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GEOMORPHOLOGY AND GEOLOGY OF THE RAMPART RANGE, COLORADO.(U)

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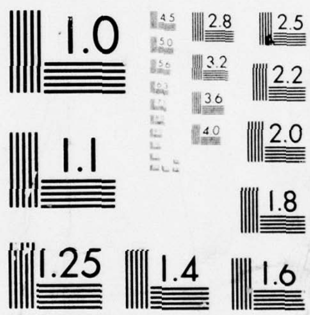
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GEOMORPHOLOGY AND GEOLOGY OF THE RAMPART RANGE, COLORADO

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MAY 1977

FINAL REPORT

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UNITED STATES AIR FORCE ACADEMY

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Department of English
USAF Academy, Colorado 80840

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAFA-TR-77-10	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER Final rept.
4. TITLE (and Subtitle) GEOMORPHOLOGY AND GEOLOGY OF THE RAMPART RANGE, COLORADO		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Major Charles L. Smith		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Economics, Geography and Management United States Air Force Academy, Colorado 80840		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DFEGM USAF Academy, Colorado 80840		12. REPORT DATE May 1977
		13. NUMBER OF PAGES 110p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

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SEP 2 1977
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rampart Range, Colorado Piedmont, Colorado Front Range, Geomorphology, Geologic History, Structure, Stratigraphy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report analyzes data relating to an area of a size seldom described in geomorphic or geologic articles, the Rampart Range of the Colorado Front Range and an adjacent portion of the Colorado Piedmont. The geomorphology, topography, drainage systems, and landscape of the study region are described. Geologic data relating to structure and history are also presented as are the characteristics and distribution of all geologic formations in the area.

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INTRODUCTION

Within the fields of geomorphology and geology there is a tendency to view the earth at either very large or very small scales. Studies either discuss areas covering a few square miles or much larger regions of thousands of square miles. An area which has dimensions of fifty by twenty-five miles is seldom discussed in detail. This report focuses on an area of this size, the Rampart Range of Colorado. The Rampart Range is frequently discussed as a portion of the Colorado Front Range with little specific information provided. In other presentations, only a very small segment of the Rampart Range is described. Studies which do treat the Rampart Range as an entity are often restricted to one aspect of its geology or geomorphology. The purpose of this report is to describe the geomorphology and geology of the Rampart Range in detail as a basis for additional studies of the region. It is assumed that most of the terms used in this report are familiar to the reader and that definitions are not required.

Many studies of geology and landforms in Colorado have focused on either the northern or southern parts of the Colorado Front Range. Such focus can be related to the mineral wealth of the "mineral belt" to the west of Denver and Boulder, and the ore deposits of the Pikes Peak Massiff south of the Rampart Range. Because the Rampart Range is between these areas, the geologic formations, history, and stratigraphy of the mountains have not been examined in detail and are subject to several interpretations. To facilitate the analysis of the mountains a small portion of the adjacent Colorado Piedmont is included in this study.

Location and Borders of the Region

The Rampart Range is a roughly triangular shaped segment of the Colorado Front Range, between the mouth of the Platte Canyon and the Ute Pass area west of Colorado Springs (Map 1). The borders of the range are formed by the plains on the east, a series of faults which extend through Ute Pass then northwestward to the South Platte River, and the South Platte River itself. Fenneman, in his book, Physiography of the Western United States, divided the Colorado Front Range into three districts; the Boulder District, in the north; the Georgetown District, west of Denver; and the South Park District, in the south.[1] William Morris Davis, in an earlier analysis of the Colorado Front Range, had separated the highlands of the Pikes Peak Massif from what he termed the South Platte Section.[2] Therefore, the Rampart Range is a portion of the South Park or South Platte District of the Colorado Front Range. The Rampart Range gets its name from the more or less even unbroken eastward facing escarpment or rampart which rises 1,000 to 2,000

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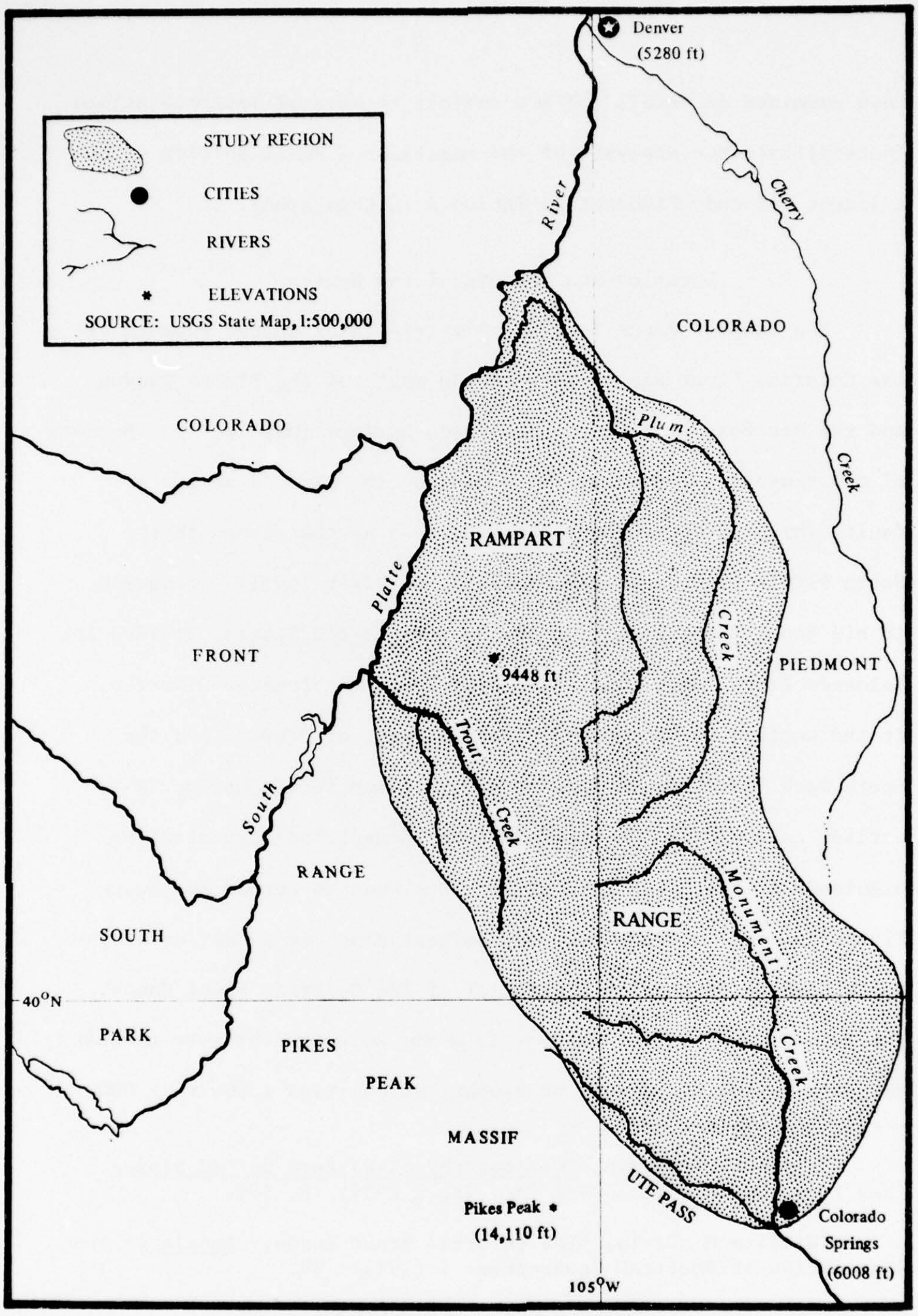
[1]Nevin M. Fenneman, Physiography of Western United States (New York: McGraw-Hill Book Co., Inc., 1931), p. 103.

[2]William M. Davis, "The Colorado Front Range," Annals of the Association of American Geographers 1 (1911): 39.



LOCATION OF THE STUDY REGION
MAP 1

feet above the surrounding plains. When Davis observed the Rampart Range for the first time, in 1877, he wrote, "It is very strange to see how suddenly they rise from a sea of land to the east, almost precipitously."[3]

One analysis of the Front Range, based on tectonic features and fault zones, concluded that the western border of the Rampart Range occurs to the east of the Ute Pass Fault zone. This view differs from that of Davis, who believed that the Ute Pass Fault marked the edge of the Rampart Range. In defining the study region, it was felt that Davis' view presented a more valid region. The area west of the fault zone forms a distinctive subdivision of the South Park District of Fenneman, which is generally lower in elevation than the Rampart Range and tends to merge into the low hills and ranges surrounding South Park. Use of the Ute Pass Fault Zone as a border places a large narrow valley, Manitou Park, within the region. Manitou Park is significant since it is an outlier of the sedimentary rocks which occur in the plains east of the Rampart Range.

The two large stream valleys of Plum and Monument Creek, which are subparallel to the eastern edge of the Rampart Range, have been included in the area considered in this report. The inclusion of this portion of the Colorado Piedmont provides a

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[3]R.J. Chorley, R.P. Beckinsale, and A.J. Dunn, The History of the Study of Landforms, Vol II: The Life and Work of William Morris Davis (London: Methuen and Co., Ltd., 1973), p. 65.

comparison with developments in the Rampart Range without adding too large a segment of the Great Plains to the study.

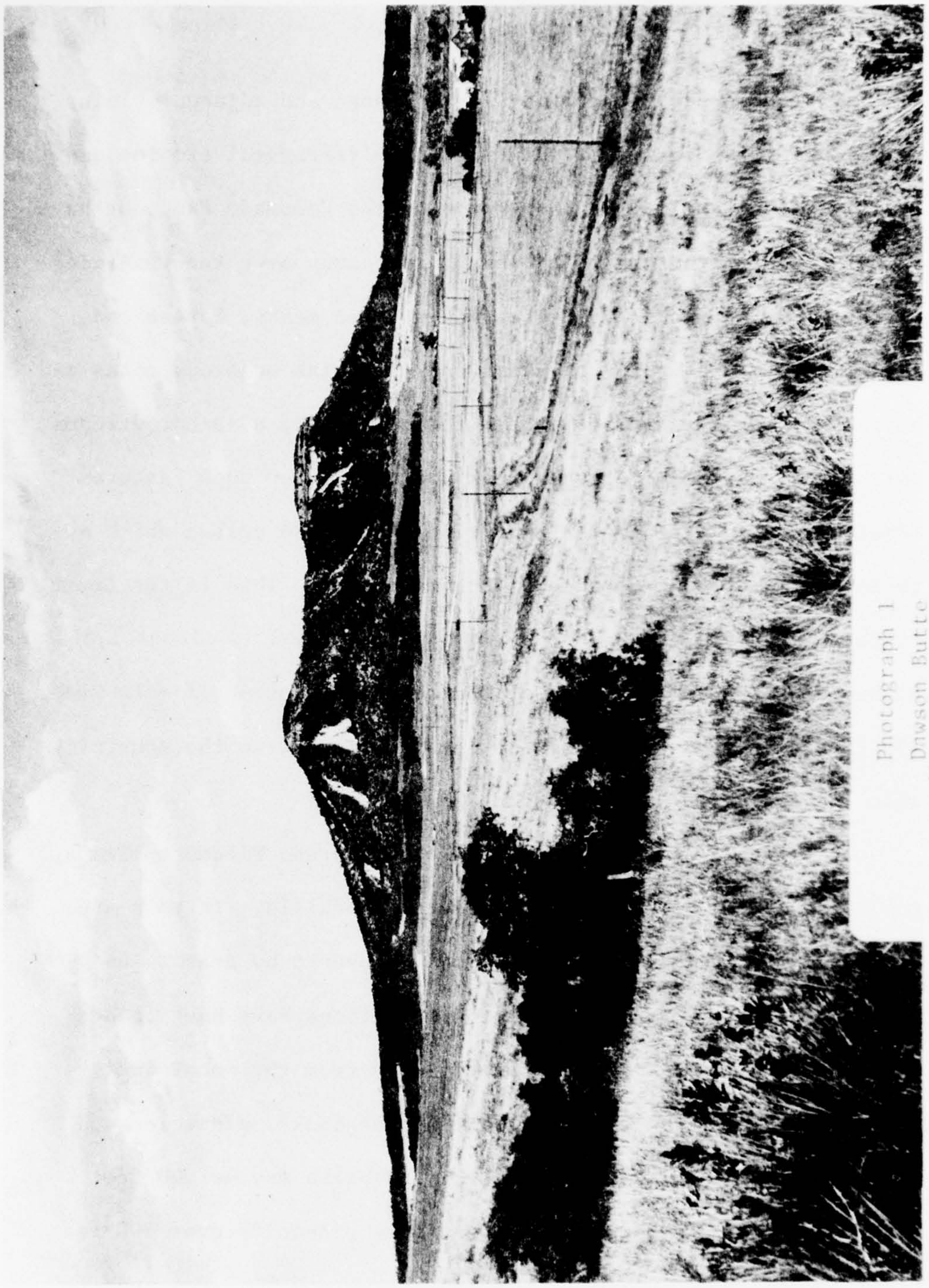
The study region, as described, extends from 104° 40' West to 105° 15' West and from 38° 50' North to 39° 35' North. The overall appearance of the region is that of a trapizoid with the north to south axis approximately 55 miles long and the maximum east to west dimensions 25 miles.

The initial section of this study focuses on the geomorphic aspects of the Rampart Range including landforms, erosional surfaces, elevations, and drainage patterns. The second major section deals with the geologic structure, history, and stratigraphy of the region, while the conclusions include a discussion of the relationships of the various components of geomorphology and geology.

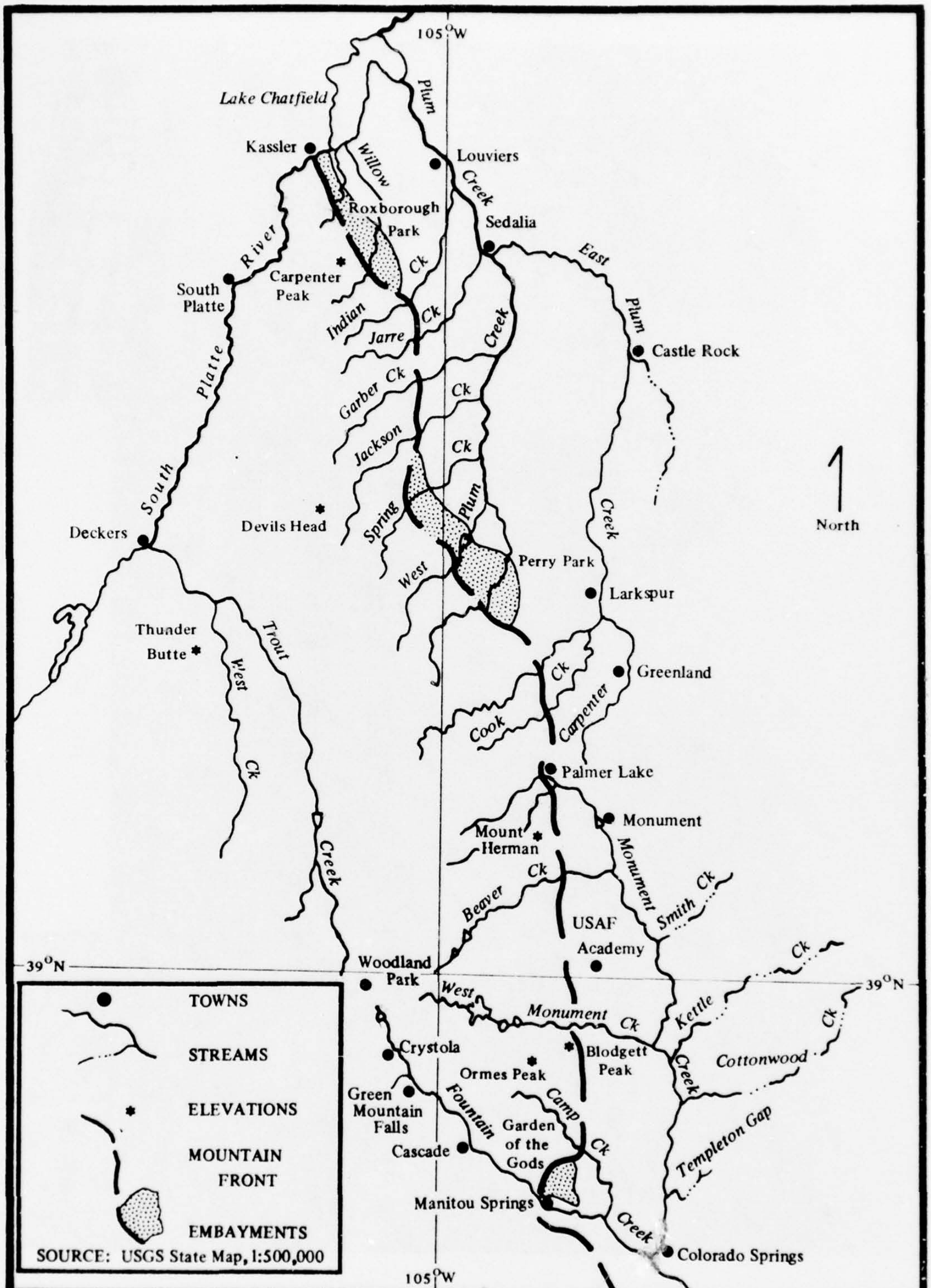
GEOMORPHOLOGY

The geomorphology of the Rampart Range and adjacent plains is primarily the result of faulting and differential erosion and, thus, varies greatly. Major streams of the Colorado Piedmont have removed much of the sediments which are common over the remainder of the Great Plains, leaving behind isolated mesas, buttes and escarpments. The valley of Plum Creek contains numerous mesas and buttes which rise several hundred feet above the adjacent streams, while the valley of Monument Creek has only a few such features (Photograph 1). The two streams rise in a broad upland which extends eastward from the base of the mountains. This is the South Platte-Arkansas Divide, or simply the divide; and is almost 1,500 feet higher than the lowest parts of the region. A one-half mile wide, 200 foot deep, gap in the divide occurs adjacent to the mountains near the town of Palmer Lake (Map 2).

