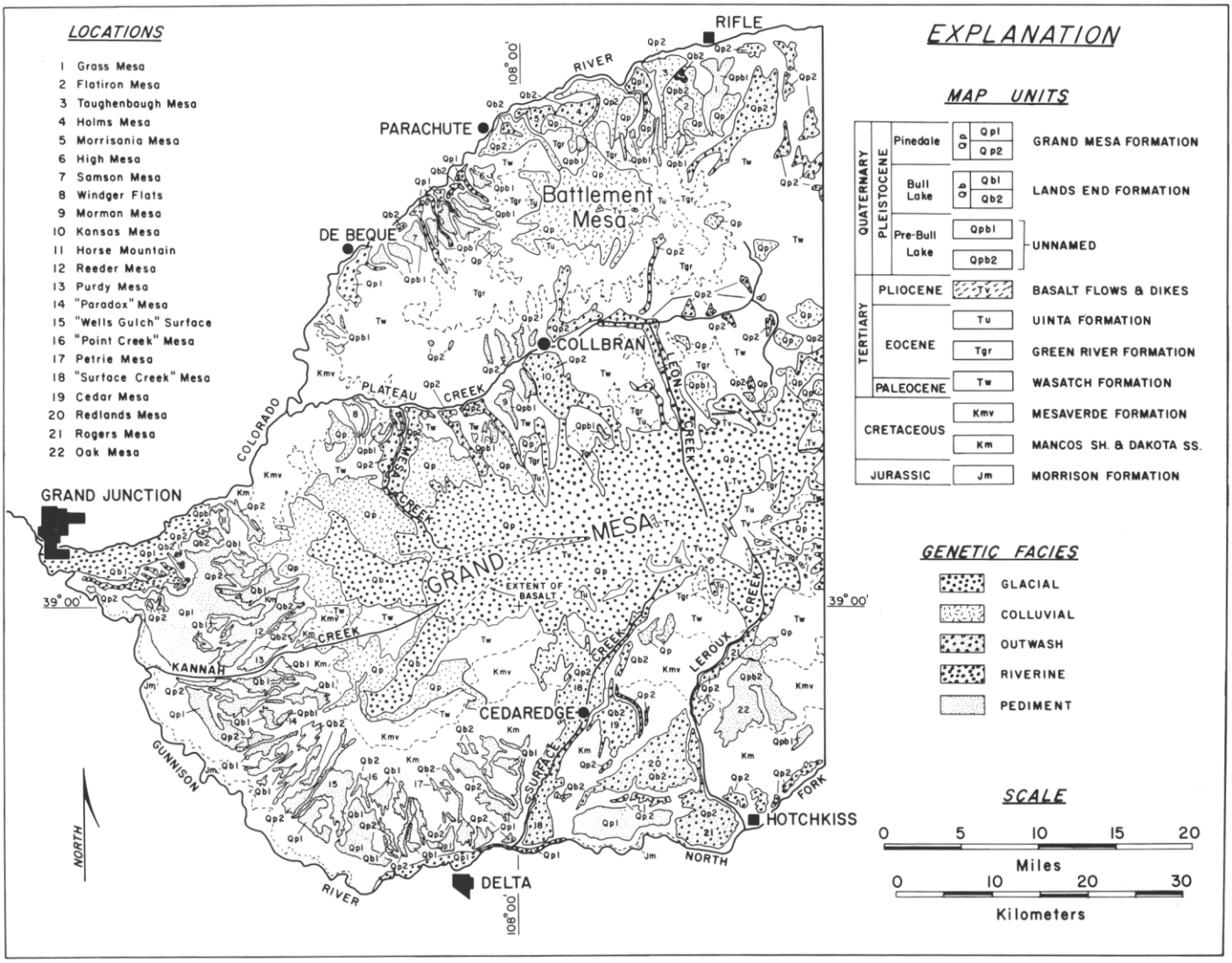

Figure 2. Geologic map of Grand Mesa area. Compiled from Yeend (1969), Sinnock (1978), Hail (1972a, 1972b) and unpublished mapping.

valleys. This could explain the "Y" shaped aerial extent of the basalt that makes up the western prongs of Grand Mesa (fig. 1). The most recent deposits in the Grand Mesa area are Pleistocene tills, alluvial gravels, pediment gravels, and colluvial deposits. In the northern half of the area (Yeend, 1969), the bulk of these deposits have been grouped into either the Lands End Formation (Bull Lake) or the Grand Mesa Formation (Pinedale). The remainder of this paper will address these deposits more fully.

