The Geology of the Derby Area
in the Denver Basin of Colorado

By Clark L. Thomas
A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Geological Engineering.

Signed

Clark L. Thomas

Golden, Colorado
April 16, 1942

Approved

H. M. Van Tungel
Apr. 24, 1942
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INTRODUCTION

The area east of Derby, Colorado, has attracted a great deal of attention of geologists in recent years. A supposed structure, "Derby Dome", so named because of its nearness to the town of Derby, is believed by some geologists to exist in the area. The region presents an interesting but difficult problem in stratigraphy. Certain workers believe there exists a large uplift in the area, as indicated by the commercial coal bearing strata found near the surface at Scranton and vicinity in this portion of Colorado. In past years several competent geologists have studied the coal seams at Scranton and some believe that the coal belongs to the Laramie formation. If this is true, the Derby area would have older beds of Laramie age surrounded by younger beds of Paleocene age.

The purpose of this thesis, therefore, is to determine the age of the surface formation exposed east of Derby. The writer was led to believe that a careful study of the area would reveal certain relationships which, when correlated and interpreted, would result in more definite determination of the age of the surface strata. If the surface formation belongs to the Laramie series, it is probable that an uplift exists; if the formation belongs in later series such as the Denver, however, it is not likely that an uplift has taken place in the area.
Procedure

A study of the area was made during the school year 1941-42 under the direction and supervision of Doctors Van Tuyl and Waldschmidt. The work included (1) studying all important outcrops in the field, (2) gathering fossils, (3) interpreting reports on the area by other writers, (4) examining all samples, (5) determining heavy mineral content on all sandstones, (6) determining insoluble residue content on limy samples, and (7) examining and interpreting information on the known Denver and Laramie formations.

Location and Area

The area specially described in this report is twelve miles northeast of Denver, Colorado, and on the eastern flank of the Denver basin. Derby dome comprises portions of Ranges 65 and 66 West, and Townships 2 and 3 South. (See Plate 1.) It includes an area approximately ten miles long and eight miles wide in Adams County. Derby dome is bounded on the south by Sand Creek and on the north by Third Creek.

The center of the supposed domal area is believed to be in the southwest quarter of Section 2, Township 3 South, Range 66 West.

County roads, which follow each section line, make the region accessible throughout the year. All roads are on the section lines in a north-south or east-west direction.

The Burlington and Union Pacific railroads parallel the western edge of the area. Near Sand Creek on the south, a
branch line of the Union Pacific railroad had, at one time, rail connections between Denver and the Scranton coal mine.

**Economic Possibilities**

If the surface formation should prove to be a part of the Laramie series, there would exist a large domal structure. The most favorable reservoir for the accumulation of oil and gas would probably be the underlying Dakota formation. The Dakota should occur at a depth of approximately 6,100 to 6,300 feet, if the surface formation is Laramie and if the Cretaceous formations below the Laramie are of normal thickness.

**Previous Work in the Area**

Since 1873 the area around Derby has been studied by the United States Geological Survey, private geologists, and palaeobotanists. The investigators have had different opinions as to the age of the surface formation. Several geologists place the latest formation at Derby dome in the Laramie series; others place it in the Denver group; and a few place the formation in the Arapahoe group. Early investigators based their conclusions on the age of the coal at Scranton and Coal Creek. These coal seams are a poor grade of lignite and contain very few, if any, good fossils.

Coal Creek, in T. 4 S., R. 65 W., is reputed to be the point of discovery of coal in Colorado. The date of the discovery is probably prior to 1860. There is a prominent lignite coal outcrop visible on the north bank of the creek.
In 1869 the area, which is now known as the Denver basin, was examined by F. V. Hayden. This was probably the first geologic survey of any importance that was made in the vicinity of Denver. The first report of the United States Geological Survey of the Territories covers this area.

G. H. Eldridge, of the United States Geological Survey, during the years 1885-87 studied in great detail the Denver area. His results show that he recognized an uplift east of Derby.

The United States Geological Survey again studied this region in connection with the investigations of the artesian water resources of the Great Plains. This survey was conducted by N. H. Darton. In his report, C. E. Siebethiel compiled information which also led to the conclusion that an anticline existed east of Derby.

In 1915 W. T. Lee studied the coals at Scranton and concluded that they belong to the Denver formation. In previous investigations the Scranton coal was placed in the Upper Laramie series.

Later, an examination of the area was made by C. T. Lupton. This survey was conducted in 1923. From his examination, he concluded that youngest surface formation on the structure belongs to the Tertiary system. Dip readings of outcrops suggested to him a structure closed to the north, east, and south. Mr. Lupton prepared a structural map of Derby dome based on logs of various test wells. Later workers in interpreting the geology of the area have not
been entirely in agreement with his interpretation.

Russel D. George, in 1927, stated the coal in the vicinity of Scranton is in the Arapahoe formation.

In 1940 a magnetometer survey of the region was made by Schoellhorn and Rummerfield and other students under the direction of the Geophysics Department of the Colorado School of Mines. A copy of the map is found in the appendix.

**Drilling Operations**

Several wells have been drilled in and near the area in search of commercial quantities of oil and gas, or of artesian water. The earliest well drilled was the Denver-Aurora test. It is located in Section 24, T. 3 S., R. 67 W. It was started by the Mid-Colorado Oil and Gas Company, in 1912 and completed in 1914 at a depth of 3,790 feet. Several shows of gas were found in shale and at 3,472-85 feet a small amount of oil in shale was encountered. The top of the Fox Hills formation in the well is placed at a depth of 1,550 feet.

The McDeb Drilling Company later started a test in the northeast part of Sec. 7, T. 4 S., R. 66 W., known as Fitzsimmons No. 1. This well was drilled to a depth of 6,038 feet. Gas was reported in the well at 1,675 feet in a sand believed to be the top of Fox Hills formation. Oil shows were reported at 2,875 and 5,330 feet. The latter oil show was probably in the Hygiene group.

Another well drilled in the area was the Swift well put down in search of artesian water. This well was located on
the east bank of the South Platte River in the northwest part of Sec. 23, T. 3 S., R. 68 W. Total drilling depth of this well was 1,470 feet. The top of the Milliken is believed to have been drilled at 1,275 feet. Several coal seams were found near the top of the hole.

In 1926, the Municipal Oil Company drilled a well in N W 1/4, S E 1/4 of Sec. 1, T. 2 S., R. 68 W. The total drilling depth of this well is 275 feet. The top of the Pierre formation in the well was placed at a depth of 50 feet, but the correlation is evidently erroneous.

The Eman Oil Corporation, in 1928, drilled in N W 1/4, N E 1/4 of Sec. 28, T. 3 S., R. 64 W. Total drilling depth was 1,090 feet. The top of the Fox Hills formation in the well is placed at a depth of 981 feet. (See appendix for driller's log).

In Sec. 12, T. 4 S., R. 68 W., a well known as the Country Club No. 1 was drilled. Top of Fox Hills in the well was placed at 1,650 feet. Total drilling depth of the well was 1,900 feet.