Between the Rampart Range and the Colorado Piedmont lies a two to four mile wide belt of dissected foothills. In this area the sedimentary formations are commonly covered by gravels and other recent deposits. Many of the formations have been folded and faulted so that they dip steeply away from the mountains. Differential erosion has made them into hogbacks, pinnacles and spires which rise above the valleys. Hogbacks may be 500 feet higher than the adjacent valleys and some pinnacles over 300 feet higher than the surrounding terrain (Photograph 2). Features of this type are limited in occurrence and those in the Garden of



Photograph 1
Dawson Butte
(Plum Creek Basin)



RAMPART RANGE STUDY REGION
MAP 2

Photograph 2
Pinnacles

the Gods, Perry Park, and Roxborough Park have gained a great deal of public interest. The area between the Garden of the Gods and Perry Park contains only a few hogbacks, while these features are more common north of Perry Park (Photograph 3).

Erosional Surfaces

Rising to the west of these features is the Rampart Range. The steep escarpment of the range is impressive as is the relatively level crest (Photograph 4). Early investigators called this surface the Rocky Mountain peneplain, and Fenneman called it the South Park peneplain.[4] Rising above the surface of this erosional surface are a few ragged ridges of monadnocks. In the southern part of the range, monadnocks such as Ormes Peak and Mount Herman rise only a few hundred feet over the erosional surface. North of Mount Herman the accordant upland is much more apparent with only Devils Head and Noodle Head rising above the general elevation of the range. Devils Head, at 9,448 feet, is the tallest peak in the range.

It is commonly accepted that there are at least two erosional surfaces in the Front Range. The Flattop peneplain is the older surface, and the Rocky Mountain peneplain is the younger. Van Tuyl and Lovering, in a study of the physiography of the Front Range, concluded that there were five or eight erosional surfaces, three incomplete surfaces and five erosional terraces. Isolated elevated

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[4] Fenneman, p. 98.

Photograph 3

Hogbacks and Ridges

peaks rising above the general level of the Rampart Range were felt to be a continuation of the Cheyenne Mountain peneplain.[5] Their view did not gain wide acceptance and the multi-surface theory was unsupported. The concept of more than one erosional surface in the Front Range was attacked in 1947 by E. Wahlstrom, who felt that folding and faulting of a single erosional surface could easily produce the appearance of two surfaces.[6] This one-surface concept also failed to achieve acceptance and the belief in two or possibly three erosional surfaces is the most widely acknowledged.

The Rocky Mountain erosional surface in the study region is highest a few miles north of Manitou Springs and then decreases in elevation northward from about the Mount Herman area until it reaches the Platte Canyon. The South Platte River separates the low northern end of the Rampart Range from the Georgetown district of the Front Range. A gradual decline in elevation toward the town of Manitou Springs marks the southern end of the Rampart Range.

The western part of the region includes the fault bordered Manitou Park. This area is distinct from the Rampart Range and has a gently rolling nature with several mesas and buttes. The park lies below the erosional surface while the mesas represent the

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[5] F.M. Van Tuyl and T.S. Lovering, "Physiographic Development of the Front Range," Bulletin of the Geological Society of America 46 (1935): 1307.

[6] Ernest E. Wahlstrom, "Cenozoic Physiographic History of the Front Range, Colorado," Bulletin of the Geological Society of America 68 (July, 1947): 571.

Rocky Mountain surface. One of the buttes, Thunder Butte, is higher than any peak in the Rampart Range and stands 2,400 feet above the adjacent valley. Several westward dipping hogbacks occur, particularly in the eastern side of the valley. Manitou Park slopes gently toward the northwest and the South Platte River.

Elevations

Elevations in the study region vary from 5,600 feet at the junction of the South Platte River and Plum Creek to 9,836 feet at Thunder Butte. The divide has an average elevation of 7,500 feet with several mesas in the Plum Creek drainage basin reaching elevations over 7,600 feet. The Rocky Mountain erosional surface is about 9,000 feet above sea level near Mount Herman, then decreases to 8,000 feet or less near Platte Canyon. Manitou Park averages 7,500 feet, with several of the mesas in the area rising to over 8,000 feet.

Although the top of the Rampart Range is believed to be an erosional surface, it is not an area of easy travel and local relief is in the order to 200 to 500 feet. The Hayden Expedition of 1873-75 considered this an unusual range and reported that, "We are at a loss to compare it with any other for considering its very moderate height, a range more rugged or one more difficult to explore cannot be found."[7] The difficulty is due to the submature

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[7]Gustavis R. Bechler, "South Park Drainage--Main or Middle Fork of the South Platte River," in Ninth Annual Report of the U.S. Geological and Geographical Survey of the Territories (New York: Government Printing Office, 1877), p. 416.

nature of the second erosional cycle as described by William Morris Davis in 1911. Initiation of the second cycle, according to Davis,

> revised east-flowing streams and their widespaced, usually insequent branches have eroded young or early mature valleys from 500 to 1,000 feet in depth, which submaturely dissect the highlands, giving them a relief of medium measure and a coarse textured form.[8]

Most of the stream valleys in the Rampart Range follow faults or joint patterns although some do cross faults.[9] Travel along stream bottoms within the Rampart Range is difficult at times as valleys are narrow with little or no floodplain. Streams exit the mountains in a series of deep v-shaped canyons with steep gradients. Many of the canyon floors contain large boulders and waterfalls which make travel from the plains to the upper reaches of the streams difficult (Photograph 5).

Drainage Systems

The drainage system of the region is dominated by five streams. These are the South Platte River, Horse Creek, Fountain Creek, Monument Creek, and Plum Creek. The South Platte River is one of the major rivers of Colorado. In the study region, only Willow and Little Willow Creeks enter the South Platte from the

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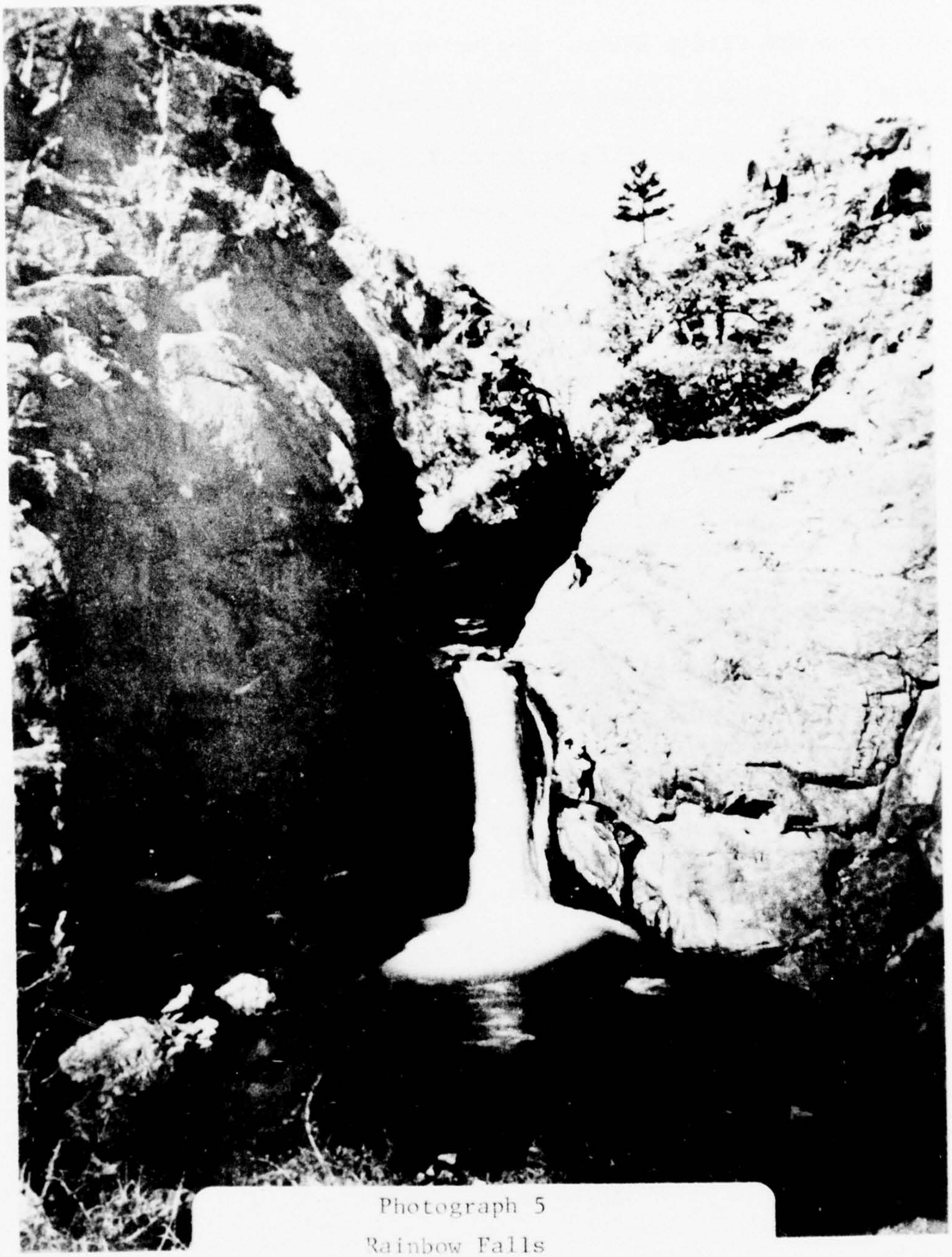
[8] Davis, p. 31.

[9] Glenn R. Scott, Quaternary Geology and Geomorphic History of the Kassler Quadrangle, Colorado, U.S. Geological Survey Professional Paper 421-A (Washington, D.C.: Government Printing Office, 1963), p. 4.



Photograph 5
Rainbow Falls

plains, Horse Creek, which is formed by the union of Trout and West Creeks in the northern part of Manitou Park, is a large tributary of the South Platte River. Beginning eight miles north of Pikes Peak, Trout Creek together with the smaller West Creek drain a total of 200 square miles of "gently rolling plateau country."[10] Fountain Creek rises about seven miles northwest of Pikes Peak and drains a 101.2 square mile basin, as it flows through Ute Pass.

Monument Creek is 37.5 miles long and begins eight miles west of the town of Monument at 9,350 feet.[11] Monument Creek drains 238 square miles with a pear-shaped water basin 20 miles wide and 23 miles long.[12] The main tributaries of Monument Creek from the Rampart Range are: Deadman's Creek, West Monument Creek, Douglas Creek, and Camp Creek. Kettle Creek, Cotton Creek, and Smith's Creek drain the Black Forest area and are the main eastern tributaries of Monument Creek. A tributary of both Monument Creek and Fountain Creek is the Shooks Run and Templeton Gap system. Originally, Shooks Run drained an area north of Colorado Springs into Fountain

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[10] Bechler, p. 422.

[11] Pikes Peak Area Council of Governments, "Open Space: Report I, An Inventory of Park, Recreation and Open Space Facilities, Sites, and Programs in the Pikes Peak Region," Colorado Springs, Colorado, 1970. (Typewritten)

[12] U.S. Army, Corps of Engineers, Flood Plain Information: Monument Creek--Colorado Springs--Colorado (Albuquerque, New Mexico: U.S. Department of Army, 1971), p. 27.

Creek. Construction of the Rock Island Railroad line partially diverted the headwaters of the drainage system toward Monument Creek. These headwaters were later completely diverted so that water now flows into Monument Creek above Colorado Springs.

The last major stream of the region is Plum Creek. Plum Creek starts near the town of Sedalia where East Plum Creek and West Plum Creek unite. Indian Creek and Jarre Creek flow from the mountains and enter Plum Creek. West Plum Creek has a mountain origin and the vast majority of its tributaries are also from the mountains. These tributaries include: Garber Creek, Jackson Creek, and Spring Creek. East Plum Creek also begins in the mountains but is primarily a stream of the plains and drains 108 square miles above the town of Castle Rock. Main tributaries of East Plum Creek are shorter than those of West Plum Creek and include Sellers Creek, Carpenter Creek, and Cook Creek. The entire Plum Creek basin, above Louviers, has a 302 square mile area.[13]

Streams flowing into Monument Creek from the mountains tend to have steeper gradients and commonly flow at right angles to the trend of the range, while those entering Plum Creek system from the mountains flow obliquely across the mountains and through less rugged valleys.[14] Streams entering Trout Creek from the Rampart Range flow in narrow gulches and the streams of the northern part

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[13] U.S. Army, Corps of Engineers, Chatfield Dam and Reservoir (Omaha, Nebraska: U.S. Department of Army, 1966), p. 10.

[14] Bechler, p. 417.

of the park have more v-shaped valleys. One of the more spectacular valleys of the study region is formed by the South Platte River in the Platte Canyon. This, "narrow and tortuous" canyon has "rough and precipitous walls."[15] The canyon contains a narrow floodplain in some areas and in others it has none. A very narrow and rough section is downstream from the town of South Platte. Here the canyon walls are 1,000 to 2,000 feet high.[16] Valleys of Plum Creek and Monument Creek in the plains have broad and shallow cross sections. Streams which originate in the South Platte-Arkansas divide have narrow, often cliff-bordered, upper valleys and broad, open valleys downstream.

As a general rule, the valleys of the region are asymetrical, with a majority of streams in the mountains downcutting their channels into the bedrock, while Monument and Plum Creeks are more actively cutting laterally.[17] In most streams some areas of deposition occur in addition to areas of channel erosion. Asymetrical

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[15] Marius R. Campbell, "The Denver and Rio Grande Western Route," Guidebook of the Western U.S., Part E, U.S. Geological Survey Bulletin 707. (Washington, D.C.: Government Printing Office, 1922), p. 20.

[16] Warren L. Peterson, Geology of the Platte Canyon Quadrangle, Colorado. U.S. Geological Survey Bulletin 1181-C. (Washington, D.C.: Government Printing Office, 1964), p. C-2.

[17] Ecology Consultants Inc., "Factors Limiting Biological Production in Monument and Fountain Creeks, El Paso County, Colorado." Colorado Springs, Colorado, 1974. (Mimeographed).

east-west valleys of the Colorado Front Range were studied by both Dr. K.O. Emery and Dr. A. Strahler with different conclusions. Emery felt that with all other things equal, steeper north-facing slopes occurred in drier parts of North America as a result of a greater amount of erosion on the south-facing slopes.[18] Strahler concluded that if all things were equal, the slopes would be equal.[19] Within the study region the east-west oriented valleys tend to have more gentle southern slopes. R.R. Hadley, of the U.S. Geological Survey, feels this is because the "rate of removal of surficial materials by sheet erosion is 50 to 75 percent greater on slopes with southerly or southeasterly exposures than on slopes that have other exposures."[20] This erosion tends to force the stream channel southward creating a steep north facing slope.

The drainage pattern of the region contains many examples of capture or piracy. Pre-Pleistocene drainage was eastward across the Rampart Range via the ancestral Arikaree River into the Great Plains of western Nebraska.[21] During the early Pleistocene, the

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[18] Mark Melton, "Intravalley Variation in Slope Angles Related to Microclimate and Erosional Environment," Bulletin of the Geological Society of America 71 (1960): 134.

