Pennsylvanian Stratigraphy of the Colorado Springs Quadrangle, Colorado.

Kenneth Phelps Mclaughlin

Louisiana State University and Agricultural & Mechanical College

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PENNylvANIAN STRATIGRAPHY OF THE
COLORADO SPRINGS QUADRANGLE, COLORADO

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The School of Geology

by
Kenneth Phelps McLaughlin
B.A., University of Missouri, 1939
M.A., University of Missouri, 1941
May, 1947
UMI Number: DP69277

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and of G. W. Strake's permission to work within the Glen Eyrie Estate.
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ABSTRACT

Detailed study of two Pennsylvanian formations, the Gleneyrie and the Fountain, within a limited area along the east flank of the Colorado Front Range indicates that such investigation is fundamental to a more thorough understanding of red bed stratigraphy.

The Gleneyrie and Fountain formations in the vicinity of the Manitou embayment were deposited in a deltaic environment during mid-Pennsylvanian time. Sediments were derived from a highland whose eastern margin closely coincided with that of the present Front Range. Climatic conditions over both the highland and the delta surface were more humid than at present.

The Gleneyrie contains a varied fauna consisting principally of ostracods and conodonts. These, in conjunction with brachiopods from a lower Fountain limestone, indicate that the two formations are of Marmaton or later age as recognized in the mid-continent Pennsylvanian section.

Detailed descriptions of the type sections of the Gleneyrie and Fountain formations are presented for the first time. Maps showing the distribution of the two formations within the Colorado Springs quadrangle and the
extent of thin limestone beds within the Fountain of the southwestern quarter of the quadrangle are included. The Gleneyrie has been raised from its former status as a member of the Fountain to the rank of formation.

Subsurface data from four wells reveal that, for a distance of 18 miles at least, the Fountain thickens eastward at a rate of approximately 100 feet per mile. Well samples indicate no marked lithologic change in the Fountain through this distance. The Gleneyrie is represented in the two easternmost of these wells by a thin section of shales and limestones at the base of the Fountain.
INTRODUCTION

Correlation among the various "red bed" formations of the Rocky Mountain province and the relationships of the "red beds" as a whole to upper Paleozoic and Mesozoic sections outside the province have long been major stratigraphic problems. Within recent years mounting interest in the oil potentialities of the Rocky Mountains has increased the necessity for solution of at least parts of these problems. Broad reconnaissance studies and correlations based on them will not supply the information needed to work out the details of Rocky Mountain stratigraphy and structure.

Detailed study of the Gleneyrie and Fountain formations has revealed new evidence as to their age and environment of origin. This evidence is presented as a contribution toward the ultimate solution of the "red bed" problems. It is hoped that the results of this work will stimulate additional detailed studies in other key areas, such as the Canon City embayment and the Arkansas Valley above the Royal Gorge, which will both verify the conclusions drawn in this paper and contribute further to our knowledge of Rocky Mountain stratigraphy.

The present study is limited essentially to the
Colorado Springs quadrangle within which there are two main areas of Pennsylvanian exposures (index map, Plate I). One of these areas, the Manitou embayment, includes the type locality and only known exposures of the Gleneyrie formation and the type locality and thickest known section of the Fountain formation. Both of these formations are of Pennsylvanian age. The second area, in the southwest quarter of the quadrangle, includes Fountain only and extends from the valley of Little Fountain Creek southwestward almost to the mouth of Beaver Creek Canyon.

In the Manitou embayment (map, Plate II) the Gleneyrie and Fountain formations were mapped in detail. A section including both formations was measured and described along the valley of Fountain Creek between Manitou and Colorado Springs, the type locality of the Fountain. Two sections of the Gleneyrie formation were measured and described near the head of Black Canyon in the northern part of the embayment. In the southwestern part of the quadrangle (map, Plate III) the area of Fountain exposures and the extent of certain limestone beds within the formation were mapped. A section of Fountain extending along the valley of Little Fountain Creek was measured and described, and sections along Turkey Creek and across Sand Creek were measured.

Field work was done during the summers of 1941, 1942, and 1946. In addition to detailed study in the Colorado Springs quadrangle the writer spent approximately one week
in reconnaissance of Garden Park at the north end of the Canon City embayment, and in observation of some of the exposures of Fountain and overlying formations between Denver and the Colorado-Wyoming state line.

Previous Work

The Fountain formation was named by Cross\(^1\) as a


series of red arkosic sandstones and conglomerates well exposed on Fountain Creek below Manitou Springs in the Colorado Springs quadrangle. He assigned the Fountain to the Carboniferous because of lithologic similarity to red beds on the Arkansas River 50 miles to the west from which Carboniferous fossils had been described. The maximum thickness measured within the Pikes Peak quadrangle was 1000 feet. No detailed description was given and no mention made of the possible environment in which these red sediments were deposited.

Prior to Cross' work the red beds along the Front Range had been assigned to the Triassic by Hayden\(^2\), who

noted a maximum thickness of 2000 feet within the Colorado Springs quadrangle but made no detailed description. "Very coarse conglomerates becoming finer eastward" were found south of Manitou Springs (in the Manitou embayment) and were interpreted as having been "laid down along the base of the Front Range as a shore line," suggesting that Hayden considered these red beds to be at least partially marine.

Finlay\(^5\), in 1907, named and described the Gleneyrie formation as 40 feet of quartz sands and black carbonaceous shales occurring immediately below the Fountain in the Manitou embayment. The shales contain fossil plants which were identified by David White as being Pottsville in age. Finlay also reported the finding of brachiopods 200 feet above the base of the Fountain but does not give further details. The publication does not include a measured section or detailed description of the Gleneyrie.

Gleneyrie deposition was interpreted as having taken place in swampy areas near sea level. The basal contact of the Gleneyrie was described as an erosional unconformity, the Gleneyrie-Fountain contact as an "unconformity with over-lap".

Finlay\(^4\), in 1916, presented a very generalized
description of the Fountain in the Manitou embayment where a maximum thickness of 4500 feet, with no duplication of section by faulting, was measured. The lowermost 90 feet was discussed and mapped separately as the Gleneyrie shale member of the Fountain. Fountain deposition was interpreted as starting under low, coastal, swampy conditions (Gleneyrie), followed by widespread terrestrial deposition of materials washed down from an arid upland. A change to marine conditions was postulated for the upper Fountain because of marine faunas found in limestones of northern Colorado that were correlated as upper Fountain equivalents. Tieje, describing the Fountain in the Colorado Springs area, noted greenish and gray sandstones, and cross bedding which dipped eastward more gently than did the formation. The Fountain was dated as Pennsylvanian, partially on the basis of a **Lingulodiscina** (lower Carboniferous brachiopod) found in a pocket of green shale 475 feet from the base of a 2000 foot section of the formation near Colorado Springs.

---


The Fountain, in Tieje's opinion, was deposited by streams wandering over a piedmont plain extending eastward from a Paleozoic Front Range during a time of semi-aridity.
The Colorado Springs quadrangle includes parts of the Rocky Mountain Front Range, the Great Plains, and the foothills between the two. Thus the rocks exposed are those of the pre-Cambrian complex of the mountain province and the Paleozoic and younger sediments which dip generally eastward off the complex. Pre-Cambrian rocks are exposed over most of the western third of the quadrangle. Outcrops of Paleozoic formations that in general dip steeply eastward form a discontinuous irregular foothill belt along the eastern and southern flanks of the mountains. Mesozoic and Tertiary formations, most of which dip gently eastward, underlie nearly all the eastern two thirds of the quadrangle which is a part of the Great Plains. Gravels of Quaternary age cover tilted and truncated Paleozoic and Mesozoic formations over large areas along the mountain front.

The following stratigraphic column shows the relationships of the Gleneyrie and Fountain to the older formations within the Colorado Springs quadrangle.
<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Mesozoic</td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td></td>
<td>Permian</td>
<td>Lykins formation</td>
</tr>
<tr>
<td></td>
<td>Permian</td>
<td>Lyons sandstone</td>
</tr>
<tr>
<td></td>
<td>Pennsylvanian</td>
<td>Fountain formation</td>
</tr>
<tr>
<td></td>
<td>Pennsylvanian</td>
<td>Gleneyrie formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Mississippian</td>
<td>Madison limestone*</td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td>Harding sandstone*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td>Manitou dolomite*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td></td>
<td>Cambrian</td>
<td>Sawatch formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unconformity</td>
</tr>
<tr>
<td></td>
<td>?</td>
<td>Rhyolite intrusives*</td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td>?</td>
<td>Pikes Peak Granite* and older crystal-line rocks.</td>
</tr>
</tbody>
</table>

*Formations upon which Pennsylvanian strata are known to rest unconformably at one or more places within the quadrangle.*
THE GLENLEYRIE FORMATION

The Gleneyrie formation consists of a series of shales and sandstones which rests unconformably on the Madison limestone and is overlain conformably and gradationally by the Fountain formation. The Gleneyrie was named by Finlay\(^6\) in 1907 at which time he described it as being 40 feet thick. In 1916 Finlay\(^7\) changed the status of the Gleneyrie to that of a member of the Fountain formation and set the thickness at 90 feet. No reason was given for these changes. Finlay apparently named the Gleneyrie from exposures of black shale and sandstone in fault contact with upper Fountain north of the mouth of Queens Canyon which at that time was called Gleneyrie Creek.


Present Status of the Gleneyrie

The writer considers the Gleneyrie to be a separate formation despite its limited extent and its gradational relationship to the Fountain. The following considerations support this conclusion and indicate that the Gleneyrie may be readily distinguished from the overlying Fountain.

(1) The Gleneyrie consists mainly of shale with thin beds of fine- to medium-grained non-arkosic sandstones whereas coarse arkosic sandstones and conglomerates greatly predominate in the Fountain.

(2) The sandstones of the Gleneyrie are even-bedded and do not show the cross bedding, filled channels, and other such sedimentary structures characteristic of the Fountain.

(3) Fossil invertebrates at various horizons in the Gleneyrie indicate that it is marine, at least in part, whereas the overlying Fountain is, in the Manitou embayment, unfossiliferous. The brachiopods reported by Finlay as occurring 200 feet above the base of the Fountain are believed to be from the fossiliferous dolomitic sandstone near the top of the Gleneyrie (unit 21, Section I).

(4) The Gleneyrie is a mappable unit in the Manitou embayment.

The Occurrence of the Gleneyrie

The most completely developed and best exposed section of the Gleneyrie, approximately 360 feet thick, is in and near Black Canyon at the north edge of the embayment and roughly three quarters of a mile southwest of Finlay's probable type locality. Most of the exposures of this section are in cuts along the Rampart Range Road and the Black Canyon Loop, both constructed in recent years.

The total extent of the Gleneyrie along the strike cannot be determined. It is overlapped by Fountain beds just south of the mouth of Williams Canyon within the town of Manitou (Plate II). Finlay states that the northernmost exposures are a short distance north of Queens Canyon and that beyond them Fountain rests on granite. However the lowest Fountain exposed is in fault contact with underlying rocks for at least several miles north of Queens Canyon. Therefore the northward extent of Gleneyrie deposition is as indeterminate as that to the south. The formation is not known to outcrop anywhere outside the Manitou embayment. The possible subsurface development of the Gleneyrie to the east is discussed in the section of this paper beginning on page 85.
Section I

Composite section of the Gleneyrie formation as exposed in and near Black Canyon, section 28, T. 13 S., R. 67 W., El Paso County, Colorado. The overall thickness was determined by plane table traverse; thicknesses of individual units were measured by Jacob staff traverse at the time the formation was described.

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness in Feet</th>
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<tbody>
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<td>To Bottom Of Unit of Formation</td>
<td></td>
</tr>
</tbody>
</table>

Fountain formation

Sandstone, red, thick-bedded, poorly consolidated, medium- and coarse-grained, arkosic, alternating with red arkosic and sandy shale.

Gleneyrie formation

23. Sandstone, white with minute black specks, massive, fine-grained; stained red on surface by wash from above.......................... 4.0 362.0

22. Shale, alternating gray and purple beds.............................. 12.0 358.0

21. Sandstone, mottled purple and light-gray, upper 3 feet massive, lower 2 feet thin-bedded, fine-grained, irregularly dolomitic, contains a few brachiopods....... 5.0 346.0

20. Shale, alternating light-gray and maroon beds..................... 15.0 341.0
Section I (continued)

<table>
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<tr>
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<tbody>
<tr>
<td>19</td>
<td>Sandstone, light-gray to white, hard, fine-grained; 2 massive beds separated by 4 inches of thin-bedded shaly sand</td>
<td>2.0</td>
<td>326.0</td>
</tr>
<tr>
<td>18</td>
<td>Poorly exposed (a few exposures of shale)</td>
<td>25.0</td>
<td>324.0</td>
</tr>
<tr>
<td>17</td>
<td>Sandstone, yellow and purple, irregularly bedded, hard, slightly quartzitic, partially arkosic, slightly shaly in lower part</td>
<td>13.0</td>
<td>299.0</td>
</tr>
<tr>
<td>16</td>
<td>Shale, varicolored, with few thin beds of white and yellow hard medium-grained sandstone, poorly exposed at top</td>
<td>75.0</td>
<td>286.0</td>
</tr>
<tr>
<td>15</td>
<td>Sandstone, mottled white and purple, hard, fine-grained, interbedded with sandy shale</td>
<td>3.0</td>
<td>211.0</td>
</tr>
<tr>
<td>14</td>
<td>Sandstone, mottled white and purple, hard, fine-grained, thick-bedded</td>
<td>8.0</td>
<td>208.0</td>
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<tr>
<td>13</td>
<td>Shale, varicolored, with a few thin beds of yellow hard fine-grained sandstone</td>
<td>32.0</td>
<td>200.0</td>
</tr>
<tr>
<td>12</td>
<td>Shale, yellow and gray, silty, calcareous, fossiliferous (ostracods and brachiopods)</td>
<td>5.0</td>
<td>168.0</td>
</tr>
<tr>
<td>11</td>
<td>Limestone, gray-brown, massive, slightly nodular, dense</td>
<td>2.0</td>
<td>163.0</td>
</tr>
<tr>
<td>10</td>
<td>Limestone, gray-brown, nodular, interbedded with sandy and fissile shale</td>
<td>2.0</td>
<td>161.0</td>
</tr>
<tr>
<td>9</td>
<td>Limestone, brown, coarsely crystalline to dense, sandy at top</td>
<td>1.0</td>
<td>159.0</td>
</tr>
<tr>
<td>8</td>
<td>Shale, purple to gray, fissile</td>
<td>1.0</td>
<td>158.0</td>
</tr>
<tr>
<td>7</td>
<td>Limestone, yellow, slightly arkosic, slightly conglomeratic, fossiliferous (poorly preserved brachiopods)</td>
<td>2.0</td>
<td>157.0</td>
</tr>
</tbody>
</table>
Section I (continued)

6. Shale, gray and yellow, silty, micaceous, with stringers of yellow fine-grained sandstone, poorly exposed. 42.0 155.0

5. Sandstone, yellow with irregular purple bands, fine-grained. 2.0 113.0

4. Chert, dark-gray to black, iron stained, finely granular to dense, jointed. 1.0 111.0

3. Shale, varicolored, with a few thin beds of yellow irregularly banded fine-grained sandstone. 72.0 110.0

2. Shale, gray, purple and brown, basal 10 feet fossiliferous (ostracods, conodonts, brachiopods, bryozoa, echinoderms). 35.0 38.0

1. Sandstone, yellow to purple, irregularly cemented, fine-grained, silty. 3.0 3.0

Madison limestone

Limestone, gray and red, dense, dolomitic, in angular unconformity with overlying Gleneyrie.

Black Canyon Section. - Varicolored sandy shales constitute approximately 80 percent of the total thickness of Gleneyrie in Black Canyon. Black shales, most of which are gray on weathered surfaces, alternate with yellow, green, brown, and purple shales; red shales are absent. The maximum observed thickness of shale unbroken by sandstone beds or stringers was 35 feet. Fossils of marine invertebrates occur in yellow and gray shales near the
base and near the middle of the section. Lithologically identical beds in other parts of the formation appear to be unfossiliferous.

Sandstones constitute roughly 15 percent of the Gleneyrie exposures in Black Canyon. In the lower half of the formation most of these sandstones are non-calcareous, ferruginous, medium- to coarse-grained and composed largely of quartz. They are commonly thin, occurring interbedded with the shales that make up the bulk of the section. Most are yellow or brown in color, a few are purple and a very few are red. Iron is present as interstitial cement supplemented by enough silica in some beds to make them quartzitic. The chief exception to the usual thinness of lower Gleneyrie sandstones is the basal sand which varies from 4 to 15 feet in thickness over a distance of not more than one fourth of a mile.

In contrast the sandstones of the upper Gleneyrie in Black Canyon are generally light-colored, fine- to medium-grained, and average from 5 to 7 feet in thickness. A light-gray hard dolomitic sandstone containing phosphatic shells of linguloid-like brachiopods occurs 20 feet below the top of the formation. Distribution of dolomite within the sandstone is irregular; in part the appearance is that of interbedded sandstone and dolomite, but at other places on the same outcrop the boundary between dolomitic sandstone and sandy dolomite cuts across bedding. On exposed surfaces the more dolomitic parts stand out in relief of
several millimeters.

The sandstone which was mapped as the top of the Gleneyrie in the Black Canyon area, and for some distance southwestward, is a persistent white fine-grained massive ledge-forming bed 4 feet thick. Its surface is stained red by wash from the overlying Fountain red beds. Under it, and separating it from the dolomitic sandstone previously described, is a 12 feet section of gray and purple shales. In an exposure (180) feet above the base of the Gleneyrie, along the lower road of the Black Canyon Loop, is an outcrop of sandy, slightly arkosic limestone containing crushed and partially dissolved brachiopod shells. The bed is 2 feet thick and occurs at the top of a section of thick shales and interbedded sandstones.

In thin section this limestone is seen to be coarsely but unevenly crystalline, with calcite constituting approximately 60 percent of the total. Most of the remainder of the specimen is made up of angular fragments of microcline perthite and subangular to rounded fragments of quartz and quartzite, a few fragments of each being as large as 8 millimeters in diameter.

Above this slightly arkosic limestone and separated from it by 1 foot of fissile shale is a 5 1/2 foot section of limestone beds, dense and slightly nodular at the top, nodular and impure in the middle, and more coarsely crystalline at the base. These were the only limestone beds observed in surface exposures of Gleneyrie, in the Black
Canyon section or elsewhere. In their nodular development these limestones resemble many found in the Fountain south of the Manitou embayment.

**Lateral changes.** - Southwestward from Black Canyon the Gleneyrie thins to 122 feet at the mouth of Williams Canyon, the southernmost exposures in which a complete section may be observed. Thinning is largely at the expense of shales, as sandstones and conglomeratic sandstones comprise 50 percent or more of the Williams Canyon section. The sandstones are more coarse-grained, more arkosic and conglomeratic, and in general more Fountain-like than in the Black Canyon area. Because of poor exposures between the two areas the exact nature of the change from a predominantly shale section to one in which coarse clastics are dominant is difficult to determine for the formation as a whole.

The top of the Gleneyrie throughout the area of exposure was mapped on the horizon above which there are no shales of appreciable thickness. In the northern part of the area, from Black Canyon to near Quarry Canyon (Plate II), this horizon is the top of the ledge-forming white sandstone previously described (unit 23, Section I). From Quarry Canyon southward the horizon used was the top of a coarse- to medium-grained bright-yellow sandstone about 6 feet thick (unit 9, Section II) conformably overlain by massive arkosic conglomeratic sandstones and underlain by several feet of gray and yellow non-
fossiliferous shale.

Within the Gleneyrie interfingering of sandstones from the south with shales from the north makes through tracing of many individual beds almost impossible. The basal beds, however, are well enough exposed that a clear picture of the lateral changes they undergo may be obtained. In Black Canyon the basal unit is a firm irregularly cemented yellow to brown medium-grained sandstone averaging 5 feet in thickness and occurring in beds 1 to 1 1/2 feet thick. To the south and west basal beds, wherever exposed, are similar but usually more quartzitic. Some are slightly conglomeratic with poorly rounded quartz pebbles up to one half inch in diameter. On the north rim of Quarry Canyon these basal sands are much more ferruginous, bright-red in color, and rather friable. There are thin layers of hematitic siltstone, purple in color, which become more numerous southward. Near the mouth of Williams Canyon the basal sands include beds up to 6 inches thick of slightly siliceous hematite.

The Gleneyrie-Madison Contact

The unconformity between the basal Gleneyrie sandstones and the Madison limestone is exhibited by the difference in attitude between the two formations. Near the head of Black Canyon the Madison strikes N 80° E and dips 32° S. The overlying Gleneyrie sandstone strikes N 75° E but dips only 18° S. At the mouth of Williams
Canyon the strike of the basal Gleneyrie beds is N 8° E and the dip is 14° E. The attitude of the underlying Madison is difficult to determine, but truncation of weathered limestone conglomerate by the overlying sandstones may be seen in road cuts east of the mouth of the Canyon.

Paleontologic Summary

Fossils were found in the following four units within the Gleneyrie:

(1) A shale (unit 2, Section I) 15 to 20 feet above the base of the formation on the Rampart Range Road. The fauna consists of ostracods and conodonts with a few poorly preserved productid type brachiopods and fragments of bryozoa, corals, and echinoderms.