PLEISTOCENE SURFICIAL DEPOSITS

At the time of Grand Mesa volcanism, it is likely that much of the uplift of the Colorado Plateau region had not yet occurred (Young and Young, 1968; Yeend, 1969; Sinnock, 1978). As uplift did occur, progressive incision by the ancestral Colorado, Gunnison and Uncompahgre rivers and their tributaries produced an ever-changing panorama of erosional, transportational and depositional surfaces. Some of the younger surfaces are nearly intact while many of the older ones are badly dissected and poorly preserved.

Classification

Yeend (1969) has provided a detailed classification of the various surficial deposits exposed from the crest of Grand Mesa north to the Colorado River. This classification (fig. 3) depicts three major episodes of gravel and till deposition, each of which was produced by a late-Pleistocene glacial event: Pinedale, Bull Lake or pre-Bull Lake. Yeend (1969) further classifies the surficial deposits on the basis of depositional processes into three facies: glacial, alluvial and colluvial. The alluvial facies is further subdivided into either terrace or pediment types. All of the fades of Pinedale age are collectively designated the Grand Mesa Formation, while all facies of Bull Lake age are designated as Lands End Formation. Pre-Bull Lake deposits are divided on the basis of suspected process; however, Yeend (1969) did not designate a formal stratigraphic name.

Sinnock (1978) provides a classification of the various surficial deposits exposed on the western and southwestern flanks of Grand Mesa. Four major levels of terraces and pediments are designated. Sinnock (1978) assigns a Pinedale age to the two lowest levels of terraces and pediments, a Bull Lake age to the upper two levels.

Hail (1972a, 1972b), in his mapping of the Cedaredge and Hotchkiss areas on the southern flank of Grand Mesa, recognized three major levels of fan and pediment gravels and one sheet of glacial till (fig. 3). He assigned a pre-Bull Lake age to the highest gravel-covered surfaces, and Bull Lake and Pinedale ages to the lower two levels, respectively. Hail (1972a, 1972b) does not directly correlate the three major levels of fan and pediment gravel with those of Yeend (1969); however, he does (1972a) equate the glacial drift with the lower till horizon of the Grand Mesa Formation.

In Figure 2 we have summarized the mapping of surficial deposits by Yeend (1969), Sinnock (1978) and Hail (1972a, 1972b). The classification of the various units is shown on Figure 3. Like previous workers, we make the initial subdivision on the basis of age, and recognize that at least six major periods (elevational levels) of gravel deposition are preserved on the flanks of Grand Mesa and Battlement Mesa. Following subdivision by age, we further classify the deposits on the basis of suspected genesis into five dominant subtypes: glacial (till and drift), outwash, pediment, riverine, and colluvial.

For the most part, our genetic subdivision of surficial deposits is similar to that of Yeend (1969), with one exception. We have subdivided Yeend's (1969) alluvial facies into riverine-type gravels and outwash-type gravels. Both types tend to be well sorted; however, outwash gravels have clasts of local provenance, whereas riverine gravels have clasts of both local and distant provenance.

Because of the similarity in position, gravel composition and depositional characteristics of gravel-veneered surfaces on the west and south flanks of Grand Mesa and those mapped and classified by Yeend (1969) to the north, we have applied the usage of the