The Bass well is in the southeast part of Sec. 3, T. 3 S., R. 66 W. The well was drilled to a total depth of 725 feet. Lupton predicts that the top of the Fox Hills would have been encountered at a depth of 1,145 feet.

The Cramner well, located in the Sec. 20, T. 2 S., R. 66 W., was drilled to a total depth of 630 feet. Lupton predicts the top of the Fox Hills should be at a depth of 1,050 feet.
The Baxter No. 1 was drilled by Oklahoma Oil Company in 1937. This well, located in S W 1/4 of Sec. 2, T. 3 S., R. 66 W., was drilled to a depth of 4,700 feet. Sample examination was made by the Mineralogical and Petrographical Laboratory of Denver and their results are found in the appendix.

The Baxter No. 2 was drilled by the same company with the intention of testing the Hygiene sand. The Hygiene sand was tested but had no gas show in this well. The total depth of this well could not be obtained by the writer. The Baxter No. 2 is 300 yards southeast of the Baxter No. 1.

As shown by the above data, most of the wells in the region showed small amounts of oil or gas. This indicates the presence of source beds for oil. This might suggest that if a favorable structure could be found in the area, oil or gas might be obtained in commercial amounts. On the other hand, most of the oil or gas occurred in shales. This might indicate that there are sand lenses interbedded in the shale, similar to those found in the Boulder Field, near Boulder, Colorado. Small amounts of oil and gas may possibly come from fractures in the shales of the Derby area.
Acknowledgments

The writer gratefully acknowledges the assistance of Doctors F. M. Van Tuyl and W. A. Waldschmidt for their constructive criticism and advice throughout the preparation of this paper. The writer also wishes to thank Doctor J. Harlan Johnson for his assistance in identifying and interpreting certain fossil plants which were found in the formations.
PHYSIOGRAPHY

Regional Relationship

The Derby dome area lies in the Colorado Piedmont Section of the Great Plains physiographic province. The Colorado Piedmont is bounded on the south by the Raton section, on the north and east by the High Plains, and on the west by the Southern Rocky Mountain province.

The Colorado Piedmont has an elevation of 6,000 feet on the west and slopes gently eastward. At the eastern border and at contact with High Plains, the elevation is 4,000 feet. The Colorado Piedmont is an elevated plain in the youthful stages of erosion.

Relief

The Colorado Piedmont is generally considered to be an undulating treeless plain. The maximum relief of the area examined rarely exceeds 100 feet. The Plains slope gently eastwardly at a rate of approximately 10 feet to the mile. Scattered throughout the Piedmont are numerous small well-developed mesas and buttes.

The foothills lying west of the area under study consist of parallel ridges and valleys developed on upturned sediments of variable resistance. These sediments dip away from the Front Range. Near Golden, Colorado, lava capped mesas form prominent relief features.
Climate and Vegetation

The Colorado Piedmont section has a semi-arid climate. In past years, reports show that the annual precipitation normally varies between ten and twenty inches of rainfall per year. The annual temperature varies between forty-five and fifty degrees Fahrenheit.

The precipitation is ample for dry farming and such crops as corn, wheat, and barley are grown. Beyond the limits of the area studied the water is stored locally in reservoirs and later used for irrigation.

Drainage

The principal river which drains the area is the South Platte. The headwaters of the South Platte and its tributaries to the west are in the crystalline rocks of the Front Range; the general flow is toward the northeast. The tributaries of the South Platte which drain the Derby region are Sand Creek, First, Second, and Third Creeks; all of which flow westward and empty into the South Platte. Streams in the past have built up rock terraces and alluvial fans along the western edge of the Piedmont.
GEOLOGY

Historical Geology

Historical geology aims to give a chronological account of the events in the earth's history. The following summary, compiled by Parker, gives an accurate account of events in the region in past geologic time.

The history before the Upper Cretaceous in the Rocky Mountains is the complex record of a great geosyncline which has been subjected to repeated invasions and retreats of the sea since Proterozoic times.

Proterozoic History

During early Proterozoic time the Cordilleran trough had developed from the Arctic Ocean or North Pacific Ocean southward to New Mexico, Arizona, and lower California. An extended subsidence in this depositional basin during this era is indicated by local accumulation of clastic sediments, some of which are as much as 30,000 feet in thickness.

Early Paleozoic History

Throughout the Cambrian continuous subsidence occurred within the area of the Cordilleran geosyncline. In Ordovician and Silurian times an upwarping of Cascadia and Siouzia caused restriction of the Cordilleran sea but the trough resisted complete revolution and deposition of limited extent continued.

In Devonian time subsidence was again the dominant feature. The line of subsidence was approximately the same as that of
earlier Proterozoic sinking and 4,000 to 6,000 feet of sediments were deposited in the area of Idaho and Utah.

Late Paleozoic

In Mississippian time there was a widespread expansion of the seas together with pronounced subsidence concentrated along the western margin of the inland sea. In late Mississippian or early Pennsylvanian time the present area of southern Colorado and northern New Mexico underwent revolution. This region, which since Proterozoic time had been one of subsidence or comparative neutrality, was bowed up into the Ancestral Rocky Mountain geanticline. Evidence that the topographic relief of these mountains was pronounced is indicated by the great thickness of sediments derived from them in Pennsylvanian time.

In Permian time there was a southward withdrawal of the seas. Erosional material from the ancestral Rockies was deposited to the east, south, and west.

Early Mesozoic

In early Triassic time there was renewed upwarping of the ancestral Rockies, Llanoria, and Siouxia which caused restriction of the sea. In the late Triassic diastrophism created the Mesocordilleran geanticline and consequently divided the Cordilleran geosyncline on the west. The true Rocky Mountain geosyncline probably developed during this time.

In Jurassic there was renewed upwarping of the Mesocordilleran geanticline. Continental and marine deposition of material derived from the ancestral Rockies continued to
Late Mesozoic History

The ancestral Rocky Mountains were eroded nearly to base level by the end of Jurassic time. During Lower Cretaceous time, the Arctic and Mexican seas advanced to the site of the ancestral Rockies. There was a continual expansion of the seas throughout this period.

Seas continued to transgress over the area during Upper Cretaceous time. The Dakota formation shows marked uniformity in thickness indicating a gently sloping surface of low relief.

During Benton and Niobrara time the seas were widespread. There was local subsidence in the great depositional basin. Utah had the greatest amount of subsidence.

At the close of Late Cretaceous or Montana time there was a pronounced orogeny within the area. It seems probable that the subsidence and overloading brought about by the great thickness of Upper Cretaceous rocks caused local disturbances in the isostatic balance which resulted in the development of new positive elements of topographic prominence.

Withdrawal of marine waters in closing of Montana time marks the close of widespread marine deposition within the Rocky Mountain geosyncline. Prominent uplift and erosion of the Rocky Mountains of Colorado began in middle Pierre time and continued until Laramie and Lance time. During this period crystalline rocks were exposed to erosion and supplied much Arkosic material to the surrounding shallow seas.
in the Fort Union epoch of Wyoming and Montana and during the deposition of the Denver formation of Colorado there was culminated the orogeny which resulted in the development of much of the structure of the present Rocky Mountain system. Volcanic activity accompanied this period of crustal deformation.