(2) A sandy limestone (unit 7, Section I) 157 feet above the base of the formation on the lower road of the Black Canyon Loop. A few crushed brachiopods were found.

(3) A shale (unit 12, Section I) 168 feet above the base of the formation in the same exposure as that of (2). The fauna consists of ostracods and brachiopods very similar to those of unit 2 of the section, but without the conodonts, bryozoa, corals, and echinoderms.

(4) A dolomitic sandstone (unit 21, Section I) 20 feet below the top of the formation along the Rampart Range Road. A few phosphatic shells of linguloid-like brachiopods were found.
The brachiopods found in units 2 and 12 include species of Chonetes and Dictyoclostus common in the Pennsylvanian but not particularly diagnostic. The ostracods and conodonts are abundant and well preserved.

The ostracod fauna includes species of the following genera; Bairdia, Cavellina, Healdia, Geisina, Monoceratina, Glyptopleura, Amphissites, Kirkbya, Hollinella, and Pseudo-paraparchites. The writer tentatively identified twelve of these Gleneyrie ostracods with species previously described, which together are diagnostic of early or middle Pennsylvanian sediments. Other ostracods in the fauna have not been described.

The following four genera of conodonts, including at least six species, were identified; Idiognathodus, Stretognathodus, Cavusgnathus, and Spathodus. No one of the six species is particularly diagnostic by itself, but as a fauna they indicate that the Gleneyrie is of Des Moines or younger age.

The position of the Gleneyrie and Fountain formations in the Pennsylvanian system as indicated by the Gleneyrie fauna is discussed in detail in the section of this paper entitled "The Age of the Gleneyrie and Fountain Formations," page 93.
THE FOUNTAIN FORMATION

General Features

The Fountain formation consists of a thick series of red irregularly bedded coarse-grained arkosic sandstones and conglomerates sparsely interbedded with thin shales and locally fossiliferous limestones. The Fountain rests unconformably on older formations at all exposures around the southern end of the Front Range except those in the Manitou embayment where it conformably overlies the Gleneyrie formation. The Fountain is overlain with apparent conformity by the Lyons sandstone throughout the area considered in this paper.

The greatest known thickness of the Fountain formation is at the type locality. Nearly 4400 feet of red sandstones and conglomerates are exposed in the valley of Fountain Creek between Manitou and West Colorado Springs (Plate II). Paleozoic exposures are cut out for a distance of about 10 miles along the mountain front by overthrusting along the Cheyenne Mountain thrust fault (Plate I). As a result Fountain exposures in the Manitou embayment are separated from those in the southwestern quarter of the quadrangle. In the latter area the thickest surface
exposures are of the order of 1500 feet. A thickness of 1287 feet of Fountain is present in the valley of Little Bear Creek (Plate III), 1470 feet in the valley of Turkey Creek, and 1490 feet across the valley of Sand Creek near the western edge of the quadrangle. Information from wells drilled near the outcrop and farther eastward indicates that the Fountain thickens rapidly toward the east. However none of the wells has penetrated a section thicker than that exposed at the type locality.

The following section of the Fountain and Gleneyrie formations was measured and described in and near the type locality of the Fountain.

Section II

Section through the Gleneyrie and Fountain formations in the valley of Fountain Creek and tributaries, sections 3, 4, 5, and 10, T. 14 S., R. 67 W., El Paso County, Colorado. Overall thicknesses were determined by plane table traverse; individual units were measured by Jacob staff traverse at the time the formations were described.
## Section II (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness in Feet</th>
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<tbody>
<tr>
<td>Lyons sandstone - Permian?</td>
<td></td>
</tr>
<tr>
<td>Sandstone, red, massive, medium- to fine-grained.</td>
<td></td>
</tr>
<tr>
<td>Fountain formation</td>
<td></td>
</tr>
<tr>
<td>46. Sandstone, red, thinly bedded, medium- and coarse-grained</td>
<td>5.0 4370.0</td>
</tr>
<tr>
<td>45. Sandstone, red, poorly exposed</td>
<td>160.0 4365.0</td>
</tr>
<tr>
<td>44. Sandstone, red with some gray beds, arkosic, slightly conglomeratic</td>
<td>265.0 4205.0</td>
</tr>
<tr>
<td>43. Sandstone, red and gray, arkosic, poorly exposed</td>
<td>400.0 3940.0</td>
</tr>
<tr>
<td>42. Sandstone, red and gray, coarse-grained, arkosic</td>
<td>15.0 3540.0</td>
</tr>
<tr>
<td>41. Sandstone, gray, thinly bedded, coarse-grained, arkosic, interbedded</td>
<td>15.0 3525.0</td>
</tr>
<tr>
<td>with red thinly bedded fine-grained micaceous sandstone</td>
<td></td>
</tr>
<tr>
<td>40. Sandstone, red, thin-bedded, massively weathering, coarse-grained, arkosic, poorly exposed</td>
<td>240.0 3510.0</td>
</tr>
<tr>
<td>39. Sandstone, red, thin-bedded, massively weathering, coarse-grained, arkosic, irregularly conglomeratic; a few cobbles as large as 6 inches in diameter</td>
<td>210.0 3290.0</td>
</tr>
<tr>
<td>38. Sandstone, red, thin-bedded, massively weathering, coarse-grained, arkosic</td>
<td>460.0 3080.0</td>
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**Section II (continued)**

<table>
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<th>No.</th>
<th>Description</th>
<th>Top</th>
<th>Base</th>
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<tbody>
<tr>
<td>37.</td>
<td>Sandstone, red, massive, coarse-grained, irregularly conglomeratic, arkosic; quartz and quartzite predominant among pebbles and cobbles.</td>
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<td>2620.0</td>
</tr>
<tr>
<td>36.</td>
<td>Sandstone, red, massive, coarse-grained, conglomeratic, arkosic; decomposed schist and biotite granite predominant among cobbles; upper 25 feet poorly exposed.</td>
<td>105.0</td>
<td>2145.0</td>
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<tr>
<td>35.</td>
<td>Sandstone, red, poorly consolidated, coarse-grained, irregularly conglomeratic, arkosic, poorly exposed.</td>
<td>280.0</td>
<td>2040.0</td>
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<td>34.</td>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic, interbedded with maroon thin-bedded fine-grained micaceous sandstone and shale.</td>
<td>109.0</td>
<td>1760.0</td>
</tr>
<tr>
<td>33.</td>
<td>Sandstone, red, coarse-grained, irregularly conglomeratic, arkosic, poorly exposed.</td>
<td>145.0</td>
<td>1651.0</td>
</tr>
<tr>
<td>32.</td>
<td>Sandstone, red, massive, coarsely conglomeratic; cobbles and small boulders of quartz, quartzite, and decomposed granite.</td>
<td>10.0</td>
<td>1506.0</td>
</tr>
<tr>
<td>31.</td>
<td>Sandstone, red, thin-bedded, coarse-grained, irregularly conglomeratic, arkosic; cobbles as large as 4 inches in diameter.</td>
<td>60.0</td>
<td>1496.0</td>
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<td>30.</td>
<td>Sandstone, red, massively bedded, coarse-grained, conglomeratic, arkosic.</td>
<td>65.0</td>
<td>1436.0</td>
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<tr>
<td>29.</td>
<td>Sandstone, red, massive, coarse-grained, arkosic.</td>
<td>3.0</td>
<td>1371.0</td>
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<tr>
<td>28.</td>
<td>Sandstone, red, irregularly bedded, conglomeratic, arkosic, with stringers and lenses of silt and shale, poorly exposed.</td>
<td>190.0</td>
<td>1363.0</td>
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</tbody>
</table>
Section II (continued)

27. Sandstone, mottled red and gray, irregularly bedded with lenses of cross-laminated sandstone, coarse-grained, conglomeratic, arkosic; sub-rounded to angular cobbles average 3 inches in diameter........ 210.0 1173.0

26. Sandstone, red, coarse-grained, coarsely conglomeratic, arkosic, interbedded with maroon fine-grained shaly micaceous sandstone; rounded and angular cobbles dominantly of quartz and quartzite...... 75.0 963.0

25. Sandstone, red, massive, coarse-grained, slightly conglomeratic, arkosic, interbedded with lenses of soft maroon shaly sandstone; rounded pebbles of granite predominate in conglomeratic fraction.............................. 15.0 888.0

24. Sandstone, mottled red and white, massive, medium- and coarse-grained, arkosic.......................... 10.0 875.0

23. Sandstone, red, massive, coarse-grained, conglomeratic, arkosic, with interbedded thin medium-grained arkosic sandstones, poorly exposed.................................................. 80.0 863.0

22. Conglomerate, red, massive, arkosic, interbedded with red and white thin-beded fine-grained arkosic sandstones and black thin shales... 55.0 783.0

21. Sandstone, red, loosely consolidated, coarse-grained, arkosic..... 10.0 728.0

20. Siltstone, red, thin-beded, micaceous, with thin stringers of white medium- and coarse-grained arkosic sandstones.......................... 40.0 718.0

19. Sandstone, pink and white, thin-beded, coarse-grained, arkosic.... 26.0 678.0
Section II (continued)

18. Sandstone, red, massively and irregularly bedded, coarse-grained, slightly conglomeratic, arkosic; lower 15 feet poorly exposed........ 48.0 652.0

17. Sandstone, gray, irregularly bedded, coarse-grained, arkosic.... 15.0 604.0

16. Unexposed........................................ 14.0 589.0

15. Sandstone, red and white, massive, coarse-grained, slightly conglomeratic, arkosic.................. 22.0 575.0

14. Shale, red, fissile, sandy, with thin beds of shaly sandstone...... 5.0 553.0

13. Sandstone, red and gray, irregularly bedded, coarse-grained, conglomeratic, arkosic................ 46.0 548.0

12. Sandstone, gray, poorly consolidated, coarse-grained, arkosic..... 38.0 502.0

11. Sandstone, red, evenly bedded, coarse-grained, arkosic, with thin stringers of cross-bedded sandstone and of conglomerate.............. 57.0 464.0

10. Conglomerate, red and gray, arkosic; angular and rounded fragments of cobble and boulder size; quartz and quartzite slightly predominate over granite.......... 4.0 407.0

9. Sandstone, red and white, massive, coarse-grained, conglomeratic, with thin beds of gray fine-grained micaceous sand; conglomeratic fraction consists of angular fragments thinly scattered along bedding surfaces.......................... 35.0 403.0

8. Sandstone, red and gray, poorly consolidated, coarse-grained, arkosic, poorly exposed............... 95.0 368.0
### Section II (continued)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Sandstone, red and gray, thick-bedded, medium- and coarse-grained, arkosic, interbedded with very coarse conglomerate.</td>
<td>112.0</td>
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<tr>
<td></td>
<td></td>
<td>273.0</td>
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<tr>
<td>6</td>
<td>Unexposed.</td>
<td>10.0</td>
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<tr>
<td></td>
<td></td>
<td>161.0</td>
</tr>
<tr>
<td>5</td>
<td>Sandstone, mottled purple, red and white, massively and irregularly bedded, medium- to coarse-grained, conglomeratic, arkosic; topped by 6 inch layer of white coarse-grained calcareous sandstone.</td>
<td>23.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>151.0</td>
</tr>
<tr>
<td>4</td>
<td>Sandstone, red, well consolidated, coarse-grained, slightly conglomeratic, arkosic.</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>126.0</td>
</tr>
<tr>
<td>3</td>
<td>Sandstone, red, thick-bedded, coarse-grained, slightly conglomeratic, arkosic; near the top, two bedding surfaces are thinly veneered by subangular pebbles and small cobbles.</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>124.0</td>
</tr>
<tr>
<td>2</td>
<td>Conglomerate, red, coarse, arkosic; large subangular cobbles of granite and smaller rounded cobbles of quartz and quartzite constitute most of the bed.</td>
<td>2.0</td>
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<tr>
<td></td>
<td></td>
<td>59.0</td>
</tr>
<tr>
<td>1</td>
<td>Sandstone, mottled white and purple, thick-bedded, coarse-grained, slightly conglomeratic, arkosic; interbedded with thin stringers of purple and red fissile silty micaceous shale.</td>
<td>57.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>57.0</td>
</tr>
</tbody>
</table>

**Gleneayrie formation**

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Sandstone, bright-yellow, coarse-to medium-grained.</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>122.0</td>
</tr>
<tr>
<td>8</td>
<td>Shale, gray and yellow (no fossils found).</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>116.0</td>
</tr>
<tr>
<td>7</td>
<td>Sandstone, purple and white, coarse-grained, slightly arkosic.</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>109.0</td>
</tr>
</tbody>
</table>
Section II (continued)

6. Shale, gray and black, with thin stringers of gray medium-grained arkosic sandstone in upper 10 feet. 28.0 102.0

5. Sandstone, gray, fine- to medium-grained, shaly. 4.0 74.0

4. Sandstone, yellow, hard, thinly bedded, medium-grained. 5.0 70.0

3. Shale, gray and black, with thin beds of yellow medium-grained slightly arkosic sandstone; poorly exposed. 40.0 65.0

2. Sandstone, red and white, slightly conglomeratic, slightly arkosic. 15.0 25.0

1. Shale, black, gray and yellow, interbedded with thin stringers of yellow medium-grained sandstone and of dark-red to black siliceous hematite. 10.0 10.0

Madison limestone - Mississippian

Limestone, much weathered, possibly brecciated, in angular unconformity under overlying Gleneyrie shales.

Conglomerates of the Fountain

In the present paper the use of the name "conglomerate" has been applied to include beds composed so predominantly of fragments of pebble size or larger that the poor sorting implied by the name "conglomerate" is not readily apparent. Such application is desirable because of the lateral changes of texture which these pebble beds undergo. Many of them become definite conglomerates, a few grade laterally into sandstones.
General lithologic description. - There are major lithologic similarities among the conglomerates of the Fountain. They are all arkosic to some degree, cleavage fragments of feldspar ranging in diameter from 4 inches to that of fine sand. Quartz fragments are of all shapes and degrees of roundness, and many of them are larger than the associated fragments of feldspar. In many of the conglomerates fragments of granite and quartzite are nearly as abundant as those of feldspar and quartz.

Fragments of quartzite are both rounded and angular and the coarse particles range in size from pebbles to small boulders. Granite fragments are subangular to rounded and most of them appear to be of a finer-grained variety than that from which the arkosic material was derived. Many of the fragments of coarser-grained granite are somewhat disintegrated. At most exposures the less weathered granite and other crystalline rocks show no correlation between size and degree of rounding. In the same conglomeratic bed angular and rounded boulders and angular and rounded pebbles, all of the same type of granite occur side by side. Apparently weathering at the source area was at least as important in controlling shape and size as was wear during transport.

Chert, schist, gneisses, and some basic igneous rocks are locally abundant. Most chert fragments are subangular to rounded and are seldom larger than small cobbles. Nearly all the schist, gneiss, and basic igneous rock
fragments are moderately rotten, fairly well rounded, and generally less than 10 inches in diameter.

Conglomerates of especial significance. - The local distribution of chert fragments within the lower few hundred feet of the formation is closely related to the distribution of formations underlying the Fountain. The source of the abundant angular to subrounded pebbles and cobbles of red, yellow, and white chert in these conglomerates must have been the Manitou dolomite and the Madison limestone both of which contain nodules and lenses of chert. The other known pre-Pennsylvanian formations of the Front Range are chert free.

The Manitou and Madison formations are discontinuous and absent for long distances along the mountain front south of the Manitou embayment. It is along this part of the mountain front that chert is most abundant in the lower conglomerates of the Fountain. In the southwestern part of the Colorado Springs quadrangle the Manitou is better preserved than the overlying Madison, which north of Red Creek outcrops only in the valley of Little Bear Creek. The Madison is more continuous south and west of Red Creek into the Canon City embayment. Prior to Fountain time the Madison was undoubtedly more extensive than at present. Molds and casts of Mississippian spiriferoid brachiopods are found in chert pebbles and cobbles of the lower conglomerates even where the Fountain rests on Manitou or pre-Cambrian rocks. Along the mountain front north of
Colorado Springs pebbles and boulders of chert, some of which contain Mississippian fossils, have been found near the base of the Fountain; throughout most of this distance the Fountain is in contact with pre-Cambrian crystalline rocks.9


In the Manitou embayment the Manitou and Madison formations are present in their thickest development between Canon City and the Colorado-Wyoming state line. Here chert is absent from Fountain conglomerates as contrasted to localities south of the embayment where fragments of chert outnumber these of quartz, feldspar, and quartzite. In the valley of Little Bear Creek some of the basal massive conglomeratic beds of the Fountain contain scattered cobbles of rhyolite up to 4 or 5 inches in diameter. Distribution of this rhyolite is restricted to Little Bear Creek valley and its tributary, Deadman Canyon. Strati-graphically the occurrence of rhyolite is limited to approximately the basal 400 feet of the formation. The eastward subsurface extent of the rhyolite bearing beds has not been determined.

The only known sources for this rhyolite are the pre-Cambrian intrusive bodies along the Paleozoic-pre-Cambrian contact just west of the Fountain outcrops in which it
occurs (Plate III). All exposures of rhyolite bearing beds are less than three quarters of a mile from the outcrops of these intrusive bodies.

Just south of the divide between Little Fountain and Little Bear Creeks Fountain overlies fresh rhyolite. Almost equally fresh fragments of the latter are incorporated in the basal conglomerates of the Fountain. Southward decomposed rhyolite becomes more abundant in the conglomerates and fresh fragments rarer. At the mouth of the southernmost canyon of the Little Bear Creek drainage Manitou dolomite overlies rhyolite which is weathered and decomposed to considerable depth.

At a few exposures Fountain conglomerates include cobbles of several varieties of red sandstone unlike any known from pre-Fountain formations. On the south side of Little Bear Creek a conglomerate 1130 feet above the base of the formation contains rounded cobbles of red fine-grained sandstone that appears identical to those of the upper Fountain and Lyons formations. Even the bleached spots so characteristic of these sandstones are present on the largest cobbles which range up to 7 inches in diameter. In an un-named gulch near the foot of the Crystal Park Toll Road (Plate II) rounded and subrounded cobbles and small boulders of red medium-grained arkosic sandstone are not uncommon in the coarse conglomerates exposed. These cobbles appear identical in composition to part of the matrix of the conglomerates and to many of the sands found
both higher and lower in the formation.

Another variety of Fountain conglomerate is exposed in a bank of the West Fork of Red Creek approximately one half mile above the junction with Red Creek (Plate III). A channel cut in thin-bedded sandstone was filled by coarse almost unbedded conglomerate containing angular and rounded cobbles as large as 4 inches in diameter. Limy nodules, worn and broken but identical to the impure nodular limestone of the Fountain, are particularly abundant among these cobbles.

Sorting of a peculiar kind is exhibited in a bed 850 feet above the base of the Fountain in the Manitou embayment. A massive sandstone is made conglomeratic by the presence of abundant well-rounded fragments of medium-grained granite. Nearly all the fragments are of a size between 15 and 25 millimeters. Larger subrounded pebbles of quartz are present but are very rare.

**Distribution of conglomerate within the Fountain.** In the two sections of the Fountain measured and described, conglomerates make up a smaller proportion of the total thickness than would be estimated from casual observation. In the Manitou embayment section conglomerates comprise approximately 15 percent of the total thickness; along Little Bear Creek they comprise approximately 26 percent of the section. In the accompanying graphs the similarity of vertical distribution of conglomerate in the two sections is quite obvious. For the Little Bear Creek
Fig. 1 - Comparison of the vertical distribution of conglomerate in two sections of the Fountain formation 14 miles apart along the mountain front.
section the percentage of conglomerate per 100 feet is shown; for the Manitou embayment section, slightly over three times as thick, the unit interval is 300 feet. Vertical and horizontal scales have been adjusted to facilitate qualitative comparison. The major difference in the two graphs is the contrast between the lower 200 feet of the Little Bear Creek section and the equivalent lower 600 feet in the Manitou embayment. The lower proportion of conglomerate in the latter is in accord with the gradational change from Gleneyrie shales and sandstones to the coarser Fountain sediments.

Stratification of the conglomerates. - Conglomerates in the Fountain commonly occur as irregular lenses of limited extent, as pockets which are definitely parts of channel fillings, and as zones within massive beds of arkosic sandstone. These latter are integral parts of the beds in which they occur and have no effect on the bedding. There is no evidence of scouring at their bases as there is at the base of an obvious channel filling. Individual beds of conglomerate which stand out as definite units and have an observable lateral extent of more than a few hundred yards along strike are almost entirely confined to the lower 700 feet of the Fountain in the Manitou embayment. As indicated in the preceding section there is, within thick units of the formation, a marked similarity in the development of conglomerate in different localities. However this similarity does not apply to individual beds.
Fig. 2.—Uniformly stratified lower Fountain in the west wall of Quarry Canyon near Manitou, Colorado. The thin dark beds are black silty shales.
Fig. 3.- Strata of Fig. 2 exposed 250 yards north of the location illustrated in Fig. 2.
Within the lower 700 feet of the Fountain in the Manitou embayment single beds of conglomerate may be traced along canyon walls for distances of 400 yards or more, the limits being set by the exposures rather than by the beds themselves. Throughout the extent of exposure these and some of the associated beds of sandstone and shaly sand maintain nearly constant thicknesses. It is probable that the gradational change from Gleneyrie to Fountain was responsible for this regularity of bedding in the lower Fountain.