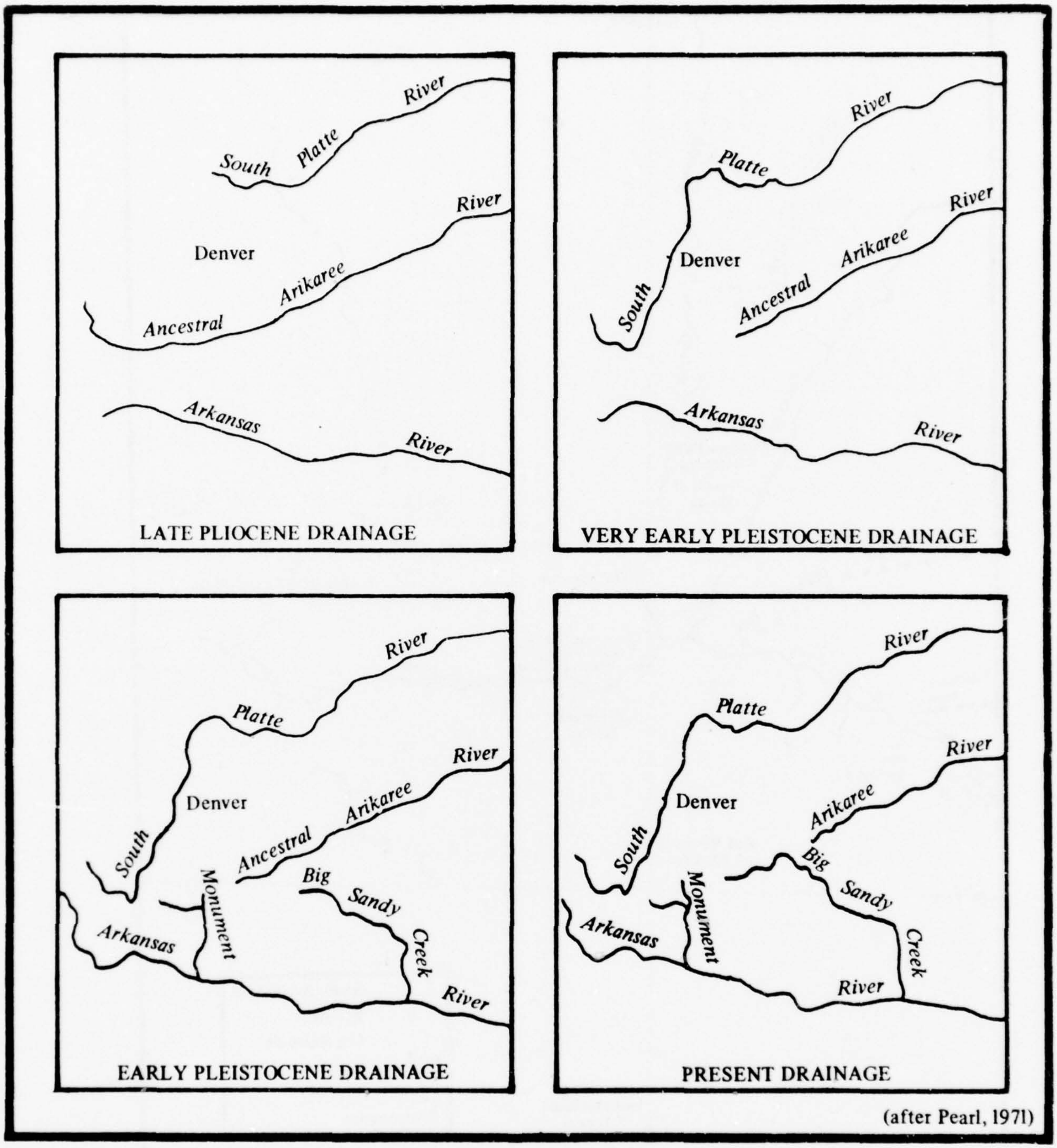
[19] Ibid., p. 135.

[20] R.F. Hadley, "Geomorphology: Erosion Rates and Processes," in Geological Survey Research, 1965. U.S. Geological Survey Professional Paper 525. (Washington, D.C.: Government Printing Office, 1965), p. 177.

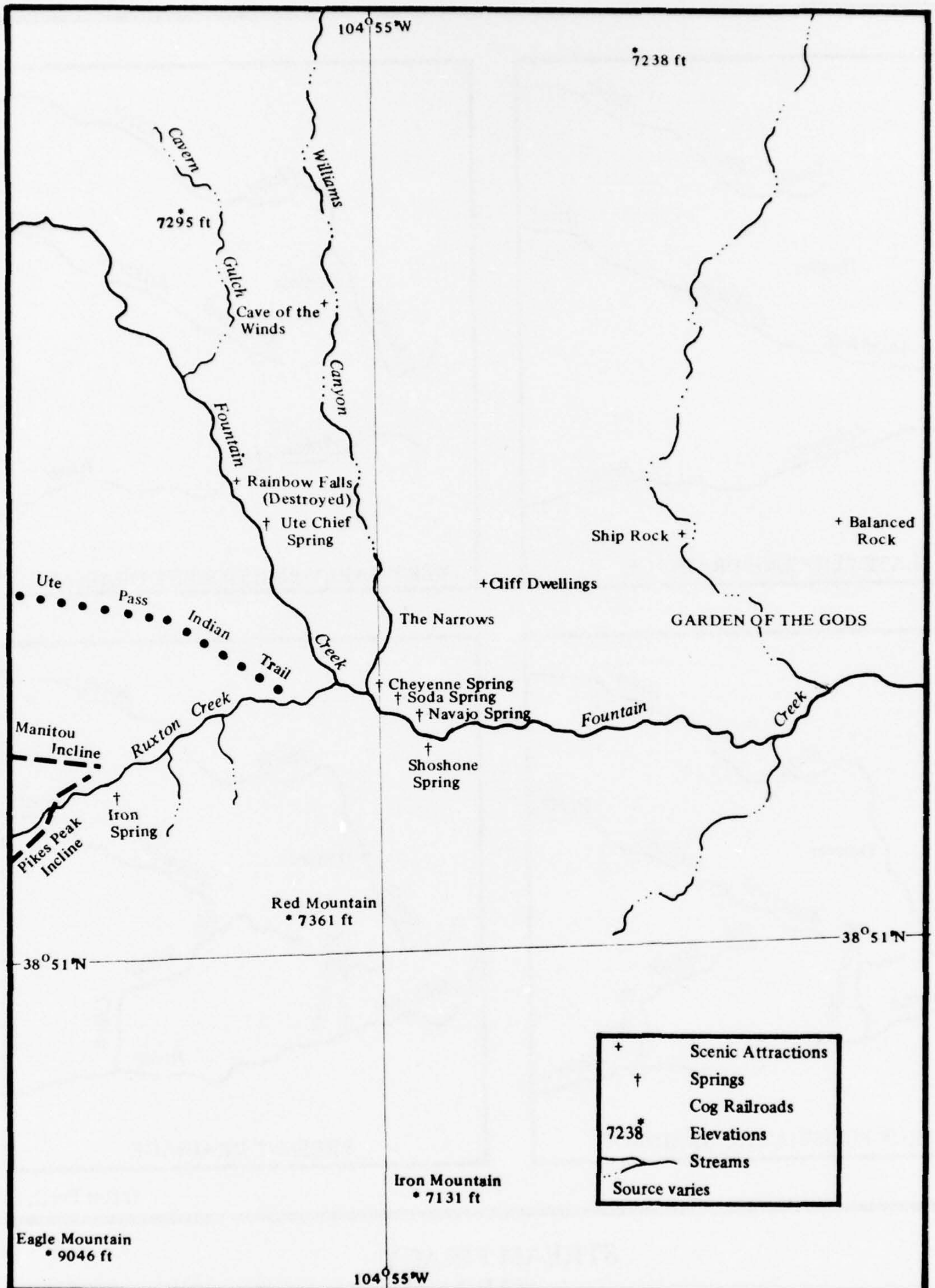
[21] R.N. Pearl, "Pliocene Drainage of East-Central Colorado and Northwestern Kansas," The Mountain Geologist 8 (1971): 25.

headwaters of the Arikaree were captured by the South Platte River, Plum Creek, and Monument Creek, due to their steeper gradients. These and other streams such as Big Sandy Creek were able to rapidly erode and remove the tertiary deposits from the region. During the development of the present drainage pattern, several streams which were eroding through the hogbacks and ridges were beheaded, leaving wind gaps such as those near Roxborough Park. Little Willow Creek previously flowed east and joined Willow Creek, but piracy has altered this pattern.

Throughout the Rocky Mountains, exposed contacts between igneous and sedimentary rocks as well as contacts between differing sedimentary beds are the site of hundreds of springs. The numerous springs in the study region should also be considered as a part of its drainage. The most famous springs occur in or near Manitou Springs (Map 4). Here several springs lie adjacent to Fountain Creek and are responsible for the name of the stream (Photograph 6). Cheyenne Indians called the stream "Boiling River" and the French term for that Indian name, Fountaine Qui Bouille, was later shortened to the present, Fountain Creek. Several natural springs occur within what is now the town of Manitou Springs. Early reports indicated that only four springs were present; however, six natural springs are in the area with two springs separated from the main cluster of four springs. The springs which were revered by the Indians add to the natural beauty of the region. In attempts to increase this beauty,



STREAM PIRACY
MAP 3



MANITOU SPRINGS
MAP 4

Photograph 6

Soda Springs
(1870)

numerous artificial springs were drilled. Other springs in the study region include one at Deckers and one in the Platte Canyon. Still others form the point of origin of streams of the plains.

Summary

The geomorphology of the study region is very heterogenous in all aspects. Elevations show great variation as does the topography in the major drainage basins. Springs are concentrated in a few locations as are the inspiring spires and pinnacles of upturned rock.

GEOLOGY

Geologic analysis of the Rampart Range and adjacent portions of the Colorado Piedmont as presented in this report is separated into geologic structure, history, and stratigraphy. There is obviously a relationship between these topics and data presented in one section may be significant to the discussion in another section.

Structure

The geologic structure and history of the Front Range has been interpreted in many ways. The entire 200 mile long Front Range has been described as: an asymmetrical fault bordered anticline;[22] an elongate dome or narrow mass of crystalline rocks surrounded by sedimentary rocks with spur anticlines plunging in a southeastern direction; a flat, fault-bounded arch approximately five times as long as wide and eight times as wide as high;[23] and as a "mosaic of fault bounded blocks."[24]

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[22]John F. Hubert, "Petrology of the Fountain and Lyons Formations, Front Range, Colorado," Quarterly of the Colorado School of Mines 60 (1960): 24.

[23]C. Maynard Boos and Margaret F. Boos, "Tectonics of the Eastern Flank and Foothills of Front Range, Colorado," Bulletin of the American Association of Petroleum Geologists 41 (December, 1957): 2608.

[24]William D. Thornbury, Regional Geomorphology of the United States (New York: John Wiley and Sons, 1965), p. 337.

Regardless of the interpretation accepted for the Front Range it definitely is a fault bordered mass which rises well above the topography to the east and west. The Range has extensive fault systems which together with six major granitic intrusions have been used by several authors to divide the range into sub units. An extensive study published in 1957, separated the Front Range into five large, fault bordered, en echelon, tectonic segments. Within these five segments a total of fifteen smaller tectonic units were identified. Two of these units are included in the study area: the Perry Park-Rampart Range Unit and the Manitou-Colorado Springs Unit.[25] The Rampart Range itself has been described as both a horst[26] and as an anticline.[27] In considering the latter view, one geologist stated that, "by protecting the sediments across the faults and around the end of the Rampart Range, an anticline is formed,"[28] This interpretation could be questioned by the conclusion that the dip of sedimentary rocks around the range might be the result of uplift of a horst and the

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[25] Boos and Boos, p. 2642.

[26] Ibid., p. 2657.

[27] Throwbridge L. Grose, "Geologic Formations and Structure of Colorado Springs Area, Colorado," The Mountain Geologist 9 (April-July, 1972): 234.

[28] William A. Fowler, "Geology of the Manitou Park Area, Douglas and Teller Counties, Colorado" (M.S. Thesis, University of Colorado, 1952), p. 24.

bending and folding of adjacent beds. In either case, the basic structure of the Rampart Range is that of a Precambrian core of metamorphosed sediments and granitic intrusions with steeply dipping, upturned, and in places overturned Paleozoic and Mesozoic sedimentary rocks along the eastern and western flanks. Cenozoic sediments and volcanic rocks also occur but in restricted areas (Map 5).

Sedimentary rocks become less steeply dipping eastward from the mountains. Adjacent to the mountains, under the Colorado Piedmont, lies the Denver Basin, a structural feature which contains sedimentary deposits as much as 13,000 feet thick. Relief from the base of the Denver Basin to the top of the Front Range reaches a maximum displacement of 21,000 feet near Denver.[29]

West of the Rampart Range lies the valley of Manitou Park. The interpretation of the geologic structure of Manitou Park depends to some extent upon the interpretation of the structure of the Rampart Range and in turn the Front Range. If the Rampart Range is considered as a horst, Manitou Park is best described as a graben. Belief in the anticlinal nature of the Rampart Range would lead to the synclinal trough concept as the true structure of the area. Both theories have supporters and logical explanations. In either case, Manitou Park consists of a large area which has been lowered and covered in part by many of the Paleozoic deposits

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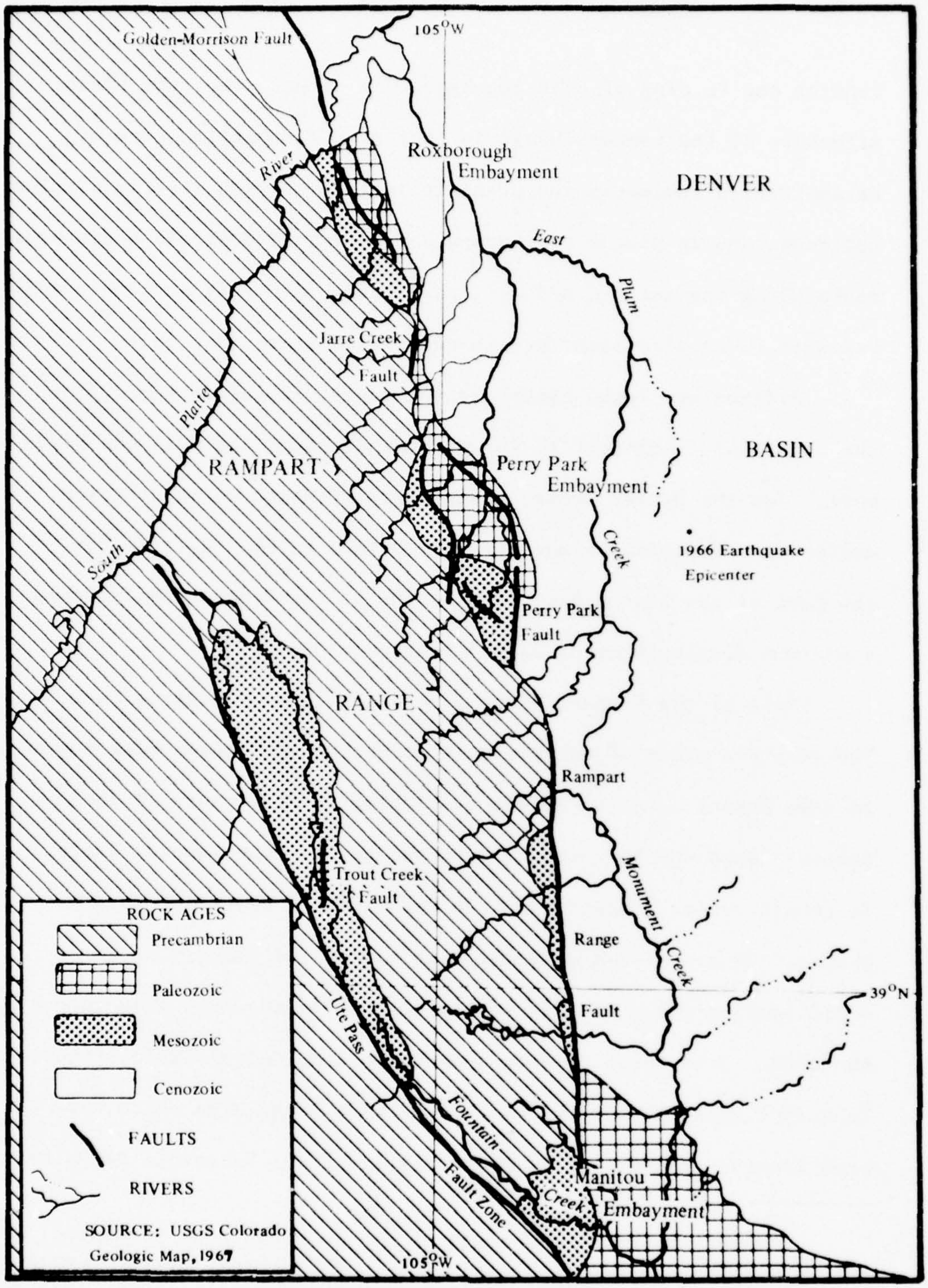
[29]Steven R. Marcus, Geology of the Mountain Zone of Central Colorado with Emphasis on Manitou Park. U.S. Forest Service Research Paper RM-113 (Fort Collins, Colorado: Rocky Mountain Forest and Range Experiment Station, 1973), p. 3.



GEOLOGIC STRUCTURE
MAP 5

which also are found in the Colorado Piedmont. No Mesozoic and only more recent Cenezoic deposits are found in the park.

Embayments

The eastern flank of the Front Range is marked by several embayments or invasions of sedimentary rocks into the Precambrian core. The largest embayment, the Canon City Embayment, marks the southern end of the Front Range and separates it from the other ranges of the Southern Rocky Mountain Physiographic Province. Within the Rampart Range three similar embayments occur, the Manitou Embayment, the Perry Park Embayment, and the Roxborough Embayment. (Map 5).