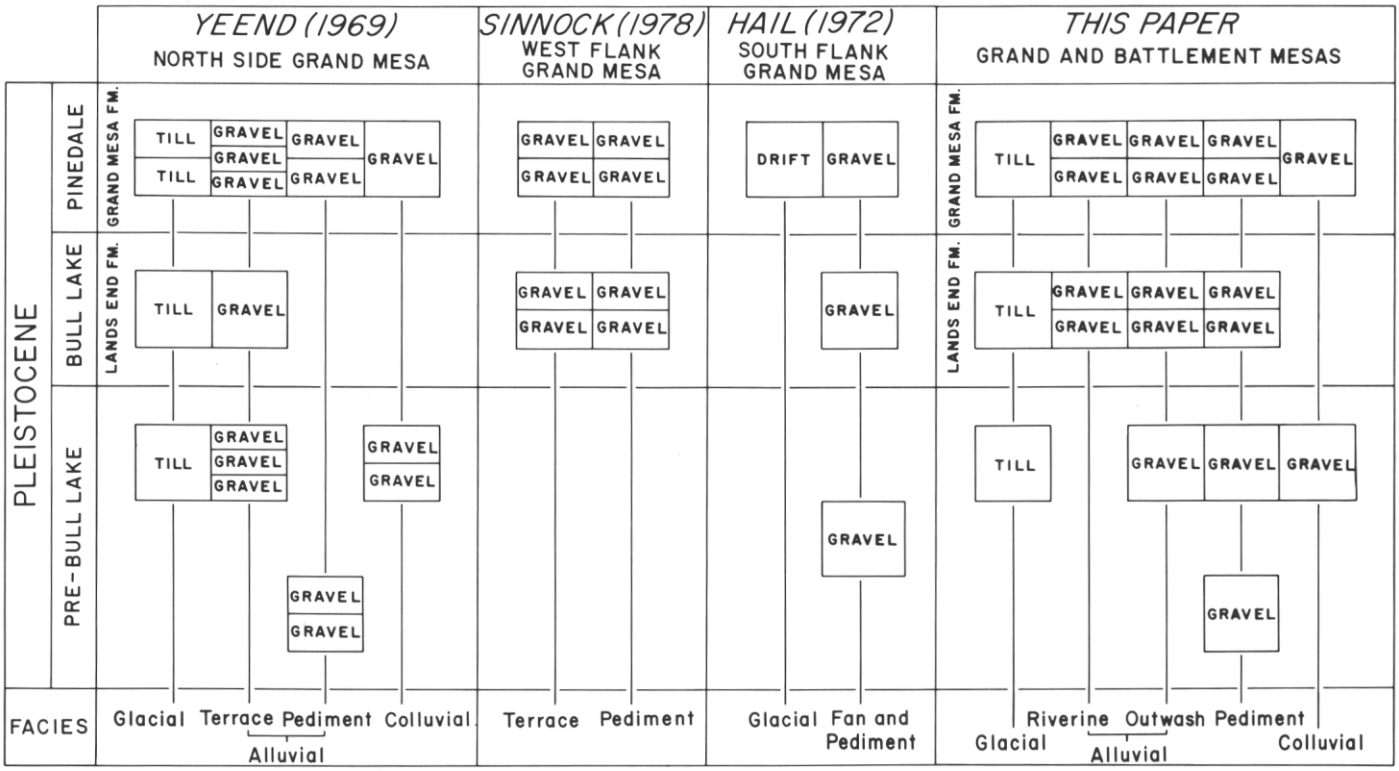

Figure 3. Classification of surficial deposits in the Grand Mesa area.

Grand Mesa and Lands End Formations to all Pinedale-aged and Bull Lake-aged deposits in the Grand Mesa area. Older surficial deposits are not designated by a formal stratigraphic name.

Description of Deposits

The five genetic types of surficial deposits (fig. 3) reflect the major depositional processes responsible for the transportation and deposition of sediment. In Figure 2, each depositional surface is designated according to its most dominant sediment type. It is certainly recognized that a given surface may have been formed by one or more transportational/depositional process. Indeed, this is the rule rather than the exception.

Glacial Deposits

Yeend (1969) recognized four separate horizons of glacial till, two of Pinedale age, one of Bull Lake age, and one of pre-Bull Lake age (fig. 3). The tills are typically poorly sorted and have weak stratification (fig. 4). The clasts are dominated by basalt, and range in size from pebbles to boulders with a matrix of sand and silt. Till horizons are generally less than 30 m thick; however, Yeend (1969) reports a 41-m thick, pre-Bull Lake till sequence at a location on the east end of Grand Mesa. The tills of the Grand Mesa and Lands End Formations are generally capped by thin soil horizons, 0.5 to 1.0 m thick. Inner-till soils are also reported.