In the same part of the section are a few conglomerate stringers marking the contacts between massive irregularly bedded sandstones. These stringers consist of veneers of subangular pebbles and cobbles from 1/2 to 5 inches in diameter. They are spread over rather even surfaces which at places truncate the bedding planes of the underlying sandstones. At no point along the exposures was a stringer observed to be more than one fragment thick; at no point does more than one pebble or cobble separate the underlying sandstone from the one above. Inequidimensional fragments are oriented with long dimensions paralleling the surfaces on which they lie.

Two such stringers, approximately 105 and 110 feet above the Gleneyrie-Fountain contact, are exposed for a distance of a little more than 100 feet on the divide east of the mouth of Williams Canyon (Plate II). Within the limits of this exposure the thinness of the stringers
Fig. 4.- "Veneer" conglomerate between massive conglomeratic arkosic sandstones. The exposure is of lower Fountain in a road cut on the divide east of the mouth of Williams Canyon.
Fig. 5.- Close-up view of the exposure illustrated in Fig. 4.
and the regularity of the underlying surfaces remain constant. In exposures along the east wall of the "cliff-dwellings" canyon, approximately 350 feet above the Gleneyrie-Fountain contact, similar conglomerate stringers occur along the bedding surfaces of irregularly bedded poorly sorted sandstones. These stringers resemble those described above in thinness and size of fragments, but lie along irregular surfaces and are truncated by overlying beds. The maximum observed extent of these latter stringers is approximately 40 feet along the exposure.

Of the conglomerates studied in the Fountain it was only in these "veneer" stringers that any arrangement of flattened fragments was noted. In the thicker conglomerates and conglomeratic zones flattened fragments are not uncommon but there is complete absence of observable orientation. In no part of the Fountain, "veneer" conglomerates included, is there evidence of imbricate structure.

Aside from the stringers described above, the comparatively well bedded conglomerates, and the conglomeratic zones within massive beds of arkosic sandstone, deposition of conglomerates was controlled largely by the configuration of the surface on which the sediments were laid down. Most of the conglomeratic bodies occur as more or less isolated pockets and lenses occupying channels scoured in the underlying sediments. These pockets and lenses are seldom of thickness greater than 8 to 10 feet. Their
wedging out between beds of sandstone, between limestone and sandstone beds, or between conglomeratic beds may be seen at almost every exposure.

Detailed descriptions of conglomerates. - Several of the lower Fountain conglomerates were studied in detail in the field for the purpose of obtaining more definite information concerning size ranges, shapes, composition, and possible orientation of fragments. Selection of subject beds for the study was more or less at random. The following three summaries are presented as characteristic but not necessarily typical of Fountain conglomerates.

1. A massive basal conglomeratic sandstone in the southernmost canyon tributary to Little Bear Creek (Plate III). The exposure is an eroded surface nearly paralleling the bedding of the formation. The matrix of the conglomerate is poorly sorted, varying from sand to fine gravel, and enclosing pebbles and cobbles up to 6 or 7 inches in diameter. Fragments between 1 inch and 4 inches in diameter comprise at least 80 percent of the coarse fraction. Boulders are very rare. Inasmuch as fragments larger than 1 inch in diameter constitute a very small part of the entire bed a numerical count of fragments as to size and composition was not made.
<table>
<thead>
<tr>
<th>Composition - in order of decreasing abundance</th>
<th>Shape</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz and quartzite</td>
<td>Subangular to rounded; sphericity rare</td>
<td>Fresh</td>
</tr>
<tr>
<td>Chert</td>
<td>Flattened and subangular. A few smaller fragments equidimensional, subangular to subrounded.</td>
<td>Fresh</td>
</tr>
<tr>
<td>Granite and pegmatite</td>
<td>Angular to rounded</td>
<td>Fresh and partially decomposed</td>
</tr>
<tr>
<td>Gneiss and schist</td>
<td>Flattened</td>
<td>Decomposed</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>Equidimensional, rounded</td>
<td>Decomposed</td>
</tr>
</tbody>
</table>

Observation of the granite and pegmatite fragments indicated no apparent correlation between degree of rounding and decomposition. The scattered rhyolite fragments are so much decomposed that their shape must be regarded as meaningless. Some of them have been indented and their shape appreciably changed by other fragments with which they are in contact. Although flattened fragments of chert, gneiss, and schist are rather abundant there is no development of imbricate structure.

2. Very coarse lower Fountain conglomerate exposed in an un-named gulch near the foot of the Crystal Park Toll Road (Plate II) at the south edge of the Manitou embayment. In a general way the conglomerates exposed in this gulch are the equivalents of those in unit 27 of Section II. Boulders up to 2 feet in diameter are present
but are not abundant. The following count was made over one square yard of exposure.

<table>
<thead>
<tr>
<th>Size (diameter in inches)</th>
<th>Description</th>
<th>Number of fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Subangular partially disintegrated granite.</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Angular milky quartz.</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Angular partially disintegrated granite.</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Rounded red shaly arkosic sandstone (stringers of identical material in the matrix).</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Cleavage fragments of feldspar.</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Subangular red shaly arkosic sandstone.</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Angular and subangular quartz and quartzite pebbles and cobbles. A few are flattened but there is no imbrication.</td>
<td>108</td>
</tr>
<tr>
<td>(Average)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Angular to subrounded granite pebbles and cobbles.</td>
<td>18</td>
</tr>
<tr>
<td>(Average)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 2</td>
<td>Angular soft red shaly siltstone.</td>
<td>11</td>
</tr>
<tr>
<td>1 - 2</td>
<td>Angular cleavage fragments of feldspar.</td>
<td>28</td>
</tr>
</tbody>
</table>

In the above count fragments over 1 inch in diameter constitute 60 percent of the entire exposure. There is a considerable break in size range below 1 inch, and the remaining 40 percent is considered to be poorly sorted matrix.
3. The following count was made over one square yard of exposure at the same locality as count number 2 but 100 feet lower stratigraphically.

<table>
<thead>
<tr>
<th>Size (diameter in inches)</th>
<th>Description</th>
<th>Number of fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Angular partially disintegrated medium-grained granite. Angular biotite schist.</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Angular biotite schist.</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Subrounded red medium-grained arkosic sandstone.</td>
<td>1</td>
</tr>
<tr>
<td>5 (Average)</td>
<td>Angular to subrounded quartz.</td>
<td>12</td>
</tr>
<tr>
<td>5 (Average)</td>
<td>Subangular to rounded partially disintegrated coarse-grained granite.</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Cleavage fragments of feldspar.</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Subangular to rounded quartz.</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>Subrounded partially disintegrated granite.</td>
<td>5</td>
</tr>
<tr>
<td>1 by 3</td>
<td>Flattened biotite schist. No imbrication.</td>
<td>6</td>
</tr>
</tbody>
</table>

In the above count fragments over 1 inch in diameter comprise approximately 80 percent of the entire exposure. The poorly sorted matrix is composed primarily of subrounded quartz fragments, a little granite in small rounded fragments, and a smaller amount of angular feldspar, all considerably less than one half inch in diameter.
Fig. 6.- Boulder conglomerate in the lower Fountain. The light-colored granitic boulder left of center is 22 inches in diameter. Exposure is in an un-named gully west of the Crystal Park Toll Road.
Fig. 7.- Boulder conglomerate and included bodies of gravel and coarse sand at the same locality as that of Fig. 6.
Sandstones of the Fountain

There is no sharp differentiation between many of the sandstones and conglomerates of the Fountain; coarse-grained arkosic sandstones grade laterally into conglomeratic sandstones and conglomerates, and the same gradation may be observed vertically. As mentioned previously sandstones and conglomerates are interbedded throughout the formation and, as a result, the stratigraphic characteristics of the conglomerates are essentially duplicated in the sandstones. Comparatively well-bedded sandstones occur in the lowermost part of the Manitou embayment section; above them discontinuous bedding, definite channel fillings, and irregularly cross-bedded zones predominate. These cross-bedded zones are the most discrete of the sandstone units in that they almost always occupy recognizable erosion troughs and are marked by thin sharp laminae of rather uniform thickness.

In general Fountain sandstones are red, arkosic, medium- to coarse-grained, and poorly sorted. The red color is primarily a result of the presence of iron oxides which may be only a stain on the surface of grains or may occur interstitially as cementing material. Cut and ground surfaces of typical sandstones and matrices of conglomerates revealed colorless, white, or pink feldspar, but none red enough to contribute appreciably to the prevailing color of the formation. Zones which are dependent on
feldspar for color appear almost white in contrast to the red layers above and below. Red pigment has probably been removed from some of the thin white beds and parts of beds. Although many of the light-colored sandstones are calcareously cemented this relationship of color to cementing material is not constant. Calcareously cemented sandstones are almost totally absent at the type locality of the formation, although there are several light-colored and white sandstones in the section. Quartz is the dominant mineral in all the sandstone beds and conglomerate matrices and constitutes the larger grains of the poorly sorted sandstones.

Following are hand lens and thin section descriptions of a typical Fountain sandstone:

Under the hand lens 90 percent or more of the rock appears to be composed of poorly sorted subrounded to angular fragments of pink feldspar and quartz 2 millimeters or less in diameter. There is a small number of larger cleavage fragments of feldspar ranging from 2 to 10 or 12 millimeters in diameter and a very few rounded fragments of chert or jasper of about the same size. The rock is well indurated.

Thin sections reveal that angular fragments of microcline perthite constitute approximately 35 percent of the rock. Plagioclase feldspar is rare. Subrounded to angular quartz makes up most of the remainder of the specimen. There are also small sparsely scattered fragments of
partially altered biotite. Black, opaque material occurring interstitially is the iron oxide which gives the sandstone its red color.

The porosity of the specimen studied in thin section is very low as a result of the compaction of the poorly sorted irregularly shaped fragments and the interstitial fillings of silty and clayey material and iron oxides. Some very irregularly shaped feldspar fragments are fitted together in a manner resembling the intergrowth of adjacent crystals in an igneous rock; between some of these there are very thin layers of sericite.

In the Manitou embayment coarse-grained sandstones similar to that described above prevail to the top of the Fountain. The result is a sharp lithologic change to the finer-grained non-arkosic sandstones of the Lyons formation.

Throughout the sandstones of the lower 1200 feet of the Little Bear Creek section most of the quartz grains over 1 millimeter in diameter are subangular to well-rounded, and a small number are frosted or pitted. Smaller grains are more angular. In this part of the section most of the quartz is colorless or gray, rarely pink. With the exception of those which are frosted or pitted, surfaces of most of the quartz grains are stained red.

Most of the feldspar in these sandstones occurs as angular to subangular cleavage fragments. Feldspar grains constitute 20 to 40 percent of the total in the sandstones
of the lower 1200 feet of the formation along Little Bear Creek, practically all the remainder being quartz. The only other mineral of any consequence is mica which makes up as much as 10 percent of the total in the most micaceous sandstones. Nearly all the recognizable mica is biotite occurring in flakes 1 to 2 millimeters in greatest dimension.

With few exceptions the sandstones of the lower 1200 feet of the Little Bear Creek section are poorly sorted. The general range of grain sizes is between 0.2 and 3.0 millimeters with finer material occurring interstitially and larger grains up to 6.0 millimeters or more tending to make many of the sandstones conglomeratic. In this lower part of the formation a few of the sandstones are comparatively well sorted, the grains ranging between 0.2 and 0.5 millimeters in diameter; grains as large as 2.0 millimeters are extremely rare. Interstitial material is commonly silty or clayey and rich in iron oxide. Calcareously or siliceously cemented zones are rare.

Southward from the embayment the upper 200 feet of the Fountain includes a number of sandstones similar to those of the Lyons. Feldspar grains in most of these constitute less than 10 percent of the mass, and the dominant grain size is near 0.25 millimeters. Rounded, pitted, and frosted grains are no more abundant than in the lower part of the formation. Clayey and silty interstitial material is less abundant, and induration by
calcareous or siliceous cements is the rule rather than the exception.

Shales of the Fountain

As has been previously mentioned shales are rare in the Fountain and their distribution within the formation is erratic. In the Manitou embayment section definite shale beds were not found higher than 700 feet above the base of the Fountain. Thin black shale beds occur at about this stratigraphic position in the west wall of Quarry Canyon (Plate II). They are exposed for nearly 400 yards along the canyon walls and are evenly interbedded with massive sandstones for the entire distance. Poor exposures up and down the canyon prevent the determination of their total extent. Below these Quarry Canyon exposures the few shales present are limited in areal extent, some appearing as lenses and others obviously occupying narrow erosion channels. Pockets of arkosic mudstone occur sparsely throughout the upper part of the formation.

Along Little Bear Creek, however, shale beds occur throughout the section; their combined thickness is approximately 90 feet of the total of nearly 1300 feet. The thickest individual bed exposed is less than 6 feet thick; many are less than 1 foot in thickness. With the exception of the topmost beds Fountain shales are highly micaceous, red, and usually somewhat sandy. Some zones
are thinly laminated, but in others lamination is almost absent; increase in sand content accompanies poor development of bedding. A few of the layers whose topographic expression is like that of shale are actually red mudstones containing as much as 10 percent of recognizable feldspar. Shales that are only slightly micaceous are exposed in the banks of Little Bear Creek near the Fountain-Lyons contact. One of these, about 1 foot thick, is purple and platy and contains no mica flakes large enough to be visible under a hand lens.

Thin shales are interbedded with both conglomeratic and non-conglomeratic sandstones. In a few exposures shales are in direct contact with coarse conglomerates. As a result of this interbedding with irregularly bedded sandstones and conglomerates most of the shales are of limited areal extent.

**Limestones of the Fountain**

**Distribution and structural features.** - No limestones were found in the Fountain formation within the Manitou embayment. This absence of limestones and almost total absence even of calcareous sandstones is one of the major differences between the formation at the type locality and exposures to the south.

Thin limestones, most of them less than 3 feet thick, are irregularly distributed throughout the Fountain of the
southwestern part of the quadrangle. The lowest of these, stratigraphically, is the "Red Creek" limestone which...  

10 Note: The names applied to this and other Fountain limestones are for convenience of reference only and are not proposed as additions to the stratigraphic nomenclature.

outcrops in the valley of Red Creek within 250 feet of the base of the formation. The highest is the "Contact" limestone used as the key bed for mapping the Fountain-Lyons contact, and which occurs in the upper part of the 100 foot interval considered the transition zone between Fountain and Lyons. Between the "Red Creek" and "Contact" limestones, particularly across the Red Creek anticline (Plate III), isolated limestone outcrops and detritus from thinly covered beds indicate the presence of at least four additional limestones within the main body of the formation.

Some of these Fountain limestones are massively bedded, others are thin-bedded and weather out in slabs. At a few places the thin-bedded limestones are folded on a small scale, the amplitude of some of the folds being as much as 1 1/2 feet with lengths up to 3 feet. This particular type of irregular bedding is probably a result of pene-contemporaneous sliding or slumping along the surface on which deposition occurred. The nature of the bedding is not constant; a single limestone may be massive, thin-bedded, and folded at different places within a few hundred yards along the outcrop.
There is a certain constancy in the relationship between Fountain limestones and the beds with which they are associated. At nearly any exposure of limestone there is an underlying nodular impure limestone or calcareous siltstone and sandstone or interbedded layers of both. Below this may occur any of the sedimentary rock types found in the formation; thinly cross-bedded sandstone is most common. Most of the limestones are unconformably overlain by conglomeratic sandstones. At some exposures evidence of erosion consists of a slight irregularity of the upper surface of the limestone together with cracks and fissures in the limestone which have been filled with clastic material. At other exposures the limestones have been distinctly channeled; some of these channels are as much as 5 or 6 feet deep (below the upper surface of the limestone) and extend into the underlying nodular layer.

In spite of erosion these limestones are distinctive among the other Fountain sediments in the magnitude of their areal extent. The exception is the "Red Creek" limestone which may be traced along the outcrop for less than one quarter of a mile. Most of the other Fountain limestones may be followed and mapped for distances up to several miles (Plate III). As indicated on the map the limestones actually outcrop over much of this distance, and their one-time presence is inferred for the remainder by the continuity of underlying nodular zones.
Fig. 3 - Section of an exposure of lower Fountain limestone, 500 feet above the base of the formation, illustrating the typical relationships of the limestone zones to overlying and underlying sandstones. The exposure is slightly south of the midway point between Little Turkey and Turkey Creeks, west of highway no. 115.
Fig. 9.- An erosion remnant of limestone buried in coarse arkosic sandstone. The exposure is of upper Fountain in Red Creek near the junction with the East Fork of Red Creek.
Fig. 10. — An erosional contact between coarse arkosic sandstones and an eroded limestone zone. The exposure is in the upper Fountain in the valley of Little Bear Creek.
Lithologic descriptions. - Thin sections were prepared from seven different specimens of the limestones. Four of these were from scattered exposures along the "Contact" limestone; two were from the "Hart" limestone, or its near equivalent (Plate III), approximately 1000 feet above the base of the formation; one was from the "Red Creek" limestone.

All specimens of the dense to lithographic varicolored "Contact" limestone are composed of microcrystalline calcite except where cavities have been filled by larger calcite crystals. Some of these cavities are partially or completely outlined by opaque to dark-brown material. There are sparsely scattered grains of quartz present in three of the four specimens. Two of the four thin sections include well-preserved cross sections of ostracod carapaces, in which the spaces between the valves are filled with large calcite crystals as are the cavities in the limestone. It is probable that the cavities, the crystals contained in them, and the carapace-enclosed crystals are of secondary origin. Where shells protrude into crystal-filled cavities, the cavity crystals, the preserved shell, and the crystals within the shell are all in the same optical orientation.

A specimen of lithographic gray "Hart" (?) limestone from the west flank of the Red Creek anticline appeared only slightly different in thin section from those of the "Contact" limestone. There are anhedral quartz grains in some of the calcite filled cavities but the single section
included no fossil remains. A thin section of the pink sandy "Hart" limestone, as it occurs on the east flank of the anticline, is composed of about 70 percent microcrystalline calcite and 30 percent small angular quartz grains and rare fragments of plagioclase feldspar. The single specimen was not fossiliferous. At an outcrop in the East Fork of Red Creek, near the Colorado Petroleum, Inc. #1 Hart location, this limestone contains large branching concretionary structures.

Thin sections of the red crystalline "Red Creek" limestone reveal it to be composed of uniformly and finely crystalline calcite with considerable ferric oxide among the crystals. A very few angular quartz grains are present. The numerous sections of foraminifera and a few of gastropods are opaque and red, apparently preserved as ferric oxide. A few of the larger shell sections, probably brachiopod remains, have been replaced by secondary calcite; the crystals of these preserved shells are in perfect optical orientation with the crystals of the surrounding limestone.

Aside from the sandy phases of the "Hart" limestone this "Red Creek" limestone contains the highest proportion of impurities of all the samples collected. Several samples of the Red Creek bed were dissolved in hot hydrochloric acid. By weight the red fine insoluble residue (largely ferric oxide) from each sample amounted to between 9 and 10 percent of the original. The insoluble residues
from other Fountain limestones was in all tests less than 3 percent by weight.

**Paleontology.** - Fossils were discovered in the "Red Creek" limestone in 1939 by students and staff attending Louisiana State University's Field Camp. Brachiopods, gastropods, bryozoa, pelecypods, and echinoderm plates, spines, and stems may be collected at the outcrop. As mentioned previously foraminiferal sections are revealed in thin sections of the limestone. The mega-fossils are none too well preserved but the writer has identified among the brachiopods *Spirifer optima, S. rockymontanus, Dietyoclostus portlockianus,* and *Derbya crassa.*

Ostracod sections, both longitudinal and transverse, are abundant in thin sections of the "Contact" limestone. They are present in specimens collected from both the east and west flanks of the Red Creek anticline. Inasmuch as sections only are available no generic or specific identifications have been attempted. However some of the longitudinal sections are very similar in outline to species of *Bairdia* and *Cavellina* found in the Gleneyrie, and transverse sections show the overlap of one valve over the other that is characteristic of these genera.

The bearing of these fossils upon interpretation as to the age of the Fountain and the conditions under which it was deposited is discussed in the section of this paper beginning on page 93.
Chert of the Fountain

A massive bed of varicolored chert, approximately 1 1/2 feet thick in its maximum development, is exposed on the west side of Red Creek between massive conglomeratic sandstones 400 feet above the base of the Fountain. Natural exposures of the chert are almost non-existent but it was discovered close to the surface in a few places between Red Creek and the next valley to the west (Plate III). The total extent along strike, as indicated by detrital material, is nearly a mile in a southwesterly direction from Red Creek. Toward the southwest the chert plays out in a zone of limestones and limy sandstones. There is no evidence to indicate that it is present east of Red Creek.

In all trenched exposures this chert bed is much fractured and broken which undoubtedly accounts for the absence of outcrops. Mapping of the bed was based on the distribution of detrital material. Broken pieces of the bedded chert are distinguishable from fragments out of the conglomerates on the following bases: they are always angular as contrasted to the rounded or subrounded shape of most fragments from the conglomerates; much of the bedded chert is blue or red as contrasted to the grays or browns of the conglomerate cherts; much of it has an opaline appearance not observed in the conglomerate fragments.
Thin section study of this bedded chert reveals it to be composed largely of chalcedony, some of which is spherulitic, with a small amount of quartz. Small subhedral bodies of calcite are present along some of the cracks. There are also a few larger corroded bodies of calcite not associated with cracks and entirely encompassed by unfractured chalcedony.