Manitou Embayment

The six by eight mile Manitou Embayment is best described as an extension of sedimentary rocks between two masses of Precambrian igneous rock and, according to one concept, is formed by the nose of a southeast plunging anticlinal spur of the Rampart Range. This spur, called the Manitou Spur or Colorado Springs Spur, forms the southern edge of the Rampart Range. The spur contains a centrally located anticline and a western syncline. The flanks of the spur are covered by the sedimentary rccks of the plains. Two large faults form the southern and eastern borders of the Manitou Embayment. Thus, the sedimentary rocks of the Manitou Embayment lie between the southern end of the Rampart Range and the Pikes Peak Massif.[30]

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[30] W.O. Crosby, "Archean-Cambrian Contact near Manitou, Colorado," Bulletin of the Geological Survey of America 10 (March, 1899): 143.

Perry Park Embayment

The Perry Park Embayment is a fault bounded four by eight mile area of tilted sedimentary rock. Within this embayment, the softer shales have been eroded and more resistant beds have formed cuestas and hogbacks. In places, the beds have been faulted so that they have almost vertical dip angles. Tall pinnacles have been created by differential erosion (Photograph 7). Hogbacks occur north of the Perry Park area, but south of the area they are not common as gravels have covered the sedimentary beds.

Roxborough Park Embayment

Although not always classified as an embayment, Roxborough Park is another area where faulting has brought the sedimentary rocks into almost vertical positions (Photograph 8). Here narrow ridges, spires, and other similar formations create a natural beauty which is equal to that in Perry Park and the Garden of the Gods.

Faults

The structure of the Rampart Range has been largely governed by the intrusion of the Precambrian Pikes Peak batholith and the various fault systems of the Front Range. The youngest and largest of the six major intrusive bodies in the Front Range, the Pikes Peak batholith covers 1,250 square miles and measures seventy-five by thirty miles. Not all of the batholith is in the Rampart Range and not all of the Rampart Range has developed from the batholith.

Photograph 7

Perry Park from the air.

Photograph 8
Roxborough Park

The Pikes Peak Massif has been formed from the Pikes Peak batholith, while older Precambrian rocks dominate the northern portion of the Rampart Range. The Front Range contains numerous faults as does the study region.

Ute Pass Fault Zone

The longest fault is the Ute Pass fault zone which separates the Rampart Range from other parts of the Pikes Peak batholith. The forty-five mile long Ute Pass fault zone begins near the base of the eastern face of Cheyenne Mountain, about twelve miles south of the study region and extends northwest through the Front Range. The nature of the fault varies along its length. It has been classified as a thrust fault near Cheyenne Mountain and as a reverse fault in Ute Pass. Along the western side of Manitou Park the nature of the fault once again changes, and in the northern part of the park the fault zone is almost vertical. The relation of areas across the fault zone is such that the Rampart Range is always the downthrown block. This is especially apparent in the Ute Pass area where the vertical separation has been estimated at 14,000 feet.[31] The fault is often difficult to observe; however, it is easily seen on aerial photographs (Photograph 9). The fault zone passes south of the valley of Fountain Creek for part of its course. In Manitou Park it occurs as an 800 to 1,700 foot wide fault zone with uncemented breccia in the southern part of the Park. The

[31]Grose, 234.

Photograph 9

Ute Pass Fault Zone

throw in Manitou Park varies from several hundred to several thousand feet and some strike-slip motion has been reported.[32]

Rampart Range Fault

Approximately one mile south of the Garden of the Gods another long and significant fault begins. This is the thirty-five mile long Rampart Range fault which has an estimated vertical separation of 15,000 feet.[33] The western side of this fault is the upthrown block and little strike-slip motion has been associated with this fault.[34]

Other Faults

The Rampart Range fault stops south of Perry Park but a series of similar faults occur in the Perry Park embayment area. Some of the faults in this area are reported to be thirteen miles long and may be as much as twenty miles long. Faults form the western border of the Perry Park Embayment; however, smaller faults separate the area from the Colorado Piedmont to the east. North of Perry Park another series of faults occurs along the eastern flank of the Rampart Range. The Jarre Creek fault, which is a high angle reverse

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[32] Marcus, p. 17.

[33] Grose, p. 234.

[34] John G. Harms, "Sandstone Dikes in Relation to Laramide Faults and Stress Distribution in the Southern Front Range, Colorado," Bulletin of the Geological Society of America 76 (September, 1965): 988.

fault, brings Cenozoic sedimentary rocks into contact with the Precambrian core of the range. It has been suggested that an extension of this fault, so far undetected, extends north to the northern edge of the study area and connects with the Golden-Morrison fault farther north.[35] Associated with all the faults along the Front Range is the deformation of the sedimentary rocks of the downthrown block by strike and dip faults.

As mentioned, the Ute Pass fault zone forms the western edge of the Manitou Park. The eastern border is formed by the Devils Head or Mount Deception fault zone. This fault zone is roughly parallel to the Ute Pass fault zone with the western side of the zone the downthrown block. The fault may be a high angle reverse fault with steep dips to the east.[36] Also within Manitou Park are two minor faults. Trout Creek fault is five miles long and lies midway between the Ute Pass fault and Devils head fault. Fish Hatchery Fault is shorter and connects Trout Creek Fault and Ute Pass fault.

In addition to the major faults described, the entire Rampart Range and foothills are crossed by many smaller faults. Signs of these curving tension faults are sags, gaps, and long straight valleys. Boos and Boos pointed to a series of east--west faults across the Rampart Range near Woodland Park which were felt to

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[35]Glenn R. Scott, Bedrock Geology of the Kassler Quadrangle, Colorado. U.S. Geological Survey Professional Paper 421-B. (Washington, D.C.: Government Printing Office, 1963), p. 109.

[36]Marcus, p. 17.

serve as a "hinge."[37] The level Rocky Mountain Erosional Surface is north of these faults while to the south, the land descends to the plains as the Colorado Springs spur. Several of the faults are believed to have originated in the Precambrian; however, the large movement along them is considered to have occurred during the Laramide Orogeny. The faults are commonly considered to be inactive since earthquakes in Colorado generally occur on the western side of the continental divide.

Recent earthquakes within the Denver Basin have been linked to the disposal of liquids by means of deep wells at the Rocky Mountain Arsonal and these earthquakes have had epicenters north of Denver. On 12 October 1966, an earthquake was recorded near the town of Castle Rock (39° 18'N 104° 46'W) with a force of three on the Richter scale.[38] Although Castle Rock lies within the Denver Basin, it is located south of the epicenters associated with the Rocky Mountain Arsonal (Map 5). Three earthquakes, all with an intensity less than four, have occurred in either the Ute Pass fault or Rampart Range fault since 1965. Thus, these faults should be considered active.[39] Studies have shown that displacement has occurred along the Rampart Range fault in recent times. On the Air Force

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[37] Boos and Boos: 2660.

[38] F.A. Hadsell, "History of Earthquake Activity in Colorado," Quarterly of the Colorado School of Mines 63 (1968): 62.

[39] Pikes Peak Area Council of Governments, "Project TEAM: Analysis of the Natural Systems," Colorado Springs, Colorado, n.d., (Typewritten).

Academy grounds, a twenty-five foot shift in Quaternary gravels has been located with the motion considered to be Yarmouth or younger in age.[40]

Sandstone Dikes

Large dikes composed of sandstone are associated with faults in the Rampart Range. The dikes tend to be vertical in nature and vary from a few inches to 300 feet in thickness and are up to eight miles in length.[41] These features often stand out as ridges in Precambrian rocks. Many of the 200 dikes are found in a roughly linear zone from Manitou Springs into Manitou Park, which closely follows the pattern of the Ute Pass fault zone. Another pattern of similar dikes appears to follow the Jarre Creek fault. Sandstone dikes which occur outside the Rampart Range in the Front Range are also associated with fault zones.[42] Grains of worn and well rounded quartz form 90 percent of the dikes. The source of the quartz is believed to be a Cambrian age sandstone which was deposited over the Precambrian core. It is believed that

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[40] Glenn R. Scott, Quaternary Faulting and Potential Earthquakes in East-Central Colorado. U.S. Geological Survey Professional Paper 700-C. (Washington, D.C.: Government Printing Office, 1970), p. C-14.

[41] W.O. Crosby, "The Great Fault and Accompanying Sandstone Dikes of Ute Pass, Colorado," Science (N.S.) 5 (April, 1897): 604.

[42] P.W. Vitanage, "Sandstone Dikes in the South Park Area, Colorado," Journal of Geology 62 (1952): 495.

the development of reverse faults in these Precambrian rocks created fissures which were filled by intrusions from the overlying sandstone.[43]

Geologic History

The geologic history of the Rampart Range and the Colorado Piedmont is subject to several interpretations. One of the problems involved in the area is that the more recent periods of tectonics, in many cases, have destroyed evidence of earlier events. Also, agreement as to the exact nature of features such as faults and their causes have not been reached. The best method to analyze the history is through an era by era and period by period portrayal of the events believed to have occurred and the evidence supporting these beliefs.

Precambrian Era

During the Precambrian Era it is felt that a sequence of shales, sandstones, and limestones were deposited in a deep basin where the Colorado Front Range and Colorado Piedmont now exist. These rocks were then uplifted, folded, faulted and intruded by several small bodies. As a result of these events, the rocks underwent metamorphism creating the Idaho Springs Formation. During the latter part of the Precambrian Era the Colorado Front Range was intruded by at least six large batholiths of which the Pikes Peak batholith is the southern-most and most recent. After the

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[43] Harms: 987.

intrusion of the granitic masses, the entire region was again uplifted and subsequently eroded to form a relatively smooth surface.

Paleozoic Era

During the Paleozoic Era continental seas advanced and retreated over the area on several occasions. In the Late Cambrian Epoch, seas advanced from the east and west. The area from Perry Park to a point south of Canon City was the Colorado Sag or Colorado Strait.[44] (Map 6) This low portion of the Transcontinental Arch between the Siouxia Uplift to the north and the Sierra Grande Uplift to the south connected the eastern sea with a western sea. Several of the Paleozoic sediments were deposited in the Colorado Sag or along the edges of the Transcontinental Arch. The presence of the arch explains in part the limited distribution of several of the Paleozoic formations within the study region. Stability of the region has been the subject of differing interpretations; however, during the time of deposition of the Sawatch Sandstone the area is commonly believed to have been stable. The Sawatch Sandstone was deposited along the edges of the Transcontinental Arch during the Late Cambrian Epoch.

During the Early Ordovician Epoch, the seas of the Cambrian period retreated. The return of the seas in the Late Ordovician

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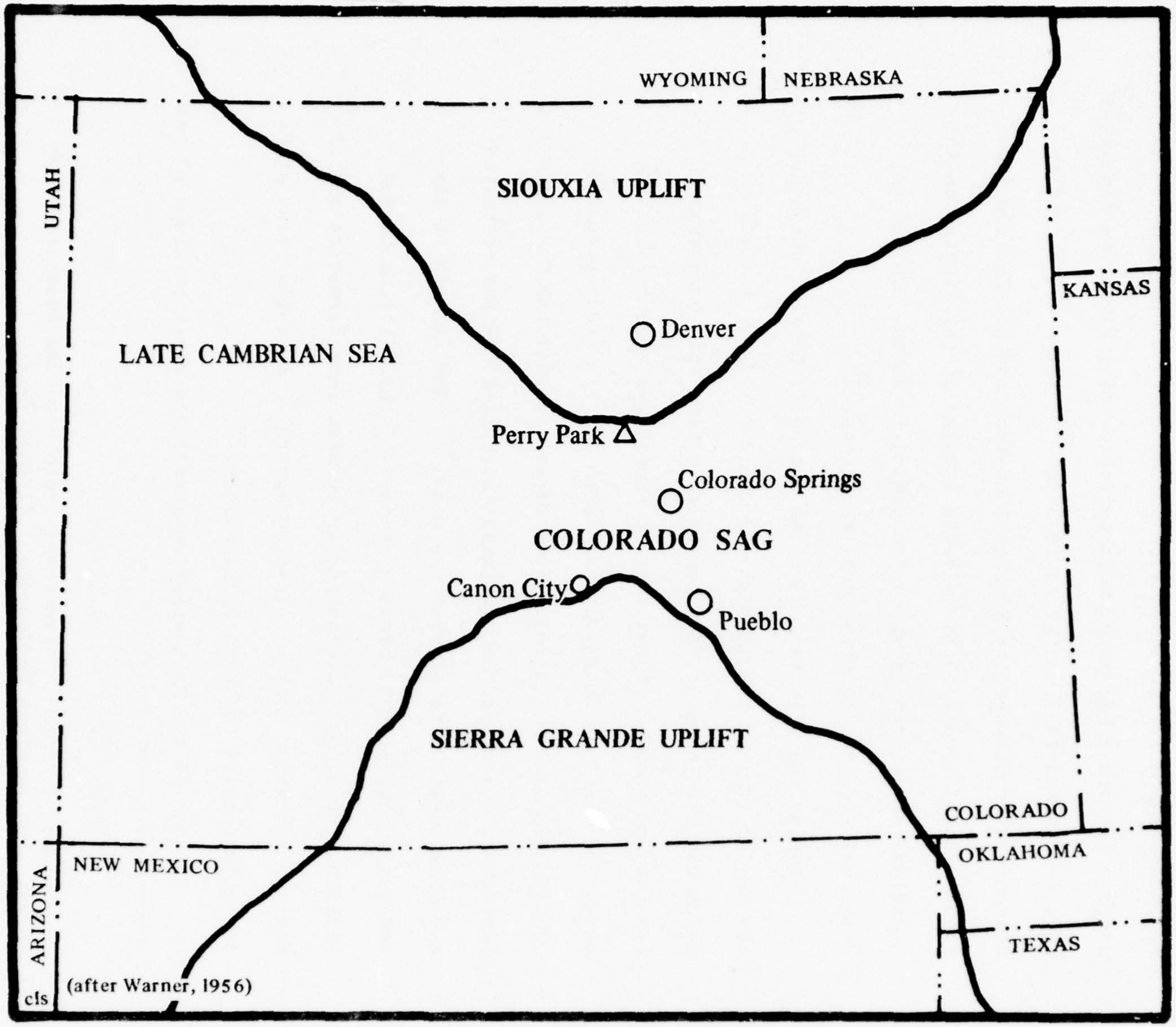
[44] John D. Haun and Harry C. Kent, "Tectonic History of Rocky Mountain Region," Bulletin of the American Association of Petroleum Geologists 49 (November, 1965): 1783.



COLORADO SAG OF LATE CAMBRIAN and EARLY ORDIVICIAN

MAP 6

was accompanied by the deposition of the Manitou Limestone. The Manitou Limestone has many characteristics of a formation deposited in a low to moderate energy environment.[45] There is an overlap disconformity between the Sawatch Sandstone and the Manitou Limestone. This disconformity reflects erosion of the Sawatch as the Cambrian Seas retreated which, according to Harms, was due to "regional flexure and structural movements."[46]

During the Silurian, Devonian and Early Mississippian Periods the region was relatively stable and above water. Formations which may have been created during this time span were removed by erosion and today no formations of these ages are found in the area. In the Late Mississippian Epoch the sea readvanced and the Williams Canyon Limestone was deposited over the Manitou Limestone. Later in the Mississippian Period the sea retreated and then advanced to recover the area.[47] The absence of the sea was accompanied by erosion of part of the Williams Canyon Limestone creating a disconformity between that formation and the Madison Limestone above it (Photograph 10). A similar disconformity exists below the Manitou Limestone.