Following the period of pronounced orogeny, which marked the transition from Mesozoic to Cenozoic times the Rocky Mountain area was not again blanketed with broad expanses of sedimentary deposition. Late Cenozoic rocks were deposited as continental deposits in comparatively restricted areas.

The history of the area can be best described as a series of broad uplifts of the previously folded mountain areas; and each of the uplifts were interrupted by cycles of erosion which caused a major subsidence and the accumulation of thick deposits of Eocene rocks.
STRATIGRAPHY

The various formations which underlie the area are shown in the generalized section of the Denver basin on the following page. Since the writer is interested only in the surface formations a detailed description of the Denver and Laramie formations are given. All formations of Cretaceous age are described sufficiently to enable those in the field to recognize them. The formations below the Dakota are not discussed in this paper because the writer believes they are of no value to the solution of the problem. Most of the description has been compiled from U. S. G. S. Monograph Number 275 and the Mines Quarterly11.

Dakota Series

The Dakota series represents the first sediments to be deposited in the Upper Cretaceous. The formation is 320 feet thick and generally consists of three important sandstone members each separated by narrow bands of shale. At the base of the formation occurs a conglomerate; at the top is found a hard, massive sandstone. The upper sandstone member is resistant to erosion and is an important hogback forming stratum.

The sandstones are composed chiefly of quartz and small amounts of mica and are commonly iron stained. Cross-bedding and ripple-marks are common.

The upper sandstone, known as the Muddy, is at some places lenticular. It carries commercial amounts of oil and
## A Generalized Section of the Denver Basin

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<th>System</th>
<th>Series</th>
<th>Formation</th>
<th>Thickness</th>
<th>Description</th>
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<td>Cenozoic</td>
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<td>Unconformity</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Paleocene</td>
<td>Denver</td>
<td>Arapahoe</td>
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<td></td>
<td></td>
<td>600</td>
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<td></td>
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<td>Unconformity (?) Laramide Revolution</td>
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<tr>
<td></td>
<td>Laramie</td>
<td></td>
<td>Laramie (none marine)</td>
<td>600</td>
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<tr>
<td></td>
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<td>Pine Hills</td>
<td>800</td>
<td>Sandstone and sandy shale</td>
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<td></td>
<td></td>
<td></td>
<td>Pierre Shale (5 zones)</td>
<td>5,000</td>
<td>Shale with interbedded sandstone and Teepee Buttes</td>
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<td></td>
<td></td>
<td></td>
<td>Niobrara</td>
<td>450</td>
<td>Shale, yellow to buff limestone, gray, dense.</td>
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<td></td>
<td></td>
<td></td>
<td>Apachepa</td>
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<td>Dark, lead-colored shale.</td>
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<td></td>
<td>Timpas</td>
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<tr>
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<td>Colorado</td>
<td></td>
<td>Denton</td>
<td>400</td>
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<td></td>
<td>Muddy</td>
<td>320</td>
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<tr>
<td>J. Morrison</td>
<td>Upper Jurassic</td>
<td>250</td>
<td>Green, gray, and chestnut, often variegated shale, nodular limestone, lensing limestone</td>
<td></td>
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<tr>
<td>M. Morrison</td>
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<td>S. Morrison</td>
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<td>T. Morrison</td>
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<td>R. Morrison</td>
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<tr>
<td>Lykins</td>
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<td>600</td>
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<tr>
<td>S. Triassic</td>
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<td>P. Perm</td>
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<tr>
<td>Lyons</td>
<td>Pennsylvanian</td>
<td>200</td>
<td>Gray to buff sandstone, massive cross-bedded</td>
<td></td>
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<tr>
<td>S. Pennsylvanian</td>
<td></td>
<td></td>
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<tr>
<td>Fountain</td>
<td>Fountain</td>
<td>1200</td>
<td>Variagated to red arkosic sandstone and conglomerate some dark red shale</td>
<td></td>
<td></td>
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<tr>
<td>P. Fountain</td>
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<td>?</td>
<td>?</td>
<td></td>
<td>Gneiss, schist, quartzite</td>
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</table>

**Disconformity**

**Unconformity**
gas in the Fort Collins area in north-central Colorado. The middle sandstone member, known as the Dakota, also carries commercial amounts of oil and gas locally in Colorado. The lower member of the Dakota series, known as the Lakota in Wyoming contains oil and gas in that State.

The shale between the sandstones is hard, and white to blue-gray in color. It is mined locally as fire clay. It is impure because of the presence of iron oxide which weathers out in the form of minute brown spots, distinctive of the horizon.

Benton Shale  

The Benton shale is the lower member of the Colorado Group and lies conformably on the Dakota series. This formation consists of black argillaceous shales passing by transitional beds into the formations above and below. The shale is made up of silts with a small amount of disseminated carbonaceous matter. Thin beds of limestone occur in the upper third of the formation. The total thickness of this series is approximately 400 feet. The formation is definitely marine in character and does not contain any sandstone.

Niobrara Formation  

The Niobrara formation constitutes the upper portion of the Colorado group. The thickness of the formation is 450 feet. A basal limestone occurs in the lower part of the formation. This member, known as the Timpas, is 30 feet thick and consists of a hard, gray fossiliferous limestone. The upper member is known as the Apishapa and consists of gray to buff calcareous shale.
The contrast in composition and color between the Apishapa and the sediments of the overlying Pierre affords a clear line of demarcation between the two formations.

Pierre Shale Lying conformably on the Niobrara is the Pierre formation. The Pierre consists of a soft, lead gray to black shale, which has a thickness of 5,000 feet. The lower third of the formation contains thin lenticular bodies of limestone.

The Pierre shale, which is the lower member of the Montana group of the Upper Cretaceous system, is composed of sediments of marine origin.

Fox Hills Formation The Fox Hills formation constitutes the upper portion of the Montana group. Between the Fox Hills and the Pierre occurs a transitional zone represented by the change from a shale to an arenaceous shale. The Fox Hills is 800 feet thick and consists of a soft, arenaceous shale, with occasional interstratified bands of clay.

Laramie Series The Laramie formation consists of alternating beds of sandstone, clay and coal. The sandstone member, which sometimes approaches 200 feet in thickness, occurs in the lower part of the formation. In the Denver basin, the basal sandstones are overlain by 400 feet of clays which have included in them lenticular bodies of sandstone. The coal seams are generally confined to the
lower 200 feet. The lower Laramie sandstones, usually white to buff in color, consist mainly of quartz with minute grains of black chert and a few other impurities. Emmons describes them as follows:

"One band of sandstone above the two lower benches is of importance as being more generally fossiliferous, and hence a valuable indicator in searching for coal. It contains a considerable percentage of lime. The fossils found are mollusks of brackish and fresh water habit, together with remains of plants. Coal seams are sometimes found in the upper clayey division; these coals are lignites with higher percentage of water than coals in the lower section."