The nature of this bedded chert and its field relationships strongly suggest that it is of secondary origin and has replaced some more soluble material. Its position between massive conglomeratic sandstones is not in accord with the theory of deposition as a silica gel on the floor of a quiet body of water. The presence of corroded calcite fragments within chalcedony and the association with limy beds both point to origin by replacement. The calcareous beds to the southwest in which the chert plays out suggest that it was limestone which was replaced.

Sedimentary Structures of the Fountain

Irregularity of bedding. - Irregular lenticular bedding is as striking a feature of the Fountain as is the red color. The limited areal extent of individual units of the formation has been described previously. However it is desirable to emphasize again the fact that the bulk of the Fountain is an aggregate of interfingering lenses. A few of these lenses are strictly depositional features but most
of them obviously occupy eroded depressions, the channels of currents that were alternately eroding and depositing during Fountain time.

It is probable that the distinction which was made between "pockets" and "lenses" in describing the conglomerates is dependent upon the relationship between present day exposures and the channels in which deposition occurred. If the exposure face is perpendicular, or nearly so, to the axis of the channel the filling material appears a relatively narrow, pocket-like body. On the other hand if the exposure face is parallel, or nearly so, to the channel axis the channel filling appears as a more extensive relatively thin lens.

The banks of most of the channels as indicated by the contacts between channel fillings and underlying scoured sediments were gently sloping, smooth, and rounded. In many exposures the lowermost of a series of cross laminae is spread evenly over these sloping bank surfaces. The rare examples of sharply cut banks are almost exclusively limited to channels cutting into or through one of the resistant limestone layers. In these channels the filling material is usually poorly stratified.

Cross bedding. - Cross bedding in the Fountain occurs on a variety of scales and in almost all types of clastic sediments, although it is best developed in medium- to coarse-grained fairly clean arkosic sandstones. In shaly sandstones cross bedding is less obvious because individual
laminae do not stand out sharply. In some exposures the structure occurs in heavily conglomeratic sandstone, but individual laminae are not sharply outlined.

The cross bedding as observed in section and on dip slope exposures strongly resembles that which Knight\textsuperscript{11}


designates as "festoon cross-lamination". Comparison of the accompanying diagram and photographs with those of Knight clearly reveals the points of similarity.

Remarkably uniform thicknesses of between one eighth and three fourths of an inch are maintained by individual laminae throughout the extent of exposures like that illustrated in the diagram. As indicated, small lenses of conglomeratic material are associated with the sets of cross laminae although the sands of the laminae themselves are seldom conglomeratic. Some of these conglomerates are obviously separated from the surrounding laminae by erosion surfaces; others appear to have been deposited just prior to the laminated sand, probably as small bars around and over which the laminae were built without appreciable halt in deposition. The best development of these thinly laminated structures is in the upper Fountain along Little Bear Creek and southward.
Fig. 11- Section of an exposure of "festoon cross-lamination" illustrating relationships of the various sets of laminae to each other and to the small conglomeratic bodies. The exposure is 150 feet below the top of the Fountain formation and one half mile due south of the Hitchrack Ranch reservoir.
In many exposures laminae of the above order of thickness are exposed for distances of 30 to 40 feet without exhibiting concavity. Their contact surfaces appear to be almost perfect planes the attitudes of which are definitely at variance with that of the formation. Field relationships suggest that these are simply fortuitous exposures of large scale examples of the "festoons". Laminae of this nature are common in exposures on the Red Creek anticline, and particularly in the Manitou embayment where concavity of cross laminae is rare.

Thicker laminae and thin beds from one fourth to 2 or 3 inches thick of poorly sorted slightly conglomeratic sandstones are developed in sets of slightly concave to plane cross laminations in some of the main hogback forming units of the lower Fountain. Individual laminae do not stand out as sharply in section as do those previously described. However on dip slopes of dissected hogbacks both areal and sectional exposures may be observed. Individual laminae within a set thicken, thin, and sometimes wedge out completely. These are the exposures which most clearly resemble those photographed by Knight as examples of "festoon cross-lamination".

An attempt was made to secure enough dip and strike readings on cross laminae to determine the direction of flow of the depositing currents. However the attempt was abandoned when it became evident that chance exposures could seldom be relied upon for the data required. There
Fig. 12. - Large scale example of Fountain cross bedding illustrating uniform thickness of laminae and their lack of concavity. The exposure is in the upper Fountain in the East Fork of Red Creek.
Fig. 13.—Cross bedding of Knight's festoon type in coarse conglomeratic sandstones of the Fountain. The exposure is at the summit of the principal Fountain hogback in the valley of Little Bear Creek.
are many exposures in which cross laminae can be observed
dipping toward the axis of the channel in which they were
deposited. There is no means of knowing the relationship
of the direction of dip of these cross laminae to the
direction of flow of the major currents within the channel.

No structures resembling "torrential cross bedding"
were observed in any of the Fountain exposures in the
Colorado Springs quadrangle.

**Mud cracks.** - Mud crack structures were observed near
the summit of the main Fountain hogback in Little Bear
Creek valley approximately 850 feet above the base of the
formation. On a few bedding planes within a red medium-
grained sandstone 15 feet thick there are low, narrow
ridges of gray to white more coarsely grained sandstone
forming polygonal patterns. There is considerable vari­
tion in the sizes of the polygons, diameters ranging from
5 inches on one bedding plane to over 18 inches on another.
At only this one locality did the writer observe such
structures in the Fountain of the Colorado Springs quad­
rangle.

**Clastic dikes.** - Clastic dikes are not uncommon in
the Fountain. Many are small, penetrating a very few
inches into overlying or underlying formations, whereas
others are 5 to 6 inches thick and one of these extends
through a bed that is 5 feet thick. Large dikes were
noted particularly in the upper Fountain in the Garden of
the Gods (Plate II) and in the lower Fountain along Little
Bear Creek. At the former locality it was possible to observe these structures in three dimensions.

At the exposures in the Garden of the Gods two beds of conglomeratic sandstone are separated by a 5 foot layer of dark-maroon massive shaly sandstone which is firm near the base and much weathered at the top. Penetrating the maroon layer from bottom to top is a vertical tabular body of the same coarse-grained material as the overlying and underlying conglomeratic sandstone. The dike varies from 3 inches to 5 inches in thickness and can be followed for a distance of 6 or 7 feet in a S 70° E direction. Nearby are five smaller dikes also trending approximately S 70° E and two others trending almost at right angles to this direction.

All eight dikes widen considerably at their bases and join the underlying conglomeratic sand with no apparent break. At the contacts between the dikes and the overlying sandstone there is less widening of the dikes, and the conformity of contact is less evident. At exposures along Little Bear Creek smaller dikes have obviously penetrated upward but failed to break through the top of the bed penetrated. These relationships indicate that the dike material was forced up from below. Dikes of this nature appear to be normal structures in formations like the Fountain. They were also observed by the writer in the Permo-Pennsylvanian red beds at Texas Creek, Colorado, in the Arkansas Valley above the Royal Gorge.
At many contacts along which sandstone overlies shale, projections of bleached sand extend downward into the shale. Stratification across the sand projections suggests that they are the result of slow filling of fissures preceding deposition of the overlying sandstone of which they are seemingly a part. The irregular, apparently eroded top surface of the shale along these contacts supports this explanation of the origin of these small sand dikes.

Other original structures of sediments such as ripple, wave, frost, and raindrop marks were not observed in the Fountain formation.

Color of the Fountain

Distribution of color. - Calculations based on measured sections indicate that over 80 percent of the total thickness of the Fountain is composed of beds that are definitely red in color. Variations from the predominant red color may be observed at many outcrops but distribution of non-red beds within the formation as a whole is erratic. In the Manitou embayment non-red beds are of consequence only in the basal 700 feet and in the upper 800 feet of the formation; in the remaining 2800 feet colors other than red are almost entirely absent. Along Little Bear Creek and to the south non-red beds are present at intervals throughout the total thickness of the formation.

Nature of the color variations. - The use of the term
"bleached" to describe portions of red beds from which the color has presumably been removed is established in geologic literature and will be so used in this paper. It should be noted however that the color change may involve actual removal of material in which case "leached" would be a more accurate term. In the Fountain, at least, some of the non-red beds, particularly the thicker ones, may never have been red. To the writer's knowledge there is no way of proving that a discrete white, gray, or green bed, even though it lies between beds of brilliant red hue, was ever red.

Inasmuch as proof of bleaching of entire beds within the Fountain is not established at the present time, attention is directed to the small scale examples where color change is more definite. Outstanding among these are the white, gray, or green bands extending from a fraction of an inch to several inches above and/or below bedding surfaces. These bands are most obvious in the upper less conglomeratic Fountain sandstones but are also developed to some extent in the lower Fountain.

At several exposures on the Red Creek anticline these bands are sharply offset by small faults. Significantly there is no color change along the fault surface which must have offered some passage to groundwater in the past if not at present. At other exposures these bands are abruptly truncated by cross laminae or other channel fill deposits. In many exposures the truncating sediments are
Fig. 14.—A small fault in the Fountain formation showing offset of color bands along two bedding surfaces. The exposure is in the upper Fountain in the East Fork of Red Creek.
more permeable than the sandstones that appear to have been bleached, yet the former show no evidence of loss of red color.

The color lines between red and non-red parts of non-conglomeratic sandstones are usually very sharp; in many exposures they are traceable across the surfaces of single grains. At shale-sand contacts color change, if present, is almost always in the sand; where the sandstone is the overlying bed of the two, projections of bleached sand may extend downward into the shale.

Many color contacts between red and non-red parts of the Fountain beds cut across laminations or follow an extremely irregular course across the exposed surfaces of massive thick-bedded units. Examples of these irregular and cross cutting color lines are more abundant in beds of poorly sorted material than in the relatively well-sorted sandstones; they are particularly abundant in the shaly zones.

In some of the dense limestones and fine-grained calcareous sandstones white spheres are found entirely surrounded by red rock from which they differ only in color. These spheres range in size from 1 1/2 inches in diameter down to those barely visible to the naked eye. In some exposures these small white spheres are so abundant they give the rocks an evenly stippled appearance.

The only evidence that loss of red color from relatively unweathered beds is going on at the present time is
in recently developed exposures of red poorly consolidated shaly sandstone where root systems of present day vegetation are uncovered. In these, individual roots are marked by white stringers and streaks extending down into the sandstone.

Relationship of the Fountain to Underlying Formations

Throughout most of the Manitou embayment the Fountain rests conformably on the Gleneyrie formation. In the southwestern part of the quadrangle the Fountain overlies older Paleozoic formations with angular unconformity or rests directly on eroded pre-Cambrian rocks.

Near the head of a small gully just south of the divide between Little Fountain and Little Bear Creeks (Plate III) eroded Manitou dolomite, dipping approximately 80° to the southeast, is directly overlain by a Fountain sandstone dipping approximately 30° in the same direction. Farther south the angular nature of the unconformity is just as much in evidence, if less spectacularly so. Along Little Bear Creek basal Fountain is in contact with all three of the older Paleozoic formations that outcrop in the region, the Ordovician Manitou dolomite and Harding sandstone and the Mississippian Madison limestone. A short distance south of Little Bear Creek Fountain rests on Pikes Peak granite and at one exposure, at least, Fountain directly overlies the rhyolite intrusives in the granite.
Contact of Fountain with any one or several of these older formations may be seen at different places southward along the mountain front. Further evidence of the angular unconformity at the base of the Fountain has been demonstrated by Glockzin and Roy in the Red Creek area.¹²


The Fountain-Lyons Contact

Most writers have accepted the 100 to 600 feet of red generally non-arkosic sandstone above the Fountain in the Colorado Springs quadrangle as equivalent to the type Lyons, of questionable Permian age, in St. Vrains Canyon, Colorado, where the Fountain and Lyons are separated by the Ingleside formation. However Lee states that the Lyons¹³


of the type locality and the Ingleside wedge out to the south and disappear north of Denver between Eldorado and Morrison, and that the Lyons of the Colorado Springs area is actually a part of the Fountain formation. He also
states that the Ingleside at St. Vrain's Canyon is unconformable with both the underlying Fountain and the overlying Lyons.

The writer visited the localities described and photographed by Lee in St. Vrain's Canyon but was unable to find any evidence for unconformities at the top and base of the Ingleside. No features of the Ingleside were observed that are not duplicated by the Fountain in the Colorado Springs area. The Lyons of the type locality differs from the red sandstones overlying the Fountain in the Colorado Springs area primarily in degree of cementation; some of the sandstone being quarried at Lyons is almost quartzitic. At Lyons individual beds within a zone of cross bedding may be traced for distances of over 100 feet along quarry walls without noticeable change in thickness. However this uniformity and magnitude of cross bedding at the type locality is only slightly more spectacular than that exposed is red sandstone quarries above the Fountain in Red Rock Canyon in the southern part of the Manitou embayment.

The writer considers the red sandstone above the Fountain in the Colorado Springs quadrangle equivalent to Lyons because of (1) lithologic and structural similarities to the type Lyons, and (2) the uncertainty of the unconformable relationship at the base of the type Lyons.

In the southern part of the Manitou embayment the contact between Fountain and Lyons is gradational, but the transition zone of the Fountain is non-calcareous and
does not include the upper limestone used for mapping in the southwestern part of the quadrangle. In Red Rock Canyon the gradation from Fountain to Lyons occurs over an interval of about 50 feet. Coarse-grained arkosic Fountain sandstone with a few small pockets and lenses of medium-grained red sand is overlain successively by thin interbedded arkosic and non-arkosic red sandstones, very slightly conglomeratic red sandstone, cross-bedded non-arkosic red sandstone, interbedded red sandstone and thin coarse conglomerates, and finally the basal Lyons sandstone which is over 200 feet thick at this locality.

For most of the distance from Fountain Creek to beyond the north edge of the embayment the Fountain is in fault contact with the Lyons or with Mesozoic formations.

In the southern part of the Colorado Springs quadrangle the upper 100 feet of Fountain is highly calcareous and includes thin beds of non-arkosic sandstone much like the main sandstones of the Lyons. This transition zone is overlain by 80 feet of red massive medium-grained non-arkosic sandstone which makes up the lowermost Lyons. Because this basal sandstone is not exposed over much of the area the "Contact" limestone in the upper part of the transition zone of the Fountain was used as the key bed for mapping purposes.

In the Colorado Springs quadrangle the Lyons as a whole is readily separable from the Fountain despite the gradational contact between the two. The middle part of
the Lyons is somewhat like the Fountain in that there are small conglomeratic and arkosic bodies. However cross bedding of the Lyons is on a much larger scale than most of that in the Fountain, and cut and fill structures are much less abundant. The sandstones of the upper Lyons are characterized by networks of resistant siliceous veinlets which stand out sharply from the weathered surfaces; these were not observed in any Fountain beds. In the southwestern part of the quadrangle the Lyons is almost identical in color to the Fountain. In the Manitou embayment, however, gray sandstones 100 feet and more thick are among the prominent hogback-forming beds of the Lyons.
Fig. 15.—A close-up view of cross bedding in the Lyons formation. The resistant veinlets in the lower beds are between one eighth and one fourth inch thick. The exposure is in the upper Lyons in the valley of Little Bear Creek.
Fig. 16.—Color banding and small fissure fills in a sandy shale of the middle Lyons formation. The exposure is in a cut of the old highway at the south end of Deadman Canyon. Note similarity to Fig. 14.
The subsurface development of Pennsylvanian strata eastward from the areas of exposure is partially revealed by cuttings and a few cores from four wells. Two of these, one drilled by Continental Oil Company and the other by Colorado Petroleum, Inc., are located on the Red Creek anticline; the other two were drilled by Continental north of Pueblo, Colorado. (Plate I) The sections penetrated by these wells indicate that for a distance of about 18 miles eastward from the outcrop the Fountain thickens at a rate of slightly more than 100 feet per mile. For at least the same distance there are only minor lithologic changes; in the easternmost of the four wells the Fountain is composed predominantly of red coarse arkosic sediments.

Samples of a complete section of Fountain are available from the Continental Oil Company #1 State, drilled in the spring of 1946, and were examined by the writer. The well is located on the Red Creek anticline in the southeast quarter of section 4, T. 18 S., R. 67 W., Pueblo County, Colorado. It is approximately one half mile down dip from the surface trace of the Fountain-Lyons contact. The total depth of the well is 1938 feet in granite. No electric log
was run and no oil shows were reported.

The hole was spudded-in in Lyons sandstone, and the first 250 feet of drilling was in that formation. The Fountain-granite contact is not less than 1820 feet beneath the surface; there is no evidence for the presence of the Gleneyrie or of any lower Paleozoic formation. Thus the thickness of the Fountain in this well is approximately 1570 feet, slightly thicker than the nearest measured section on the surface.

As would be expected the cuttings indicated that the lithology of the Fountain at this location is much the same as in the nearby surface exposures. Red coarse-grained arkosic sandstones and conglomerates, with thin beds of red silty and micaceous shales, and dense varicolored limestones constitute the entire Fountain section and appear identical with their counterparts at the surface.

The Colorado Petroleum, Inc., #1 L. V. Hart was drilled 4 miles northwest of Continental's #1 State, in section 17, T. 17 S., R. 67 W., El Paso County, Colorado. The operators spudded-in and drilled approximately 1000 feet through coarse arkosic sediments that differed in no way from the Fountain as exposed at the surface. Although Fountain was logged to the total depth of 3504 feet, it is the writer's belief that the base of the Fountain is not lower than 1022 feet beneath the surface and that the hole was drilled in pre-Cambrian igneous rocks from slightly above 1090 feet to the total depth. Following is the evidence leading to
this conclusion, part of which is based on the writer's examination of a cut of the samples from the well.

(1) Between 1022 feet and 1070 feet the cuttings showed a quantity of dense to finely crystalline red-brown glauconitic dolomitic limestone very similar to much of the Ordovician Manitou formation as it occurs at the surface.

(2) The cuttings below 1070 feet, which were logged at the well as granite wash, are composed of quartz and feldspar as are most of the Fountain sandstones. However crystalline association of fresh feldspar, quartz, and biotite, an association rare in cuttings above 1070 feet and in the Fountain at the surface, was of common occurrence.

(3) Nine rock bits were used in drilling from the surface to 1050 feet; 69 rock bits were used in drilling from 1050 feet to 2285 feet. Below 1080 feet shreds of steel, apparently from the drill bit, are abundant in the cuttings.

(4) The electric log shows marked increase in resistivity in the interval between 950 feet and 1100 feet.

<table>
<thead>
<tr>
<th>Depth in feet</th>
<th>Normal Resistivity Curve Value in Ohm-meters</th>
<th>Lateral Investigation Curve - Value in Ohm-meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 950</td>
<td>10 to 60</td>
<td>10 to 60</td>
</tr>
<tr>
<td>950 to 1050</td>
<td>40 to 150</td>
<td>30 to 100</td>
</tr>
<tr>
<td>1050 to 1090</td>
<td>250 to 750</td>
<td>500 to 1250</td>
</tr>
<tr>
<td>Below 1090</td>
<td>500 to 2250</td>
<td>1000 to 20,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(values lower than 5000 rare)</td>
</tr>
</tbody>
</table>
Oil shows and oil stains in the cuttings were logged at various depths between 1934 and 2955 feet by the geologist on the well. Tests in open hole and through perforations indicated no possibilities of production. The samples had been washed before they were examined by the writer and no attempt will be made to explain these reported oil shows in what is, in this paper, considered to be the basement complex.

The well was completed as an artesian water well through perforations in the interval 925 feet to 950 feet. In the summer of 1946, six months after completion, the well was flowing a very small stream, less than one quarter inch, of non-potable water.

In 1942 Continental Oil Company drilled its #1 Young in section 11, T. 19 S., R. 65 W., Pueblo County, Colorado, to a depth of 6112 feet. The location is some eighteen miles east of the nearest exposures of Fountain. Samples were run by Darby Petroleum Corporation and interpreted as follows;¹⁴

¹⁴E. A. Koester, Darby Petroleum Corporation - written communication to C. J. Roy, Louisiana State University - December 1942.
<table>
<thead>
<tr>
<th>Depth</th>
<th>Formation</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2085</td>
<td>Top of Lyons sandstone</td>
<td></td>
</tr>
<tr>
<td>2290</td>
<td>Top of Fountain formation - coarse arkosic material with some fine red sandstone and dark-red silty shale.</td>
<td></td>
</tr>
<tr>
<td>5710</td>
<td>Top of Gleneyrie formation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mottled maroon and green arkosic shales</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>coarse arkosic sandstone with gray to black waxy hard shale in lower part</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>coal and carbonaceous shale</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>coarse white quartzitic sandstone</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>dense waxy gray-green shale</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>white micaceous sandstone</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>biotitic black shale with two seams of hard coal</td>
<td>20</td>
</tr>
<tr>
<td>5860</td>
<td>Top of Madison limestone (may also be Williams Canyon, Devonian, and Manitou present)</td>
<td></td>
</tr>
<tr>
<td>6065</td>
<td>In granite</td>
<td></td>
</tr>
</tbody>
</table>

The well was abandoned at 6112 feet. To the writer's knowledge no oil shows were reported and no electric log was run. No fossils were mentioned by Mr. Koester in his communication.