The most extensive tills are those of the Grand Mesa Formation (fig. 2), covering most of the top of Grand Mesa, the landslide bench, and extending down various stream valleys onto the flanks of Grand Mesa. Yeend (1969) mapped till down to an elevation of 1,646 m in the vicinity of Plateau Creek. This low elevation is unusual for the Rocky Mountain area and several subsequent workers (e.g., Sinnock, 1978) have challenged the concept. In actuality, the lower limit of Pinedale till deposition is difficult to place because clearly defined terminal and recessional moraines are not present, and because the tills have been locally reworked into outwash or colluvial deposits. In Figure 2, the lower limit of Pinedale till occurrence is placed at about 2,000 m on the north side of Grand Mesa, and at about 2,300 m on the south side (Hail, 1972a, 1972b).

The Bull Lake till of the Lands End Formation is present over most of the western half of Grand Mesa; however, it is exposed at the surface only on the two western prongs of the Mesa. Elsewhere it is buried by till of the Grand Mesa Formation. Yeend (1969) reports that Bull Lake till was deposited down to an elevation of 1,768 m on the north flank of Grand Mesa. Again, this is difficult to verify because of the lack of terminal moraines and the lateral gradation of till into outwash and colluvial gravels.

The pre-Bull Lake till is present at a single location near Chalk Mountain on the eastern end of Grand Mesa at an elevation of more than 3,050 m (Yeend, 1969). This small exposure is not shown on Figure 2