In upper Laramie there are small lenticular bodies of sandstone, innumerable concretionary ironstones from 2 to 4 feet in diameter, and narrow local seams of impure lignitic material. The sandstones differ somewhat from those of the lower Laramie in that they contain varying amounts of lime, are of greater hardness, and are lenticular in character. Numerous plant remains are found in the sandstones.

Ironstones form one of the distinguishing features of the upper Laramie. Somewhat similar concretions occur in the overlying Denver-Arapahoe; however, they are less abundant.

The very characteristic Laramie invertebrates remains are Ostrea Glabra and a species of Unio which are considered decisive as to the age of the formation.

There is supposed to exist a considerable unconformity between the upper Laramie and the Denver-Arapahoe formation.
Arapahoe Formation

The Arapahoe is considered by some geologists to be the basal part of the Tertiary. The sediments are fresh-water deposits of unknown lateral extent. The formation is approximately 600 feet thick.

The lower division of the Arapahoe is well developed next to the foothills and consists of pebbles of all older indurated rocks, silicified wood, ironstones, chert, silicified limestone, and, locally, fragments of coal occur.

The Arapahoe formation is distinguished from the Laramie by the sandy nature of its clays, by fewer ironstones, and by the generally brighter colors.

Denver Formation

The Denver formation may be in the lower Tertiary or possibly in the Upper Cretaceous. Fossils found recently near Golden, Colorado, indicate that the Denver formation may be part of the Upper Laramie. The fossils obtained from a water well, recently dug in the Denver formation near Golden, are characteristic brackish-water Laramie types. This suggests that the Denver should be included in the Laramie group.

The Denver formation is 1,400 feet thick, contains andesitic debris, and shows good cross-bedding. In the Golden area it contains three interbedded lava flows. The formation was deposited in shallow water as indicated by the standing plant remains and tree stumps. This formation has sandstone members which contain as much as 55 per cent cal-
The most striking characteristics of this formation are the standing plants and stumps, large amount of andesitic debris, and the high lime content of certain sandstones.

The lower part of the Denver locally contains minerals characteristic of eruptive rocks. The more characteristic of these are quartz, feldspar, augite, hornblende, and biotite.

The Denver formation found in the plains area has certain characteristics which are not present in the other Denver areas. These characteristics are: first, large three feet or more in diameter, usually in a sandy matrix; second, abundance of nodules, sometimes pebbles are rare; third, the sandstones are easily disintegrated; fourth, certain sandstone layers are made up of sandstone concretions which join one another to form a bed of uniform thickness. The concretionary or lenticular sandstones generally form good outcrops.
METHOD OF INVESTIGATION

The writer, in investigating the Derby dome, divided the work into three parts: first, the review of the available printed matter relative to the area; second, exposures of the Denver and Laramie formations were visited and studied in outlying areas; and third, the outcrops of the Derby dome area were studied and samples collected for examination in the laboratory.

Field Work

Soil and sand cover much of the area surrounding Derby dome and it was therefore impossible to find many good outcrops except along creeks and in highway cuts. The writer believes that nearly all important outcrops of the area were visited and studied.

The field work included (1) examining the Derby structure by automobile and noting any prominent features, such as outcrops, gullies, and changes in the soil; (2) walking out a large part of the area; (3) collecting samples at important outcrops; (4) determining the correct attitude of the outcrops; and (5) studying areas of known Laramie and Denver formations.

After the area was covered by automobile, locations of the prominent features were plotted on a map for future reference. Other outcrops were located by walking out a large part of the area.
When an outcrop was visited, its location was plotted on a map. Samples were taken at the outcrop and brief descriptive notes were made. Each sample was kept in a cloth bag and labeled with a number corresponding to the number on the map.

Several areas were visited throughout the investigation which contained good outcrops of known Denver and/or Laramie formations. Such areas included Table Mountain, Green Mountain, Golden Clay Pits, Bear Creek, Cherry Creek, Murphy Creek, High Line ditch, and Sand Creek.
Laboratory Work

The laboratory work included (1) examination of the hand specimens, (2) microscopic examination of crushed samples, (3) insoluble residue determinations, (4) the search for microfossils, (5) grain size measurements, and (6) heavy mineral separations.

A hand lense and a binocular microscope were used to determine the mineral content, character, texture, and color of the samples.

The samples were crushed to approximate grain size and the mineral composition and grain size were determined by microscopic examination. The size of the grains was measured with a calibrated micrometer placed in the eyepiece of a binocular microscope.

An insoluble residue determination was made on each sample which showed any appreciable amount of lime. The laboratory procedure used was as follows: The sample was broken into small chunks and weighed. It was then placed in a beaker and 100cc. of dilute hydrochloric acid added. The sample was allowed to stand in the acid for 24 hours and if the reaction was not complete another 100 cc. of dilute acid was added. When the reaction had ceased, it was ready for filtering. The filter paper was weighed and placed in a funnel and the insoluble residue then filtered. The residue was dried and weighed. Calculation of the percentage of soluble material in the sample was next. Examination of the in-
soluble matter under the microscope followed and physical properties were noted.

For preparation of the sample for microfossil study, the decanting process was used. The process consists of washing the material and pouring off the muddy water until the whole becomes entirely clear. The material was then examined under a binocular microscope of a magnification of sixty diameters.

The following procedure was used in the heavy mineral determination: The separation liquid was bromoform with a specific gravity of 2.84. Two glass funnels were placed one above the other. The upper funnel was fitted with a short rubber tube and clamp. A small glass test tube was fitted into the rubber tube. Fifty cubic centimeters of bromoform were poured into the funnel, then the weighed crushed sample was placed in the bromoform, stirred, and allowed to stand for about 15 minutes. When all of the heavy minerals had settled, the clamp was closed and the test tube containing the heavy mineral residue was removed. The clamp was opened and the bromoform was filtered through the lower funnel. The sample was washed with alcohol, dried, and weighed. The percent of heavy minerals in the sample was calculated and the heavy minerals determined.
RESULTS OF INVESTIGATION

Field Work
Criteria for Correlation

The field investigation has revealed several significant facts which may influence the solution of the problem. The author believes correlation might be made from certain observed features which were noticed in the Derby and outlying areas. Probably some of the following geologic features may be useful in correlation.

Sink-hole Depressions

The author noted, in the area visited, numerous small sink-hole depressions in the creek bottoms. These sink-holes are approximately two feet deep and ten to fifty feet long. Their width depends upon the lateral extent of the stream bed. The sink-hole depressions at the Derby area are very similar to the depressions found in certain areas known to be underlain by the Denver formation.

Boulders

Another noticeable geologic feature which might be correlated is the presence of several large yellowish-brown sandstone boulders, embedded in a softer sandy matrix. These boulders range in size from five to seven feet in diameter. Sandstone boulders of this size are generally found only in the Denver formation of the Plains area.
Modular Stratum

A third possible feature of value for correlation are the layers of nodular sandstone, in which the nodules join to form a bed of uniform thickness. This is a distinctive structure found only in the Denver formation of the Plains area as stated by Cross. The Laramie formation is not known to have any similar structure.