In the latter part of 1946 the Continental Oil Company drilled its #1 Paige 16 miles north of Pueblo and 15 miles east of the nearest Fountain outcrop on the Red Creek anticline. The well is in section 6, T. 18 S., R. 64 W., Pueblo County, Colorado. The following brief summary of
Paleozoic formations penetrated and the description of the Fountain is based on the writer's examination of cuttings and cores.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2910</td>
<td>Top of Lyons</td>
</tr>
<tr>
<td>3190-3390</td>
<td>Gap in samples</td>
</tr>
<tr>
<td>3390</td>
<td>In Fountain</td>
</tr>
<tr>
<td>6605</td>
<td>Top of Gleneyrie ?</td>
</tr>
<tr>
<td>6715</td>
<td>Top of Madison limestone</td>
</tr>
<tr>
<td>6916</td>
<td>Top of Manitou dolomite</td>
</tr>
<tr>
<td>6932</td>
<td>Total depth - in dolomite</td>
</tr>
</tbody>
</table>

The total thickness of the Fountain in this well is over 5200 feet, as the Fountain-Lyons contact is within the 200 feet interval for which there are no samples. The top of the Gleneyrie formation equivalent was picked at the depth at which brown and variegated green and red shales and siltstones become predominate over red coarsely arkosic sandstone. The depth of the first appearance of pink dense dolomitic limestone was picked as the top of the Madison. According to these figures the Gleneyrie formation is 110 feet thick, 40 feet thinner than recognized in the Continental #1 Young seven miles south.

Although conglomeratic beds are difficult to recognize in well cuttings the Fountain section in this well is apparently less conglomeratic than in the surface exposures to the west. Fragments of feldspar and quartz up to 10 millimeters in diameter, suggestive of the poor sorting
characteristic of the beds at the surface, are of common occurrence in the samples. However, abundant quartzite was not observed above 6190 feet, 400 feet above the base of the Fountain. No significant amount of chert, the other principal constituent of conglomerates at the surface, was noted above the Madison.

Feldspar can be recognized in most of the coarse-grained sandstones although it is subordinate in amount to quartz. Under the microscope feldspar could not readily be identified in sandstones of grain size under 0.5 millimeters. Acid etching indicated that very little feldspar is present in these sandstones.

The calcareous nature of many of the sandstones in these red beds which underlie several thousand feet of younger sediments is more evident than in the surface exposures. In general the amount of calcareous material varies with coarseness of grain. Calcareous sandstones are numerous, calcareous siltstones less so, and calcareous shales are rare.

A peculiar association was noted in some of the coarse-grained sandstones. Under the microscope grains of dark, sometimes red, silty shale could be recognized as constituents of uncrushed fragments of sandstone. In all such specimens the shale fragments were rounded and of about the same size as the quartz and feldspar grains making up the bulk of the sandstones.

Gray, green, and black shales are more abundant in
the cuttings from this well than in the surface exposures. Below 6605 feet, in what is considered to be the Gleneyrie formation, cores of shale and silty shale show irregular green, brown, and red streaks that are entirely unrelated to bedding. The same irregularities of color distribution may be observed at the surface. None of the hard waxy black shale reported from the Gleneyrie in the Continental \#1 Young was observed in the cuttings of this well.

Distribution of limestone within the section of this well does not correlate with that of the surface sections. Limestone fragments were not observed in the cuttings above 4600 feet, at least 1300 feet below the Fountain-Lyons contact. Below that depth thin, finely crystalline, varicolored limestones appear to be quite numerous.

The only fossils observed were in the interval between 6560 feet and 6595 feet. They consisted of a few segments of crinoid stems, and three or four crushed and corroded ostracod valves. The latter are similar in outline to some of the ostracods from surface exposures of Gleneyrie but preservation was too poor to allow definite identification.
THE AGE OF THE GLENEYRIE AND FOUNTAIN FORMATIONS

The Gleneyrie and Fountain have long been considered as lower Pennsylvanian formations without very definite paleontologic evidence. However the writer believes that


the invertebrate fossils of the Gleneyrie and Fountain indicate that the two formations are equivalent to, or perhaps younger than, some part of the Des Moines series of the Pennsylvanian section of Kansas.

Evidence of the Gleneyrie Fauna

Ostracods of the Gleneyrie. - The 12 species tentatively identified by the writer plus others not identified were checked by Mrs. E. H. Nadeau (Betty Kellett). Mrs. Nadeau is of the opinion that at least two, and possibly eight, species of the fauna are undescribed forms. Of the remaining, Bairdia hoxbarenensis Harlton, Geisina arcuata (Bean), and Kirkbya clarocarinata Knight range from the
TABLE II
RANGES WITHIN THE MID-CONTINENT PENNSYLVANIAN SECTION OF SPECIES IDENTIFIED IN THE GLENEYRIE AND FOUNTAIN FORMATIONS

<table>
<thead>
<tr>
<th>SERIES</th>
<th>MORROW &amp; WAPANUCKA FORMATIONS</th>
<th>LAMPASAS FORMATIONS</th>
<th>DES MOINES</th>
<th>MISSOURI</th>
<th>VIRGIL</th>
<th>PERMIAN SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP</td>
<td>(Oklahoma)</td>
<td>(Oklahoma)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSTRACODS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bairdia hoxbarensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geisina arcuata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monoceratina ardmorensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healdia formosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphissites wapanuckensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirkbya clarocarinata</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Glyptopleura spinosa</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CONODONTES</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Idiognathodus lobatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; aff. I. claviformis</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Streptognathodus cancellosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cavusgnathus flexa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; giganta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spathodus minutus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRACHIOPODS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derbya crassa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dictyoclostus portlockianus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirifer opimus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; rockymontanus</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Marston upward in the mid-continent section; *Glyptopleura spinosa* Harlton and *Healdia formosa* Harlton are known only in the Des Moines series; *Monoceratina ardmorensis* Harlton and *Amphissites wapanuckensis* Harlton (*Polytylites wapanuckensis* of Cooper, 1946) are limited to the Morrow and possibly the Lampasas series. The distribution of these seven species within the mid-continent Pennsylvanian section is shown in Table II.

In general this ostracod fauna is of a lower or middle Pennsylvanian type, probably not younger than Des Moines. However the fauna includes nearly as many undescribed species as known ones and presents some new associations of known species. These ostracods as well as the conodonts listed in the next paragraphs are to be figured and described in detail in the near future.

**Conodonts of the Gleneyrie.** - The Gleneyrie conodont fauna consists of six species of four genera that are characteristic of the Pennsylvanian, and several species that are as yet undescribed. The following have been identified by the writer, *Idiognathodus lobatus* Gunnell, *Idiognathodus aff. I. claviformis* Gunnell, *Streptognathodus cancellosus* (Gunnell) Ellison, *Spathodus minutus* Ellison, *Cavusgnathus flexa* Ellison and *Cavusgnathus giganta* Gunnell. In the mid-continent Pennsylvanian section these six species are associated only within the Missouri series.
In addition to the above an undescribed species of *Streptognathodus* and a specimen questionably referred to *Polygnathodella* are present. The latter genus has not been reported in the upper Pennsylvanian.

A more detailed stratigraphic distribution of the six conodont species identified is presented in Table II. It is apparent that while the conodont fauna appear younger than that of the ostracods, four of the conodont species are known from Des Moines strata. Inasmuch as these six conodonts are rather long range species the ostracods are probably more diagnostic. It is concluded that the Gleneyrie is equivalent to some part of the Des Moines series of the mid-continent section, but that faunal evidence does not permit closer correlation.

Evidence of the "Red Creek" Limestone Fauna of the Fountain

Of the fossils present in the "Red Creek" limestone only the brachiopods were studied by the writer. Most of these are poorly preserved and difficult to recover from the limestone but study of many specimens revealed four species that could be identified.

One of these brachiopods was identified as *Derbya crassa* (Meek and Hayden) which ranges through most of the Pennsylvanian. Several specimens of a medium sized productid-type brachiopod were referred to *Dictyoclostus*
P. portlockianus (Norwood and Pratten) which ranges from the base of the Des Moines series nearly to the top of the Missouri series. This species is considered to be identical to Productus inflatus var. coloradoensis Girty which occurs in the Pennsylvanian Hermosa and Weber formations south and west of the Colorado Springs quadrangle.¹⁶


Specimens of Spirifer rockymontanus Marcou and Spirifer opimus Hall (S. boonensis Swallow of Girty) are the most abundant of the brachiopods in the "Red Creek" fauna. Both of these species have been reported by Girty and others from many localities in the Hermosa and other Pennsylvanian formations in central and southwestern Colorado and appear to be two of the most abundant brachiopods in the Pennsylvanian red beds of the Rocky Mountain region. They are considered to be indicative of Cherokee (lower Des Moines) age. However both are very diversified species; the number of varieties of each has in the past caused considerable controversy as to whether both, or either, are valid species. Representatives of each are widely spread geographically but, according to the literature, are not especially abundant in any area except the Rocky Mountains.

Table II shows that although the species represented
in the Gleneyrie and Fountain formations vary widely as to stratigraphic range the individual ranges tend to overlap and center near the Des Moines series of the mid-continent Pennsylvanian section.
Interpretations and conclusions concerning conditions prevailing in the Colorado Springs quadrangle during and to some extent before Pennsylvanian time follow. They are based primarily on evidence presented thus far, but additional evidence that would not have been pertinent to preceding parts of this paper are introduced in subsequent paragraphs.

Pennsylvanian formations in the Colorado Springs quadrangle represent the landward portions of a deltaic mass deposited in a subsiding trough east of the highland from which the sediments were derived.

That the Pennsylvanian formations in the Colorado Springs quadrangle were deposited under marine or near sea level conditions is made evident by the following facts.

(1) There are at least three zones within the Gleneyrie formation which contain marine or brackish water faunas. The lowest of these is near the base of the formation, the highest near the top.

(2) The fauna of the "Red Creek" limestone in the southwestern part of the quadrangle indicates that for a short period in early Fountain time marine conditions
prevailed locally.

(3) The limestone beds higher in the Fountain are of much greater areal extent than the individual beds of sandstone and conglomerate with which they are associated. This relatively great extent indicates pronounced change in environment of deposition from that in which the sandstones and conglomerates accumulated.

(4) Ostracods in the "Contact" limestone at the top of the Fountain which in section appear identical to ostracods of the marine Gleneyrie fauna are strong evidence that these limestones are also deposits of marine environment.

Inasmuch as individual zones throughout the total thickness of Pennsylvanian sediments include marine deposits, it follows that deposition of the entire thickness of sediments must have taken place near sea level. The non-fossiliferous but not necessarily non-marine portions of both the Gleneyrie and Fountain formations may be either subaerial or subaqueous deposits. For example, the "veneer" conglomerates described from the lower part of the Fountain at the type locality are completely unlike the conglomerates of the filled channels. However they closely resemble the thin scattering of pebbles and cobbles that may be spread over both the tidal and shallow water portions of an open, otherwise sandy, beach.

Aside from these "veneer" conglomerates the evidence indicates that nearly all the Fountain conglomerates are results of the action of currents that were alternately
scouring and depositing. Imbricate structure, preferred orientation of fragments, and other features supposedly diagnostic of deposition in certain environments are completely absent from Fountain conglomerates. Predominance of certain rock and mineral types within the conglomerates is more indicative of conditions at the source from which they were derived than of environment of deposition.

In addition to fossil and lithologic evidence pointing to deltaic deposition, there is the evidence furnished by the chief characteristics of the Fountain sediments. The irregular bedding and other sedimentary structural features exhibited by the Fountain are much more characteristic of large present day deltas than are the top-set, fore-set, bottom-set bed relationships so often shown in diagrams. \(^{17}\)


Irregular lenticular bedding, filled channels, and cross bedding are the normal results of meandering aggrading streams typical of deltaic plains. Lenticular bedding and cross bedding are of common occurrence in the upper deposits of the alluvial section of the Mississippi River. Dissected sand bars exhibit a pattern of cross bedding that duplicates that of the "festoon" type in all respects; furthermore gravels are associated with the cross-bedded sands where currents are scouring the basal graveliferous
unit of the alluvial section.\textsuperscript{18} Even during periods of relatively constant stage the channel and banks of the lower Mississippi River are subject to change. Sand bars are built, others are shifted or destroyed. The channel is deeply scoured at some places while similar deep scours are being filled at others. The recent history of the Lower Mississippi River alluvial plain and of the Mississippi delta has been one of constantly shifting stream courses.\textsuperscript{19}

\textsuperscript{18}H. N. Fisk, "Geological Investigation of the Alluvial Valley of the Lower Mississippi River," Conducted for the Mississippi River Commission, (1944) p. 18; Fig. 68; Plate 35.

\textsuperscript{19}H. N. Fisk, \textit{Ibid.}, pp. 37, 49-51.

It is not necessary to appeal to sharply changing stream gradients and water volumes and sudden changes in the supply of sediment to account for the sedimentary structural features in the Fountain formation.

During mid-Pennsylvanian time the Manitou embayment is believed to have been a principal center of deltaic accumulation. The absence in the Fountain of this area of fossils and limestone beds and almost complete absence of calcareous sediments of any kind suggest that in this area the delta was being built outward and upward too rapidly during Fountain time to allow development of marine em-
bayments. The thickness of Fountain measured through the type locality in the Manitou embayment is nearly three times as great as the maximum thickness of the formation in the southwestern part of the area studied. However the similarity of vertical distribution of conglomerates through the Manitou embayment and Little Bear Creek sections indicates that the latter section is complete as compared to the type section. Thus the Fountain in the southwestern part of the quadrangle represents delta flank accumulation and the limestones developed there were probably deposited in delta-flank depressions some of which were

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open to the sea.

In the Colorado Springs quadrangle the eastern margin of the Paleozoic highland from which Fountain sediments were derived coincided closely with that of the present day Front Range.

The only known source for the rhyolite in the Fountain conglomerates of Little Bear Creek valley are the pre-Cambrian intrusive bodies which occur at the edge of the present day mountain mass along the granite-sediment contact. Inclusion of fragments of this rhyolite within Fountain conglomerates and overlap of exposed rhyolite by Fountain beds indicates that these intrusive bodies were
a part of the eroded highland but were not high enough to escape burial under Fountain sediments. During Pennsylvanian time the eastern part of the Paleozoic highland must have barely included these rhyolite intrusives just as does the main mountain mass of the present day Front Range.

Deeply weathered rhyolite underlying Manitou dolomite in the southernmost canyon tributary to Little Bear Creek and unconformities within the Paleozoic section are evidence that at least this part of the Front Range was a positive element as early as pre-Manitou time and throughout most of the Paleozoic.

The Manitou embayment is part of a structural low that was long a negative element in the generally positive highland. The Sawatch formation, the Manitou dolomite, and the Madison limestone are present in the embayment in their thickest development between Canon City and the Colorado-Wyoming state line, over much of which distance they are very thin or absent. Inasmuch as the top contact of each is an unconformable one it is apparent that these formations were more protected from erosion in the Manitou embayment than elsewhere along the mountain front. Unconformably overlying the Madison limestone in the embayment, and present nowhere else along the mountain front, is the Gleneyrie formation at least part of which is marine. Overlying the Gleneyrie is the thickest known section of the Fountain formation.

Thus the distribution of certain constituent rocks,
the sources of which are known, in the Fountain conglomerates and the distribution and thickness of the Paleozoic formations in the Colorado Springs quadrangle lead to one conclusion. Within the quadrangle the eastern margin of the Paleozoic highland coincided closely with that of the present Front Range, even to the presence of a structural low at the location of the present Manitou embayment.

The Paleozoic highland from which Fountain sediments were derived was subject to more humid conditions than prevail at present and was probably less rugged than the present day Front Range.

The major source of clastic material of the Fountain in the area studied was the Pikes Peak granite which is coarsely granular to coarsely porphyritic. The constituent minerals are in the following proportions by weight. 21


<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>33.4%</td>
</tr>
<tr>
<td>Microcline</td>
<td>55.2%</td>
</tr>
<tr>
<td>Oligoclase</td>
<td>2.6%</td>
</tr>
</tbody>
</table>
| Accessory minerals | 10.8%   (primarily biotite, some hornblende, apatite, etc.)

Microcline perthite is the dominant feldspar of the sandstones and conglomerate matrices of the Fountain but
comprises less than 50 percent of these sediments. Quartz makes up nearly all the remainder. The feldspar appears fresh in hand specimens but it should not be construed that the granite was simply disintegrated and the feldspar transported to its present position in the Fountain sediments. The drop in proportion of microcline to quartz in the sediments indicates that at least half of the original amount of feldspar was lost in weathering of the granite.

The significant feature of the coarse fraction of Fountain conglomerates is the predominance of quartz, quartzite, and chert fragments over those of feldspar or of granite and other crystalline rocks. Inasmuch as the highland was primarily granitic the fact that substances less easily decomposed than granite are predominant in the conglomerates indicates that weathering conditions were those under which granite tends to decompose. At the present time mantle rock, where present, over most of the Front Range is composed primarily of feldspar-rich gruss and pebbles, cobbles, and boulders of granite.

A weathered zone approximately 90 feet thick and of lateritic character underlies the Fountain on Flagstaff Mountain near Boulder, Colorado, 75 miles north of the Colorado Springs quadrangle. The top of this zone grades downward into friable rock which, in turn, grades into fresh Boulder Creek granite. Wahlstrom states that
"recent weathering has not affected the thoroughly decomposed rocks in the pre-Fountain weathered zone." The writer knows of no large area in the Front Range where, under the present climate, such a lateritic zone has formed.

Studies and X-ray analyses summarized by Raymond show that the pigment of red soils in warm moist regions is largely hematite. Chemical and geologic evidence is introduced to demonstrate that under surface or near-surface conditions limonite is not, by dehydration, altered to hematite which is also the dominant pigment of the "red beds", but to goethite which imparts a brown or gray-brown color. Therefore the red pigment in formations like the Fountain must be hematite crystallized from hydrous ferric oxides during the formation of red soils on the land area from which the sediments were derived. Raymond concludes that red color in sediments is not necessarily an indication of deposition under arid conditions but does indicate that the source area of the sediments was warm.
and humid.

Rock fragments of boulder size are present only locally in the Fountain, and boulder conglomerates are rare and locally concentrated near the base of the formation. The thick coarse conglomerates in the gully west of the Crystal Park Toll Road in the southern part of the Manitou embayment have no comparable counterparts in the type section of the formation less than a mile to the north. The writer believes that had the highlands of Fountain time been comparable in ruggedness and relief to the present Front Range much of the Fountain would compare in coarseness to the Quaternary gravels of the "mesas" that flank the Front Range. In the latter boulders are relatively abundant over much larger areas than are the local boulder conglomerates of the Fountain.

The region in which Fountain sediments accumulated was more humid than it is at present.

Reference has been made to the evidence introduced by Raymond to the effect that red color in sediments is not necessarily an indication of deposition under arid conditions. Because hematite in red sediments is present as free particles of minute size and as stain on grain surfaces, both vulnerable to deflation and wind abrasion, Raymond reasons that, of the various environments to which red sediments may be carried, it is in an arid region that red color is least likely to be preserved.
In the Fountain red beds the truncating of bleached zones by channel fill deposits which show no loss of color is indisputable evidence that this particular bleaching occurred as a result of some agent which, at the time of deposition, was available to the zone now bleached. The fact that some of the truncating channel fill sandstones and conglomerates are even more permeable than the bleached zones indicates that circulation of ground water was of limited importance in the bleaching process.

Keller\textsuperscript{25} has presented analyses of iron contents of

\textsuperscript{24} E. Raymond, "The Significance of Red Color in Sediments," Am. Jour. of Science, CCXIII (1927), 234-251.


bleached and unbleached red beds and results of laboratory experiments to show that bleaching of red beds is accomplished by two steps. Ferric oxide is extremely stable and insoluble under normal surface and near-surface conditions and must be reduced to the ferrous state before becoming soluble in the weak groundwater acids. Thus Keller apparently includes an actual removal of material in the bleaching process. He adds that hydrogen sulphide, the active reducing agent of ferric oxide in nature, is derived (1) from sulphide waters from beneath the surface, (2) by
sulphate reducing bacteria, or (3) from decaying organic material.

The first two of these sources of hydrogen sulphide are not likely to be of importance in very recently deposited sediments. It is more reasonable to suppose that decaying organic material was incorporated in the sediments. The fact that bleached bands so commonly follow surfaces between depositional units of the Fountain is interpreted as evidence of the presence of vegetation on those surfaces. Had the organic material been carried in with the sediments the resulting color changes would be more uniform throughout the beds. Favorable climatic conditions, certainly not arid, were required in order that vegetation of any kind could gain hold on exposed surfaces of the rapidly accumulating Fountain sediments. The black shales in the Gleneyrie, the fossil plants reported by Finlay\textsuperscript{26}

\textsuperscript{26}G. I. Finlay, "The Gleneyrie Formation and its Bearing on the Age of the Fountain Formation in the Manitou Region, Colorado," \textit{Jour. of Geol.}, XV (1907), 588.

from that formation, and the black shales of the lower Fountain in Quarry Canyon support this interpretation.
SUMMARY

The Pennsylvanian formations of the Colorado Springs quadrangle are believed to be the landward portions of deposits of successive deltas which had their apexes in the Manitou region. For the most part the rate of accumulation of sediments exceeded that of submergence of the deltaic mass with the result that after Gleneyrie time few marine or brackish water deposits were incorporated in the great thickness of coarse sediments, and fossils are consequently rare. The kind of sediments supplied and the nearness of the source area are responsible for the red color and coarse texture of the Fountain.
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APPENDIX A

Section of the Fountain formation in the valley of Little Bear Creek, section 10, T. 16 S., R. 67 W., El Paso County, Colorado. The overall thickness was determined by plane table traverse; individual units were measured at the time the formation was described.