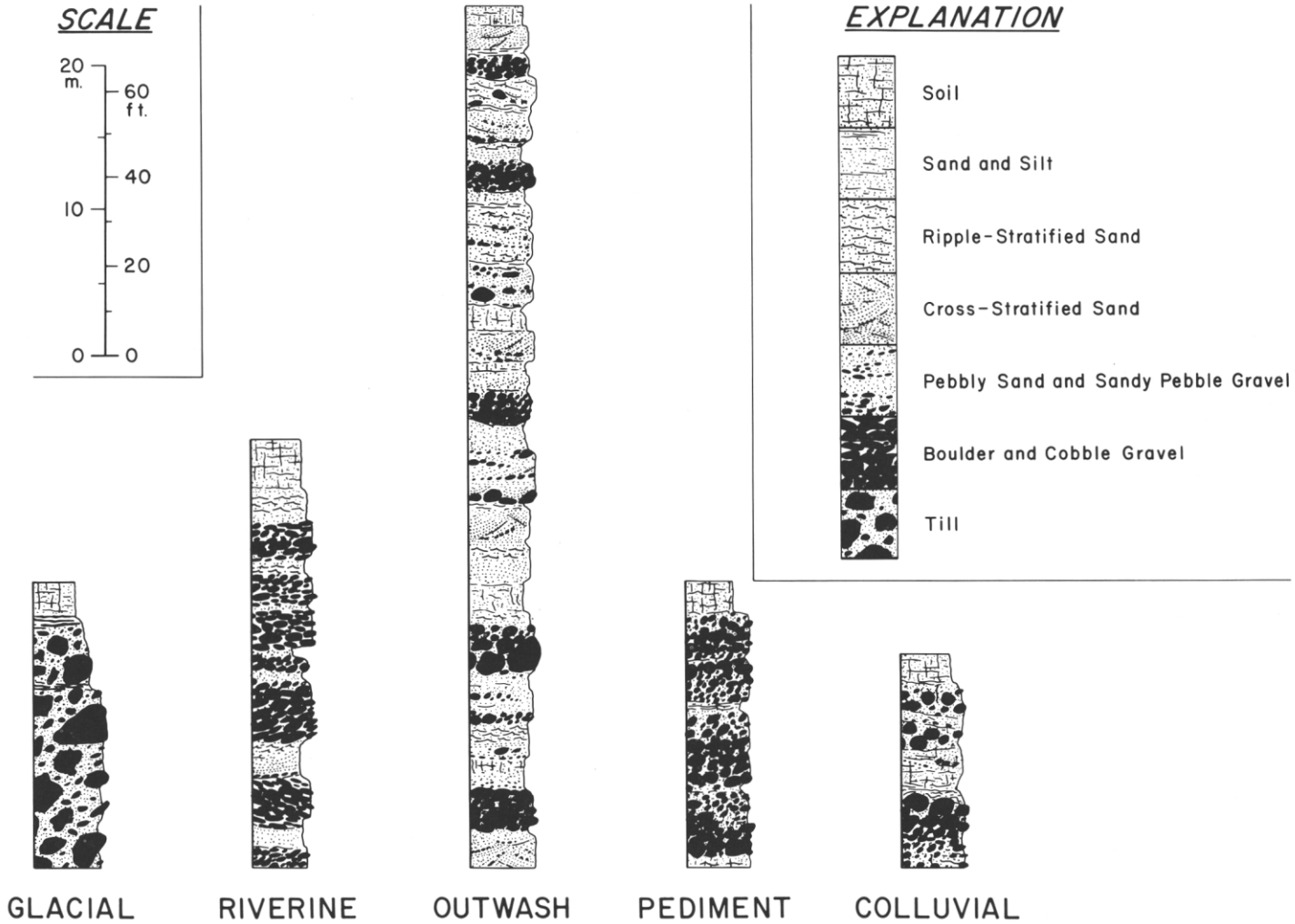

Figure 4. Sedimentologic characterization of surficial deposits in the Grand Mesa area.

Riverine Deposits

Pleistocene alluvial gravels associated with the major rivers lateral to Grand Mesa and Battlement Mesa are designated as riverine facies. As mentioned in a previous section, this term is applied to well-sorted sands and gravels which have clasts of mixed provenance, as compared to outwash and pediment gravels which have clasts of local provenance.

Riverine deposits occur in four distinct levels: two of Pinedale age, and two of Bull Lake age (fig. 3). The various levels are conspicuous near Delta and Grand Junction (fig. 2) where they form well-preserved terraces lateral to the Gunnison and Colorado rivers. Riverine gravels are generally 10 to 25 m thick and are comprised of alternating beds of well-sorted, imbricated pebble and cobble gravel, and cross-stratified and ripple-stratified sand and silt (fig. 4). The highest Bull Lake riverine terraces are generally about 170 m above local baselevel, while the lowest Pinedale terraces are usually less than 20 m above baselevel. The stratification sequences (fig. 4) of riverine deposits suggest deposition in a meandering fluvial environment.

Outwash Deposits

Outwash deposits formed by glacial meltwaters are common on both the north and south sides of Grand Mesa and also on the north and south flanks of Battlement Mesa. Typically, they are found in close proximity to the modern-day streams (Leroux, Surface, Mesa, and Leon Creeks). Outwash surfaces have the largest dimensions of all the surfaces exposed in the study area. For example, the Pinedale outwash surface associated with the Surface Creek drainage system is nearly 27 km long and has a surface area of about 80 km'.

The longitudinal profiles of the more prominent outwash and pediment surfaces flanking Grand Mesa and Battlement Mesa are shown on Figure 5. The major Pinedale outwash surfaces on the south side of Grand Mesa are Rodgers Mesa (fig. 5 0 and "Surface Creek" Mesa (fig. 5 e), whereas on the north side, the major surfaces are in the Mesa Creek (fig. 5 c) and Leon Creek drainages (fig. 2). Depositional gradients for these surfaces average about 90 m/km and the distal portions of the surfaces project about 70 m above the present-day baselevel (Gunnison River, North Fork of Gunnison River, and Plateau Creek). Bull Lake outwash surfaces, such as Redlands Mesa (fig. 5 f) and Cedar Mesa (fig. 5 e), have depositional slopes averaging 135 m/km, and project to an elevation 340 m above local baselevel.

The outwash deposits are comprised of gravel, sand and silt, and range in thickness from 15 to 60 m. On the south side of Grand Mesa, the pebbles, cobbles and boulders are predominantly basalt with rare sandstone and mudrock, whereas on the north side, clasts of basalt, sandstone and marlstone are more equally abundant. Statification of the outwash sediment is generally quite striking (fig. 4), and is strongly suggestive of deposition in a braided-river environment. Gravel horizons representative of channel-bar deposition are interbedded with channel-fill cross-stratified sand, pebbly sand, and coarse silt. Cross-stratification is dominated by high-angle, medium-scale planar and trough types. Ripple-stratified sand and silt are locally common, including climbing ripples. For the most part, the stratification and textural sequences are similar

