# STRUCTURAL GEOLOGY OF THE GARDEN OF THE GODS, COLORADO

by

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## ABSTRACT

The Garden of the Gods is located northwest of Colorado Springs in the foothill belt of the Front Range in Colorado. The rocks exposed in this region include igneous and metamorphic Pre-Cambrian rocks of the mountain mass and Paleozoic and younger sedimentary rocks of the foothill belt and piedmont. Notable geomorphic features of the region are the mountains, the basin-like piedmont, hogbacks of the foothill belt, and broad, nearly flat erosion surfaces. Structural features of the region not in the Garden of the Gods include the Ute Pass fault, the Rampart Range anticline, and the Manitou Park syncline.

Two principal thrust faults, as well as many minor faults, occur in the Garden of the Gods. The Glen Eyrie fault extends for at least six miles northward from Fountain Creek. The average strike of this fault is N25W and the dip varies from 50 to 70 degrees west. The minimum stratigraphic separation and throw along this fault at Glen Eyrie are 4,500 feet and 5,500 feet, respectively. The Hidden Inn fault is a back thrust which extends for 1.5 miles northward from the central Garden of the Gods to Glen Eyrie. It is older than the Glen Eyrie fault and has an average strike of North-South and dip of 60 degrees east. The minimum stratigraphic separation and throw along this fault north of the Garden are 750 feet and 1,300 feet, respectively.

An analysis of the Glen Eyrie and Hidden Inn faults indicates that the pre-faulting structure of the area was a slightly overturned monocline.

# INTRODUCTION

## Location of the Area

The Garden of the Gods is an irregular area of about 1.2 square miles located 4 miles northwest of downtown Colorado Springs, Colorado. The area has long been of scenic interest to the general public because of the unusual exposures of red sandstone ridges which rise to as much as 300 feet above the valleys, and various peculiar erosional forms, such as the Balanced Rock in the western part of the Garden.

Geologically, the Garden is located in the North-South trending foothill belt of the Rocky Mountain Front Range, which is bounded on the east by the Colorado Piedmont. Because of the structural complexity of this belt, it seemed advisable to study not only the Garden of the Gods but also the adjoining areas where the sedimentary strata have been obviously effected by tectonic movements. Therefore, the detailed geologic map (Plate 6) accompanying this paper includes all but the extreme western portion of the Garden of the Gods and the areas adjoining the Garden for about 3 miles both north and south. The mapped area of about 9 square miles is located with reference to various cultural and general geologic features on the index map (Plate 1).

INDEX MAP

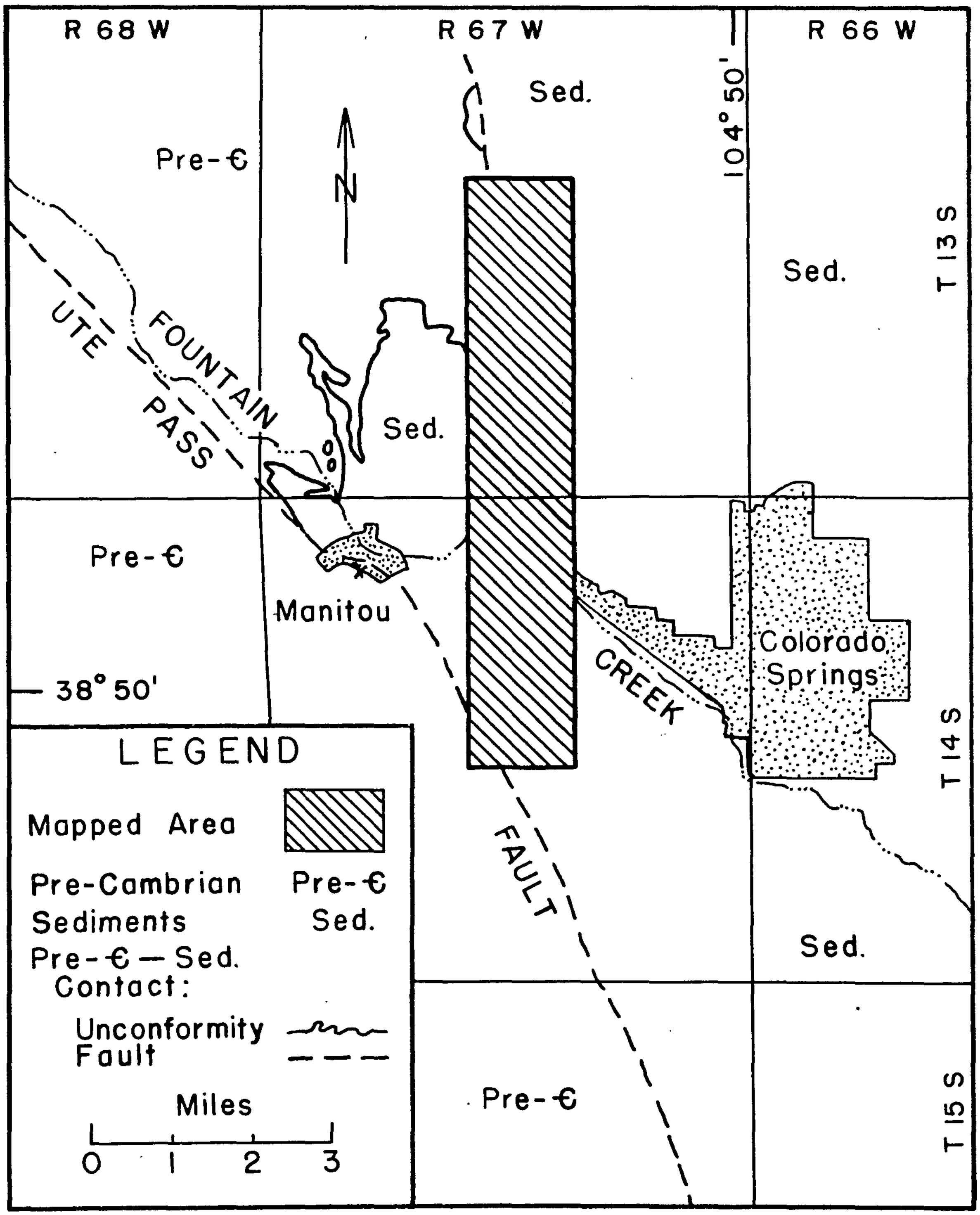


**Plate 1. Index map of the Garden of the Gods area.**

## Previous Work

Many geological reports of a reconnaissance nature have included the mapped area described in this paper and adjoining regions. Hayden (1869) first mentioned the Garden of the Gods in his preliminary report of the geology of Colorado and New Mexico, and Crosby (1895) has described the Ute (Pass) fault and accompanying sandstone dikes. The most detailed reconnaissance geologic report is the Colorado Springs Folio (Finlay, 1916) in which is included a list of some work done prior to that date. A paper by Bloesch (1919) was published in German concerning the tectonics of the Front Range in Colorado, in which he mentions some phases of the structural geology of the Garden of the Gods.