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lyons sandstone</strong></td>
<td></td>
</tr>
<tr>
<td>Sandstone, red, massive, fine-grained</td>
<td></td>
</tr>
<tr>
<td><strong>Fountain formation</strong></td>
<td></td>
</tr>
<tr>
<td>63. Shale, red, slightly micaceous.......</td>
<td>1.0</td>
</tr>
<tr>
<td>62. Sandstone, gray, medium-grained, slightly calcareous.................</td>
<td>3.0</td>
</tr>
<tr>
<td>61. Unexposed.........................</td>
<td>2.0</td>
</tr>
<tr>
<td>60. Shale, red, slightly micaceous.......</td>
<td>5.0</td>
</tr>
<tr>
<td>59. Limestone, gray, nodular, dense.......</td>
<td>0.5</td>
</tr>
<tr>
<td>58. Sandstone, red, coarse-grained, arkosic, calcareous.....................</td>
<td>0.5</td>
</tr>
<tr>
<td>57. Shale, purple, platy, non-micaceous..</td>
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</table>
APPENDIX A (continued)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>56</td>
<td>Sandstone, red, medium- and coarse-grained, slightly arkosic, calcareous, interbedded with red micaceous shale</td>
<td>9.0 1274.0</td>
</tr>
<tr>
<td>55</td>
<td>Sandstone, white, fine-grained, micaceous</td>
<td>1.0 1265.0</td>
</tr>
<tr>
<td>54</td>
<td>Shale, red, very sandy</td>
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</tr>
<tr>
<td>53</td>
<td>Conglomerate, gray, arkosic; pebbles up to 1 inch in diameter</td>
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<tr>
<td>52</td>
<td>Sandstone, pale-red, medium-grained, calcareous</td>
<td>4.0 1262.0</td>
</tr>
<tr>
<td>51</td>
<td>Limestone, gray, nodular, dense (<em>Contact</em> limestone)</td>
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<td>Sandstone, red, massive, medium-grained, slightly conglomeratic, arkosic</td>
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<td>Sandstone, red, thin-bedded, fine-grained</td>
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<tr>
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<td>Sandstone, red, thick-bedded, poorly consolidated, coarse-grained, arkosic, interbedded with red sandy micaceous shale</td>
<td>26.0 1245.5</td>
</tr>
<tr>
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<td>Limestone, reddish-brown, nodular, finely crystalline</td>
<td>2.5 1219.5</td>
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<td>Sandstone, red, coarse-grained, slightly conglomeratic, arkosic</td>
<td>5.0 1217.0</td>
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<td>Sandstone, red, thin-bedded, fine-grained, arkosic</td>
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<tr>
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<td>Limestone, purple, nodular, dense, sandy</td>
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<td>Sandstone, red, medium-grained, calcareous</td>
<td>2.0 1207.5</td>
</tr>
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<td>Sandstone, red, thin-bedded and cross-bedded, coarse-grained, arkosic</td>
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<tr>
<td>41</td>
<td>Unexposed</td>
<td>5.0 1171.5</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Depth</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>40</td>
<td>Sandstone, red, thin-bedded, coarse-grained, arkosic, poorly exposed</td>
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</tr>
<tr>
<td>39</td>
<td>Limestone, red and purple, slightly nodular, dense, sandy, ferruginous; top surface eroded</td>
<td>5.0</td>
</tr>
<tr>
<td>38</td>
<td>Sandstone, red, irregularly cross-bedded, medium- and coarse-grained, conglomeratic, arkosic, calcareous in upper 1 foot</td>
<td>36.0</td>
</tr>
<tr>
<td>37</td>
<td>Limestone, mottled red and purple, poorly bedded, nodular, very sandy; top surface eroded</td>
<td>9.0</td>
</tr>
<tr>
<td>36</td>
<td>Sandstone, pale-red, thin-bedded, medium-grained, calcareous</td>
<td>4.0</td>
</tr>
<tr>
<td>35</td>
<td>Sandstone, red, poorly bedded, coarse-grained, conglomeratic, arkosic</td>
<td>5.0</td>
</tr>
<tr>
<td>34</td>
<td>Sandstone, red, irregularly bedded, fine-grained, silty, calcareous</td>
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</tr>
<tr>
<td>33</td>
<td>Limestone, red, nodular, sandy, ferruginous</td>
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</tr>
<tr>
<td>32</td>
<td>Shale, red, silty, micaceous</td>
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</tr>
<tr>
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<td>Sandstone, red, poorly consolidated, medium-grained, arkosic, poorly exposed</td>
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<td>Unexposed</td>
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</tr>
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<td>Unexposed</td>
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<tr>
<td>25</td>
<td>Conglomerate, red, arkosic</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Amount</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>24.</td>
<td>Unexposed</td>
<td>35.0</td>
</tr>
<tr>
<td>23.</td>
<td>Sandstone, red, thin-bedded, medium-grained, shaly, calcareous</td>
<td>17.0</td>
</tr>
<tr>
<td>22.</td>
<td>Sandstone, gray, thinly cross-bedded, coarse-grained, arkosic</td>
<td>5.0</td>
</tr>
<tr>
<td>21.</td>
<td>Sandstone, red, cross-bedded, coarse-grained, arkosic, calcareous, with stringers of coarse conglomerate</td>
<td>29.0</td>
</tr>
<tr>
<td>20.</td>
<td>Sandstone, red and white, irregularly bedded with some cross-bedding, coarse- to fine-grained, arkosic, calcareous</td>
<td>54.0</td>
</tr>
<tr>
<td>19.</td>
<td>Sandstone, red, thinly cross-bedded, fine- to coarse-grained, arkosic</td>
<td>8.0</td>
</tr>
<tr>
<td>18.</td>
<td>Sandstone, red, irregularly cross-bedded, coarse-grained, arkosic, interbedded with red micaceous shale</td>
<td>30.0</td>
</tr>
<tr>
<td>17.</td>
<td>Sandstone, red and gray, irregularly cross-bedded, coarse-grained, arkosic, interbedded with stringers of conglomerate consisting mainly of pebbles</td>
<td>98.0</td>
</tr>
<tr>
<td>16.</td>
<td>Sandstone, gray and pale-red, thinly bedded, medium-grained, slightly conglomeratic, arkosic, interbedded with deep-red micaceous shale; poorly exposed</td>
<td>57.0</td>
</tr>
<tr>
<td>15.</td>
<td>Conglomerate, red, coarse (composed mainly of cobbles, some of which are rhyolite), arkosic</td>
<td>62.0</td>
</tr>
<tr>
<td>14.</td>
<td>Unexposed</td>
<td>41.0</td>
</tr>
<tr>
<td>13.</td>
<td>Conglomerate, pale-red, thick-bedded, fragments mainly large pebbles, arkosic</td>
<td>33.0</td>
</tr>
<tr>
<td>12.</td>
<td>Shale, deep-maroon, sandy, micaceous</td>
<td>4.0</td>
</tr>
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</table>
## APPENDIX A (continued)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Conglomerate, pale-red and gray, massive, fragments mainly large pebbles, arkosic.</td>
<td>10.0</td>
<td>375.5</td>
</tr>
<tr>
<td>10</td>
<td>Sandstone, red, thin-bedded, coarse-grained, arkosic, alternating with red, fissile, ferruginous, micaceous shale.</td>
<td>23.0</td>
<td>365.5</td>
</tr>
<tr>
<td>9</td>
<td>Sandstone, red, thick-bedded with a few thin cross-bedded layers, coarse-grained, arkosic, with a few thin stringers of pebble-size conglomerates.</td>
<td>110.0</td>
<td>342.5</td>
</tr>
<tr>
<td>8</td>
<td>Sandstone, red and gray, irregularly bedded, coarse-grained, arkosic, interbedded with red, sandy micaceous shale.</td>
<td>3.5</td>
<td>232.5</td>
</tr>
<tr>
<td>7</td>
<td>Sandstone, pale-red, thick-bedded and cross-bedded, coarse-grained, arkosic, with a few stringers of coarse conglomerate near the top.</td>
<td>32.0</td>
<td>229.0</td>
</tr>
<tr>
<td>6</td>
<td>Sandstone, gray, coarse-grained, micaceous, arkosic; and red, sandy micaceous shale.</td>
<td>1.0</td>
<td>197.0</td>
</tr>
<tr>
<td>5</td>
<td>Conglomerate, red, thick-bedded, coarse, arkosic; cobbles up to 4 inches in diameter of quartz and fine-grained granite.</td>
<td>25.0</td>
<td>196.0</td>
</tr>
<tr>
<td>4</td>
<td>Shale, red, poorly bedded, sandy, coarsely micaceous.</td>
<td>5.0</td>
<td>171.0</td>
</tr>
<tr>
<td>3</td>
<td>Sandstone, gray and red, thick-bedded, coarse-grained, conglomeratic (cobbles of chert and quartzite most numerous), arkosic.</td>
<td>135.0</td>
<td>166.0</td>
</tr>
<tr>
<td>2</td>
<td>Shale, red and gray, fissile, sandy, micaceous.</td>
<td>5.0</td>
<td>31.0</td>
</tr>
<tr>
<td>1</td>
<td>Sandstone, mottled red and white, irregularly bedded, in part poorly consolidated, arkosic.</td>
<td>26.0</td>
<td>26.0</td>
</tr>
</tbody>
</table>
APPENDIX A (continued)

**Harding sandstone**

Sandstone, white, hard, fine-grained.
APPENDIX B

Sample descriptions of formations penetrated in Continental Oil Company's No. 1 State, S 1/2 of the NE 1/4 of the NE 1/4 of the SE 1/4 of Sec. 4, T. 18 S., R. 67 W., Pueblo County, Colorado. Total depth 1938 feet. Dry and abandoned May 1946. (Samples described by the writer.)

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth in feet</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Lyons sandstone - Permian ?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone, red, medium-grained; mixed with surface material................</td>
<td>0-34</td>
<td>34</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, micaceous.......................................</td>
<td>60</td>
<td>26</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red fine-grained micaceous sandstone</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, mottled red and white, fine-grained................................</td>
<td>110</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, micaceous, typical Lyons........................</td>
<td>150</td>
<td>40</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic................................</td>
<td>160</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, fine- to medium-grained, micaceous............................</td>
<td>220</td>
<td>60</td>
</tr>
<tr>
<td>Sandstone, white, fine-grained..................................................</td>
<td>222</td>
<td>2</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic........................................</td>
<td>230</td>
<td>8</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained micaceous................................</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>Fountain formation - Pennsylvanian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandstone, pale-red, coarse-grained, calcareous, arkosic....................</td>
<td>270</td>
<td>20</td>
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</table>
### APPENDIX B (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some dense gray and purple limestone...</td>
<td>280</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>290</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; interbedded white fine-grained mica-</td>
<td>300</td>
</tr>
<tr>
<td>aceous sandstone and dark-maroon shaly arkosic sandstone........................</td>
<td></td>
</tr>
<tr>
<td>Sandstone, red and white, fine- to medium-grained..................................</td>
<td>310</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, slightly conglomeratic, arkosic..................</td>
<td>350</td>
</tr>
<tr>
<td>Sandstone, red and white, medium- to coarse-grained, arkosic....................</td>
<td>370</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, slightly conglomeratic, arkosic..................</td>
<td>390</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic..................................</td>
<td>400</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, slightly conglomeratic, arkosic..................</td>
<td>410</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some dense red and gray limestone.....</td>
<td>420</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, slightly conglomeratic; some red silty shale.....</td>
<td>440</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic..................................</td>
<td>490</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained, micaceous..................................</td>
<td>505</td>
</tr>
<tr>
<td>Sandstone, red and white, medium- to coarse-grained, slightly conglomeratic, arkosic</td>
<td>510</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic................................................</td>
<td>535</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained, micaceous..................................</td>
<td>540</td>
</tr>
<tr>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>560</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained.</td>
<td>570</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>600</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained, micaceous.</td>
<td>610</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>630</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic.</td>
<td>650</td>
</tr>
<tr>
<td>Sandstone, red, medium-grained, arkosic; some silty shale and dense gray limestone</td>
<td>660</td>
</tr>
<tr>
<td>Sandstone, red, fine- to medium-grained, micaceous; some dense gray limestone</td>
<td>680</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>715</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, micaceous.</td>
<td>720</td>
</tr>
<tr>
<td>Sandstone, dark-red, poorly consolidated, coarse-grained, arkosic.</td>
<td>730</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>735</td>
</tr>
<tr>
<td>Shale, red, silty, micaceous; some red dense limestone.</td>
<td>740</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic.</td>
<td>750</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic.</td>
<td>770</td>
</tr>
<tr>
<td>Sandstone, red, medium- to fine-grained, shaly, arkosic.</td>
<td>775</td>
</tr>
<tr>
<td>Limestone, gray and purple, dense.</td>
<td>780</td>
</tr>
<tr>
<td>Sandstone, red, medium-grained, arkosic.</td>
<td>790</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, micaceous; some red dense limestone.</td>
<td>800</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic.</td>
<td>920</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red silty micaceous shale</td>
<td>930</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>950</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some white fine-grained micaceous sandstone</td>
<td>960</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red silty micaceous shale</td>
<td>975</td>
</tr>
<tr>
<td>Sandstone, gray, fine-grained, micaceous; some red dense limestone</td>
<td>985</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1000</td>
</tr>
<tr>
<td>Sandstone, white and red, fine-grained, micaceous</td>
<td>1015</td>
</tr>
<tr>
<td>Sandstone, red, medium- and coarse-grained, arkosic</td>
<td>1100</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some white fine-grained micaceous sandstone</td>
<td>1110</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red silty shale and red dense limestone</td>
<td>1120</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1180</td>
</tr>
<tr>
<td>Sandstone, white finely mottled with gray, fine-grained</td>
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</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1240</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red micaceous siltstone and red and gray dense limestone</td>
<td>1260</td>
</tr>
<tr>
<td>Sandstone, red, medium- and coarse-grained, arkosic; some white fine-grained sandstone</td>
<td>1310</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1350</td>
</tr>
<tr>
<td>Sandstone, red, medium- and coarse-grained, arkosic</td>
<td>1360</td>
</tr>
<tr>
<td>Description</td>
<td>Code</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic</td>
<td>1370</td>
</tr>
<tr>
<td>Sandstone, red and white, fine-grained, micaceous</td>
<td>1380</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic</td>
<td>1395</td>
</tr>
<tr>
<td>Shale, red, silty, micaceous</td>
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</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1435</td>
</tr>
<tr>
<td>Shale, red, silty, micaceous</td>
<td>1440</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>1450</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some white fine-grained sandstone</td>
<td>1460</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic, considerable magnetite</td>
<td>1500</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; some red silty micaceous shale</td>
<td>1510</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, slightly conglomeratic, arkosic</td>
<td>1580</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic, abundant magnetite</td>
<td>1600</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; with red silty micaceous shale</td>
<td>1610</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic; abundant magnetite</td>
<td>1620</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic</td>
<td>1720</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic, many large quartz fragments</td>
<td>1790</td>
</tr>
</tbody>
</table>
APPENDIX B (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Year</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic, rounded pebbles, weathered igneous rocks</td>
<td>1820</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic, fragments of fresh granite</td>
<td>1930</td>
<td>110</td>
</tr>
<tr>
<td>No samples</td>
<td>1938</td>
<td>8</td>
</tr>
</tbody>
</table>
APPENDIX C

Sample description of the lower part of the Fountain formation in the Colorado Petroleum, Inc., No. 1 L. V. Hart, SE 1/4 of Sec. 17, T. 17 S., R. 67 W., El Paso County, Colorado. Total depth 3505 feet. Dry and abandoned, March 1946. (Samples described by the writer.)

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth in feet</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fountain formation - Pennsylvanian</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale, red, micaceous, with arkosic sand.</td>
<td>0-40</td>
<td>40</td>
</tr>
<tr>
<td>Conglomerate, arkosic with fragments of quartz, granite, basalt and limestone.</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, micaceous, arkosic</td>
<td>160</td>
<td>70</td>
</tr>
<tr>
<td>Limestone, white, silty; some red medium-grained arkosic sandstone</td>
<td>170</td>
<td>10</td>
</tr>
<tr>
<td>Gap in samples</td>
<td>180</td>
<td>10</td>
</tr>
<tr>
<td>Limestone, red, dense; and red calcareous micaceous shale</td>
<td>190</td>
<td>10</td>
</tr>
<tr>
<td>Shale, red, calcareous, micaceous; and white silty limestone</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, arkosic..</td>
<td>210</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, micaceous, arkosic</td>
<td>220</td>
<td>10</td>
</tr>
<tr>
<td>Siltstone and shale, red, micaceous; some red fine-grained arkosic sandstone</td>
<td>230</td>
<td>10</td>
</tr>
</tbody>
</table>
APPENDIX C (continued)

Sandstone, white, fine-grained, calcareous................................. 240 10
Sandstone, red, coarse-grained, arkosic.. 280 40
Shale, red, micaceous, calcareous; some red finely crystalline limestone..... 290 10
Siltstone and shale, red, calcareous..... 300 10
Limestone, red, silty; some red calcareous shale............................. 320 20
Limestone, white, silty; some white medium-grained calcareous arkosic sandstone................................. 330 10
Sandstone, red, fine-grained, arkosic.... 340 10
Sandstone, red, coarse-grained, arkosic.. 350 10
Sandstone, red, fine-grained, micaceous; some red micaceous shale............. 360 10
Sandstone, red, medium-to coarse-grained, arkosic............................ 370 10
Siltstone, red, micaceous, calcareous.... 390 20
Sandstone, red, coarse-grained, conglomeratic, arkosic......................... 420 30
Sandstone, red, medium-grained, arkosic.. 470 50
Shale, red, micaceous, calcareous; some red calcareous siltstone............... 480 10
Sandstone, red, coarse-grained, conglomeratic, arkosic, large fragments of quartz................................. 540 60
Sandstone, red, coarse-grained, conglomeratic, arkosic, with fragments of dark-gray granite................................. 550 10
Limestone, red, finely crystalline; some red micaceous calcareous shale........ 560 10
Sandstone, red and gray, coarse-grained, conglomeratic, arkosic.................. 580 20
APPENDIX C (continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, red, medium-grained, arkosic</td>
<td>590</td>
<td>10</td>
</tr>
<tr>
<td>Shale, red, micaceous, calcareous</td>
<td>600</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic, arkosic</td>
<td>610</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>690</td>
<td>80</td>
</tr>
<tr>
<td>Sandstone, red, medium-grained, arkosic; considerable magnetite</td>
<td>800</td>
<td>110</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>850</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, red, medium- to coarse-grained, arkosic; considerable magnetite</td>
<td>950</td>
<td>120</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, conglomeratic; abundant magnetite</td>
<td>970</td>
<td>20</td>
</tr>
<tr>
<td>Shale, red, silty, micaceous</td>
<td>990</td>
<td>20</td>
</tr>
<tr>
<td>Shale, red, silty, micaceous; some white fine-grained sandstone</td>
<td>1000</td>
<td>10</td>
</tr>
<tr>
<td>Shale, gray, silty, micaceous</td>
<td>1010</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red, medium-grained, conglomeratic, arkosic</td>
<td>1020</td>
<td>10</td>
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**Manitou dolomite - Ordovician**

| Description                                                                 | Number | Frequency |
| Dolomitic limestone, red, slightly silty; abundant white chert              | 1070   | 50        |

**Granite - Pre-Cambrian**

Fragments of fresh feldspar, quartz and biotite in crystalline association which was not observed higher; quartz is extremely angular, fresh and glassy. Shreds of steel off drill bit common in samples below 1070.
APPENDIX D

Additional data on the Colorado Petroleum, Inc. No. 1
L. V. Hart, El Paso County, Colorado.

I. Copy of a report by J. R. Lowell, Jr., concerning the testing of the well.

COLORADO PETROLEUM, INC.

PETROLEUM BUILDING
WICHITA 2, KANSAS

"Re: L. V. Hart no. 1 WILDCAT
800' East of West Line and
50' North of South Line SE 1/4
Sec. 17-17S-67W, El Paso
County, Colorado. Red Creek
Anticline."

"The above captioned well was drilled from 0' to 3505' with rotary tools. At 1934' to 1939' a small show of oil was encountered, another at 2248' to 2256', another at 2475' to 2480', another at 2482' to 2488', another at 2496' to 2500', and another at 2502' to 2507'. The above mentioned shows were small in respect to porosity and saturation. The best shows occurred between 2890' and 2955'. In this zone there were three different shows, the first from 2890' to 2896', the second from 2908' to 2921', and the third from 2930' to 2955'. The samples in this zone varied in saturation from good oil shows to fair oil stains. All the above mentioned shows were of live oil. The next staining was encountered at 3035' to 3065' but the oil in these samples was dead, which means that volatile properties of the oil had evaporated leaving only the residue."
APPENDIX D (continued)

"After completion of the rotary work a cement plug was set between 2970' and 3120' to plug off the bottom of the hole in preparation to test the shows of oil between 2890' and 2955'. 5-1/2 pipe was set at 2872', leaving 98' of open hole, which was ample to make the above mentioned test.