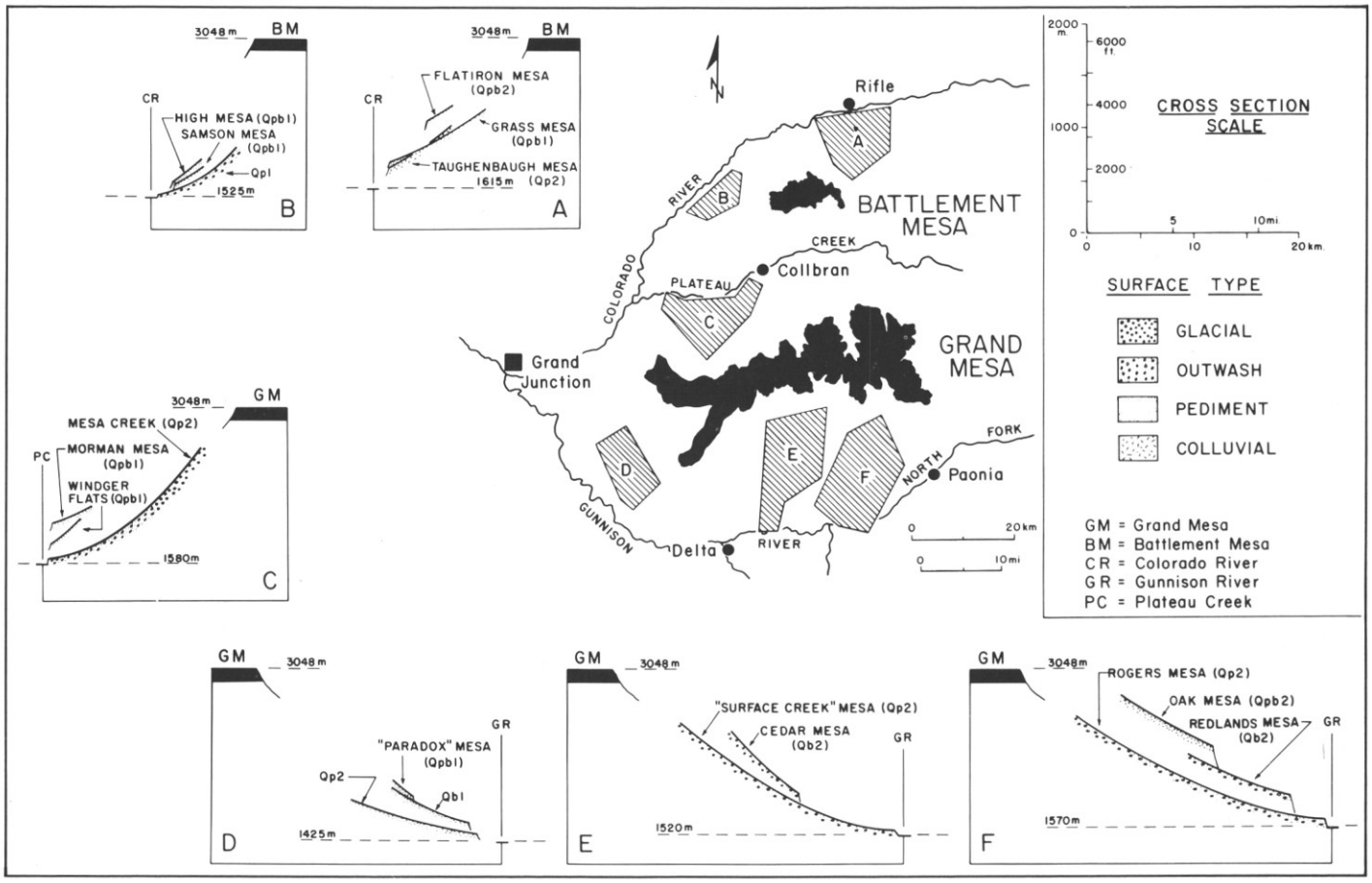

Figure 5. Topographic profiles of pediment, outwash and colluvial surfaces flanking Grand Mesa and Battlement Mesa.

to the "Donjek type" braided river deposits described by Miall (1977) from the Yukon Territory, Canada.