The end of the Mississippian Period and early portions of the

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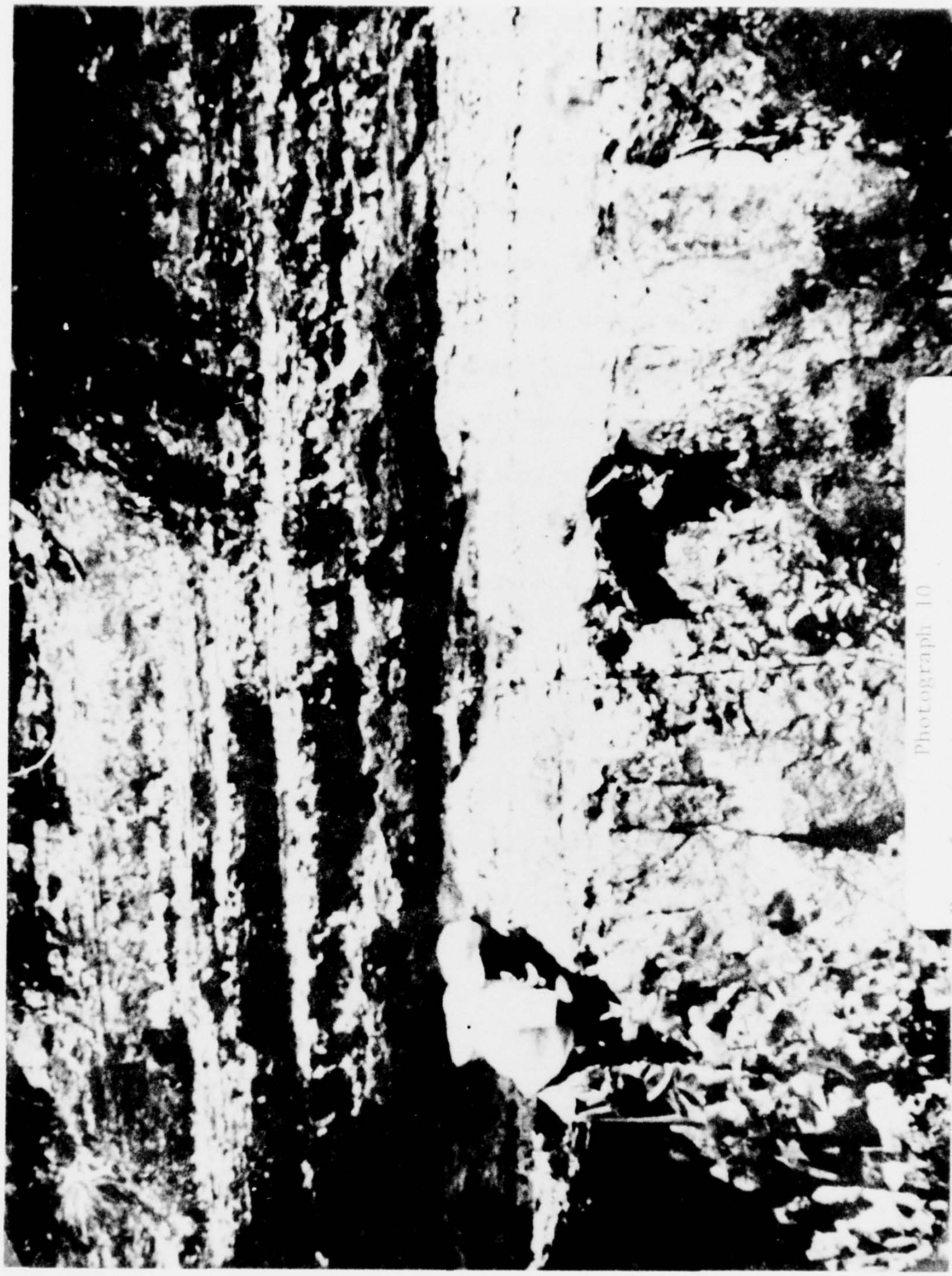
[45]Marcus: 10.

[46]John C. Harms, "Structural History of the Southern Front Range," The Mountain Geologists 1 (1964): 94.

[47]Haun and Kent: 1785.



Photograph 10
Unconformity between William Canyon
Limestone and Manitou Limestone.

Pennsylvanian Period were marked by the retreat of the eastern sea as land began to rise to form a large mountain range, which is commonly called the "Ancestral Rocky Mountains." During the formation of the mountains, the upper surface of the Madison Limestone was transformed into a well developed karst topography with numerous solution cavities and sink holes. This period of erosion is responsible for the interesting caves in the Manitou Springs area. It is felt that the upper portion of the Madison Limestone was removed by erosion during the Early Pennsylvanian Epoch.[48] In some areas, the entire sequence of early Paleozoic sediments were removed exposing the Precambrian erosional surface.

During the Pennsylvanian Period the Ancestral Rocky Mountains lay slightly east of present location of the Front Range with structural relief in the region estimated at 5,000 feet.[49] Arkoses of the Fountain Formation were deposited above sea level on an alluvial plain.[50] This plain was formed by the coalescing of alluvial fans on a piedmont plain during a period of semiaridity.[51] Deposits of the Fountain Formation have been classified as follows:

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[48] Marcus: 14.

[49] W.W. Mallory, "Outline of Pennsylvanian Strategraphy of Colorado," in Guide to the Geology of Colorado (Denver, Colorado: Geological Survey of America, 1960), p. 26.

[50] Harms, Structural History: 96.

[51] Fowler, p. 20.

80 per cent stream channel conglomerates and sandstones, 17 per cent flood plain clayey siltstones and shales, and 3 per cent deltaic laucustrine clayey sandstones and siltstones.[52] The earlier Paleozoic as well as Precambrian formations, which had been uplifted, provided the materials used to create the Fountain Formation. The Fountain Formation lies over the Manitou Limestone at an angular unconformity which in places exceeds 30 degrees.[53] The angular disconformity resulted from the uplifting and folding of the Manitou Limestone followed by erosion which produced a smooth surface. Deposition of the younger sediments of the Fountain Formation was upon the eroded surface.

The Ancestral Rocky Mountains and the surface of portions of the upper Fountain Formation may have been tectonically lowered rather than eroded as the Permian Lyons Sandstone lies conformally above the Fountain Formation. In the Permian Period, seas re-entered the area and the Lyons Sandstone was deposited as a series of coastal sand deposits and eolian dunes. As the sea advanced the shales and limestones of the Lykins Formation were deposited conformally over the Lyons Sandstone in a marine environment. Seas remained over the area during the Late Permian and Early Triassic Epochs as the Lykins Formation has been classified as an upper Permian and possible lower Triassic rock stratigraphic unit.

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[52] Marcus: 15.

[53] Harmes, Structural History: 96.

Mesozoic Era

During the Middle and Late Triassic Epochs another slight uplifting of the region occurred and any other Lower Triassic sediments, if present, were removed. A portion of the Lykins Formation was truncated during this time.[54]

Arctic Seas advanced and retreated over the area during the Jurassic Period; however, no marine deposits occurred or are evident today.[55] The shale and marlstone members of the Ralston Creek Formation and Morrison Formation of the Upper Jurassic were deposited in fresh water lakes and swamps of the region. The gypsum facies of the Ralston Creek Formation was deposited in shallow saline lagoons. The contact between the Ralston Creek Formation and the Lykins is one of an overlap unconformity. Following a retreat in the Late Jurassic, the Arctic Sea gradually spread across the region during the Early Cretaceous, and united with a sea extending northward from the Gulf of Mexico. This spreading can be traced by the sequence and ages of the Lower Cretaceous formations. The lower member of the Purgatorie Formation or Lytle Formation is primarily of flood plain origin while the upper member of the Purgatorie Formation and Dakota Sandstone or South Platte Formation are of marine origin. These latter formations were deposited in shallow seas or along coastal zones. The age of the formations

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[54] Harms, Structural History: 96.

[55] Scott, Bedrock Geology, p. 113.

becomes younger toward the south indicating a southward spread of the seas. The sea separated during the Middle Cretaceous as the Transcontinental Arch was reformed.[56] In the Late Cretaceous Epoch the seas readvanced and the three formations of the Benton Group were all deposited in deep waters. Although the Niobrara Formation is also of deep water origin, it lies disconformally over the Benton Group, reflecting a retreat and advance of the seas. The extensive Pierre Shale also includes beds deposited in deep waters; however, it is separated from the Niobrara Formation by another disconformity indicating another retreat and advance of the seas. By the end of the Late Cretaceous Epoch the region of the Colorado Front Range was part of a large marine basin with a total of 10,000 feet of marine sediments.[57]

Laramide Orogeny

The Late Cretaceous also marked initiation of the Laramide Orogeny as the present Front Range of Colorado began to rise. With the increase in elevation the nature of sedimentation in the region changed. In contrast to the deep water Pierre Shale, the Fox Hills Sandstone has a brackish, shallow water limestone component which was followed by a regressive sequence of sandstones and coals known as the Laramide Formation.[58]

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[56] Haun and Kent: 1791.

[57] Harms, Structural History: 96.

[58] Scott, Bedrock Geology, p. 104.

It is believed that at the beginning of the Laramide Orogeny uplift was relatively rapid, creating an angular unconformity between the Laramie Formation and the Dawson Formation which reaches 40 degrees near Colorado Springs. Coarse conglomeratic beds at the base of the Dawson Formation are a reflection of this rapid uplift. The rate of uplift slowed for a period as evidenced by the sandstones, shales, and siltstones of the Austin Bluffs Member of the Dawson Formation. Arkosic deposits of the Colorado Springs Member of the Dawson reflect a later increase in the rate of uplift. The Colorado Springs Member, the major part of the Dawson Formation, was "deposited in a moderate gradient coallescing alluvial fan environment as streams flowed from west to east from the uplifted Rampart Range."[59]

Because only the lowest portions of the Dawson Formation have been dated as part of the Cretaceous, the upper portions indicate the continuation of the Laramide Orogeny into the Cenozoic Era. As a measure of the total amount of change in relief which took place during the Laramide Orogeny, Scott stated that 25,000 feet of arching occurred near the center of the Front Range with 17,000 feet of similar motion near the edges of the range.[60]

The exact nature of the force which caused this great change

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[59] Rodney J. Eichler, "Geomorphology and Engineering Geology of the Cottonwood Creek Area, Pikeview and Falcon Northwest Quadrangles, El Paso County, Colorado," (M.S. Thesis, Colorado School of Mines, 1973), p. 111.

[60] Scott, Bedrock Geology, p. 109.

in structural relief has been the subject of a great deal of investigation and speculation. Initial theories were often based upon incomplete field work and the most commonly held view proposed that the Colorado Front Range was the result of vertical uplift. Later studies expressed the opinion that lateral compression was the driving force behind the creation of the Front Range. Although the concept of vertical uplift continued to have support. Walter Bucher, in his 1933 book, Deformation of the Earth's Crust, pointed out that in dealing with the Front Range "accurate, detailed structural observations [were] surprisingly scant."[61] In spite of this, Bucher expressed his support for the lateral compression belief,and the view became commonly accepted by many geologists. The concept of vertical uplift began to reappear in geologic literature in the early 1960's. One leader in this renaissance, J.C. Harms, based his conclusions in part upon the presence and age of sandstone dikes. The age of these dikes was the subject of differing views. Glenn Scott considered them to be of Cambrian age and presented his view that a period of instability in the Late Cambrian Epoch reopened Precambrian tension cracks in the bedrock. Sands from the Sawatch Sandstone then entered these cracks to form the sandstone dikes.[62] Scott also stated that near the peak of the

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[61] Walter H. Bucher, The Deformation of the Earth's Crust (Princeton, New Jersey: Princeton University Press, 1933), p. 162.

[62] Scott, Bedrock Geology, p. 113.

Laramide Orogeny the Precambrian faults were reactivated and the sandstone dikes faulted.[63] Harms disagreed with this concept and pointed out the presence of sediments within the sandstone dikes, which he believed to have been derived from the Pennsylvanian Formation. Based upon these fragments, he felt that the dikes intruded the Precambrian core sometime after the end of the Pennsylvanian Period. Since the dikes are generally parallel to the Laramide age faults, Harms concluded that they are probably Laramide in age.[64] The occurrence of the dikes on the upthrown block led to the belief that their occurrence was the result of dip-slip movement, "along steeply westward dipping convex upward fault surfaces."[65]

One paper provided the lateral compression theory with a driving mechanism, Continental Drift. It is proposed that as the continental block of North America began to override the oceanic plate of the Pacific Ocean, the distribution of stress through the western United States led to the forcing of the relatively stable Colorado Plateau toward the east. This motion resulted in the compression of materials between that plateau and the relatively immobile Mid-continental Craton. As the Front Range was being forced

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[63] Ibid., p. 114.

[64] Harms, Sandstone Dikes: 996.

[65] John C. Harms, "Structural Geology of the Eastern Flank of the Southern Front Range, Colorado," (PhD Thesis, University of Colorado, 1951), p. 413.

upward, the adjacent Denver Basin was being depressed. In this theory the southern end of the Wet Mountains to the South of the Canon City Embayment mark the western end of the Wichita lineament, a large strike-slip fault.[66] Little compression occurred south of that fault.

The nature of the faults in the Front Range has also been intensely studied. Most of the faults, including the Ute Pass fault and Rampart Range fault, are believed to be high angle reverse faults. Existence of such faults can be used to support both the theory of vertical uplift and that of lateral compression as the method of creation of the Front Range. The concept uniting lateral compression and continental drift does provide an explanation for the Denver Basin which also is believed to have reached its present configuration by the end of the Laramide Orogeny.[67]

Regardless of the method of formation, the Colorado Front Range provided the source of the arkosic deposits of the Dawson Formation as the "Ancestrial Rocky Mountains" had for the Fountain Formation.

Cenozoic Era

The Tertiary Period of the Cenozoic Era was marked by the termination of the Laramide Orogeny. Near the end of the Eocene

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[66] John K. Sales, "Crustal Mechanics of Cordilleran Foreland Deformation: A Regional and Scale-Model Approach," Bulletin of the American Association of Petroleum Geologists 52 (October, 1968): 2023.

[67] Charles A. Martin, "Denver Basin," Bulletin of the American Association of Petroleum Geologists 49 (November, 1965): 1908.

Epoch, the surface of parts of the Dawson Formation was covered by a layer of rhyolite or welded tuff. The source of this material has not been definitely located. Richardson, in 1915, suggested a source near the divide between the Arkansas and Platte drainage basins, but this has not been confirmed. Signal Butte, located thirty-five miles southwest of Castle Rock and outside the study area,is a late Tertiary intrusive plug and was suggested as a source for the Douglas Rhyolite.[68] Another study concluded that the rhyolite or tuff is most closely related to ash flows found in the Thirty-nine Volcanic Field approximately eighty miles from the Castle Rock area. However, this is not generally believed to be the source area, due to the distance involved. R.B. Taylor, of the USGS regional office in Denver, feels that the source may be in the Sawatch Range, which is even farther away. It is possible that research presently being conducted may result in a determination of the source of the Douglas Rhyolite.

Considerable erosion followed the deposition of the Douglas Rhyolite and resulted in the formation of terrain having as much as 1,000 feet of relief.[69] The Oligocene Epoch was marked by the creation of the Rocky Mountain erosional surface and deposition of the material eroded from the mountains over eastern Colorado

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[68]Fred E. Walsh, Jr., "The Geology of the Castle Rock Area, Douglas County, Colorado," (M.S. Thesis, Colorado School of Mines, 1969), p. 68.

[69]Harms, Structural History, p. 97.

and in the Colorado Piedmont. The 300 feet thick sediments were deposited by the ancestors of the present rivers of the region. The Castle Rock Conglomerate is of Oligocene age and was formed from wash and fluvial deposits in the stream channels and on adjacent areas of the region. Primary source for this conglomerate was the Pikes Peak granite which was exposed at this time.[70]

It was the random deposition of the Castle Rock Conglomerate and Douglas Rhyolite which is today responsible for the differing topography on the two sides of the divide. Where either of the two formations occur they form the cap for the buttes and uplands or have retarded erosion creating the buttes. Areas south of the divide lacked this protective layer and the result has been the more open and rolling topography.

During the late Pliocene there was a slight uplifting in the area of the Rampart Range and a change in the climate.[71] This resulted in increased erosion of the mountains. The headwaters of the South Platte River and several rivers of the Pikes Peak Massif and South Park area united as one river and exited the mountains at about the location of the present West Monument Creek.

The change to a cooler climate and slight uplift resulted in the glaciation of the Front Range during the Quarternary Period.

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[70] John A. Ames, "Geology of the Dawson Butte Area, Castle Rock Quadrangle, Colorado," (M.S. Thesis, University of Illinois, 1950), p. 164.

[71] Glenn R. Scott, "Nonglacial Quaternary Geology of the Southern and Middle Rockies," in The Quaternary of the United States, ed. H.E. Wright and D.G. Frey (Princeton, N.J.: Princeton University Press, 1965), p. 247.

Glaciation was primarily the result of the changed climate rather than the uplift, as the Rampart Range is believed to have been at almost the same elevation since the Pliocene.[72] The Rampart Range was not glaciated; however, there was a tremendous increase in runoff and sediment loads in the streams of the region.[73] These increases, coupled with several changes in base level, have resulted in the formation of the pediments and terraces observable today adjacent to the mountains. The initial stages of glaciation deposited much of the Nussbaum Alluvium over the vast majority of the Castle Rock Conglomerate and lower formations.[74] Later erosion removed a great deal of alluvium and left the reworked materials as the younger alluvial deposits. Tributaries of the South Platte and Arkansas Rivers cut their valleys headward through these deposits toward the divide and captured the eastward flowing streams to create the present drainage pattern.[75] These captures caused some of the lowering of base level already mentioned.

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[72]Scott, Bedrock Geology, p. 112.

[73]Thomas N. James [James T. Neal], These Beautiful Hills (Palmer Lake, Colorado: Filter Press, 1971), p. 9.

[74]Paul E. Soister, Relation of Nussbaum Alluvium (Pleistocene) to the Ogallala Formation (Pliocene) and to the Platte-Arkansas Divide, Southern Denver Basin, Colorado. U.S. Geological Survey Professional Paper 575-D (Washington, D.C.: Government Printing Office, 1967), p. 45.

[75]Pearl: 29.

Stratigraphy

As one enters the Rampart Range and adjacent areas from the east, the variety of rock formations is easily noted. This is especially true in the Manitou Embayment. Faulting has eliminated sequences of formations in several areas with the result that some formations are restricted to only one or two locations. In other areas recent deposits have buried older formations. Formations also change greatly in thickness throughout the region and may vary by as much as 3,000 feet. As an overview to the stratigraphy of the study region it should be noted that the formations of Precambrian Era are covered in places by as much as 13,000 feet of sedimentary rocks while in others the Precambrian rocks are exposed. A few of the sedimentary formations are quite thin, twenty-five to thirty feet, while others are over 8,000 feet thick.

Precambrian Formations

The Precambrian core of the study region consists of four formations.