Inclination of Strata

Another distinctive, perhaps valuable fact, is that the strata at the outcrops show very little, if any, dip. This might be a possible local or regional correlation feature. By assuming that certain strata are widespread, the same formations should be found in different areas at Derby dome and possibly in outlying localities.

Special Minerals

A fifth possible correlation feature is the presence of some hornblende or augite in a silicified sandstone at several localities. Other minerals are present in the Derby samples in the same proportion as those samples from outlying areas. This might be useful in determining the age of the strata exposed at Derby dome area.

Sand Content of Clays

Another possible criteria for comparison of the Derby and outlying areas is the high sand content in the shales of the Denver formation. This possibly is of little value because of the great lateral variation in the character of the Denver formation.
PLAN VIEW OF DERBY DOME AREA

PLATE 1
Plant remains might afford another criteria for correlation if a detailed examination of all plant remains could be made. Because of the slight differences in the flora of the Laramie and Denver formations, comparison should be made by using actual fossil remains and not from the description in print.

Exposures in the Area

Five localities were found which showed outcrops of importance in the Derby dome area. Generally, most of the outcrops are partly covered by the overlying soil and sand. For exact location of these outcrops see Plate 1.

Area One

The area, two miles north of the Baxter No. 2 test, shows good outcrops of sandstone and shale. Samples were taken from the north bank of a small creek which flows in approximately an east-west direction. Several large sandstone boulders were found in the bottom of the creek. These boulders vary in size from five to seven feet in diameter.

The strata exposed consist of dark gray to brown shales interbedded with yellowish brown calcareous sandstone. Several ironstone concretions are embedded in the shales. The shales, which are arenaceous, have an abundance of fossil-leaves of deciduous trees, stems and twigs, and small amounts of petrified wood.

The sandstones consist most of quartz grains with some
calcite, biotite, hornblende, and tourmaline. The yellowish brown color in certain sandstones is probably due to iron staining.

The sandstone boulders have a yellowish brown color and uniform texture. They are made up chiefly of quartz grains, but contain small amounts of altered feldspar and biotite.

Good fossils, which might be used in determining the age of the formation, are lacking in the outcrops. There are no measurable dips at any place along the outcrops.

Along the creek bed are numerous sink-hole depressions which are probably caused by the leaching of calcareous cementing material of the sandstones. These depressions are approximately two feet deep and forty feet long. The sides are vertical, and in most cases the depressions are filled with water.

The writer is of the opinion that the following factors observed in this area may have some bearing on the solution of the problem. These factors are (1) the outcrops show no measurable dips, (2) the large sandstone boulders are present in loosely consolidated sandstone, (3) the presence of small ironstone concretions, (4) the presence of feldspar and hornblende, and (5) the sink-hole depressions found along the creek bed.

Area Two In this area several good sandstone outcrops are found along the banks of a small creek which flows through Sections 28 and 33, T. 2 S.,
The outcrops are two miles north and four miles east of the Baxter No. 2 test.

The sandstone is of fine texture, light gray to buff color, very compact, and slightly cemented with silica. Small pyrite concretions and cross-bedding are very common in some places. At a few points the hard resistant sandstone has been undercut by the creek to such a degree that it breaks under its own weight. Large slabs are present which give an apparent dip of about 25° E., but this should not be mistaken for the actual dip of the beds in place. At other places the cross-bedding might be mistaken for the dip of the beds.

Sink-hole depressions are found in the bottom of the creek, and are similar to the depressions found in area one. The sandstone appears to have a very high content of lime. The action of ground and surface water has dissolved part of the cementing material in the sandstone which forms these depressions. The sandstone forms good outcrops along the banks of the creek, and on weathering it tends to form an irregular surface.

The writer believes the following points noted in this area to be of some importance in correlating this formation: (1) The formation has no appreciable dip, (2) the sandstones are of very fine texture, and (3) the content of calcium carbonate in the sandstone is very high.
Area Three

Area three lies approximately one-half mile north and three miles east of the Baxter No. 2 well. A light gray sandstone found in the area is similar in character to the sandstone described in the previous area. Underlying this sandstone is a reddish brown sandstone which contains numerous leaves of deciduous trees. The plant remains are poorly preserved and cannot be positively identified. They do appear, however, to be similar to plant remains of the Laramie group.

The light gray sandstone is very fine, compact, and highly calcareous. It consists mostly of quartz grains with some feldspar, hornblende, and organic matter. The hornblende crystals are generally found to occur in thin layers of coarser material interbedded in the sandstone.

The character of the sandstone outcrops indicate that ground and surface waters are dissolving away parts of the surface rock. Numerous sink-hole depressions are present along the creek bed. The sandstone outcrops fail to show any measurable dips.

The writer believes that the outcrops of areas two and three are parts of the same formation and that the formation is widespread and essentially horizontal.

Area Four

This area lies in the south half of Sec. 29 and in the north half of Sec. 32 of T. 2 S., R. 65 W., and is approximately one-half mile west of area two. Two thin sandstone beds are found interbedded with
sandy shales. The sandstones differ considerably in color, the upper one being a dark reddish brown and the other a light gray. The outcrops generally occur where there are sink-hole depressions or at some point where the creek has under-cut the strata. The hard, fine textured, reddish brown sandstone contains numerous plant remains; the writer recognized a few good palm leaves and branches, together with several magnolia leaves.

About 200 yards west of the outcrop of reddish brown sandstone are found good outcrops of the light gray sandstone which has an apparent dip of 18 degrees east. By digging into the surrounding soil, it was found that the dip is due to slumping of large slabs of sandstone. The sandstone consists principally of quartz grains and calcite with some mica. It is underlain by arenaceous shale which contains crystals of selenite. The plant remains that were found are too poorly preserved to permit positive identification.

It is the opinion of the writer that the sandstones found in this area are of approximately the same horizon as of previously described areas.

Area Five This area is one mile northwest of the Baxter No. 2 test. The area contains the best outcrops of the region and has exposures which can be traced for one hundred and fifty yards. The outcrops are found along the banks of two gullies. The more prominent gully is locally 30 feet wide and 40 feet deep. A small
ravine, three hundred yards west of the above-mentioned gully, contains a few good outcrops of shale and sandstone.

The arenaceous shales exposed in the small ravine are green to brown and black in color, and contain a considerable number of selenite crystals. Thin layers of reddish brown sandstone are interbedded with the shales. There are no measurable dips at any of these exposures.