More recent work done in the region includes that by Roy (1940) on the Ute Pass fault and that by Glockzin and Roy (1945) which describes the Red Creek area south of Colorado Springs. McLaughlin (1947) described the Pennsylvanian stratigraphy of the Colorado Springs region and Maher (1950) described the Pre-Pennsylvanian stratigraphy of that region and adjoining areas. Some aspects of the geomorphology of the region have been described by Tator (1952).

A detailed study of the area described in this paper was begun in 1942 by D. J. Woods, but his work was interrupted by World War II and not subsequently completed. The present study is independent of work done by Woods.

The mapped area is included in the areas covered by several topographic maps published by the United States Geological Survey. The 30-minute Colorado Springs quadrangle (scale, 1:125,000) published in the

Folio (Finlay, 1916) has been subdivided into four, 15-minute quadrangles (scale, 1:62,500). The 15-minute Colorado Springs quadrangle lies in the NW1/4 of the 30-minute quadrangle and contains the mapped area. Each of the 15-minute quadrangles has been subdivided into four, 7.5-minute quadrangles (scale, 1:24,000). Portions of the mapped area lie on all four of these subdivisions of the 15-minute Colorado Springs quadrangle, which has been divided into quarters as follows: NE1/4, Pikeview; NW1/4, Cascade; SW1/4, Manitou; SE1/4, Colorado Springs. The 15- and 7.5-minute quadrangles were compiled by multiplex methods from aerial photographs taken in July 1947.

## Scope of the Present Study

### Purpose of the study.

The present study was undertaken as a field research problem to partially fulfill the requirements for the degree of Master of Science in Geology at Iowa State College.

Throughout the study, emphasis has been placed on the structural geology of the mapped area and its relationship to the general structural features of the Colorado Springs region.

### Methods used

The field mapping was done on enlarged aerial photographs (scale, 6.75 inches per mile) from which the accompanying geologic map (Plate 6) has been prepared. Stereoscopic coverage of the area with contact prints of aerial photographs (scale, 2.3 inches per mile) was also used and was most helpful in local areas of complex structure. The aerial photographs were taken in July 1947, and are sold by the United States Geological Survey. Contact prints which were used included the following: Symbol, GS-ET; Roll number, 4; Print numbers, 56 to 62, inclusive.

# GENERAL GEOLOGY

## General Statement

The major geologic features of the Colorado Springs region are the mountain mass and the basin-like Colorado Piedmont which extends eastward from the mountains. The mountains rise abruptly from an elevation of 6,500 feet at the edge of the piedmont to an elevation generally around 9,500 feet with Pikes Peak, 14,109 feet, being the highest point in the region.

Igneous and metamorphic Pre-Cambrian rocks constitute the main mass of the mountains, whereas Paleozoic and younger sedimentary rocks of great variety underlie the foothills and the piedmont. In the vicinity of Manitou the sedimentary beds are thicker and areally extend farther to the west than is usual along most of the mountain front. This westward extension of the sedimentary beds is known as the Manitou embayment. The Pre-Cambrian-Paleozoic contact in this region is both one of deposition and faulting, the latter type being the more extensive.

Principal geomorphic features in the Colorado Springs region include the hogbacks of the foothill belt and broad, nearly flat erosion surfaces which slope away from the mountains.

# Stratigraphy

## General statement

Rocks which occur in the mapped area range in age from Pre-Cambrian to Upper Cretaceous. All periods of the Paleozoic are represented except the Silurian and Devonian. The Triassic is the only period of the Mesozoic for which there is probably no stratigraphic record. The stratigraphic relationships for the uppermost Paleozoic or lowermost Mesozoic formations have not been definitely established.

The mapped rock units used on the accompanying geologic map (Plate 6) are listed in the stratigraphic table (Table 1). Each unit consists of one or more formations and unconformities are indicated by a double line between two formations. The age, thickness, and general lithology of each formation is given. A thickness marked with an asterisk (*) is one taken from the geologic map (Plate 6) which differs from a thickness given in the Folio (Finlay, 1916). Additional information concerning the nine mapped rock units is given below.

## Pre-Cambrian

The most abundant Pre-Cambrian rock occurring in the Colorado Springs region is the Pikes Peak granite. This granite is coarsely crystalline and contains microcline perthite and quartz as dominant minerals. It has been intruded into older gneiss, schist, and quartzite which now occur in isolated local bodies within the granite. Locally, the granite weathers to form gruss which may cover the slopes to a depth of one or more feet.

Table 1. Stratigraphic Column of the Garden of the Gods Area

| Mapped Rock Unit | Formation | Age | Tkness (feet) | General Lithology |
|---|---|---|---|---|
| Post-Benton | Pierre | Upper | 2500 | gray shale |
| | Apishapa | | 400 | buff-gray calcareous shale |
| | Timpas | | 50 | gray limestone |
| Benton | Codell | | 10 | buff sandstone |
| | Carlile | | *150 | buff-gray calcareous shale |
| | Greenhorn | | 50 | gray limestone |
| | Graneros | Cretaceous | 200 | black shale |
| Dakota | Dakota | | 100 | white to brown sandstone |
| | Fuson | Lower | 145 | gray shale |
| | Lakota | Cretaceous | 145 | white to brown sandstone |
| Morrison | Morrison | Jurassic? | *400 | shale; sandstone; limestone |
| Lykins | Lykins | Permian? | *100 | red shale and sandstone |
| Lyons | Lyons | | 850 | red to white sandstone |
| Fountain | Fountain | Pennsylvanian | 4370 | red sandstone and conglomerate |
| | Glen Eyrie | | 362 | shale; sandstone |
| Pre-Fountain | Hardscrabble | Mississippian | 100 | limestone |
| | Williams Canyon | | 30 | limestone |
| | Manitou | Ordovician | 187 | limestone and dolomite |
| | Ute Pass | Cambrian | 14 | red dolomite |
| | Sawatch | | 51 | red sandstone and dolomite |
| Pre-Cambrian | Pre-Cambrian | Pre-Cambrian | -- | granite |

Three other granite masses along with pegmatite and syenite dikes have been intruded into the Pikes Peak granite (Finlay, 1916, pp. 4-5). About 12 miles south of Colorado Springs there occur basalt dikes and a small body of rhyolite which are younger than the granite.

## Pre-Fountain

The Hardscrabble formation defined by Maher (1950) is in part equivalent to the Madison formation of other writers (Brainerd and others, 1933; McLaughlin, 1947). These writers consider the Williams Canyon formation as Devonian in age rather than Mississippian.

These Pre-Fountain sedimentary rocks occur within the mapped area only in the vicinity of Glen Eyrie. Here they form a dip slope over the Pre-Cambrian rocks just west of the hogback belt of younger formations.

The thicknesses quoted (Table 1) from Maher (1950) were measured in Williams Canyon, 2.5 miles southwest of Glen Eyrie.