Idaho Springs Formation

The oldest of these, in fact, the oldest rocks of the entire Front Range, occurs in the northern part of the study region outside the Pikes Peak batholith and in isolated patches on the top of the batholith. This is the Idaho Springs Formation with four members; a basal biotite-sillimate schist, a biotite schist, a quartzite member, and an upper member which is a mixture of quartzites and lime silicates.[76] All of these were formed by the metamorphism of older sequences of sandstones, shales, and limestones which were deposited in a Precambrian basin.[77] Metamorphism and the creation of the Idaho Springs Formation is believed to have occurred approximately 1.5 billion years ago.[78] The nature of the Idaho Springs Formation varies greatly from place to place; however, in the Rampart Range the biotite-sillimate schist member is a yellowish gray, well foliated rock in which the foliations follow initial bedding. The biotite-schist member is restricted in the study region and has a light gray color which is mottled with black. Concentrations of biotite in the formation indicate the old bedding plains. The quartzite member consists of quartz gneiss, hornblende genisses, and granitized quartzites. These vary from light gray to black, but are most commonly medium gray. Rocks in this group which are generally even grained occur along the eastern edge of the mountains in the northern part of the region. The upper member is fairly complex and includes a dark gray to dark green amphobolite. This amphibolite, which is a fine to medium grained gneiss, is often highly foliated. The lime silicates of this member are

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[76] Boos and Boos: 2610.

[77] Scott, Bedrock Geology, p. 113.

[78] Donald H. Johnson, "Geology of the Devils Head Quadrangle, Douglas County, Colorado," (M.S. Thesis, Colorado School of Mines, 1961), p. 60.

restricted in the study region. Near the edges of the Pikes Peak batholith a series of granitized metasedimentary rocks such as granite gneiss and migmatite occur. Composition varies, but most of these pale red or grayish orange rocks are granitic in composition and well foliated.[79] The Idaho Springs Formation tends to form rugged terrain where present.

Silver Plume Granite

The remainder of the Precambrian formations of the study region are granites. The Silver Plume granite in the extreme northern part of the region is a biotite-muscovite granite of pale red color of fine to medium grain. Crystals of microcline and biotite tend to be somewhat aligned. A similar granite may be observed near Carpenter Peak, just south of Roxborough Park, and forms large rounded knobs with protruding feldspar crystals.[80]

Pikes Peak Granite

The most common granite of the region is the Pikes Peak granite which forms the Pikes Peak batholith. This is a reddish brown to pink mass that varies from a granite to quartz monzonite. Pikes Peak granite has a coarse, even grained to porphyritic texture with major constituents of microcline, orthoclase, quartz, and biotite. The pinkish color of the formation is due to an abundance of feldspars which occur in crystals up to one inch long.

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[79] Scott, Quaternary Geology, p. 80.

[80] Ibid., p. 82.

Biotite booklets may be as much as a half inch in size. Quartz grains tend to be white or gray and one half inch in diameter. The average sample of Pikes Peak granite consists of 33 per cent quartz, 53 per cent microcline, 11 per cent biotite, and 3 per cent oligoclase.[81] Pikes Peak granite weathers into rounded forms through the process of exfoliation with the weathering occuring along the numerous joint systems of the formation. Weathered surfaces are often rough due to the protusion of phenocrysts. The weathered material forms a very coarse angular gravel or grus, which may locally be twenty-five feet thick. Pegmatites are not considered to be common in the Pikes Peak granite; however, they do occur near the edges of the Pikes Peak batholith and in isolated areas within the large body.

Windy Point Granite

In several places on the crest of the Rampart Range, small outcrops of another Precambrian Era granite occur. The Windy Point granite was named for its type location at an elevation of 12,000 feet on the side of Pikes Peak. This is a gray to pink, prophyritic granite or quartz monzonite with biotite occurring in rounded clusters.[82] Using the principles of ascendancy and descendancy, the

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[81] Marcus, p. 16.

[82] Glenn R. Scott and Reinhard A. Wofus, Reconnaissance Geologic Map of Colorado Springs and Vicinity, Colorado, Scale 1:62500, U.S. Geological Survey Miscellaneous Field Studies Map MF 482 (Denver, Colorado: U.S. Geological Survey, 1973).

occurrence of this granite and remnants of the Idaho Springs formation have been used to support the view that the present top of the Rampart Range was close to the structural top of the Pikes Prak batholith.[83]

The surface of the Pikes Peak batholith presents a relatively smooth erosional surface along its sides on which the younger sedimentary rocks lie at an angular unconformity.

Paleozoic Formations

There are eight formations of the Paleozoic Era in the study region. The oldest of the two Cambrian aged formations is the Sawatch Sandstone.

Sawatch Sandstone

This formation is restricted in its occurrence and is found only in Manitou Park, Perry Park, the Manitou Embayment, and along the foothills just west of Colorado Springs.[84] A thick arkosic base and a fine grained sandstone upper member characterize the Sawatch. It is a well bedded formation containing large subrounded to well rounded quartz grains in a very fine matrix at the base.[85] Color in the base is white to light gray, while the upper sandstone

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[83] Boos and Boos: 2657.

[84] Marcus, p. 10.

[85] A. E. Brainerd, H. L. Baldwin, and I. A. Keyte, "Pre-Pennsylvanian Stratigraphy of Front Range in Colorado," Bulletin of the American Association of Petroleum Geologists 17 (April, 1933): 379.

member is red, pinkish, or brown and calcareous.[86] Thickness of the Sawatch varies from one hundred feet in Perry Park to twenty-five feet at the Air Force Academy and forty-five feet in Williams Canyon, in the Manitou Embayment. In Manitou Park, the exposures of the Sawatch Sandstone are as much as sixty-eight feet thick. Of use in determination of the geologic history and structure of the region is the fact that along the eastern flank of the Front Range the beds of the Sawatch Formation dip to the east while in Manitou Park the beds of this and other formations dip at low angles to the west.[87]

Peerless Dolomite

An overlap unconformity separates a thin, dark red, glauconitic sand and coarsely granular dolomite from the Sawatch Sandstone.[88] The age of this eight to sixteen foot thick layer is uncertain as some geologists place it in the Late Cambrian Epoch, while others feel it is Ordovician in age. The formation has been observed primarily in Manitou Park and within the Manitou Embayment. In 1894, Cross identified this as the Ute Pass Dolomite. Later study of the Sawatch Sandstones outside the Rampart Range led to the conclusion, based on fossil correlations, that the Ute

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[86] George L. Robb, "The Geology of Northern Perry Park, Douglas County, Colorado," (M.S. Thesis, Colorado School of Mines, 1949), p. 13.

[87] Boos and Boos: 2661.

[88] Grose: 230.

Pass Dolomite of the Manitou Park area is in reality a part of the Peerless Dolomite which occurs above the Sawatch Sandstone in the area north of Leadville, Colorado. What had been described as Ute Pass Dolomite in the Williams Canyon area of the Manitou Embayment was judged to be different in nature and included in a Lower Ordovician limestone formation.[89] Thus, the Ute Pass Dolomite has been abandoned as a formation in the Rampart Range and the Peerless Dolomite which occurs in the Manitou Park area replaced it.

Manitou Limestone

The Manitou Limestone, of which the Ute Pass Dolomite is now considered the basal member, is a well bedded, fossiliferous dolomite and limestone of the early Ordovician epoch. Color at the base of the formation is rusty red while the upper parts are buff to light gray. The formation changes upwardly from a dolomite to a calcareous sandstone, then to a limestone, and finally to another dolomite.[90] Beds are thinner towards the top of the Manitou Limestone than at the base. It has been suggested, in a 1974 article, by Gerhard, that the Manitou Limestone in the Rampart Range is the southeastern facies of the two facies which occur within the formation. The lower unit of this three member facies is named the Helena Canyon member and is a twenty foot thick segment of conglomeritic dolomite,

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[89] Joseph Berg and Reuben J. Ross, "Trilobites from the Peerless and Manitou Formations, Colorado," Journal of Paleontology 33 (January, 1959): 108.

[90] Fowler, p. 11.

dolomite, and limestone. This undoubtly correlates to the Ute Pass Dolomite as initially defined by Cross. Above this member lies the Ptarmigan Chert lower member which is gray massive dolomite with "abundant bedded chert."[91] The upper member, the Leavick Tarn Dolomite is a gray to green, massive dolomitized limestone containing some mud lumps. Thickness of the entire Manitou Limestone formation varies from the 218 feet at the type location in Williams Canyon near Colorado Springs, to 87 feet in Manitou Park (Photograph 11). In Manitou Park the limestone formation occurs as a narrow band of almost vertical rocks along the eastern border of the park. On the eastern face of the Rampart Range the formation has been eroded into several flatirons which have been quarried as sources of limestone.

Williams Canyon Limestone

No rocks of the Silurian or Devonian Periods have been located within the study area. Thus, the two formations of the Mississippian Period lie disconformably on the older formations. The lower of these is the Williams Canyon Limestone and is restricted to Manitou Park, Perry Park, and the Manitou Embayment. This is a thinly bedded, limestone and dolomite with partings of gray calcareous shale and sandstone layers.[92] Colors vary from light

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[91] Lee C. Gerhard, "Redescription and New Nomenclature of Manitou Formation, Colorado," Bulletin of the American Association of Petroleum Geologists 58 (July, 1974): 1400.

[92] T.S. Lovering and E.N. Goddard, Geology and Ore Deposits of the Front Range, Colorado. U.S. Geologic Survey Professional Paper 223 (Washington, D.C.: Government Printing Office, 1950), p.32.

Photograph 11

Williams Canyon

cream gray to pale reddish with gray mottling. The structure is microcrystalline to finely crystalline with chert nodules a common occurrence. The base of the formation is a conglomeritic dolomitic limestone.[93] Thickness of the Williams Canyon Limestone varies from thirty to forty-five feet. The limestone forms a small hogback in the northern end of Perry Park, but in most parts of the study region it forms subdued features.

Madison Limestone

Also of Mississippian age is the Madison Limestone which consists of pink, gray, buff or brown sandy dolomitic limestone. Although separated from the William Canyon Limestone by a disconformity, the two formations are considered as a single formation in some studies. In other studies the Madison Limestone is referred to as a part of the Hardscrabble Limestone. The massive formation shows little evidence of bedding and is fine to medium crystalline in structure.[94] Some sandstone beds occur in this cherty formation and tend to form steep escarpments where present.[95] The Madison Limestone is between eighty and one hundred feet thick and is very restricted in the study region. It occurs only within

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[93] George B. Morgan, Jr., "Geology of Williams Canyon Area, North of Manitou Springs, El Paso County, Colorado," (M.S. Thesis, Colorado School of Mines, 1950), p. 39.

[94] Grose: 230.

[95] Brainerd, et al.: 391.

the Manitou Embayment and a short distance north of the embayment along the edge of the mountains.

Fountain Formation

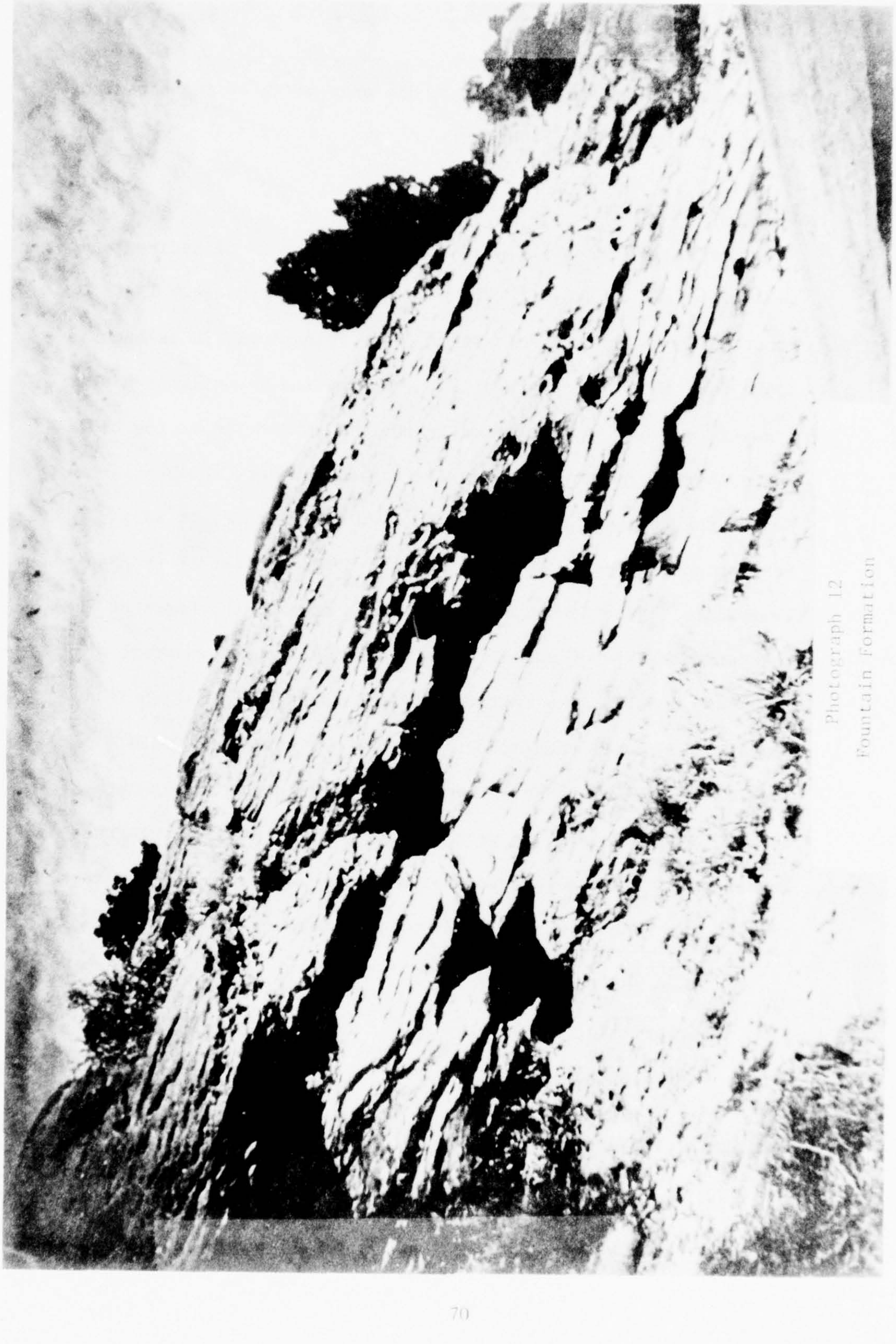
During the Pennsylvanian Period, thick beds of sediments were deposited on the site of the Colorado Front Range. The Fountain Formation, the oldest of these formations, is as much as 4,500 feet thick (Photograph 12). Most of the Pennsylvanian age deposits are not as restricted in their distribution as the older sedimentary formations already described; however, the basal member of the Fountain Formation, the Glen Eyrie Shale, is very restricted and occurs only in the Glen Eyrie portion of the Manitou Embayment.[96] The Glen Eyrie Shale has a maximum thickness of 362 feet and consists of multicolored shales with thin sandstone and limestone beds.[97] The remainder of the Fountain Formation is a complex of arkosic conglomerate and arkosic sandstones with minor lenticular beds of red or green shale.[98] Fragments of granite, quartz, and feldspars, as well as mica pebbles occur within the formation.[99] Arkosic conglomerates, which are a very common rock type in the formation, are reddish brown with cross bedding a

[96] Boos and Boos: 2626.

[97] Grose: 231.

[98] Lovering and Goddard, p. 34.

[99] George I. Finlay, Colorado Springs: A Guidebook (Colorado Springs, Colorado: The Outwest Co., 1906), p. 6.



Photograph 12
Fountain Formation

common feature. The coarse grained arkosic sandstones are yellowish gray.[100] Iron oxide forms the most common cement although silica and carbonates do occur as cementing agents.[101] Portions of the Fountain Formation which contain a silica cement tend to be resistant to erosion and form several of the unusual formations in the study region, e.g., those in the Garden of the Gods (Photograph 13). Due to faulting and differential this formation may lie over several older formations. It rests on the Williams Canyon Limestone in some areas and upon the Manitou Formation in others. In places with extensive faulting, the Fountain Formation may rest directly upon the Precambrian core of the Rampart Range.

Lyons Sandstone

Permian Period deposits in the Rampart Range area are represented by the Lyons Sandstone and Lykins Formations. The Lyons Sandstone is older and consists of medium and finely grained, red and white quartzose sandstone. The lower member is a brick red massive sandstone with cross bedding.[102] Iron oxide forms the cementing agent of this member.[103] The middle member of the Lyons

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[100] Scott and Wobus.

[101] Scott, Quaternary Geology, p. 88.

[102] Finaly, p. 7.

[103] D.J. Varnes and Glenn R. Scott, General and Engineering Geology of the United States Air Force Academy Site, Colorado. U.S. Geological Survey Professional Paper 551 (Washington, D.C.: Government Printing Office, 1967), p. 12.