The gully, which lies in N E 1/4 of Sec. 3, T. 3 S., R. 66 W., has been cut deep enough to expose about 40 feet of the section. At the bottom of the gully there are green color, arenaceous clays. Above the clays is a bed of loosely consolidated, gray sandstone. The sandstone has thin layers of green, brown, and black shales interbedded with it. Several of these shale beds are only a few inches thick and contain an abundance of organic material. Several small ironstone concretions are embedded in the sandstone and shale. Towards the head of the gully the formation changes into a light yellowish brown sandstone, interbedded with dark brown layers of organic matter which vary from one to ten inches in thickness. At this point in the gully, a fairly resistant sandstone outcrops and forms a ledge one foot thick. The sandstone is made up of lenticular concretionary masses, approximately two feet long, joined together to form a bed of uniform thickness. The concretionary sandstone is exposed on either side of the gully for more than one hundred feet. The ledge is easily noted because of the adjoining concretions
and the black shale above and below. On weathered surfaces the sandstone is loosely consolidated, but it is still more resistant than the surrounding strata. This yellowish brown sandstone is rich in moderately well preserved ferns, several of which are lying perpendicular to the bedding planes of the formation. Several fern remains were collected but their identification could not be determined. All of the formations in this area have no measurable dips.

Lying above the concretionary sandstone layer is a violet, shaly sandstone, which contains many leaf fragments and an abundance of small hexagonal prisms of unidentified material, presumably a hexagonal mineral. The prisms are violet in color, and are made up of thin hexagonal plates cemented or grown together. They are up to 2 millimeters in length.

The writer believes that the following factors observed in this area will have an important bearing on the solution of the problem: (1) beds are horizontal, (2) plant remains are found perpendicular to the bedding planes, thus indicating quick burial, and (3) the sandstone concretions which are confluent with each other so as to give a sandstone bed of uniform thickness. All of these factors are characteristic of the Denver formation.

The remainder of the Derby area contains only a few outcrops and they are of no importance. Several small exposures of shale and sandstone were noted at scattered point in the area, but these outcrops were, in most cases, only a few square
feet in area. The dip, structure, or possible fossil content of these outcrops could not be determined. Small pieces of petrified wood can be found in the area where sandy soil exists. The area south of the Baxter wells lacks good outcrops.

**Examination of Exposures in Outlying Areas.**

In order to become familiar with features to be expected as distinctive of certain formations, the author proceeded to examine strata definitely established as Denver or Laramie in age. Specimens were collected for comparison, and structures observed similar to those in the Derby area.

**Known Laramie Exposures**

The region about Golden, Colorado, has excellent exposures of the Laramie formation. It consists of alternating beds of sandstone, clay, and coal which are strongly upturned. Plant fossils, including palm leaves and deciduous trees, are present together with a few brackish-water and fresh-water types of invertebrates.

The sandstones vary from a yellowish brown to a gray color and consist mainly of quartz with minute amounts of cherty material.

The sandstones do not have the same character as those found in the Derby area, but the fossils are similar.

**Known Denver Exposures**

Several areas were studied where the Denver formation is known to outcrop. These areas included Table Mountain, Golden, Colorado; east
of Morrison, Colorado; and portions of the High Line Ditch, Sand Creek, Toll Gate Creek, and Murphy Creek.

The area near Golden was examined only for the purpose of gathering samples and noting characteristic features of the formation. The sandstones found near the base of South Table Mountain are poorly consolidated and variable in texture; gray to yellowish brown in color; and consist mostly of quartz grains with some olivine, pebbles of lava, and andesitic material. The shaly sandstone layers contain numerous plant remains, including palm leaves, magnolias, and some petrified wood.

The Denver formation near Morrison, Colorado, has a high content of lime in the sandstone. The area was examined but the sandstone, to which W. Cross refers as having a lime content of 54.59 per cent, could not be located. Outcrops found in the area are not similar in character to those found at Derby; therefore, no samples were collected or examination made.

The Denver formation of the Plains area is different from that near Golden and Morrison, Colorado. The sediments are generally finer, andesitic pebbles are small or absent, very slight dips are not measurable, numerous nodules occur in certain sandy layers, the beds are gray to yellow and brown in color and easily disintegrated. The writer examined the area eight to ten miles south of the Baxter wells for known Denver outcrops.
At High Line Ditch and Sand Creek, the outcrops are very poor and at Toll Gate Creek several very good outcrops were found.

At Toll Gate Creek, in SW 1/4 of T. 4 S., R. 66 W., sandstone and shale are interbedded. The sandstone is gray to reddish brown in color and the outcrops compare favorably with those of the Derby area. Several leaves and twigs are found in the sandstone. Several sink-hole depressions are also found in this area. At a few places concretionary sandstone beds, composed of quartz grains, muscovite and magnetite, stained with limonite, are present. They are approximately one and one-half feet in diameter and generally form small low ridges. The shale contains a considerable amount of sand, and a small amount of plant remains. The beds in the area show no measurable dips. They have been referred by earlier workers to the Denver formation. In the writer's opinion, this represents essentially the same portion of the Denver formation as occurs in the Derby area.

The portion of Murphy Creek which was examined showed a few exposures of sandstone. The color of the sandstone varies from yellowish brown to gray. One concretionary sandstone member was found. The concretions are very hard, and dark in color. Part of this area is now the army bombing field and could not be visited.

Summary

The writer concludes from his field studies that the
strata in the Derby area has the characteristics of both the Denver and Laramie formations. The mineral composition, petrified wood, concretionary sandstone layer, vertical buried plants, calcareous sandstones, horizontal beds, and large sandstone boulders would place the area in the Denver formation. On the other hand, such evidence as the mineral composition, cherty material, impure lignitic material, fossiliferous sandstone, and large concretions of sandstone and ironstone, would place the strata in the Derby area in the Laramie series.

Laboratory Examination

Various laboratory tests were made on the samples gathered in the field. The following facts, found as the result of the examination, may have some bearing on the solution of the problem. These are (1) mineral assemblage, (2) insoluble residue content, and (3) heavy mineral content.

Description of Samples

The hand specimen was examined first, then crushed to approximately grain size and the minerals determined. The following descriptions give the location, character, and mineral composition of each sample examined.

Derby Dome Exposures:

Sample Number 1. A sandstone sample collected at a point on the north bank of a small creek in SE 1/4 of Sec. 26, T. 2 S., R. 66 W. It has a yellowish brown to light gray color. The texture is medium and the grains are well consol-
idated on fresh surfaces.

Mineral Composition:

Quartz - grains largely angular; few show marked degree of rounding; some stained by iron; colorless to milky. Average size about 0.65 millimeter. Abundance - 80 per cent.

Calcite - Pale yellow color; found as cementing material in the sandstone. Rather abundant - about 15 per cent.

Glaucnite - A few grains; all show marked degree of rounding, and green color.

Obsidian - black glassy material; shows conchoidal fracture; irregular shape.

Magnetite - few grains; some show crystal faces. Average size about 0.30 millimeter. Strongly magnetic.

Chert - similar to moss agate; transparent to translucent; marked degree of rounding.

Sample No. 1-1. This sample was collected near sample one and was taken from a sandstone layer near the bottom of the creek. The sandstone has a yellowish gray color, texture is from medium to coarse, and the grains are loosely cemented.

Mineral Composition:

Quartz - subangular to round grains; average diameter about 0.50 millimeter. Colorless and transparent. Abundante - about 80 per cent.

Calcite - acts as cementing material. Fairly abundant - about 18 per cent.

Feldspar - few pieces and badly altered.

Magnetite - small, uniform, well rounded grains. Few broken crystals. Some coated with limonite.