## Fountain

The Fountain formation is the most extensive Paleozoic formation in the region, occupying an area of about 4 square miles in the Manitou embayment where its greatest thickness is found. It is composed ". . . of a thick series of red irregularly bedded coarse-grained arkosic sandstones and conglomerates sparsely interbedded with thin shales . . ." (McLaughlin, 1947, p. 1947). In the Manitou embayment, conglomerates compose about 16 per cent of the Fountain formation and are concentrated in the lower half of the formation (calculated from graphical data, McLaughlin, 1947, p. 1953).

After making a detailed study of the Fountain and Glen Eyrie formations, McLaughlin (1947, pp. 1975-1980) concluded that these formations ". . . represent the landward parts of a deltaic mass deposited in a subsiding trough east of the highland from which the sediments were derived" (p. 1975). Evidence cited by him in support of this conclusion includes brackish-water faunas from the Glen Eyrie and the presence of limestone beds in the Fountain (south of Colorado Springs) which are relatively extensive compared with the irregular beds of sandstone and conglomerate which ". . . may be either subaerial or subaqueous deposits" (p. 1976).

The more resistant beds of the Fountain formation form low hogbacks in the western portion of the Manitou embayment where the dips are 20 degrees or less. To the east the beds dip progressively more steeply until they are nearly vertical and form hogbacks up to 100 feet in height.

Lyons

The Lyons formation consists largely of non-arkosic quartzose sandstone with minor amounts of arkosic conglomerate locally present in the middle portion of the formation. Lower Lyons sandstone is red to pink in color and forms all but one of the major ridges which are up to 300 feet in height in the central Garden of the Gods. The one exception is formed by upper Lyons sandstone which is white to gray in the Garden and characteristically contains silica veinlets which stand out on the weathered rock surface. In the vicinity of Glen Eyrie the ridges are somewhat lower and continue to decrease in height northward where the upper Lyons sandstone is yellow to buff in color.

## Lykins

The thickness of the Lykins formation here used (100 feet) was measured by pace traverse normal to the strike along an old railroad cut just south of Fountain Creek where the beds are nearly vertical. Finlay (1916, p. 7) gives the thickness as "less than 200 feet".

The formation consists largely of red shale and sandstone; however, two excellent marker-beds of limestone, 20 feet apart, occur near the middle of the formation. The lower of the two limestones is generally more resistant to weathering and is about 35 feet from the base of the formation. These two marker-beds are clearly visible on aerial photographs and they were used entirely for mapping the Lykins contacts, the top and bottom contact lines being placed just east and west of the two limestone beds.

The middle portion of this formation typically forms a low ridge about 25 feet wide. Locally, two sharp low ridges are found where the shale between the two limestone beds has been removed.

## Morrison

The Morrison formation consists largely of gray and maroon shale with lesser amounts of sandstone, limestone, and gypsum. It usually forms a broad valley between the more resistant Lykins and Lakota-Dakota hogbacks.

This formation was measured in the same manner and at the same location as the Lykins, except that the traverse was somewhat curved. The thickness estimated from this traverse is 400 feet. This thickness agrees with the width of outcrop of nearly vertical strata on the geologic map

(Plate 6). Finlay (1916, p. 7) states the maximum thickness as 245 feet. He includes the gypsum in the Lykins formation which may account for some of the difference in thickness, though where these sections were measured, there is no gypsum.

### Dakota

This group of rocks typically forms one of the most continuous and highest hogbacks in this region. The principal ridge-forming formation is the Dakota which varies from a well-cemented to a quartzitic sandstone. The Lakota sandstones are generally less resistant than those of the Dakota and thereby form a lower hogback which locally may not be apparent. The Fuson shales and sandstones usually form a shallow trough between the two sandstone formations. The thickness of this unit varies somewhat depending on its proximity to a major fault. From a point one-half mile north of Valley Reservoir No. 1 south to Fountain Creek, no Dakota hogback exists and the formations are irregular in occurrence. This is probably the result of major faulting in and near this area which fractured the Dakota and Lakota rocks to such an extent that they were easily eroded.

### Benton

The Graneros, Greenhorn, and Carlile formations are typically found underlying a broad, relatively low valley between the Dakota and Codell-Timpas hogbacks. The Greenhorn limestone, being more resistant than the shales above and below it, generally forms a very low ridge near the center of this valley.

The thickness of the Carlile (150 feet ) was obtained as the difference between the approximate thickness of the Benton group (400 feet), taken from the geologic map (Plate 6) and the total thickness of the Graneros and Greenhorn (250 feet ). Finlay (1916, p. 8) states the thickness of the Carlile as 60 feet and that it ". . . is best exposed in the cut at the reservoir southeast of the Garden of the Gods. . . ." At this locality (near Valley Reservoir No. 2) the shale formations of the Benton group are notably thinner than elsewhere in the region.

The Codell sandstone is one of the best marker-units in the Garden of the Gods area. With the overlying Timpas limestone it forms a prominent low hogback which is more continuous than any other in the area.

### Post-Benton

Lower Apishapa occurs on the eastern side of the Codell-Timpas hogback. Pierre shale comprises the bedrock of an area which extends eastward from the Apishapa for one mile at the northern end and 5 miles at the southern end of the mapped area. Upper Cretaceous formations above the Pierre include the Fox Hills and Laramie sandstones which are overlain unconformably by the Dawson arkose of Tertiary age (Finlay, 1916, p. 10).

## Geomorphology

### General statement

The hogbacks of the foothill belt are formed by the resistant formations of the upturned and eroded sedimentary strata which dip eastward from the mountain front. The drainage of the foothill belt is generally of the trellis type, though the overall drainage pattern of the Colorado Springs region is a dendritic one. The main consequent stream of the region is Fountain Creek which flows out of the mountains through Ute Pass into the Manitou embayment and thence 40 miles southward into the Arkansas River at Pueblo, Colorado.

## Erosion surfaces

The rather extensive erosion surfaces which occur in the Colorado Springs region and the processes which formed them have been studied in detail by Tator (1949, 1952). Much of the following has been taken from these papers, and they should be consulted for a more complete treatment of the subject. The writer is in accord with the conclusions reached by Tator.

The surfaces are remarkably flat and slope away from the mountains toward the major drainage lines of the region. The slopes range from up to 600 feet per mile near the mountains to only a few tens of feet per mile on the extreme downslope portions of the surfaces. They are formed on the upturned sedimentary strata and in general truncate all formations without regard to lithology. One notable exception to this is the Dakota sandstone which typically stands above the surfaces and thereby forms a barrier to the drainage on the surfaces. Although there are some bedrock surfaces which are essentially free of alluvium, most of them are covered rather uniformly by a few tens of feet of coarse alluvium and some deposits slightly over 100 feet in thickness exist. The alluvium is usually massive and is composed predominantly of igneous and metamorphic rock fragments ranging in size from coarse sand to boulders one or more feet in diameter.