Photograph 13

Garden of the Gods

Sandstone is an arkosic conglomerate similar in nature to the Fountain Formation. The upper member is a white to reddish strongly crossbedded sandstone.[104] Thickness of the formation varies from 116 feet near the mouth of the Platte Canyon to 850 feet near Colorado Springs. The formation is absent in Manitou Park. Large pronounced hogbacks mark the occurrence of the formation in the northern part of the region. In the Garden of the Gods, large sheets of the Lyons Sandstone rise 250 feet above their surroundings (Photograph 14).

Lykins Formation

The Lykins Formation is composed of five distinct members. Harriman Shale, a red arenaceous, thin bedded, silty shale with one thin white or reddish sandy limestone bed, is the lowest member of the formation. Impure limestones with very thin beds of red siltstones form the Falcon Limestone member. This yellowish gray limestone is either thinly laminated or massive in nature. Bergen Shale is the middle member and consists of thinly bedded, red arenaceous shales and mudstones.[105] The Glennon Limestone member has a grayish orange to pink, or yellowish brown and gray color with thinly bedded sandy limestone layers. The layers are commonly folded or faulted and contain nodules or red chert.[106]

[104] Grose: 231.

[105] Charles H. Ellis, "Geology and Pennsylvanian Paleontology of Perry Park, Colorado," (M.S. Thesis, University of Colorado, 1958), p. 25.

[106] Scott, Quaternary Geology, p. 91.

Photograph 14
Lyons Sandstone

The uppermost member of the Lykins Formation is the Strain Shale member. This is a reddish brown silty shale with layers of light green shales and grayish orange sandstones. The Strain Shale Member is much thicker than other members of the formation and in one location accounts for as much as 320 feet of the total 463 feet of the formation.[107] The Lykins Formation thins in the area between the Manitou Embayment and Perry Park with an estimated thickness of 1,000 feet near Manitou Springs, 180 to 200 feet at the Air Force Academy and 500 feet near the northern end of the study area. The Lykins as a formation tends to be easily eroded and forms a valley between more resistant formations. The Glennon Limestone member does occasionally form a small hogback.

Overview of Paleozoic Formations

The Lykins is the youngest of the Paleozoic Era formations in the study region. Thus, the formations of Paleozoic age are: the Sawatch Sandstone, Manitou Limestone, Peerless Dolomite, Williams Canyon Limestone, Madison Limestone, Fountain Formation, Lyons Sandstone and Lykins Formation. Since several of these formations are very restricted in their occurrence, the thickness of the Paleozoic rocks varies greatly within the area (Table I). In the Colorado Springs area these rocks have a total thickness of 6,260 feet,[108] while near Jarre Canyon at the

[107] Joel N. Van Sant, Refractory-Clay Deposits of Colorado. Bureau of Mine Report of Investigation 5553 (Washington, D.C.: Government Printing Office, 1959), p. 11.

[108] Scott and Wobus.

TABLE I

PALEOZOIC FORMATIONS *

FORMATION	PERIOD	LOCATION AND THICKNESS (feet)					
		Manitou Park	Colorado Springs	USAF Academy	Perry Park	Jarre Canyon	Kassler
Lykins Formation	Permian	0	200	180	235	490	386
Lyons Sandstone	Permian	0	850	300	380	270	235
Fountain Formation	Pennsylvanian	0-1000	4400	4500	2500	2200	2250
Madison Limestone	Mississippian	0-50	440	0	0	0	0
Williams Canyon LS	Mississippian	0-40	130	0	45	45	0
Manitou *Limestone* (incl. Ute Pass Dol.)	*Ordovician*	0-116	215	280	0	8	0
Sawatch Sandstone	Cambrian	0-68	25	25	100	87	0
TOTAL		0-1274	6260	5285	3260	3100	2871

* Compiled from Various Sources.

northern end of Perry Park, the total thickness is only 3,100 feet.[109]

Mesozoic Formations

The Mesozoic Era is represented by many formations; however, there are none of the Triassic Period. Jurassic formations include the Ralston Creek Formation and Morrison Formations.

Ralston Creek Formation

The Ralston Creek Formation has many facies within the study region with a shale-marlstone facies in the north and a gypsum facies in the south. The gypsum facies is a fine grained yellow sandstone and siltstone which contains massive gypsum beds as well as pink and white spar bands. Near the center of the formation is a chert bed containing rounded masses of chalcedon up to one-fourth inch in diameter.[110] The northern facies is a yellow-gray, dense limestone with silty calcareous shales and fine grained sandstone beds. Distribution of the facies varies greatly in the region. As a rule, the limestone facies is dominant to the north of the Rampart Range with the Gypsum facies dominant south of the region. In the northern part of the study region the limestone facies occur as far south as Bear Creek. The gypsum facies is common between Bear

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[109]William H. Ballew, "Geology of Jarre Canyon Area, Douglas County," (M.S. Thesis, Colorado School of Mines, 1957), various pages.

[110]Ellis, p. 29.

Creek and Deer Creek where the Limestone facies becomes dominant and forms the major facies between Deer and Jarre Creeks. In Perry Park, the gypsum facies is dominant.[111] A twenty foot high exposure of the formation at the Air Force Academy is primarily gray limestone. Because it is a thin formation with repeated changes in facies and difficult to trace, several investigators have mapped the Ralston Creek Formation as a part of the more easily detected Morrison Formation.

Morrison Formation

The Morrison Formation is of late Jurassic age and occurs throughout the northern Great Plains. It is a many colored mixture of massive, green and red, sandy shales, white sandstones, and gray limestones.[112] Scott, working in the Kassler Quadrangle just north of Perry Park, observed four units of the Morrison Formation. The basal unit consisted of four massive to thickly bedded yellowish gray sandstone layers separated by bands of red or greenish gray siltstone layers separated by bands of red or greenish gray siltstones. A series of reddish gray siltstones and gray claystones with limestone and sandstone layers formed the second unit. Hard massive limestones and sandstones with lime cememt separating larger beds of yellow gray siltstone and claystone made up the third unit. The uppermost unit consisted of red

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[111] Scott, Bedrock Geology, p. 91.

[112] Robb, p. 36.

silty claystones and sandstones.[113] Thickness of the Morrison Formation increases both northward and eastward throughout the Colorado Front Range and Colorado Piedmont, but in the Rampart Range the formation is thinner and varies from 225 feet in the south to 380 feet in the north.

Dakota Group

The Cretaceous Period is represented in the study region by an extensive sequence of deposits. Because of the extensive area covered and the diversity of facies, the division of Cretaceous rocks into formations has been the subject of a great deal of discussion.

Initial geologic investigations in the Colorado Plains and foothills led to the identification of a sequence of early Cretaceo rocks initially called the Dakota group which lie under the easily recognized Benton Group. Studies in the southern portion of the Front Range and in the Canon City Embayment led to the division based on an unconformity of the Dakota Group into the Purgatorie Formation and Dakota Sandstone. Work in the northern portion of the Colorado Front Range led to a classification of the Dakota Group as a five member unit, named the Dakota Formation. The uncor formity used in the south is absent in the north. Thus, there were two classification systems in use for the same sequence of rocks.

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[113] Scott, Quaternary Geology, p. 93.

In an attempt to resolve the problems caused when working in areas such as the Rampart Range where both systems are used, a third classification system was proposed by Waage in 1955 for use throughout the Front Range. The new scheme has been used north of Perry Park,but the older classification system is more commonly used south of that area. The Dakota Group has several natural lithogenetical divisions and the lower unit of the group is the same throughout the distribution of the formation. Depending upon the scheme employed, this is either the Lytle Formation or Lytle Sandstone member of the Purgatorie Formation. The remainder of the Dakota Group has a greater variation throughout the Front Range and in the southern portion of the area is separated into a second member of the Purgatorie Formation and three members of the Dakota Sandstone. Under the system used in the northern Front Range the upper unit of the Dakota Group forms the five membered South Platte Formation.[114] To facilitate description and analysis of the Dakota Group, both the southern and northern classification systems will be discussed with a description of the rock units involved.

The Purgatorie Formation consists of the lower Lytle Sandstone member and the upper Glencairn Shale member. A disconformity separates the two members. White to gray massive, fine to coarse grained sandstones and conglomeratic sandstones with infrequent

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[114] Karl M. Waage, Dakota Group in Northern Front Range Foothills, Colorado. U.S. Geological Survey Professional Paper 274-B (Washington, D.C.: Government Printing Office, 1955), various pages.

irregular beds of vari-colored claystones mark the Lytle Sandstone Member. The sandstones contain granules and pebbles of chert and quartzite while the claystones are silty to sandy and red or green in color. The Glencairn Shale member is a black to olive brown shale with thin, brown sandstone beds.[115] Silty shales and siltstones also occur in the Glencairn Shale member.[116]

As used in the southern portion of the Front Range, the Dakota Sandstone refers to a three member series of interbedded buff, yellow or gray, thin to thickly bedded, quartz sandstone and gray shale.[117] Cross-bedding is a common feature as are hollow ironstone nodules. The quartz grains are held in a siliceous cement.[118] The Dakota sandstone is a very erosion resistant formation and forms high and lengthy hogbacks along much of the southern Front Range (Photograph 15).

The classification system used for the Dakota Group north of Perry Park identifies the Lytle as a distinct formation. The only difference between the Lytle in the north and in the south is a greater occurrence of claystones in the north. The other parts of the Dakota Group are identified as the South Platte Formation with five members. The two lower members, the Plainview Sandstone

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[115] Van Sant, p. 12.

[116] Waage, p. 120.

[117] Grose: 231.

[118] Robb, p. 40.

Photograph 15

Dakota Sandstone Hogback

member and a thicker unnamed member, are similar to the Glencairn Shale of the Purgatorie Formation. The remaining three members of the South Platte are the Kassler sandstone, Van Bibber shale, and the unnamed upper member. The South Platte Formation is a sequence of sandstones and shales which also form high and long hogbacks.

One aspect of the Dakota Group which has led to the establishing of different subdivisions of the group is its distribution. The group is common along the northern portion of the Front Range and in the area from the Canon City Embayment to the Manitou Embayment, but its distribution within the study region is limited. It occurs only within the Manitou Embayment, in Perry Park, and in the extreme northern portion of the region. At the Manitou Embayment, the Dakota Group varies from 100 to 200 feet in thickness, while in the northern part of the region it is about 300 feet thick.

Graneros Shale

Another large group of formations which have been the subject of differing interpretations is the Benton Group which was separated into three formations by G.K. Gilbert in 1896. In many later studies these Upper Cretaceous formations were considered as a single unit; however, today the three formations are considered valid but often mapped together. The Graneros Shale is the lowest formation and consists of hard black siltstones and olive black clayey shale with iron stained concretions in the upper parts.[119]

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[119] Varnes and Scott, p. 12.

Brown clacareous sandstones also are present in the formation.[120]

Greenhorn Limestone

Above the Graneros Shale lies the Greenhorn Limestone which is a gray limestone containing very dense yellowish gray sandstones and shales. The fossiliferous formation has been divided into three members, the lower Lincoln Limestone member, the middle Hartland Shale member, and the Upper Bridge Creek Limestone member. The Lincoln Limestone member is composed of gray to black limy shales with thin platy limestone at the top and bottom. Light gray chalky shales with one or more thin beds of chalky limestone characterize the Hartland Shale Member. The Bridge Creek Limestone is a cherty limestone and limy shale mixture.

Carlile Shale

The Carlile Shale formation is the uppermost unit of the Benton Group and can be characterized as a sequence of thinly bedded shales with calcareous sandstones.[121] Four members of the Carlile have been identified. The Fairport Chalky Shale member has alternating beds of grayish yellow nodular chalky marls and tan chalky shales. The Blue Hills member is a dark gray to black noncalcareous silty to shale with thin brown shale layers and a thin gray line grained sandstone at its base. The Codel Sandstone member is a tan gray or red finely crystalline limestone with sand

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[120] Ballow, p. 49.

[121] Grose: 232.

grains.[122] The Juana Lopez member forms the top of the Carlile Formation and is a grayish brown sandy limestone composed of shell fragments.[123]

Distribution of one or more of the formations of the Benton Group is widespread but all members seldom all occur in the same location. The Graneros Shale is similar to the Dakota Group as it faulted out north of Colorado Springs but reappears in the northern portions of the study area. The Benton Group is commonly mapped as a single unit and in most places from 300 to 500 feet thick. The Benton Group is easily eroded and forms broad valleys between more resistant beds.

Niobrara Formation

The Niobrara Formation lies above the Benton Group and is also separated into two members; the Fort Hays Limestone member and the upper Smoky Hill Shale member. The Fort Hays Limestone is a bluish gray to white medium crystalline, well bedded limestone containing some buff colored shales.[124] The Smoky Hill Shale member consists of buff calcareous shales with thinly layered limestones. The Niobrara Formation varies from a thickness of 450 feet near Colorado Springs to 530 feet at the Air Force Academy

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[122]Scott, Nonglacial Quarternary Geology, p. 95.

[123]Scott and Wobus.

[124]Ballew, p. 52.

and 570 feet in the northern portion of the study region. The Fort Hays member forms a "persistent gray hogback" in Perry Park.[125]

Pierre Shale

Above the Niobrara lies the thickest formation of the Colorado Piedmont, the Pierre Shale. These soft, gray, marine shales are reported to be up to 8,000 feet thick. As a general rule these are dark gray to black clay shales, arenaceous shales and fine grained argillaceous sandstones.[126] The Upper Cretaceous formation has been separated into five sub-units or members. The Sharon Springs member at the bottom is a dark brown to black clay shale with oval gray calcareous concretions and thin layers of yellow limonite. The second member is often called the rusty zone and is composed of gray to black shale with numerous ironstone beds. Vertical cylindrical columns of gray fossiliferous limestone in black clay shales mark the Teepee Zone. As the name implies the gray shales of the Cone-In-Cone unit contain abundant cone-in-cone formations as well as lime concretions, thin sandstones and ironstones. The transition cone consists of buff to grayish blue shales with thin beds of fossiliferous sandstones and limestones.[127] Thicknesses of 8,000 feet for the Pierre Shale have been reported from the area of Jarre Canyon with 5,000 feet of the formation

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[125] Ellis, p. 36.

[126] Ballew, p. 55.

[127] Finlay, p. 403.

reported from the Colorado Springs area. The Pierre Shale Formation tends to form broad flat areas.

Fox Hills Sandstone

During the early geologic research of the Colorado region the Pierre Shale was included in the Montana Group with the Fox Hills Sandstone. The Fox Hills Sandstone has been divided into two units. Buff to olive-brown sandy shales with thin, limy sandstones form the lower unit. The upper unit is an olive brown to gray thinly bedded soft sandy shale.[128] An olive to yellow gray fine-grained sandstone member which had calcium carbonate as a cement and some cone-in-cone structures is present in the middle of the formation. This middle unit forms ridges or prominent escarpments within the study region. Thickness of the Fox Hills ranges from 250 feet near Colorado Springs to 185 feet in the north.

Laramie Formation

A one word description of the Upper Cretaceous Laramie Formation would be complex. This is a formation of interbedded yellowish gray, well graded, fine grained sandstones, olive gray to pale yellow brown clayey shales, hard limonitic brown sandstones, white conglomerate and brown to black subbituminous coal. The

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[128]Varnes and Scott, p. 13.

coal beds, when present, are thin and lenticular in nature.[129] Some small sandy ironstone nodules occur in the yellowish gray sandstones which have either a calcium carbonate or silica cement. The Laramie Formation varies in thickness from 250 feet near Colorado Springs to 650 feet at the northern end of the study region. The massive yellowish gray sandstones of the formation form steep escarpments in several areas.

Dawson Formation

The youngest Cretaceous formation in the study region is the Dawson Formation, which ranges from late Cretaceous to Paleocene or Eocene in age. This formation was initially described as a part of the Monument Creek Group by Hayden in 1872, but was separated from the Castle Rock Conglomerate in 1910. In the Denver area there is an interfingering of the Dawson Formation and the Denver Formation. Studies have identified five members of the Dawson Formation. These five members do not exist throughout the formation; the three upper members are in the Plum Creek Basin and the three lower members are in the Monument Creek area. Buff, well cemented conglomerates and quartz sandstones form the Cragmore Member at the base of the Dawson. Chert nodules are common and well rounded in the Cragmore Member which has a conglomertic base and grades into sandstones near the

[129] Ballew, p. 59.

top of the member.[130] The Austin Bluffs Member, which forms the main portion of the Dawson near Colorado Springs, consists of soft olive-gray to dark brown fine grained massive lenticular sandstones, silty shales and andesitic siltstones. Some bentonite lenses are present within the member. The Colorado Springs Member has buff to yellow, cross bedded, lenses of arkosic sandstores, pebble conglomerates, gray shales and a few coal beds.[131] The arkosic units are medium to very coarse grained with well developed crossbedding. The next member of the Dawson Formation is the Bald Mountain Member, a dense light colored quartz pebble conglomerate with a silt and fine sand matrix. The Bald Mountain Member is held together by a chalcedony cement.[132]

The uppermost member of the Dawson Formation is the Douglas Rhyolite. Detailed study of the Dawson Formation has led some geologists to the conclusion that the Douglas forms a distinct and separate formation. Regardless of its classification, the Douglas Rhyolite is a relatively hard, porous, fine textured welded tuff of reddish gray to pink color.[133] This Rhyolite serves as a cap on several mesas and buttes of the region (Photograph 16).