Glaucnite - greenish color; well rounded grains.

Chert - glassy; black color; irregular fragments.

Sample Number 2. The sample was taken from a large sandstone boulder found in S E 1/4 of Sec. 26, T. 2 W., R. 66 W. It has weathered on the surface to a brownish yellow color. Diameter of the boulder is about 5 feet.
Mineral Composition:

Quartz - colorless; subangular; and irregular grains. Abundance - about 75 per cent.
Calcite - impure and has a pale yellow color. Acts as the cementing material and consists of about 20 per cent of the sandstone.
Magnetite - highly magnetic; small amount; and uniform in size; subangular to round.
Biotite - good hexagonal prism along with thin irregular pieces.
Topaz - colorless; long prismatic crystals.
Ilmenite - small granular grains; black color.

Sample Number 3. This sample was collected near the bottom of a small creek in NW 1/4 of Sec. 33, T. 2 S., R. 66 W. The sandstone has a yellowish brown color.

Mineral Composition:

Quartz - grains very fine and well rounded. Colorless and transparent. Abundance - 85 per cent.
Calcite - acts as cementing material in the sandstone. Fairly abundant - about 14 per cent.
Biotite - good tabular hexagonal prisms.
Muscovite - small flakes of light color; sheets are tabular.
Magnetite - well rounded, few grains show some crystal faces.

Sample Number 4. Sandstone sample collected in the SW 1/4 of Sec. 28, T. 2 S., R. 65 W. This sandstone has a buff color, and fine to medium texture.

Mineral Composition:

Quartz - fairly uniform in size and shape. Several grains are stained with iron. Average size is about 0.28 millimeter. Abundance - 80 per cent.
Calcite - creamy white color. Acts as the cementing material in the sandstone.
Tourmaline - black color grains. Grains are irregular in size and shape.
Biotite - thin tabular hexagonal prisms.
Chert - small, black color, irregular grains.
Garnet - reddish brown color; irregular grains.
Sample Number 5. This sample was collected near sample four and in the N E 1/4 of Sec. 33, T. 2 S., R. 65 W. The sandstone has a dark gray color, some banding, and cross-bedding is evident at the outcrop.

Mineral Composition:

Quartz - grains are fine and uniform in size. Average size about 0.25 millimeter. Angular to subangular shape. Abundance - about 85 per cent.

Calcite - pale yellow color. Acts as cementing material. Abundance - about 14 per cent.

Biotite - occurs as small flakes or as well formed hexagonal prisms.

Sample Number 6. Sample was collected in the N E 1/4 of Sec. 5, T. 3 S., R. 65 W. This light gray sandstone is fine grain with a few large fragments scattered throughout it. The sample shows some banding.

Mineral Composition:

Quartz - fine; uniform size grains; slight iron staining on a few; angular to round in shape. Abundance - about 30 per cent.

Calcite - white to light gray color. Acts as the cementing material.

Hornblende - found in long prismatic crystals; dark green color.

Muscovite - light brown color and found only as small thin plates.

Magnetite - well rounded. Black color.

Organic matter is found scattered throughout the specimens.

Sample Number 7. The sample was collected at a point on the south bank of a creek in S E 1/4 of Sec. 5, T. 3 S., R. 65 W. The sandstone has a reddish brown color, fine texture, very hard, and contains some plant remains.
Mineral Composition:

Quartz - colorless; subangular to round grains; several iron stained.
Calcite - dull gray color. Rather abundant - 18 per cent.
Muscovite - very small amount. Occurs as flakes.
Magnetite - trace.
Organic content high.

Sample Number 26. The sample was collected at an outcrop of sandstone at the bottom of a wash in N E 1/4 of Sec. 3, T. 3 S., R. 66 W. The sandstone is loosely consolidated and has a yellowish brown color.

Mineral Composition:

Quartz - iron stained; subangular; uniform size; and a few show marked degree of rounding.
Muscovite - small flakes of light color.
Calcite - dull white color. Very small amount.
Gypsum - few nail-head crystals of selenite.

Sample Number 26-1. This sample was taken at a shale outcrop underlying the above described sandstone. (Sample 26). The sandy shale has a light gray to brown color and contains numerous plant remains.

Mineral Composition:

Quartz - iron stained grains which are subangular to round in shape. Average size about 0.50 millimeter. Abundance - about 30 per cent of the original sample.
Gypsum - several nail-head crystals of selenite. Average size about 2.50 millimeters. Transparent and white milky color.
Biotite - small prisms.
Glauconite - all show marked degree of rounding. Greenish color.
Tourmaline - black color; usually fragments of crystal.
Sample Number 27-1. This sample was collected at the bottom of a gully in the N E 1/4 of Sec. 3, T. 3 S., R. 66 W. It was taken from a thin bed of black shale which contains numerous plant leaves and twigs.

Mineral Composition:

Calcite - very small amount probably less than one per cent.
Anhydrite - small cubes. Less than one per cent.
Biotite - small flakes. Less than one per cent.
Organic matter makes up the greater share of this specimen.

Sample Number 27-2. The sample comes from a sandstone which overlies the black shale (Sample 27-1). The yellowish gray sandstone is loosely consolidated and contains a few plant remains. The grains are uniform in size.

Mineral Composition:

Quartz - coarse grains; uniform size; and slight amount of iron staining. Average size of the grains about 0.65 millimeter. Abundance - 90 per cent.
Garnet - pink color; irregular fragments; transparent. Rather abundant - about 5 per cent.
Monazite - slightly rounded yellow grains.
Magnetite - few grains. Mostly round; some irregular. Light coating of limonite.
Tourmaline - few crystal fragments; black color.

Sample Number 27-3. Sample comes from a loosely consolidated sandstone layer which is 6 feet from the bottom of the gully. The sandstone has light purple color and is easily recognized. This sandstone contains several leaf and twig fragments.
Mineral Composition:

Quartz - grains are slightly stained. Subangular to round in shape. Size is uniform.
Biotite - good hexagonal prisms.
Unknown - small hexagonal prisms which have a reddish brown color. The diameter varies between 0.20 and 2.00 millimeters. Appears to be several small disks cemented or grown together. Specific gravity less than 2.84.

Sample Number 27-A. Sample was collected at a point along the bottom of the gully. The rock is a light brown arenaceous shale which contains numerous plant remains. The sample was washed and the following minerals determined.

Mineral Composition:

Quartz - very fine; well rounded; colorless grains.
Tourmaline - few crystal fragments; black color; few show good hexagonal outline.
Biotite - few small sheets of mica.
Limonite - few small irregular masses; yellow brown color.

Sample Number 29. This sample was collected along the south bank of the creek in S E 1/4 of Sec. 29, T. 2 S., R. 65 W. The sandstone makes good exposure at several places along the creek. It is light gray color, very resistant, and high in calcium carbonate.