The processes which formed these surfaces are active at the present time in the stream valleys of the region, widening the valleys and flattening their floors. Valley widening is accomplished by retreat of the valley walls, caused by weathering and mass wasting of the wall material which accumulates at the base of the slopes and is removed by the stream. The streams respond to the characteristically local, torrential rainfall and transport relatively large volumes of weathered material in a short period of time, sometimes an hour or less, after which they contain a small amount of water or become dry. During times of torrential runoff the streams are capable of scouring deeper channels. If this scouring action eats through the valley alluvium to the bedrock floor, it will be eroded. When there is not enough water to carry the moving debris out of the valley, it will be deposited in the channel, thus forming a local dam or channel plug. These plugs are found in old channels and commonly consist of boulders and tree trunks "cemented" with finer material. Over a long period of time a stream will occupy all possible channel positions on the valley floor. If the climate is uniform during this time the volume of torrential runoff and therefore the depth of scour will also be uniform, and an essentially flat valley floor will be formed. A semiarid climate such as now exists in the region seems to be the ideal one for these processes to operate effectively. During a more humid climate a stream would flow continually, keeping its channel open and deepening only that one channel. An alternation of semiarid and semihumid climatic conditions would account for the various surface levels found in the Colorado Springs region.

Remnants of older surfaces which are now being destroyed by erosion in the Garden of the Gods area may be seen west of the Dakota hogback, south of Fountain Creek and north of Glen Eyrie. Just south of Douglas Creek a larger surface remnant extends eastward beyond the Dakota hogback. East of the Garden, three different surface levels occur which are collectively known as "The Mesa". Much more extensive surfaces may be seen south of Colorado Springs.

# STRUCTURAL GEOLOGY

## General Statement

The major structural feature of the Front Range has long been recognized as an eroded monocline of Laramide age (Hayden, 1869). Sedimentary strata once nearly horizontal were upturned in the zone which now forms the foothill belt and passed over the Pre-Cambrian core of the newly uplifted mountains. Associated with this uplift were major faults generally in or near the foothill zone. Reconnaissance work indicates that much of the present mountain front is bounded on the east by zones of major faulting.

The major fault along the mountain front in the Colorado Springs region is the Ute Pass thrust fault which generally strikes in a north-northwesterly direction and dips from 25 to 50 degrees to the west. The minimum stratigraphic and horizontal displacements along this fault are 5,000 feet and 8,000 feet, respectively (Roy, 1940). It has been traced northward for slightly more than 50 miles, beginning at a point about 15 miles south of Colorado Springs (Glockzin and Roy, 1945). This fault has been referred to as the Cheyenne Mountain overthrust by Roy (1940) and typically has clastic dikes associated with it (Roy, 1946). These dikes have been found predominantly on the upthrown block or along the fault plane. They are believed to have been formed in fractures resulting from the fault movement into which quicksand-like material composed of water and crushed rock was forced. The dike rock is usually fine- to medium-grained sandstone but may contain coarse sand and pebbles.

In the Garden of the Gods area the sedimentary strata generally dip at a high angle. The strata in the Manitou embayment to the west, however, dip at angles generally less than 25 degrees, indicating that this area was part of the uplifted mountain mass which underwent relatively minor deformation.

Northwest of the Manitou embayment the mountains are locally known as the Rampart Range. They were formed as a broad, North-South trending anticline about 8 miles wide which has since been stripped of its sedimentary cover. This anticline is paralleled on the west by a doubly plunging, asymmetrical syncline which is about 20 miles long and 4 miles wide. The roughly elliptical area which it embraces is called Manitou Park. Rocks exposed in the syncline include steeply dipping older Paleozoics on the east limb, and essentially horizontal and gently eastward dipping Fountain beds in the center and on the west limb, respectively. The syncline is bounded on the west by the Ute Pass fault.

A detailed study (Glockzin and Roy, 1945) of the structure of the Red Creek area 20 miles south-southwest of Colorado Springs revealed a thrust fault and local folding. This area is located at the southern end of the Front Range in Colorado. The Red Creek fault has been called a back thrust because it dips steeply away from the mountains rather than toward them as is more common along the Front Range.

The two most significant unconformities in the Colorado Springs region occur at the Pre-Cambrian-sedimentary contact and at the base of the Pennsylvanian rocks. The surface of the Pikes Peak granite on which the Cambrian sediments were deposited is a remarkably flat one. It is well exposed in Queens Canyon (the valley of Camp Creek west of Glen Eyrie) and in Ute Pass northwest of Manitou.

The Pennsylvanian Fountain formation overlaps all older formations and in some places rests on the Pre-Cambrian rocks. In the Manitou embayment it rests conformably on the Glen Eyrie formation which lies unconformably on Mississippian rocks (McLaughlin, 1947). In the Red Creek area, definite evidence of Pre-Fountain folding has been found which may have influenced the location of the Laramide structures (Glockzin and Roy, 1945).

## Faulting in the Garden of the Gods

### General statement

Two main thrust faults, the Glen Eyrie and Hidden Inn faults, as well as many minor faults, are present in the Garden of the Gods. The extreme southwest corner of the area mapped is crossed by the Ute Pass fault, movement along which has caused the Fountain and younger sedimentary beds to be dragged eastward.

Plate 2 is a reproduction of an aerial photograph of the central Garden of the Gods on which the two main faults are traced. Eight structure cross sections of the area are given on Plates 4 and 5 with corresponding lettered cross section lines on the geologic map (Plate 6).