Clast size increases proportionally upslope in all of the outwash gravels studied. In the most proximal portions, basalt clasts as large as 5 m in diameter have been observed. On the distal ends of the outwash surfaces, maximum clast size rarely exceeds 0.5 m. At these locations, the outwash sequence commonly rests unconformably upon well-sorted, well-stratified, imbricated riverine gravels. This suggests that the outwash detritus prograded outward from the mountain front onto the alluvial plains of the major rivers.

Pediment Deposits

Pedimentation during the Pleistocene and possibly Pliocene produced a distinctive array of gravel-veneered surfaces on the western flanks of both Grand Mesa and Battlement Mesa (fig. 2). These surfaces are numerous and conspicuous in the area between Delta and Grand Junction, and between Parachute and DeBeque. For the most part, the pediments formed only on weak Mancos Shale or Wasatch Formation.

Six levels of pediments are present (fig. 3). The oldest surficial deposits in the study area, Oak Mesa near Hotchkiss (fig. 5 f), and Flatiron Mesa near Rifle (fig. 5 a), are thought to have formed by pedimentation. Oak and Flatiron Mesas are clearly pre-Bull Lake in age and may be as old as Pliocene. Their distal ends project to an elevation about 400 m above present-day baselevel. Younger, pre-Bull Lake pediments have also been recognized (Yeend, 1969). These surfaces are most abundant northwest of Battlement Mesa (e.g., High Mesa and Sampson Mesa (fig. 5 b)). They project to an elevation about 160 m above present-day baselevel.

Two levels of Bull Lake pediments and two levels of Pinedale pediments are present between Delta and Grand Junction (Sinnock, 1978). The Pinedale pediments generally project to an elevation 20 to 60 m above local baselevel, while the Bull Lake pediments project to between 150 and 250 m.

Sediment deposited on the pediment surfaces rarely exceeds 20 m in thickness, and is dominated by pebble- to boulder-sized gravel clasts composed predominantly of basalt, sandstone and marlstone. Gravel clasts are generally poorly sorted and commonly are partially supported by a sand matrix (fig. 4). Stratification is weakly developed, and where present, generally occurs as graded and reverse-graded bedding. These sedimentologic characteristics suggest that the dominant depositional agents accompanying pedimentation were mudflows and debris flows with some local reworking by sluggish streams. Sinnock (1978) noted "kettle-like" depressions on some pediment surfaces flanking the west side of Grand Mesa, suggesting that glacial ice blocks were possibly rafted to low elevations (1,650 to 2,100 m) during deposition of sediment on the pediment surfaces.

Colluvial Deposits

Colluvial deposits are common high on the flanks of Grand Mesa (beneath the basalt cap), and make up nearly all of the top of Battlement Mesa (fig. 2). The majority of these deposits are thought to be of Pinedale age, although several pre-Bull Lake colluvial surfaces have been mapped near Vega Reservoir (Yeend, 1969). On the north slope of Battlement Mesa, mudflows and debris flows have moved downslope from the solifluction mantle capping the mesa, over pre-existing pediment and outwash fans and surfaces, and onto riverine gravels of the Colorado River. Examples of this situation are Taughenbaugh, Holms, and Morrisania Mesas (fig. 2). The gravels beneath the Pinedale colluvial deposits are usually Bull Lake in age. This explains why surfaces like Taughenbaugh Mesa project to a higher elevation above local baselevel (fig. 5 a) than would ordinarily be expected for Pinedale surfaces.

Colluvial deposits are quite variable in thickness, ranging from more than 100 m in local pockets on the landslide bench of Grand Mesa to 10 to 20 m on the distal portions of fan-shaped mudflows. Hetergeneous clast compositions and textures prevail, although well-stratified sands and gravels may be locally common. Dominant processes appear to have been landsliding and slumping high on Grand and Battlement Mesas, and dominantly mudflows and debris flows at lower elevations. Solifluction was very active on the crest of Battlement Mesa during all glacial periods, but most noticeably during Pinedale time.

ACKNOWLEDGMENTS

We wish to thank R. G. Young and J. D. Powell for reading the manuscript and offering suggestions for its improvement. C. Lepp was very helpful in compiling data for this paper. S. Rex typed the manuscript, and we thank her for this assistance.

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