The above mentioned zone between 2899' and 2955' was shot with 130 qts. of solidified nitroglycerin, the results of which were negligible. However, while cleaning out this zone in preparation of our shot there was a small show of free oil which in all probability had accumulated on the face of the rocks and drilling mud. This very quickly exhausted itself and was no more than a good rainbow at any time from then on.

With no oil from the above mentioned zone we then perforated with Halliburton gun perforating machine the following zones, of which each received 10 shots; 2507' to 2502', 2500' to 2496', 2493' to 2482', 2480' to 2475', 2256' to 2248', and 1939' to 1934'. Had any of these shows had sufficient saturation and porosity this perforating would have given proof thereof.

At the request of Mr. R. G. Harrison, we perforated the zone between 2614' and 2622', which was done with 10 shots. From the sample cuttings neither Fanny Carter Edson nor the Shell Oil Corporation geologist find any stains whatsoever in this zone. Additional water was encountered as a result of this shot.

The artesian water which was encountered between 925' and 950' was perforated for benefit of Mr. L. V. Hart in lieu of surface damages to his property.

It is the belief of Fanny Carter Edson and numerous other geologists that the Red Creek Anticline has sufficient oil bearing formations within its bounds to produce commercially. Due to the fact that granite wash is no source bed for oil and it, therefore, has to migrate from a source bed into the granite wash. If the source beds for this oil are ever found in the Red Creek Anticline in all probability they will
APPENDIX D (continued)

produce in commercial quantities. Therefore, it is my belief that we still have some value in the 3000 odd acres under lease.

Enclosed is a sample log prepared by Fanny Carter Edson, geologist on the above mentioned well."

By: (Signed) J. R. Lowell, Jr.
April 4, 1946
APPENDIX D (continued)

II.

Copy of the sample descriptions from the surface to total depth, and a geological report by Fanny Carter Edson. Samples described by Fanny Carter Edson, geologist on the well.

Colorado Petroleum Inc.
L.V. Hart No. 1 Wildcat
800 feet East of West Line
50 feet North of South Line
SE 1/4 Section 17-17S-67W
Red Creek Anticline
El Paso County, Colorado

ELEVATION: 6200' Ground

Commenced: 11-18-45
Completed drilling: 2-20-46

This well spuds 200 to 300 feet below the top of the Fountain Formation which is exposed in a hill just southeast of the well.

0-10 Very coarse free granite wash.
10-35 No sample.
38-42 Fine red gritty shale.
42-80 No sample.
80-90 Coarse gravel fragments of various igneous rocks.
90-100 Coarse free granite wash.
100-110 Coarse free granite wash.
110-140 Very coarse free granite wash.
140-155 Medium free granite wash.
155-163 Fine red gritty shale.
163 Set 10-3/4" surface pipe.
165-173 Medium fine cemented limy granite wash.
173-180 Free coarse granite wash.
180-190 Red gritty shale- some dense red limestone.
190-195 Red gritty shale.
195-215 Medium limy cemented granite wash.
215-217 Pale green coarsely micaceous shale.
217-222 Dense red-brown limestone.
222-225 Red coarsely micaceous grit.
225-235 Medium limy cemented granite wash.
APPENDIX D (continued)

235-237 Red coarsely micaceous grit.
237-257 Coarse free granite.
257-275 Medium cemented granite wash.
275-276 Dense buff limestone.
276-287 Coarsely red micaceous grit.
287-290 Dense red limestone.
290-303 Micaceous red grit.
303-304 Dense red limestone.
304-325 Hard red coarsely micaceous very fine grit.
325-338 Coarse free granite wash.
338-341 Fine limy granite wash.
341-350 Coarse free granite wash.
350-351 Pale green micaceous shale.
351-360 Fine red limy cemented granite wash.
360-370 Coarse free granite wash.
370-385 Micaceous gritty red shale.
385-390 Coarse free granite wash.
390-400 Medium free granite wash - little lime cement.
400-409 Medium free granite wash.
409-410 Red micaceous grit.
410-469 Coarse free granite wash.
469-480 Red coarsely micaceous grit.
480-485 Coarse limy granite wash.
485-549 Coarse free granite wash.
549-559 Red micaceous grit.
559-560 Dense red limestone.
560-580 Coarse free granite wash.
580-590 Medium free granite wash.
590-593 Medium cemented limey granite wash.
593-598 Coarsely micaceous red grit.
598-600 Dense red limestone.
600-625 Coarse free granite wash.
625-630 Cemented limey granite wash.
630-680 Coarse free granite wash.
680-690 Slightly finer free granite wash.
690-700 Medium to coarse granite wash.
700-730 Coarse free granite wash.
730-750 Medium free granite wash.
750-760 Medium to coarse granite wash.
760-770 Coarse free granite wash.
770-780 Medium free granite wash.
780-790 Medium to coarse granite wash - little lime cement.
790-819 Coarse free granite wash.
819-821 Red micaceous shale.
821-850 Coarse free granite wash.
850-860 Coarse free granite wash, broken red chert pebbles.
860-870 Coarse free granite wash.
870-890 Coarse to medium free granite wash.
890-950 Coarse free granite wash.
APPENDIX D (continued)

930-940 Coarse free granite wash, trace of red micaceous shale.
940-948 Coarse free granite wash.
948-953 Red coarsely micaceous grit.
953-960 Coarse free granite wash, trace of yellow chert.
960-978 Medium free granite wash.
978-985 Red micaceous grit.
985-998 Coarse free granite wash, trace of chert and pale greenish-white sandy limestone.
998-1005 Red micaceous grit.
1005-1010 Fine granite wash cemented with lime.
1010-1022 Coarse granite wash cemented with lime.
1022-1040 White tripolitc and vitreous chert, and dense red-brown dolomitic limestone.
1040-1060 White, pale buff, pink, semi-translucent and vitreous chert.
1060-1070 Red-brown finely crystalline glauconitic dolomitic limestone, and chert as above.
1065 Two inch flow of artesian water broke through the drilling mud at 1065', but may have been encountered above this depth.
1070-1098 Medium free and cemented granite wash.
1098-1102 Red micaceous grit.
1102-1118 Coarse fresh fragments of granite wash, trace of chert and trace of gypsum.
1118-1123 Red micaceous grit.
1123-1138 Coarse fresh fragments of granite wash, little white semi-translucent chert.
1138-1142 Red micaceous grit and a trace of purple plastic shale.
1142-1158 Coarse granite wash, a little olive-drab, red and white chert.
1158-1161 Red micaceous grit.
1161-1175 Coarse worn granite wash, some white vitreous chert.
1175-1180 Coarse red grit and maroon plastic shale.
1180-1188 Coarse free granite wash.
1188-1192 Red micaceous grit.
1192-1200 Coarse free granite wash, trace of olive-drab vitreous chert.
1200-1210 Coarse free granite wash, abundant biotite.
1210-1220 Coarse free granite wash, trace of black shale and white semi-translucent chert.
1220-1221 Red micaceous grit.
1221-1230 Coarse free granite wash, abundant mica.
1230-1238 Medium free granite wash.
1238-1242 Red micaceous grit.
1242-1250 Medium free granite wash.
1250-1252 Red micaceous grit.
1252-1270 Fragments of fresh granite, little white semi-translucent chert.
APPENDIX D (continued)

1270-1272  Red micaceous grit.
1272-1280  Worn medium granite wash.
1280-1288  Coarsely micaceous white worn granite wash-
           sandstone, white semi-translucent chert.
1288-1292  Red micaceous grit.
1292-1296  Fresh granite fragments.
1298-1302  Red micaceous grit.
1302-1315  Medium worn granite wash.
1315-1320  Red micaceous grit.
1320-1323  Coarse granite wash and chalky gyp.
1323-1326  Cored, recovered 2' of fresh granite.
1326-1350  Medium worn granite wash.
1350-1355  Medium worn granite wash and fresh granite
           fragments.
1355-1360  Medium worn granite wash, trace of dense
           red-brown limestone.
1360-1361  Red micaceous grit.
1361-1370  Medium worn granite wash, trace of grey-brown
           finely crystalline limestone.
1370-1380  Medium worn granite wash.
1380-1390  Medium worn sandy granite wash.
1390-1400  Fragments of fresh granite.
1400-1409  Medium worn granite wash, trace of semi-
           translucent chert.
1409-1410  Red micaceous grit.
1410-1420  Medium worn granite wash, trace of red-brown
           limestone, and red micaceous grit.
1420-1430  Medium worn granite wash, trace of red-brown
           limestone and gyp.
1430-1440  Medium worn granite wash, trace of white semi-
           translucent chert.
1440-1450  Medium worn sandy granite wash, trace of red-
           brown dense limestone.
1450-1459  Medium worn sandy granite wash.
1459-1460  Red micaceous grit.
1460-1470  Medium worn sandy granite wash, trace of red-
           brown limestone.
1470-1472  Red micaceous grit.
1472-1480  Medium worn sandy granite wash.
1480-1481  Coarse red micaceous grit.
1481-1490  Medium worn sandy granite wash, trace of gyp.
1490-1500  Medium worn sandy granite wash.
1500-1505  Red very finely micaceous shaly very fine sand-
           stone.
1505-1510  Medium to fine sandy granite wash, trace of
           red-brown limestone.
1510-1528  Medium to fine sandy granite wash, trace of
           red-brown limestone.
1528-1530  Red micaceous grit.
1530-1550  Medium worn granite wash.
APPENDIX D (continued)

1550–1560 Medium to worn fine granite wash.
1560–1570 Medium to fine worn granite wash, trace of red-brown limestone.
1570–1580 Medium to fine worn sandy granite wash, trace of red-brown dense limestone.
1580–1590 Medium to fine worn sandy granite wash, some fresh granite fragments.
1590–1600 Medium to fine worn sandy granite wash.
1600–1610 Medium granite wash, some sharp fresh granite fragments.
1610–1630 Medium to fine worn granite wash.
1630–1633 Coarse white granite wash-sandstone.
1633–1640 Medium to fine worn granite wash, trace of grey, red-brown limestone.
1640–1650 Medium to fine worn granite wash, few fresh sharp granite fragments.
1650–1655 Tightly cemented irregular granite wash.
1655–1670 Irregular worn granite wash and fresh granite fragments.
1670–1678 Worn granite wash and coarse white micaceous granite wash-sandstone.
1678–1680 Coarsely micaceous red grit.
1680–1690 Worn granite wash, trace of dense red-brown limestone.
1690–1700 Worn granite wash and sharp fresh granite fragments.
1700–1710 Worn granite wash, red finely micaceous sandstone, coarsely micaceous red grit and trace of red-brown limestone.
1710–1740 Medium to fine granite wash, trace of white chert, red-brown limestone and red grit.
1740–1750 Medium to fine red cemented and free granite wash.
1750–1760 Medium to fine worn granite wash, trace of red grit.
1760–1780 Fine free worn sandy granite wash, trace of red grit.
1780–1795 Fine loosely (gyp?) cemented granite wash.
1795–1800 Coarsely micaceous red grit and medium free worn granite wash.
1800–1815 Medium worn granite wash, fine cemented gypsiferous granite wash.
1815–1820 Fine sharp glassy granite wash.
1820–1830 Medium to fine granite wash, trace of red-brown shale and dark grey-green gritty shale.
1830–1840 Fine sharp granite wash.
1840–1850 Medium to fine granite wash, trace of red finely micaceous sandstone.
1850–1860 Medium to fine granite wash, some cemented with gyp.
APPENDIX D (continued)

1860-1870 Fine to medium granite wash, trace of red coarsely micaceous grit.
1870-1880 Fine sharp granite wash.
1880-1890 Fine and medium sharp and worn granite wash.
1890-1900 Granite wash as above, trace of coarse white cemented micaceous granite wash-sandstone.
1900-1910 Granite wash-sandstone as above and medium granite wash, some cemented hard.
1910-1920 Fine sharp granite wash.
1920-1934 Fine sharp granite wash, trace of buff and red-brown dense limestone.
1934-1939 Granite wash-sandstone with trace of live oil.
1939-1950 Medium to fine worn granite wash, some cemented.
1950-1960 Medium to fine worn granite wash, little red coarsely micaceous grit.
1960-1970 Fine angular granite wash, little fine red micaceous sandstone.
1980-1990 Medium to fine granite wash, little cemented.
1990-2000 Medium to fine sandy granite wash, a little red coarsely micaceous grit.
2000-2010 Medium to fine sandy granite wash.
2010-2020 Fine angular granite wash, trace of red micaceous grit.
2020-2025 Coarse white micaceous granite wash-sandstone.
2025-2035 Medium to fine granite wash.
2035-2040 Coarse white micaceous granite wash-sandstone.
2040-2042 Fine red micaceous sandstone.
2042-2050 Fine granite wash, some cemented and coarse sharp quartz fragments.
2050-2060 Medium fine worn granite wash, trace of red-brown dense limestone.
2060-2070 Irregular worn granite wash, some cemented, trace of red micaceous grit and coarse granite wash-sandstone.
2070-2075 Coarse white micaceous granite wash-sandstone.
2075-2090 Medium to fine granite wash, micaceous red grit, trace of red-brown dense limestone.
2080-2090 Medium to fine granite wash, some cemented, trace of red-brown dense limestone.
2090-2100 Cemented medium to fine granite wash, trace of gritty red shale.
2100-2111 Medium to fine granite wash, a little finely micaceous red shale and red-brown limestone.
2111-2114 Sharp fresh granite fragments.
2114-2119 Medium to fine granite wash.
2119-2122 Sharp fresh granite fragments.
2122-2150 Free and cemented medium fine granite wash.
2150-2140 Fine to medium granite wash, some cemented, white granite wash-sandstone, and red micaceous grit.
APPENDIX D (continued)

2140-2150 Fine to medium free granite wash.
2150-2160 Fine to medium cemented granite wash, trace of white granite-wash-sandstone and red micaceous grit.
2160-2170 Fine to medium cemented granite wash, trace of coarse white granite wash-sandstone.
2170-2180 Medium, some fine worn granite wash. Trace of red micaceous grit.
2180-2188 Fine worn granite wash.
2188-2190 Brown coarsely micaceous shale.
2190-2200 Coarse granite wash and white granite wash-sandstone.
2200-2210 Medium to fine worn granite wash.
2210-2220 Cemented medium to fine granite wash and red micaceous grit.
2220-2230 Medium cemented granite wash with red coarsely micaceous shale streaks.
2230-2249 Medium to fine granite wash less cemented, red grit, coarse white granite wash-sandstone.
2249-2256 Fine worn granite wash, very small show of oil.
2256-2258 Loosely cemented granite wash.
2258-2264 Free worn glassy quartz and feldspar (water?).
2264-2280 Cemented medium granite wash and red grit.
2280-2290 Medium cemented granite wash.
2290-2300 Medium quartz and granite wash, some cemented.
2300-2307 Cemented granite wash and white coarse granite wash-sandstone.
2307-2320 Medium to fine granite wash, a little cemented.
2320-2330 Fine granite wash, red grit, trace of red-brown dense limestone.
2330-2340 Medium to fine granite wash, some cemented, a little white granite wash-sandstone.
2340-2350 White granite wash-sandstone and medium granite wash.
2350-2360 Fine to medium granite wash, some cemented, trace of red shale.
2360-2368 Coarse granite wash, red micaceous grit, trace of dense buff limestone pebbles, faint oil stain.
2368- Shut off water from upper hole, mixed weight and viscosity mud.
2368-2372 Fresh granite fragments.
2372-2379 Fresh granite, granite wash, red-brown limestone, red grit, granite wash-sandstone.
2379-2380 Fresh granite.
2380-2386 Granite wash and red grit.
2386-2390 Fresh granite.
2390-2394 Fine granite wash gravel.
2394-2406 Fresh granite.
2406-2422 Worn granite wash and red micaceous grit.
APPENDIX D (continued)

2422-2426 Fresh granite.
2426-2430 Worn granite wash.
2430-2435 Biotite schist, and fresh granite.
2435-2438 Granite wash and red grit.
2438-2440 Fresh granite.
2440-2446 Granite wash, red grit, red-brown limestone.
2446-2450 Fresh granite.
2450-2452 Biotite schist.
2452-2456 Fresh granite.
2456-2460 Red shale and grit, red-brown limestone.
2460-2468 Worn granite wash, red grit, granite wash-sandstone, biotite schist.
2468-2475 Fresh granite.
2475-2480 Granite wash and red grit, slight show of black oil.
2480-2482 Fresh granite, and green quartz diorite.
2482-2488 Granite wash, red grit, and white opaque chert, slight black oil show.
2488-2490 Granite wash and red grit.
2490-2496 Fresh granite.
2496-2500 Red grit and granite wash, very slight trace of black oil.
2500-2504 Fresh granite and granodiorite.
2504-2507 Granite wash, granite wash-sandstone, red grit, slight trace of black oil.
2507-2530 Granite wash, red grit, trace of chert and trace of maroon shale.
2530-2538 Black and white biotite schist and diorite.
2538-2570 Fresh granite with interbedded schist, diorite, worn granite wash, red grit, and red-brown limestone.
2570-2582 Fresh granite, schist, diorite.
2582-2588 Fresh pink (very quartzose) granite.
2588-2596 Granite wash and granite wash-sandstone.
2596-2601 Granite wash, red grit, and red shale.
2601-2614 Fresh basic igneous rock (gabbro?).
2614-2617 Granite wash and red grit.
2617-2625 Fresh gabbro.
2625-2630 Fresh granite.
2630-2643 Fresh granite, biotite schist, diorite.
2643-2650 Fresh gabbro.
2650-2655 Fresh granite.
2655-2662 Fresh gabbro.
2662-2667 Fresh granite.
2667-2674 Worn granite wash, red grit, red-brown limestone, chert.
2674-2679 Fresh granite.
2679-2682 Granite wash.
2682-2686 Fresh pink granite.
2686-2690 Red grit, shale and granite wash.
APPENDIX D (continued)

2690-2696 Biotite schist and pink granite.
2696-2700 Granite wash, red grit, red-brown limestone
    and red-brown shale.
2700-2718 Fresh biotite schist.
2718-2722 Fresh red granite.
2722-2730 Granite wash-sandstone, red grit, red-brown
    limestone, tripolitic chert.
2730-2732 Red grit and shale.
2732-2742 Cemented red shaly granite wash.
2742-2748 Granite wash, red shale, granite wash-sandstone.
2748-2750 Fresh biotite schist.
2750-2756 Fresh diorite and fresh granite.
2756-2758 Fresh gabbro.
2758-2764 Granite wash, gyp, red grit, and tripolitic
    chert.
2764-2780 Fresh pink granite.
2780-2790 Coarse worn granite wash, red grit and cemented
    granite wash.
2790-2800 Coarse granite wash, red grit, little gyp, red
    chert, and tripolitic chert.
2800-2807 Coarse granite wash, trace of very fine white
    sandstone, trace of red grit.
2807-2809 Fresh granite.
2809-2820 Coarse granite wash, trace of biotite schist.
2820-2825 Granite wash, trace of red grit.
2825-2827 Fresh pink very quartzose granite.
2827-2830 Coarse granite wash-white sandstone.
2830-2836 Granite wash.
2836-2838 Biotite schist.
2838-2840 Fresh red grit.
2840-2842 Fresh gabbro.
2842-2844 Fresh red grit.
2844-2846 Fresh pink granite.
2846-2849 Granite wash and red-brown limestone.
2849-2850 Fresh pink granite.
2850-2852 Granite wash.
2852-2856 Fresh pink and red granite.
2856-2858 Red grit.
2858-2860 Fresh gabbro.
2860-2863 Fresh pink granite.
2863-2866 Fresh granite wash and red grit.
2866-2868 Fresh pink granite.
2868-2874 Soft red grit, cemented granite wash, red-brown
    limestone, trace of gyp and granite wash-
    sandstone.
2874-2886 Fresh pink granite.
2886-2890 Coarse granite wash and red grit.
2890-2896 Coarse granite wash, many fragments oil stained.
2896-2898 Fresh granite and biotite schist.
2898-2908 White coarse granite wash-sandstone and cemented
    granite wash.
APPENDIX D (continued)