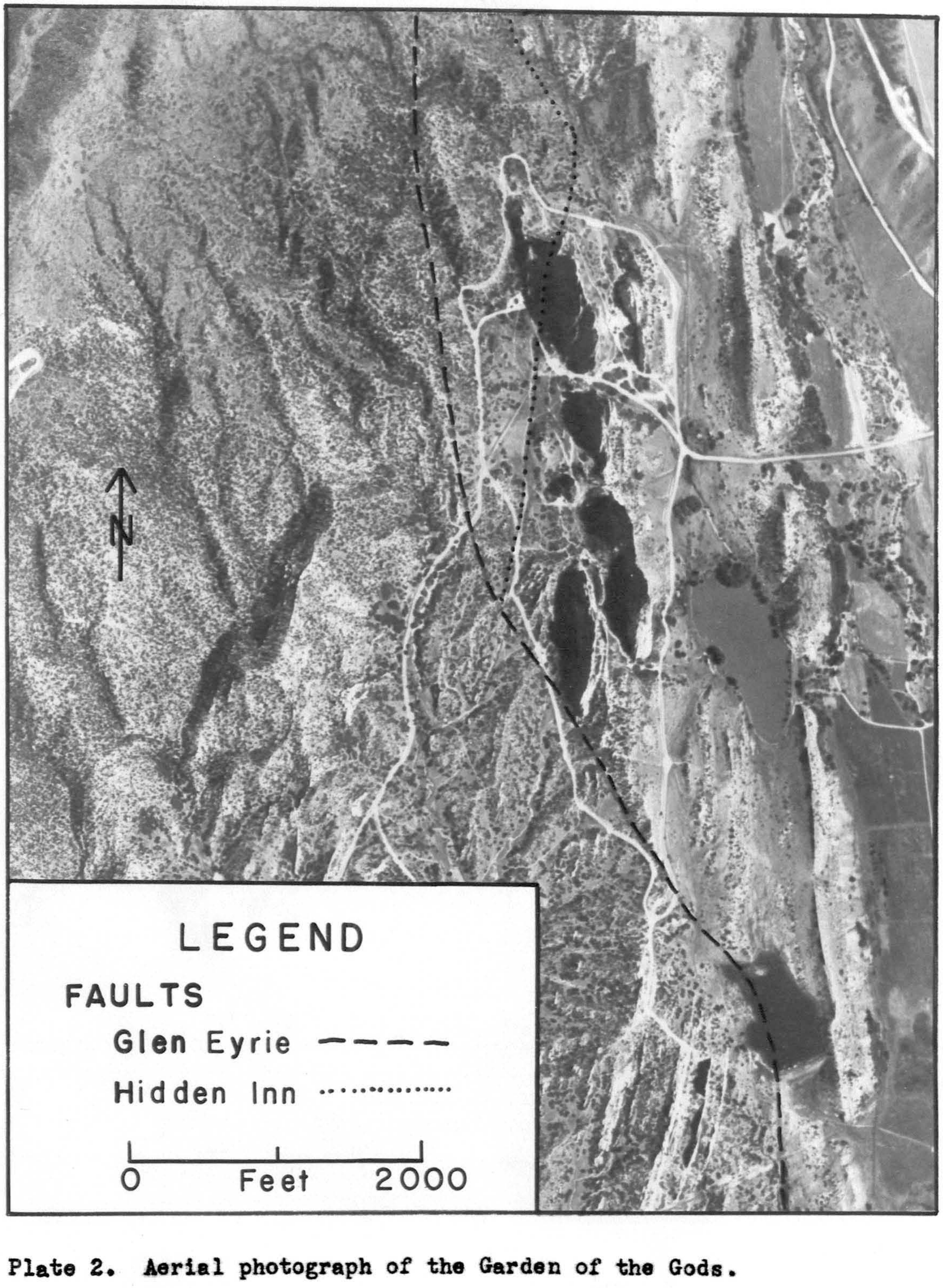


Plate 2. Aerial photograph of the Garden of the Gods.

Glen Eyrie fault

This is the major fault in the Garden of the Gods area and it was traced for a distance of about 6 miles north of Fountain Creek. Finlay (1916, p. 12) states that it extends 10 miles north of Fountain Creek. The fault is here named after the Glen Eyrie estate which adjoins the Garden to the north.

Evidence for the existence of this fault includes Pennsylvanian Fountain sandstone resting on Jurassic Morrison shales; significant differences in attitude between Fountain beds which are closely associated areally; Pre-Fountain limestone in contact with extreme upper Fountain rocks; and Pre-Cambrian granite in contact with middle Fountain sandstone.

This fault is well exposed in a gully about 3 feet deep at a point 300 feet south of Valley Reservoir No. 2. Here the fault strikes about N5W and dips 50 degrees to the west. The Fountain sandstone on the western, upthrown block rests on upper Morrison shales of the downthrown block. The fault plane is very distinct. Eastward, the Dakota and Benton rocks have been greatly deformed so that here they are only about one-half of their normal thickness. The resistant Dakota beds are only locally distinguishable.

The mapping of the fault south of Valley Reservoir No. 2 was based largely on inference. It was traced directly for about 1,500 feet along a creek, and thereafter passes beneath an urban area and cannot be traced. The writer believes that the fault passes just east of the Benton group along the south side of Fountain Creek, and thence through the Timpas and Apishapa formations into the Pierre shale, where it ends. There is no evidence of faulting in the Benton or older rocks just south of Fountain Creek, but the formations appear to have been dragged to the west.

On the bottom of Valley Reservoir No. 2 the Fountain is still in contact with upper Morrison shale. The Dakota does not appear on the reservoir bottom, though just northwest of the reservoir the Dakota beds are bent sharply southeastward and strike toward the reservoir. Finlay (1916, p. 12) states that Fountain is in contact with Graneros shale at this reservoir. The present writer did not observe this relationship, but Graneros black shale does occur at the north end of the reservoir.

As measured in a gully between the two roads 1,000 feet northwest of Valley Reservoir No. 2, the strike of the fault is N35W and the dip is 60 degrees west. From this point northwest and north to the vicinity of Glen Eyrie, the location of the fault trace was determined on the basis of attitudes of the Fountain beds in the hills northwest of the Hidden Inn. Because a consistent and significant difference in attitude exists between Fountain beds which are closely associated areally, the fault was drawn in the position shown on the geologic map (Plate 6). West of the fault trace, Fountain beds dip generally less than 50 degrees east, but east of it the beds dip more than 70 degrees east and some are overturned and dip steeply to the west.

The Pre-Fountain limestones just west of the fault in the vicinity of Glen Eyrie have been greatly brecciated, and north of Camp Creek, the valley along which the fault passes is floored with alluvium. On the west side of the valley, Pre-Fountain rocks dip 55 degrees to the east, and east of the valley, nearly vertical Lyons sandstone forms a high hogback ridge. No Fountain is exposed for a distance of 3,000 feet north of Camp Creek, but Fountain may be present under the Valley. The gradational Fountain-Lyons contact on a stream divide just north of the valley is near its eastern side, and the rocks on the western part of this divide are of the Glen Eyrie formation and are either on the up thrown block or represent part of a slice.

About 1,000 feet northwest along the fault trace, granite is on the west and Fountain on the east side of the fault. Both rocks are brecciated and the fault zone apparently dips steeply into the hillside to the west. Northwestward beyond this point for 1.5 miles the fault forms the contact between the granite and the Fountain formation. This fault contact is covered by soil and vegetation, but where this is removed the brecciated rocks characteristic of the fault zone are apparent.

The average strike of the fault north of the Garden of the Gods is N10W, but the dip of the fault cannot be accurately measured because there are no exposures of the fault plane. Actually, the writer doubts the existence of a fault "plane" north of the vicinity of Valley Reservoir No. 2. The evidence seems to indicate that the fault plane, so well exposed near the reservoir, is replaced northward along the strike of the fault by a fault "zone" in which the rocks are greatly brecciated. The writer followed this zone of brecciated material across irregular topography and reached the conclusion that the dip of this fault zone is to the west at an angle greater than 70 degrees.

Finlay (1916, p. 12), in describing this fault near Valley Reservoir No. 2 states that the ". . . apparent overthrust relation may be due to compression and forward movement of the granite mass after it was uplifted and faulted by normal displacement, whereby the fault plane, formerly vertical, was tilted. . . ." He presents no evidence in support of this statement and the present writer found none. Therefore, all of the existing field evidence indicates that the Glen Eyrie fault is truly a high-angle thrust fault.

The displacement along the Glen Eyrie fault was calculated on the basis of the formation thicknesses given in Table 1. If only dip slip is considered, the stratigraphic separation is essentially equivalent to heave since the strata are nearly vertical. Just south of Valley Reservoir No. 2, the minimum stratigraphic separation is 2,000 feet and the minimum throw is 1,600 feet. These values were calculated using the dip of 50 degrees for the fault, allowing for the thinning in the Dakota and Benton sections, and assuming that 250 feet of upper Fountain has been faulted out (estimate from the geologic map (Plate 6)). At Glen Eyrie just north of Camp Creek, the minimum stratigraphic separation is 4,500 feet and the minimum throw is 5,500 feet, using the dip of 70 degrees for the fault. These calculations indicate that the displacement along the Glen Eyrie fault increases significantly from south to north along its strike.