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[130] Lawrence R. Kittleman, Jr., "Post-Laramie Sediments in the Southern Part of the Denver Basin, Colorado," (M.S. Thesis, University of Colorado, 1956), p. 22.

[131] Eichler, p. 23.

[132] Kittleman, p. 49.

[133] Ellis, p. 46.

Photograph 16

Douglas Rhyolite Caprock

The Dawson Formation is wide spread in the higher elevations of the plains of the study region and forms the upper portions of several mesas and buttes as well as the divide. No complete section of the Dawson has been located and the five members are not constant over the area. The Cragmore Member can not be identified outside the Colorado Springs area and the Austin Bluffs member changes facies so frequently that it also is not recognizable outside the Colorado Springs area.[134] Total thickness of the Dawson Formation has been computed at over 3,200 feet. The computation was based on a well bore which penetrated 2,400 feet of the formation in an area where 800 feet of the formation were exposed above the well.[135] This well was located near Palmer Lake on the South Platte-Arkansas divide. In the Colorado Springs area, only an estimated 1,180 feet of the formation occur. Near Castle Rock, the Dawson Formation is only half that thick, about 575 feet. The Dawson Formation tends to form steep slopes rather than cliffs, but in the Monument Creek Basin several erosional remnants of the Dawson stand as large pillars (Photograph 17). The Colorado Springs Member forms unusual structures or short pinicles called "Hoodoos."[136]

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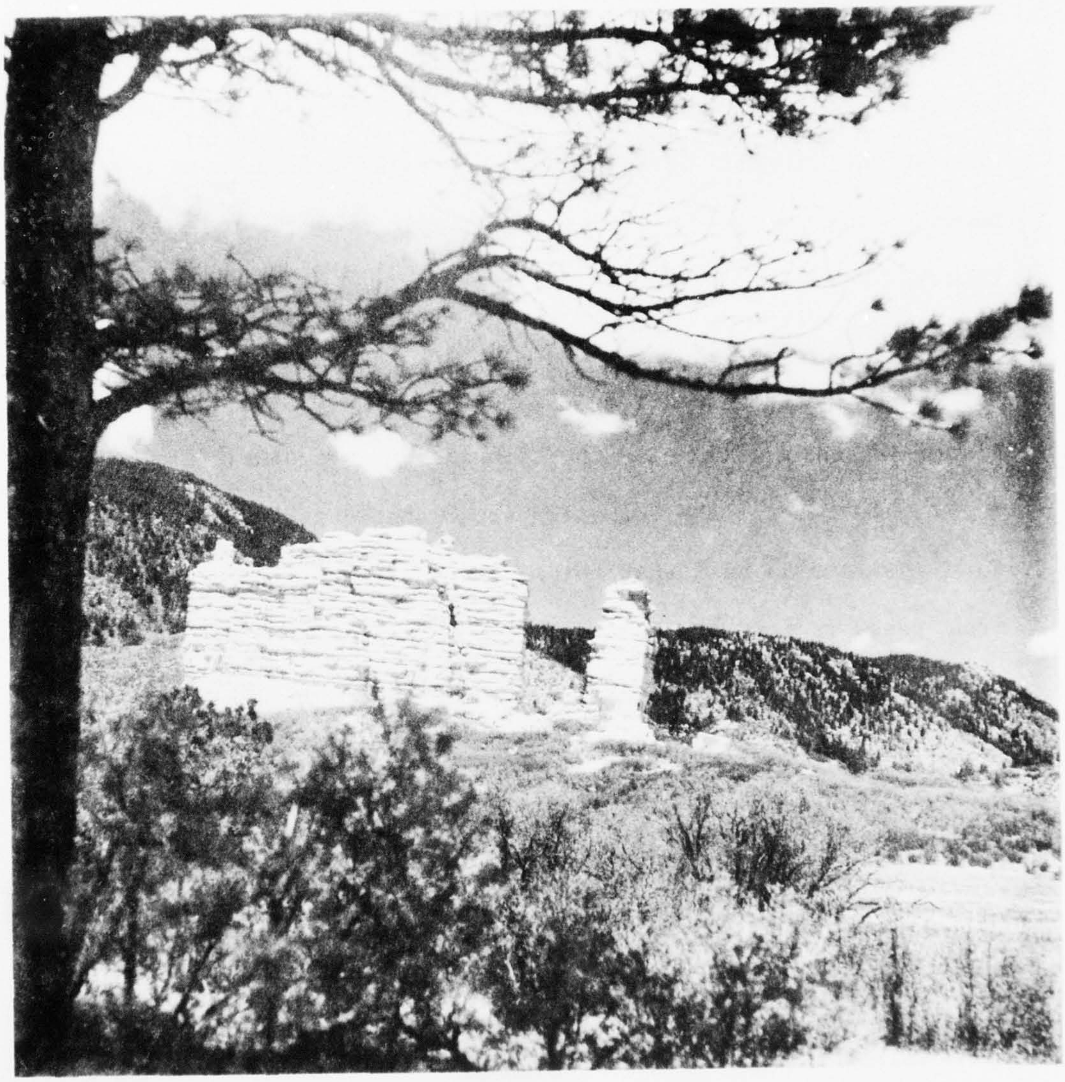
[134]Kittleman, p. 37.

[135]Ibid., p. 19.

[136]Walsh, p. 20.



Photograph 17

Cathedral Rock
(Dawson Arkose)

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GEOMORPHOLOGY AND GEOLOGY OF THE RAMPART RANGE, COLORADO.(U)

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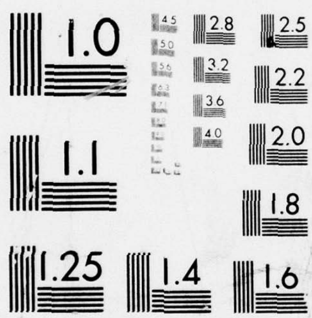
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Overview of Mesozoic Formations

It is believed that only the lower 500 or so feet of the Dawson Formation are of the Cretaceous Period.[137] The Mesozoic Era in the study region therefore is represented by ten formations and one group: the Ralston Creek Formation, Morrison Formation, Dakota Group, Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Formation, Pierre Shale, Fox Hills Sandstone, Laramie Formation and Dawson Formation. Thickness of these formations varies from 11,310 feet at Jarre Canyon to 7,545 feet at the Air Force Academy (Table II).

Cenozoic Formations

Cenozoic deposits within the study region include the upper part of the Dawson Formation, the Castle Rock Conglomerate, both of the Tertiary Period, and gravels and eolian deposits of the Quaternary Period.

Castle Rock Conglomerate

Resting above the Dawson Formation in some areas is the Castle Rock Conglomerate formation of the Oligocene Epoch. Very resistant in nature, the formation forms the cap rock of many buttes and mesas. This pink to brown coarse cross-stratified boulder conglomerate contains arkosic sandstones as well as fragments of volcanic rocks. Cementing the subangular to poorly rounded materials of the conglomerate is a silica cement. A thin, unnamed

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[137] Varnes and Scott, p. 14.

TABLE II

MESOZOIC FORMATIONS*

FORMATION	PERIOD	LOCATION AND THICKNESS (feet)					
		Manitou Park	Colorado Springs	USAF Academy	Perry Park	Jarre Canyon	Kassler
Dawson Formation	Cretaceous	0	500	500	na***	800	500
Laramie Formation	Cretaceous	0	240	250	na	600	660
Fox Hills Sandstone	Cretaceous	0	250	280	na	100	185
Pierre Shale	Cretaceous	0	5000	5000	6000	8000	5200
Niobrara Formation	Cretaceous	0	450	500	560	500	570
Benton Group**	Cretaceous	0	500	300	565	590	550
Dakota Sandstone	Cretaceous	0	160	100	300	330	300 (South Platte FM)
Purgatorie Formation	Cretaceous	0	200	300	160		40 (Lytle FM)
Morrison Formation	Jurassic	0	225	225	260	300	360
Ralston Creek FM	Jurassic	0	20	20	127	90	45
TOTAL		0	7545	7475	Incom.	11,310	8410

* Compiled from Various Sources
** Includes Carlile Shale, Greenhorn Limestone and Graneros Shale
*** Data unavailable

rhyolite ashflow tuff of pink gray or maroon color is also present as is a "small amount of finely divided gold."[138] Total thickness of the formation ranges from a few feet to three hundred feet.

Bald Mountain Gravel

The oldest of deposits of the Quaternary Period is the Bald Mountain Gravel of brown clayey, silty and sandy gravels which occurs atop the Precambrian Pikes Peak Granite near the headwaters of West Monument Creek. These deposits, which are poorly sorted and poorly stratified, contain boulders three feet in diameter. The gravels were derived from the Pikes Peak Granite and the Idaho Springs Formation, while the larger rocks are of a volcanic origin and are believed to be from the Cripple Creek area.

Nussbaum Alluvium

The Nussbaun Alluviam, considered to be possibly of Nebraskan Age, is a brown or gray, poorly sorted, cobble and boulder gravel which becomes a well sorted coarse sand in valley fill areas. Deposits range from twenty to 145 feet in thickness and may be 450 feet above the present stream beds.[139] Containing fragments of rhyolite and arkosic conglomerate materials from the arkosic Dawson Formation and Castle Rock Conglomerate, the Nussbaum was believed by Scott to have possibly been deposited on a south sloping erosion surface.

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[138] Lovering and Goddard, p. 42.

[139] Scott, Nonglacial Quarternary Geology, p. 245.

Rocky Flats Alluvium

The Rocky Flats Alluvium is also of Nebraskan age and forms dissected pediments of reddish brown, poorly sorted and well stratified, fragments of Pikes Peak Gravel.[140] The deposits contain boulders up to twenty feet in diameter and are twenty-five to fifty feet thick.[141] Pediments covered with the Rocky Flats Alluvium lie 250 to 380 feet above the nearest stream beds. Lehman Ridge Gravels is a term used for these deposits on the Air Force Academy.

Verdon Alluvium

Pediments 190 to 250 feet above present streams are generally covered with fifteen to thirty-five feet of Verdos Alluvium. These are Kansan or Yarmouth in age and consist of fragments of Pikes Peak Granite which are generally in the form of coarse sands. Boulders up to six feet in diameter occur.[142] In some areas the lower portion of these deposits may contain a layer of volcanic ash.

Slocum Alluvium

The Slocum Alluvium of Illinoian or Sangamon Age lies eighty to 120 feet above streams. A well stratified composition of reddish brown fragments of Pikes Peak Granite, this alluvium has

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[140] Ibid., p. 245.

[141] Varnes and Scott, p. 20.

[142] Ibid., p. 20.

coarse gravel to sandy texture. Slocum Alluvium may also include reworked Rocky Flats or Verdes Alluvium deposits and occurs on the flat and slightly dissected floors of several valleys.[143] On the Air Force Academy grounds this deposit is called the Pine Valley Gravel.

Louviers Alluvium

The highest terraces within the study area are covered by Louviers Alluvium. These Early Wisconsin Age deposits lie on terraces thirty-five to eighty feet above present streams and consist of a reddish brown well stratified coarse sand facies and a yellowish brown medium to coarse textured unconsolidated sand facies. Deposits are three to 120 feet thick[144] and called the Kettle Creek Alluvium on the Air Force Academy grounds.

Broadway Alluvium

Broadway Alluvium or Monument Creek Alluvium is of Late Wisconsian age and is the middle major terrace lying twenty to forty-five feet above streams. These deposits are believed to have been laid down by the adjacent streams and are ten to twenty-five feet thick.[145]

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[143] Scott, Nonglacial Quarternary Geology, p. 245.

[144] Ibid., p. 245.

[145] Varnes and Scott, p. 26.

Pre-Piney Creek Alluvium

This is a light-brown silt and sand deposit of early recent age with some pebbles. Fossil mollusks are also present. The Pre-Piney Creek Alluvium is found on terraces twenty to twenty-five feet above the present streams. In the southern part of the study region these deposits are not identified.

Piney Creek Alluvium

The Piney Creek Alluvium of recent age is a silty alluvial deposit on low terraces nine to twenty feet above streams and consists of poorly consolidated light brown sands and black silts with poorly consolidated humic or organic materials.[146] This is also known as the Husted Alluvium.

Woodland Park Alluvium

Within the Manitou Park three terraces can be identified which are cut by many streams and composed of Quarternary gravels. None of these deposits have been correlated with the terraces of [illegible]tern slope of the Rampart Range. The middle terrace was [illegible]ated as the Woodland Park Alluvium.[147]

Eolian Deposits

In addition to the alluvium deposits, windblown deposits of sand and loess are also present. The larger sand deposits generally lie east of Plum Creek and Monument Creek. Some occur between the

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[146] Scott, Nonglacial Quarternary Geology, p. 246.

[147] Marcus, p. 18.

lower reaches of East and West Plum Creeks as well as west of Monument Creek. The sands are yellowish brown quartz grains which are stratified and range from medium to coarse grains. Thicknesses range from less than ten to over thirty feet. In the area east of Monument Creek, low dune-like ridges and irregular patches are mixed with arcuate, barchan shaped and parabolic dunes all of which are grass covered.[148] Some of the longitudinal dunes may be as much as seventy feet thick and over a mile in length.[149] The pattern of the sands indicate deposition by northwesterly winds during the Late Wisconsin or Early Holocene Age. Loess deposits have been separated into three time periods. In the northern portions of the region, a loess of Sangamon age occurs between the Slocum and Louviers Alluvium Deposits. This is a clayey silt of moderate brown color which is often unmappable.[150] The source of this material is believed to be the South Platte valley.[151] An Early Wisconsian age loess is present between the Louviers and Broadway Alluvium. A yellowish brown calcareous silty sand, this loess is believed to have originated along the South

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[148]Varnes and Scott, p. 27.

[149]Eichler, p. 62.

[150]Glenn R. Scott, Geology of the Littleton Quadrangle, Jefferson, Douglas, and Arapahoe Counties, Colorado. U.S. Geological Survey Bulletin 1121-L. (Washington, D.C.: Government Printing Office, 1962), p. L-25.

[151]Scott, Quarternary Geology, p. 63.

Platte River and from exposed deposits of Pierre Shale.[152] The loess deposits found in the southern portion of the study region are of Early Holocene age and are a light yellowish brown silt with some very fine sands. A calcareous soil in the upper portions of the ten foot deposits.[153]

Overview of Cenozoic Formations

The Cenozoic Era in the study region is represented by two formations, nine alluvial deposits, and three eolian or loess deposits. These formations are, from oldest to youngest: Dawson Formation, Castle Rock Conglomerate, Nussbaum Alluvium, Rocky Flats Alluvium, Verdos Alluvium, Slocum Alluvium, an older loess, Louviers Alluvium, a younger loess, Broadway Alluvium, Pre-Piney Creek Alluvium, Eolian Sands, Piney Creek Alluvium, and the Post-Piney Creek Alluvium. Total thickness of these deposits varies from forty to eighty-five feet at Manitou Park to 1,227 feet at the USAF Academy (Table III).

Summary

The geologic structure, history, and stratigraphy of the study region is very complex and in part subject to several interpretations. The effect of these aspects upon the geomorphology of the region can be shown by several examples. One of the more obvious examples is that the more resistant formations which have been upturned by structural upheaval form many dominant features on the landscape.

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[153] Scott and Wobus.

TABLE III

CENOZOIC FORMATIONS*

FORMATION	PERIOD	LOCATION AND THICKNESS (feet)						
		Manitou Park	Colorado Springs	USAF Academy	Perry Park	Jarre Canyon	Kassler	Castle Rock
Post-Piney Creek Alluvium	Holocene		0	0	na**	na	12	na
Piney Creek Alluvium	Holocene		20	5-12	na	na	4-15	na
Eolian Sands	Holocene		20	10-30	na	na		na
Pre-Piney Creek Alluvium	Pleistocene		0	0	na	na	8-15	na
Broadway Alluvium	Pleistocene		50	15-20	na	na	12-15	na
Younger Loess	Pleistocene		10	0	na	na	5-15	na
Louviers Alluvium	Pleistocene	0-25 Undiff. Alluvium	40	3-15	na	na	15-120	na
Older Loess	Pleistocene		0	0	na	na	4	na
Slocum Alluvium	Pleistocene		40	0	na	na	10-90	na
Verdos Alluvium	Pleistocene		100	5-50	na	na	10-35	na
Rocky Flats Alluvium	Pleistocene		50	25-500	na	na	10-40	na
Nussbaum Alluvium	Pleistocene		80	0(?)	na	na	0	na
Castle Rock Cong.	Origocene	40-60	0	0	na	300	0	150
Dawson Formation	Paleocene	Woodland Park FM	1180	600	na	1200	575	525
TOTAL		40-85	1590	663-1227			660-936	800

* Compiled from Various Sources

** Data not available

CONCLUSIONS

Extensive variation in all aspects of the geomorphology and geology are present throughout the Rampart Range. The relations between the variables are extremely difficult to determine and measure. This report is intended to shed some light upon some of these relationships by analyzing the geologic structure, history, and stratigraphy as well as geomorphology of a medium sized segment of the Colorado Front Range.

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