2908-2914 Granite wash, good oil show.
2914-2921 Granite wash-sandstone with faint oil stain.
2921-2930 Granite wash, red grit and granite wash-sandstone.
2930-2945 Granite wash, trace of red grit and gyp, fair oil stain.
2945-2954 Fresh gabbro fragments, fair oil stain.
2954-2960 Fresh red granite.
2960-2964 Granite wash and red grit.
2964-2968 Fresh red granite.
2968-2970 Red grit.
2970-2978 Fresh gabbro, a little basalt.
2978-2982 Granite wash and red grit.
2982-2987 Fresh granite.
2987-3008 Granite wash, red grit, trace of red-brown limestone, trace of chert.
3008-3022 Fresh pink granite.
3022-3027 Red grit and red-brown limestone.
3027-3034 Fresh pink granite and gabbro.
3034-3042 Red grit, red-brown limestone, granite wash-sandstone, dead oil stain.
3042-3060 Fresh pink granite.
3060-3066 Cemented granite wash, trace of gyp, light uniform oil saturation.
3066-3070 Fresh pink granite.
3070-3071 Granite wash.
3071-3074 Fresh pink granite.
3074-3078 Cemented granite wash, trace of gyp.
3078-3082 Fresh pink granite.
3082-3085 Red grit, trace of red-brown limestone.
3085-3086 Fresh pink granite.
3086-3090 Red grit and granite wash.
3090-3092 Fresh pink granite.
3092-3095 Granite wash with pink cherty dolomite pebble.
3095-3096 Fresh pink granite.
3096-3099 Fresh gabbro.
3099-3101 Fresh pink granite.
3101-3102 Granite wash, trace of pink dolomite, gyp.
3102-3103 Fresh pink granite.
3103-3110 Cemented granite wash, red grit, trace of white vitreous chert.
3110-3113 Fresh granite.
3113-3115 Cemented granite wash and red grit.
3115-3120 Fresh gabbro.
3120-3122 Fresh granite.
3122-3123 Granite wash, trace of chert, red-brown limestone.
3123-3125 Fresh granite.
3125-3126 Granite wash, trace of chert, red-brown limestone.
3126-3130 Fresh granite.
3130-3132 Fresh gabbro and granite wash.
3132-3140 Fresh gabbro and fresh granite.
APPENDIX D (continued)

3140-3142 Red grit and tripolitic chert.
3142-3150 Fresh granite and a little gabbro.
3150-3158 Granite wash, red grit, trace of dolomite.
3158-3160 Fresh granite.
3160-3172 Granite wash, red grit, trace of red-brown limestone.
3172-3174 Fresh granite.
3174-3177 Coarse granite wash-sandstone, drilled rough, lost some mud from pits.
3177-3204 Fresh gabbro.
3204-3212 Granite wash, red grit, gyp.
3212-3215 Fresh red granite.
3215-3217 Red grit and white chert.
3217-3219 Fresh red granite.
3219-3223 Fresh gabbro.
3223-3225 Fresh red granite.
3225-3226 Granite wash, tripolitic chert.
3226-3240 Fresh granite.
3240-3248 Granite wash, red grit, trace of gyp.
3248-3260 Fresh granite, little gabbro, vein quartz.
3260-3266 Granite wash, granite wash-sandstone, red grit and red shale.
3266-3268 Fresh granite.
3268-3276 Granite wash, red grit, red-brown limestone, trace of gyp and tripolitic chert.
3276-3280 Fresh granite.
3280-3286 Coarse granite wash, red grit, tripolitic chert.
3286-3291 Fresh gabbro.
3291-3300 Coarse granite wash, granite wash-sandstone, red-brown limestone, gyp, chert.
3300-3302 Fresh granite.
3302-3304 Red grit.
3304-3306 Fresh gabbro.
3306-3314 Granite wash, granite wash-sandstone and red grit.
3314-3320 Coarse granite wash, trace of gyp and red-brown limestone.
3320-3323 Granite wash and red grit.
3323-3334 Fresh granite, gabbro, and dark-green schist.
3334-3350 Coarse granite wash.
3350-3352 Fresh granite.
3352-3356 Granite wash, red-brown grit, and red-brown limestone.
3356-3363 Fresh pink granite.
3363-3366 Granite wash, red-brown grit, red-brown shale and red-brown limestone.
3366-3378 Fresh granite and gabbro.
3378-3378 Coarse worn quartz, red-brown grit, trace of red-brown limestone.
3378-3384 Fresh pink granite.
APPENDIX D (continued)

3384-3394 Cemented granite wash, coarse worn quartz, red grit, gyp and white vitreous chert.
3394-3396 Fresh pink granite.
3396-3399 Coarse worn quartz and pebbles of cemented granite wash.
3399-3402 Fresh pink granite.
3402-3404 Fresh gabbro.
3404-3406 Fresh pink granite.
3406-3408 Fresh gabbro.
3408-3410 Granite wash and granite wash-sandstone.
3410-3412 Biotite schist.
3412-3414 Red grit.
3414-3420 Granite wash, granite wash-sandstone, trace of grey limestone, yellow chert and gabbro.
3420-3425 Fresh granite.
3425-3429 Coarse granite wash, red grit, tripolitic chert.
3429-3431 Fresh granite.
3431-3440 Mostly red micaceous grit, a little coarse granite wash and red-brown limestone, trace of chert.
3440-3446 Mostly red grit, coarse granite wash, red-brown limestone, trace of chert.
3446-3448 Red grit and granite wash, small show of free black oil.
3448-3452 Coarse granite wash.
3452-3460 Fresh pink granite and a little gabbro.
3460-3470 Red grit, coarse granite wash, red-brown limestone and gyp.
3470-3476 Fresh pink granite.
3476-3481 Cemented granite wash, red grit and granite wash-sandstone.
3481-3486 Fresh pink granite and a little gabbro.
3486-3492 Granite wash, trace of gyp and white vitreous chert.
3492-3500 Granite wash, red grit, red-brown limestone, a little fresh granite and gabbro.
3500-3504 Cored 4', recovered 1' of fresh pink granite.
3504 TOTAL DEPTH

WELL IS STILL IN FOUNTAIN FORMATION AT ITS TOTAL DEPTH

BY: (Signed) Fanny Carter Edison

PCE/wf/jh
APPENDIX D (continued)

GEOLOGICAL NOTE.

"There is a possibility that the well penetrated a fault or faults between 1022 and 1070 feet, for the following reasons:

1. The sediments changed character markedly at this point. Above 1022 feet the granite wash was typical more or less unconsolidated erosional detritus, and contained no fresh igneous rocks.

2. The hardness of the formation changed markedly at this point. Nine bits, only, were used from surface to 1050 feet for an average of 117 feet per bit; 69 bits were used between 1050 and 2285 feet for an average of 18 feet per bit.

3. Artesian water broke through the drilling mud at 1065 feet, which may, however, have been encountered higher in the hole.

4. The Manitou-type of dolomitic limestone and chert between 1022 and 1070 feet may actually be a sliver of Manitou, thrust faulted into its present position. (Or it may be detrital boulders of Manitou dolomite.

5. The pattern of the Schlumberger changes markedly between 1022 and 1070 feet, that is, one type of pattern characterizes the interval from the surface to 1022 feet; a different pattern is more or less uniformly maintained from 1070 to 3500 feet, total depth.

It will be noted that if the Manitou? between 1022 and 1070 feet has been thrust into its present position, the following beds are absent above it. Any Fountain of the type encountered below 1070 feet, any beds of Glen Eyrie, Mississippian, Harding age, much Manitou. It, therefore, becomes almost necessary to postulate a second fault between the Manitou? sliver and the overlying loosely consolidated Fountain detritus. The combination of circumstances necessary to bring about these conditions seems pretty fantastic to me and I prefer to consider the Manitou-type material between 1022 and 1070 feet as detrital.
The basic igneous rocks (and if they, why not the fresh granites as well?) encountered in the lower part of the hole can be regarded as intrusive sills and/or against this interpretation, for the following reasons:

1. If all the fresh igneous rocks are regarded as intrusive, the lower part of the hole, below 2568 feet, is made up almost entirely of intrusives with so little sedimentary material I cannot conceive conditions under which the sediments would not have been absorbed and incorporated in the intrusive magmas, or at least very highly metamorphosed by those intrusions.

2. The contacts between the fresh igneous rocks and the sediments are sharp, and so little metamorphic material is present as to be negligible.

SUMMARY:

The most logical explanation for the deposits encountered by this well, it seems to me, is to regard the whole section as a mechanically formed, terrestrial molasse. The lower part, below 2568 feet, could be a talus deposit of blocks and boulders formed adjacent to its source; the middle part, 2568 to 1022 feet, could have been formed by torrential mountain streams with a very steep gradient; the upper part of those same streams when the mountains had been reduced in height and receded somewhat geographically, and the stream gradients were more gradual.

BY: (Signed) Fanny C. Edson
III

Copy of the electrical log of the Colorado Petroleum, Inc., No. 1 L. V. Hart.

(in pocket)

IV

Temperature data on Colorado Petroleum, Inc., No. 1 L. V. Hart. Data supplied by Francis Birch, Committee member on experimental geology and geophysics, Harvard University, from temperature survey made in October 1946.

<table>
<thead>
<tr>
<th>Depth in feet</th>
<th>Observed Temperatures in degrees Fahrenheit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>61.7</td>
</tr>
<tr>
<td>200</td>
<td>64.0</td>
</tr>
<tr>
<td>500</td>
<td>67.1</td>
</tr>
<tr>
<td>1000</td>
<td>72.5</td>
</tr>
<tr>
<td>1200</td>
<td>74.9</td>
</tr>
<tr>
<td>1400</td>
<td>77.1</td>
</tr>
<tr>
<td>1500</td>
<td>78.4</td>
</tr>
<tr>
<td>1600</td>
<td>79.0</td>
</tr>
<tr>
<td>1800</td>
<td>80.7</td>
</tr>
<tr>
<td>2000</td>
<td>82.0</td>
</tr>
<tr>
<td>2300</td>
<td>83.2</td>
</tr>
<tr>
<td>2600</td>
<td>87.0</td>
</tr>
<tr>
<td>2800</td>
<td>89.2</td>
</tr>
</tbody>
</table>

Mean annual air temperature at Colorado Springs - 47.3°F.
APPENDIX E

Sample descriptions through the Gleneyrie, Fountain, Lyons, and lower Lykins formations in Continental Oil Company's No. 1 Paige, SE 1/4 of the NW 1/4 of the NW 1/4 of Sec. 6, T. 18 S., R. 64 W., Pueblo County, Colorado. Total depth 6932 feet. Dry and abandoned March 1946. (Samples described by writer.)

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth in feet</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the Lykins formation - Permian?</td>
<td>2645</td>
<td></td>
</tr>
<tr>
<td>Sandstone, maroon, fine-grained and green shale</td>
<td>2650</td>
<td>5</td>
</tr>
<tr>
<td>Sandstone and shale, red</td>
<td>2690</td>
<td>40</td>
</tr>
<tr>
<td>Sandstone, red and gray, fine-grained; some shale and anhydrite</td>
<td>2740</td>
<td>50</td>
</tr>
<tr>
<td>Limestone, dark-gray, dense; some gray shale</td>
<td>2760</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, slightly calcareous; some red shale and</td>
<td>2810</td>
<td>50</td>
</tr>
<tr>
<td>anhydrite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale, black; some red sand and anhydrite</td>
<td>2870</td>
<td>60</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained; dark-gray and green shale; some red limestone</td>
<td>2890</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained and gray, fine-grained; dark-gray and green</td>
<td>2910</td>
<td>20</td>
</tr>
<tr>
<td>shale</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Lyons sandstone - Permian?

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample No.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, red, medium-grained, well sorted; some dark-gray shale</td>
<td>3120</td>
<td>210</td>
</tr>
<tr>
<td>Sandstone and siltstone, dark-red to almost black</td>
<td>3150</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, red and gray, fine-grained, slightly calcareous; some green shale</td>
<td>3190</td>
<td>40</td>
</tr>
<tr>
<td>Gap in samples</td>
<td></td>
<td>200</td>
</tr>
</tbody>
</table>

### In the Fountain formation - Pennsylvanian

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample No.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, red and gray, coarse-grained, calcareous, arkosic</td>
<td>3430</td>
<td>40</td>
</tr>
<tr>
<td>Sandstone, dark-red and gray, fine-grained, slightly calcareous, micaceous; some gray and black silty shale</td>
<td>3450</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, pale-red, medium-grained, calcareous, slightly arkosic; thinly interbedded dark fissile shale</td>
<td>3520</td>
<td>70</td>
</tr>
<tr>
<td>Shale, gray to black, silty; some red calcareous sandstone</td>
<td>3540</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, pale-red, medium-grained, calcareous, arkosic; thinly interbedded dark-gray and green shale</td>
<td>3780</td>
<td>240</td>
</tr>
<tr>
<td>Sandstone, red, poorly consolidated, fine to medium-grained, calcareous, arkosic; some dark fissile shale</td>
<td>4500</td>
<td>720</td>
</tr>
<tr>
<td>Sandstone, red, very coarse-grained, arkosic</td>
<td>4515</td>
<td>15</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, silty; some dark shale</td>
<td>4540</td>
<td>25</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, arkosic</td>
<td>4570</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, silty, micaceous; interbedded loose calcareous sandstone and silty shale</td>
<td>4680</td>
<td>110</td>
</tr>
<tr>
<td>Limestone, red, dense; some green shale</td>
<td>4685</td>
<td>5</td>
</tr>
<tr>
<td>Sandstone, red, fine-grained, silty, micaceous; interbedded loose calcareous sandstone and silty shale</td>
<td>4840</td>
<td>155</td>
</tr>
<tr>
<td>Sandstone, red, very coarse-grained, micaceous, arkosic; some poorly consolidated calcareous sandstone</td>
<td>5280</td>
<td>440</td>
</tr>
<tr>
<td>Shale, red, sandy, micaceous</td>
<td>5310</td>
<td>30</td>
</tr>
<tr>
<td>Siltstone, red, very micaceous; thinly interbedded red and gray dense dolomitic limestone</td>
<td>5450</td>
<td>140</td>
</tr>
<tr>
<td>Limestone, light-gray, finely crystalline</td>
<td>5460</td>
<td>10</td>
</tr>
<tr>
<td>Siltstone, red, very micaceous</td>
<td>5490</td>
<td>30</td>
</tr>
<tr>
<td>Sandstone, red, very coarse-grained, calcareous, arkosic</td>
<td>5610</td>
<td>120</td>
</tr>
<tr>
<td>Shale, red and gray, silty, calcareous</td>
<td>5680</td>
<td>70</td>
</tr>
<tr>
<td>Sandstone, red, coarse-grained, calcareous, arkosic; some dark-gray and green shale</td>
<td>6190</td>
<td>510</td>
</tr>
<tr>
<td>Conglomerate? Large fragments, over 10 mm, of quartzite with some red, coarse-grained, slightly calcareous, arkosic sandstone</td>
<td>6210</td>
<td>20</td>
</tr>
<tr>
<td>Siltstone, dark-red, micaceous; some fine-grained red sandstone</td>
<td>6230</td>
<td>20</td>
</tr>
<tr>
<td>Sandstone, red, coarse- to medium-grained, calcareous, arkosic; some black shale</td>
<td>6370</td>
<td>140</td>
</tr>
<tr>
<td>Conglomerate? Clear white quartz fragments, some larger than 10 mm. in diameter</td>
<td>6380</td>
<td>10</td>
</tr>
<tr>
<td>Sandstone, red and gray, coarse- to medium-grained, slightly calcareous, arkosic; some red shale</td>
<td>6515</td>
<td>135</td>
</tr>
</tbody>
</table>
APPENDIX E (continued)

Core - Sandstone, brownish-gray, conglomeratic, with cleavage fragments of feldspar over 10 mm. in diameter, arkosic, non-calcareous. 6517 2

Core - Sandstone, red to brown, very coarse-grained, slightly quartzitic, arkosic. 6521 4

Core - Shale, brownish-red, hard, silty, slightly micaceous. 6523 2

Sandstone, red and gray, coarse- to medium-grained, calcareous; interbedded red shale. 6605 82
(echinoderm stem segments and poorly preserved ostracod valves 6560-65 and 6585-90)

Gleneayrie formation - Pennsylvanian

Limestone, gray to black, finely crystalline. 6610 5

Gap in samples. 6612 2

Core - Shale, dark-green, hard. 6626 14

Core - Sandstone, light-gray, coarse-grained, quartzitic, slightly arkosic, micaceous. 6629 3

Core - Sandstone, brown, hard, coarse-grained, shaly, micaceous. 6635 6

Core - Shale, brown, hard, sandy. 6637 2

Core - Shale, variegated brown, red, green, hard, sandy. 6638.5 1.5

Core - Siltstone, bright-green, hard. 6643 4.5

Core - Siltstone, red, green, and gray, hard, sandy. 6646 3

Core - Sand, gray, hard, fine-grained, quartzitic, slightly arkosic. 6647 1

Core - Sand, gray, hard, fine-grained, quartzitic. 6648 1
APPENDIX E (continued)

Core - Shale, green, hard.......................... 6649 1
Core - Shale, mottled maroon and green, hard.......................... 6650 1
Core - Limestone, greenish-gray, finely crystalline.......................... 6651 1
Core - Limestone, red, finely crystalline.......................... 6652 1
Core - Limestone, gray, finely crystalline.......................... 6653 1
Core - Limestone, gray, finely crystalline, sandy, thin shale breaks........ 6654 1
Core - Limestone, mottled red and gray, finely crystalline.......................... 6655 1
Core - Limestone, brown, coarsely crystalline; thin streaks green shale.. 6661 1
Core - Limestone, gray, finely crystalline.......................... 6662 1
Core - Limestone, dark-brown, finely crystalline.......................... 6663 1
Core - Limestone, red, finely crystalline.......................... 6664 1
Limestone, red and gray, finely crystalline, slightly dolomitic........... 6680 16
Sand, red, fine-grained, calcareous....... 6700 20
Limestone, red to gray, finely crystalline, dolomitic; some hard dark-gray shale.......................... 6715 15

Madison limestone - Mississippian

Limestone, pink and gray, dense.
VITA

The writer was born on April 16, 1917, in Blackfoot, Idaho. He graduated from Smith-Cotton High School, Sedalia, Missouri, in June of 1935. In August of 1939 he graduated from the University of Missouri with a Bachelor of Arts degree in geology, followed in May of 1941 by a degree of Master of Arts in Geology from the same institution. The thesis submitted in partial fulfillment of the requirements for the latter degree dealt with "The Conodont Fauna of the Dutchtown Formation of Southeastern Missouri" (unpublished). The writer was employed as a graduate assistant in Geology by Louisiana State University from June 1941 until August 1942, during which time he began a course of study and research directed toward the degree of Doctor of Philosophy. He was visiting Instructor in Geology at Centenary College in Shreveport, Louisiana, during the academic year 1942-43 and in May of 1943 he went to San Antonio, Texas, as field and subsurface geologist for the Stanolind Oil and Gas Company. In October of 1945 the writer returned to Louisiana State University as Instructor in Geology. Since that time he has continued graduate course work and research in stratigraphy leading to the degree of Doctor of Philosophy.
INDEX MAP

DISTRIBUTION OF PENNSYLVANIAN FORMATIONS AROUND THE SOUTHERN END OF THE COLORADO FRONT RANGE

- PENNSYLVANIAN EXPOSURES STUDIED IN DETAIL
- PENNSYLVANIAN EXPOSURES IN ADJACENT TERRITORIES
- COLORADO SPRINGS QUADRANGLE
- FAULT TRACE
- WELL & THICKNESS OF PENNSYLVANIAN STRATA

COLORADO SPRINGS

TELLER COUNTY
FREMONT COUNTY
LITTLE FOUNTAIN CREEK
CONTINENTAL STATE
PUEBLO COUNTY
CONTINENTAL YOUNG
TURKEY CREEK
ARKANSAS RIVER
PUEBLO R 65 W
R 64 W
R 67 W
R 68 W
R 69 W
R 70 W
R 71 W
T 13 S
T 14 S
T 15 S
T 16 S
T 17 S
T 18 S
T 19 S
T 20 S
Wells and thicknesses of Pennsylvanian strata are indicated.
SOUTHWESTERN PART OF COLORADO SPRINGS QUADRANGLE
EL PASO, FREMONT AND PUEBLO COUNTIES, COLO.

- **C-J-K** PERMIAN (?) AND MESOZOIC FMS.
- **Cly** PERMIAN (?) LYONS SANDSTONE
- **Cf** PENNSYLVANIAN FOUNTAIN FM.
- **Contact Limestone**
- **“Hart” Limestone**
- **“Turkey Creek” Limestone**
- **“Red Creek” Chert**
- **“Red Creek” Limestone**

- **O-C** PRE-FOUNTAIN PALEOZOIC FMS.

- **rhy** PRE-CAMBRIAN RHYOLITE
- **Ppg** PRE-CAMBRIAN PIKES PEAK GRANITE

---

**SECTION MEASURED AND DESCRIBED**

---

**FAULT TRACE**

---

**MILES**
COMPANY: Colorado
WELL: Hart #/ RUN NO.: one
FIELD: w c SURVEY: SEC I- L T S -S
COUNTY: El Paso
STATE: CO
FILING NO.: * 

BILLION: D.F.S
OF G.L: 6200

Reading.
Last Reading.
Footage Measured
Casing Shoe Depth:
Max. depth reached
Bottom Depth:
Depth Datum

SCHLUMBERGER DRILLER
DRILLER DIAMETER OF HOLE MUD CHARACTERISTICS SPACINGS

: 7 - 7 / 2
Nature: ...
Weight: 1.2 *
Viscosity: 35
F. Resistivity: 3.8 @ 38°F.

REMARKS
OBSERVERS SELF-POTENTIAL millivolts
RESISTIVITY Normal
EXAMINATION AND THESIS REPORT

Candidate: Kenneth Phelps McLaughlin

Major Field: Geology

Title of Thesis: Pennsylvanian Stratigraphy of the Colorado Springs Quadrangle, Colorado

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: 5/8/47