Hidden Inn fault

This thrust fault extends for about 1.5 miles north from the center of the Garden of the Gods to the valley of Camp Creek at Glen Eyrie. It is here named after the Hidden Inn which is located in the Garden and near which this fault is well exposed. This fault is probably the one referred to by Glockzin and Roy (1945, p. 825) as the Rampart Range fault.

This prior naming of the fault was not brought to the attention of the present writer until after the geologic map (Plate 6) was completed.

Two unusual features of this fault should be noted. First, younger rocks have been thrust over older rocks; and second, the fault dips steeply away from the mountains, thereby constituting a back thrust as defined by Glockzin and Roy (1945).

An excellent exposure of the fault (Plate 3) is located at the intersection of the fault trace and cross section line L-M on the geologic map (Plate 6). Here the fault plane strikes N15E and dips 60 degrees east, but 400 feet south the strike is North-South and the dip is 60 degrees east. Lower Lyons sandstone of the upthrown block rests on overturned upper Fountain beds of the downthrown block.

About 500 feet south of this exposure, the fault trace passes into the Fountain formation and may be traced about 200 feet farther. From this point in the Fountain southward toward the Glen Eyrie fault, there is no evidence to indicate the exact location of the fault trace. Normal attitudes of the Fountain beds south of the Glen Eyrie fault indicate that the Hidden Inn fault does not extend into this locality and that it has been truncated by the Glen Eyrie fault.

Northward from the exposure first mentioned above, the fault trace was mapped as the Fountain-Lyons contact and is nowhere well exposed, though brecciation of the Lyons sandstone near the fault is common. All except part of the upper Lyons formation has been faulted out to a point about 1,000 feet south of Camp Creek. From this point to Camp Creek, most of the Lyons formation is present. There is no evidence of major faulting in the Lyons or Fountain formations north of Camp Creek and east

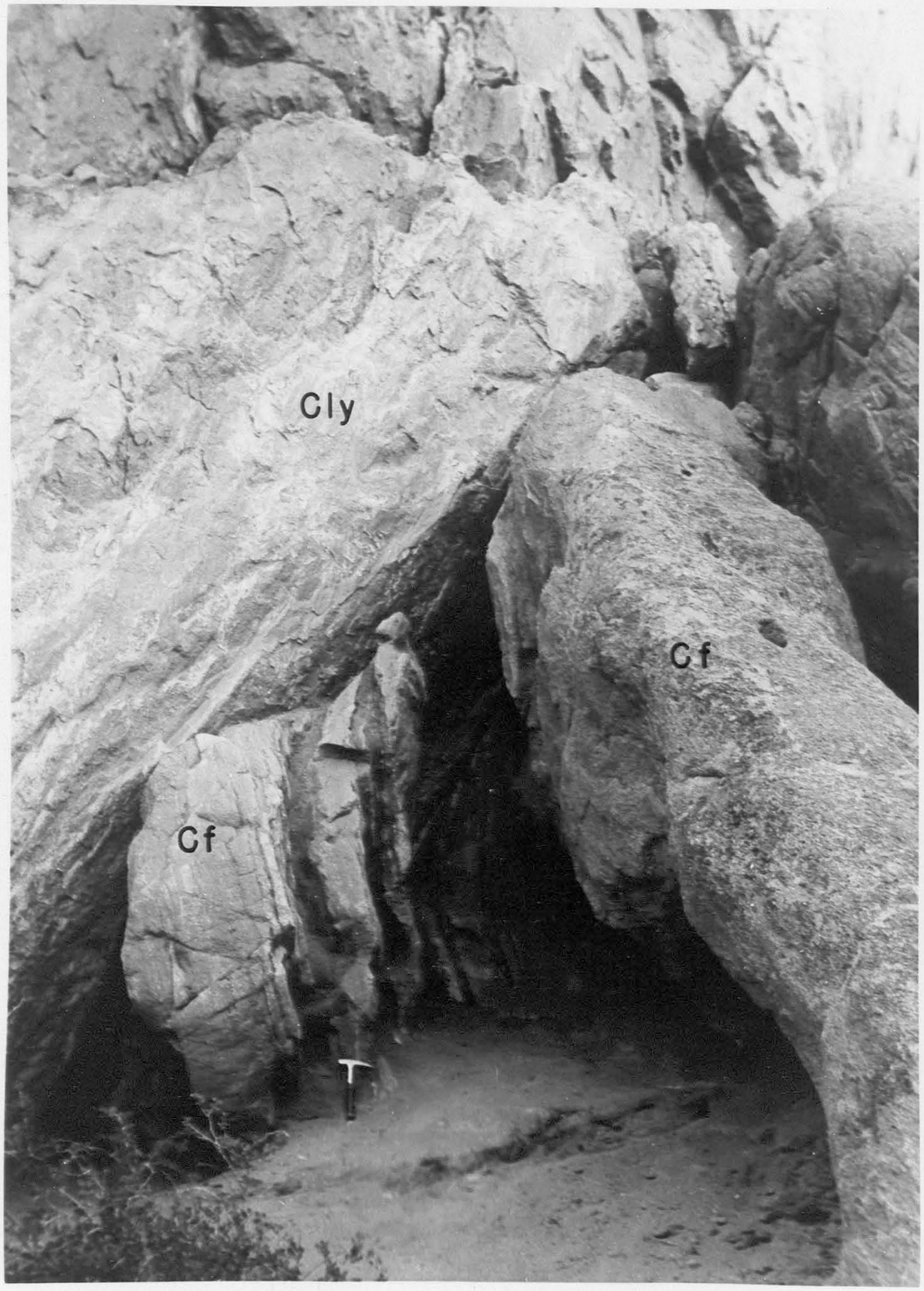


Plate 3. Hidden Inn fault. (This view is south. Lyons sandstone, Cly, of the eastern, upthrown block rests on Fountain sandstone, Cf.)

of the Glen Eyrie fault in the mapped area. This evidence indicates that the Hidden Inn fault has been truncated by the Glen Eyrie fault near Camp Creek as it has been in the central Garden of the Gods.

The displacement along the Hidden Inn fault was calculated in the same manner as that for the Glen Eyrie fault. The maximum amount of Lyons sandstone faulted out between the Garden and Glen Eyrie was taken as the minimum stratigraphic separation (heave) and the dip of 60 degrees for the fault plane was used. These data give a stratigraphic separation of 750 feet and a minimum throw of 1,300 feet.

## Other faults

Two main diagonal faults as well as a myriad of small faults with displacements ranging from less than an inch to a few tens of feet occur in the Garden of the Gods.

The two diagonal faults occurring in the central part of the Garden are most easily traced near the two high Lyons hogbacks just west of Valley Reservoir No. 1. Of these two faults, the western one is more extensive and has a strike which varies from North-South to N30E. The strike of the east fault averages N60E. The dips of both faults as estimated from the topographic expression of the fault traces are east to southeast at a very high angle. Most of the movement along these two faults is horizontal as indicated by drag in the Lykins formation. The vertical movement which has occurred is normal displacement. For the west fault, gap and offset equal about 200 feet each; and for the east fault, offset is about 150 feet and the gap is probably less than 100 feet. The upper Lyons sandstone has overridden the Lykins formation on the north side of this fault. The absence of the Dakota hogback north of Valley Reservoir No. 1 can probably be best explained as the result of movement along these two faults.

The faulting south of Valley Reservoir No. 2 is so complex that only three principal ones are shown on the map (Plate 6). The only formations traceable for any appreciable distance are the Codell and Greenhorn. Varying lithology of the Morrison, Dakota, and Benton rocks, which include much shale, and the close proximity of the locality to the Glen Eyrie fault have been determining factors in the development of this complex faulting.

About 1,200 feet south of Camp Creek there is a small transverse fault in the Lykins formation which may extend westward across the Hidden Inn fault, but the field evidence for this extension is not conclusive.

The Codell sandstone has a rather erratic attitude throughout its extent and appears to be faulted in many places. Some of these minor faults are indicated on the geologic map (Plate 6), but many of them are probably the result of local slumping in the Codell formation.

## History of the faulting

The writer believes that the best possible reconstruction of the pre-faulting structure in the Garden of the Gods area would produce a slightly overturned monocline which was uplifted near the end of the Mesozoic era. This monocline would be certainly post-Benton in age since the Benton rocks have been upturned in the foothill zone which was formed during the period of monoclinal uplift.

The determination of the ages of the two major faults in the area was based on the following criteria. The Glen Eyrie fault is known to cut the upturned Benton rocks at Fountain Creek which indicates that this fault is younger than the monocline. The Hidden Inn fault is older than the Glen Eyrie fault which truncates it, unless they are contemporaneous. This seems unlikely since the two faults dip in opposite directions and their displacements are such as to oppose each other. The youngest rocks faulted by the Hidden Inn fault are Permian Lyons sandstones, which places a maximum age limit on the fault as late Permian.

If a simple monocline with nearly vertical dips in its steepest central portion is assumed, the Glen Eyrie fault may be reconstructed quite satisfactorily using the data available in the vicinity of Valley Reservoir No. 2. However, this cannot be done if the data obtained at Glen Eyrie are used. The high angle of the fault and the relatively gentle dip of the Pre-Fountain rocks would result in contact between these beds and similarly dipping Fountain or Lyons beds, rather than vertical beds of these formations. Therefore, the monocline must not have been a normal monocline throughout its entire extent.

The Hidden Inn fault, as previously stated, is unusual in that younger rocks have been thrust over older rocks. The older rocks (Fountain) must have been above the younger rocks (Lyons) in the unfaulted structure, and this relationship would have existed if the monocline had been slightly overturned eastward. Evidence of overturned Fountain beds exists on the downthrown block of the Hidden Inn fault, north of the Hidden Inn. At this locality good examples of overturned, stream crossbedding were observed. This evidence strongly indicates that the Hidden Inn fault is younger than the overturned monocline.

Movement along the Hidden Inn fault in the vicinity of Glen Eyrie would place nearly vertical upper Fountain and lower Lyons beds in a position which could be reached by the Pre-Fountain strata displaced along the high-angle Glen Eyrie fault. This would result in the various strata being in the positions which are now observed.

Other faults in the area, including the two principal ones near Valley Reservoir No. 1, are probably of the same age as the Glen Eyrie fault because they are closely associated with it as noted on page 29.

None of the faults in the area mapped has any known connection with the Ute Pass fault. In view of the similarity between the Ute Pass and Glen Eyrie faults, especially outside of the Manitou embayment, it seems quite possible that they are equivalent features at different locations along the mountain front.

Evidence to indicate the reason for the back thrust relationship of the Hidden Inn fault was not discovered. It would be interesting to know if this fault was ever connected with or related to the Red Creek back thrust (Glockzin and Roy, 1945) prior to Ute Pass and Glen Eyrie faulting, or whether these back thrusts are simply minor features along the Front Range.

## CONCLUSIONS

(1) The Laramide monocline which forms the eastern margin of the Front Range was slightly overturned in the Colorado Springs region.

(2) Two major thrust faults, the Hidden Inn and the Glen Eyrie faults, occur in the Garden of the Gods.

(3) The Hidden Inn back thrust fault is a high-angle fault dipping east and is younger than the monocline.

(4) The Glen Eyrie thrust fault is a high-angle fault dipping west and is younger than both the monocline and the Hidden Inn fault.

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Plate 2 is a reproduction of a portion of an aerial photograph (GS-ET, 4-59) obtained from the United States Geological Survey.

# APPENDIX

# CROSS SECTIONS

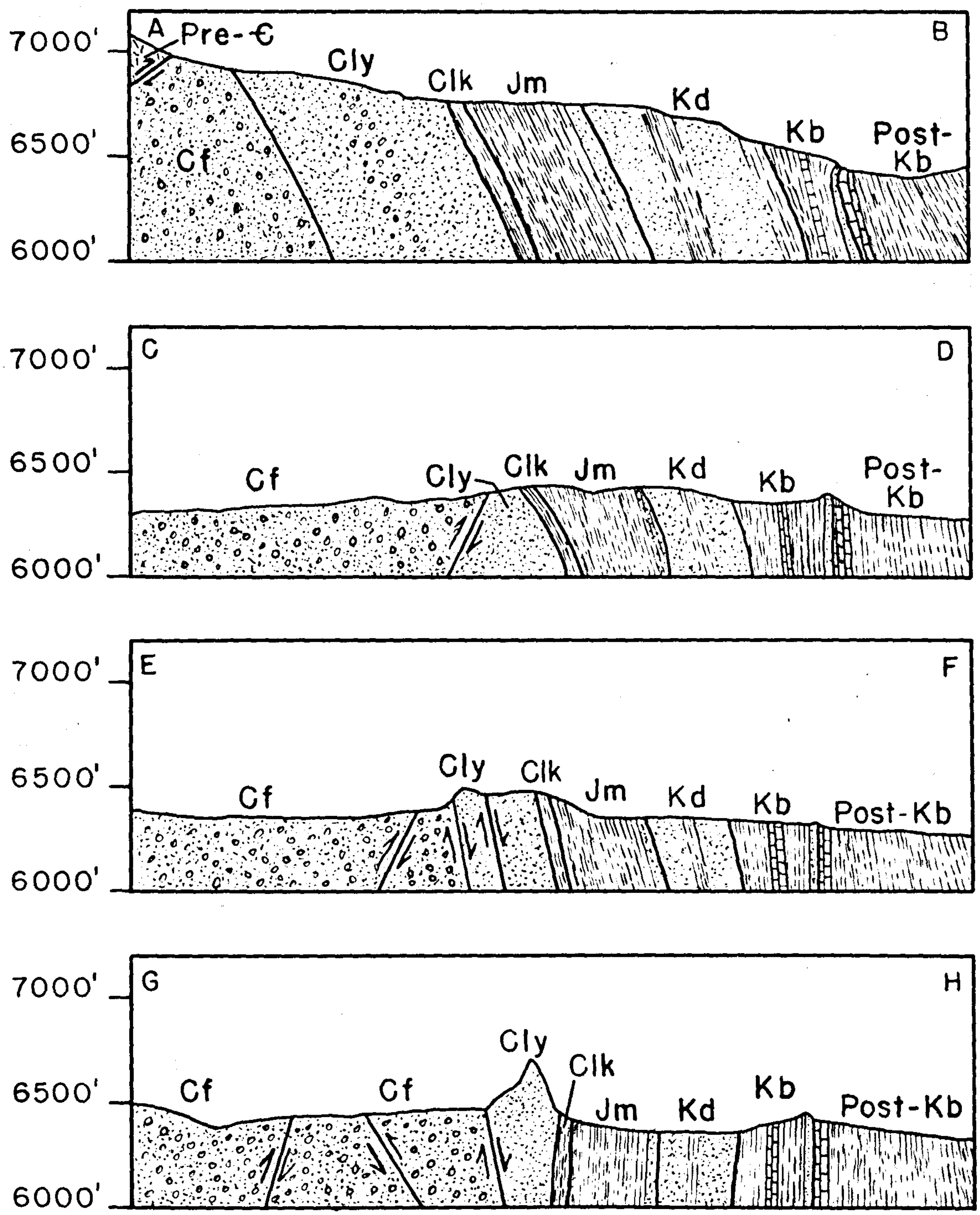


**Plate 4. Cross sections of the Garden of the Gods area.**

# CROSS SECTIONS

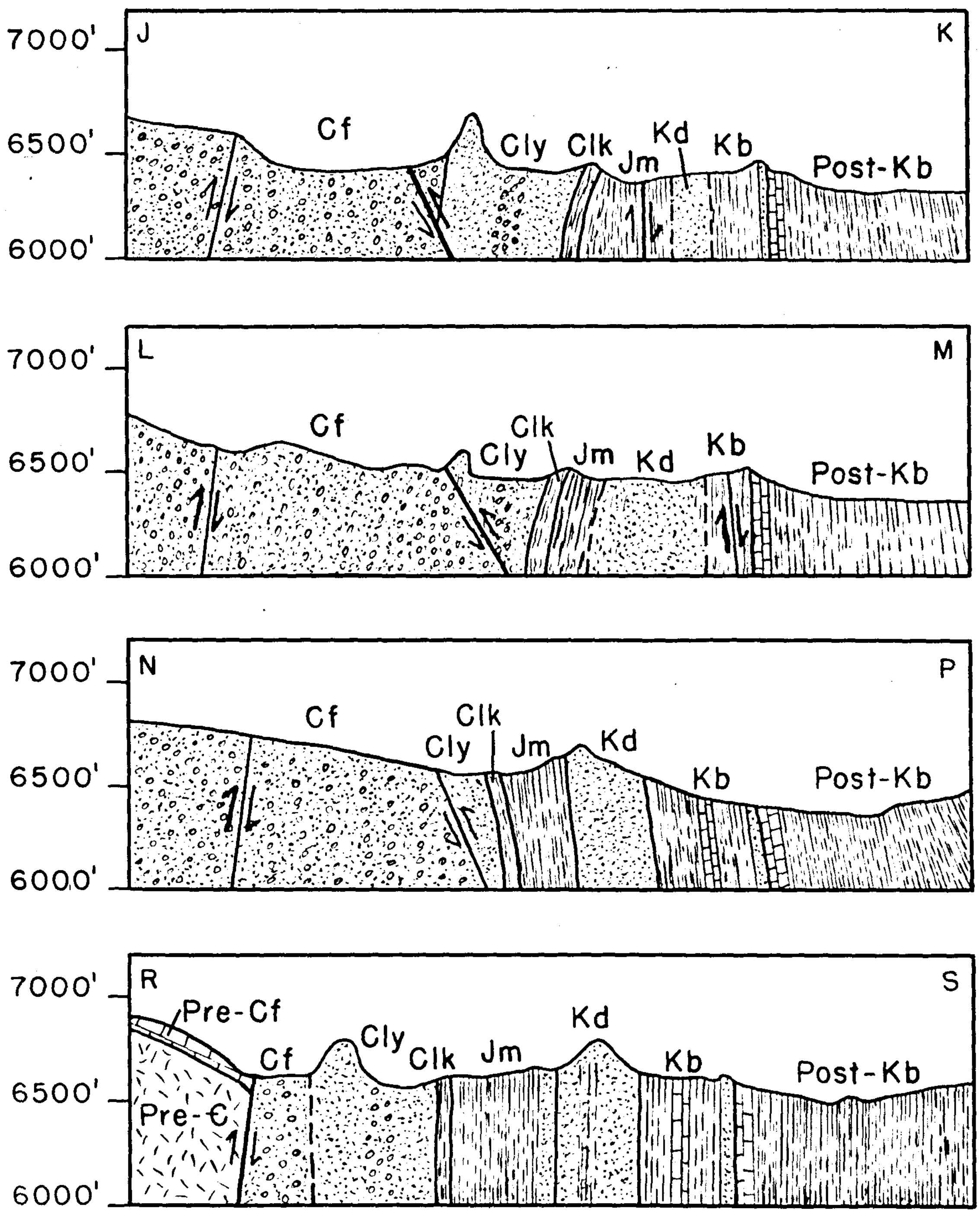


**Plate 5. Cross sections of the Garden of the Gods area.**


PLATE 6
GEOLOGIC MAP
GARDEN OF THE GODS AREA
EL PASO COUNTY, COLORADO
BY RONALD E. WILCOX
1952
North
LEGEND
MAPPED ROCK UNITS
Post-Kb
Post-Benton Cretaceous
Kb
Benton Cretaceous
Kd
Dakota Cretaceous
Jm
Morrison Jurassic
Clk
Lykins Permian
Cly
Lyons Permian
Cf
Fountain Pennsylvanian
Pre-Cf
Pre-Fountain Paleozoic
Pre-Є
Pre-Cambrian
GEOLOGIC SYMBOLS
Formations
Faults
Streams
Strike and Dip
Overturned Beds
Vertical Beds
CULTURAL SYMBOLS
Roads
Colorado Springs, City Limits
Section Lines
Section Corners
SCALE
Feet
0
1000
2000
UTE PASS FAULT
BEAR CREEK
FOUNTAIN CREEK
VALLEY RESERVOIRS
No. 2
No. 1
GLEN EYRIE RESERVOIRS
GLEN EYRIE FAULT
HIDDEN INN FAULT
CAMP CREEK
DOUGLAS CREEK
GLEN EYRIE
COLO. 336
COLO. 230
COLO. 164
US. 24
T 14 S
T 13 S