Mineral Composition:

Quartz - grains well rounded; fine; colorless.
  Average size of grains about 0.25 millimeter. Abundance - about 75 per cent.
Calcite - white color; massive; acts as cementing matter in the sandstone.
Gypsum - few small crystals of selenite. Colorless.
Muscovite - small light color flakes.
Sample Number 30. This sample was collected about one hundred yards east of sample 29. The rock is a reddish brown, very hard, calcareous sandstone. The sandstone is fine grain, contains several leaves of deciduous trees, and slight banding.

Mineral Composition:

Quartz - fine grain; subangular in shape; and uniform size. Average size about 0.30 millimeter. Strong iron staining. Some grains show marked degree of rounding.
Calcite - brownish color; and massive. Acts as cementing material in the sandstone.
Muscovite - small flakes; light brown color.
Chert - black color; glassy; irregular shape grains.
Biotite - good tabular prisms.
Magnetite - few crystals, with many fragments.
Slight coating of limonite on some grains.

Known Denver Exposures:

Sample Number 31. This sample was taken from a sandstone member at the base of the Denver formation near Golden, Colorado. It is a dark gray to yellow-brown color, medium texture, loosely consolidated sandstone.

Mineral Composition:

Quartz - grains iron stained; angular; few grains showing marked degree of rounding. Number of grains are colorless. Average size about 0.60 millimeter. Abundance - about 80 per cent of the sample.
Calcite - pale yellow color; probably the cementing material in the sandstone. Fairly abundant - about 10 per cent.
Biotite - occurs as good tabular prisms.
Muscovite - thin flakes of mica. Usually light golden color.
Magnetite - small uniform grains along with few crystals. Strongly magnetic. Rather abundant - about 8 per cent.
Olivine - light transparent green crystals. Long prismatic habit, usually not altered.
Chert - few pieces of black glassy fragments.
Unknown - small reddish brown color prism. Similar to that in Sample No. 27-3.

**Sample Number 32.** Sample was collected at an outcrop on Toll Gate Creek in the S W 1/4 of T. 4 S, R. 66 W. The rock is a loosely consolidated, light yellow gray sandstone. Very coarse texture and the grains are fairly uniform in size. Similar to Sample One.

**Mineral Composition:**

- **Quartz** - angular to subangular shape; few show marked degree of rounding. Average size about 0.70 millimeter. Abundance - about 75 per cent.
- **Calcite** - acts as cementing matter; usually dirty white color. Slight staining by iron. Fairly abundant.
- **Magnetite** - abundant; uniform size; and well rounded to subangular in shape. Strongly magnetic.
- **Feldspar** - possibly orthoclase. Pink color and irregular masses. Some altered.
- **Garnet** - few pieces; brown color; mostly broken fragments.
- **Tourmaline** - black color; occasional crystal, but generally fragments.

**Sample Number 32.** This sample was collected at an outcrop near sample 32. The sandstone has a dark yellowish brown color, coarse grain, and irregular grain size. The sample comes from an outcrop along the west bank of Toll Gate Creek.

**Mineral Composition:**

- **Quartz** - abundant; angular to round; slightly iron stained; and irregular in size. Average size about 0.50 millimeter. Some secondary quartz.
- **Magnetite** - abundant; well rounded to subangular; uniform size grains. Few good octohedron crystals.
- **Biotite** - good black tabular prisms.
Muscovite - small amount.
Calcite - dull yellow color, acts as cementing agent.
Limonite - found as coating on the magnetite grains.

Sample Number 34. This sample was a part of a sandstone boulder found in the same locality as samples 32 and 33. The sandstone is hard, strongly magnetic, and gray brown color.

Mineral Composition:
Quartz - well rounded; iron stained; uniform in size. Average size about 0.35 millimeter. Abundance - about 70 per cent.
Calcite - irregular masses around the grains. Gray color.
Magnetite - abundant enough to cause the sandstone to be magnetic. Uniform size and rounded shape.
Limonite - as coating on the magnetite grains.
Muscovite - fairly large tabular sheets; light silver gray color.
Biotite - good tabular prisms. Few flakes scattered throughout sample.

Known Laramie Exposures:

Sample Number 35. This sample was taken from the clay pits near Golden, Colorado. The sandstone has a distinct yellow color, even grain, and medium texture.

Mineral Composition:
Quartz - medium grain and uniform size. Grains are subangular to angular in shape and show some signs of iron staining.
Biotite - scattered flakes throughout the specimen. Brown to black in color; small pieces.
Tourmaline - black color; in long prismatic crystals; and opaque; several small crystal fragments.
Calcite - brownish color due to iron stain. Small amount present.
Topaz - one crystal terminated on one end. Brown color.
Magnetite - very small amount, often stained with limonite. Very magnetic.
**Sample Number 36.** This sample of known Laramie was also collected at the clay pits near Golden, Colorado. It is a fine grain, light yellow gray sandstone.

**Mineral Composition:**

- **Quartz** - fine grain, subangular to rounded, and fairly uniform in size. Average size of grains about 0.30 millimeter. Abundance - about 90 per cent.
- **Calcite** - a small amount of calcite is present and acts as a cementing agent.
- **Muscovite** - several small flakes; silver gray color.
- **Unknown** - black staining material probably manganese dioxide.

**Summary**

The above laboratory examinations have revealed certain factors which may have some bearing on the solution of the problem. These are: (1) the mineral content of the Derby samples corresponds closely to that of the Denver formation and (2) the character and proportion of the mineral assemblage of the Derby samples are similar to those of the Denver formation.

In most cases, the writer found the Derby samples to consist mostly of quartz with small amounts of impurities and sometimes chert. These characteristics might possibly place the formation at Derby dome in the Laramie series, except for the fact that certain characteristics of the Denver formation were also found. These characteristics are: (1) the presence of constituent of eruptive rocks -- obsidian, olivine, hornblende, and feldspar; and (2) the large amount of calcite in many of the sandstones.
Heavy Mineral Determination

A heavy mineral determination was made on several of the sandstone samples gathered in the Derby dome and outlying areas. The samples included eight from the Derby area, four from known Denver area, and two from known Laramie formation.

The results and the percentage of heavy minerals present in each sample are tabulated below.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Original Weight</th>
<th>Heavy Mineral Weight</th>
<th>Percentage Heavy Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Derby</td>
<td>13.392 grs.</td>
<td>0.080 grs.</td>
<td>0.60%</td>
</tr>
<tr>
<td>1-1</td>
<td>6.695 grs.</td>
<td>0.015 grs.</td>
<td>0.45%</td>
</tr>
<tr>
<td>2 Denver</td>
<td>12.088 grs.</td>
<td>0.065 grs.</td>
<td>0.54%</td>
</tr>
<tr>
<td>4 Denver</td>
<td>10.415 grs.</td>
<td>trace</td>
<td>0.00</td>
</tr>
<tr>
<td>5 Denver</td>
<td>8.052 grs.</td>
<td>trace</td>
<td>0.00</td>
</tr>
<tr>
<td>6 Denver</td>
<td>9.600 grs.</td>
<td>trace</td>
<td>0.00</td>
</tr>
<tr>
<td>29 Denver</td>
<td>12.090 grs.</td>
<td>0.010 grs.</td>
<td>0.08%</td>
</tr>
<tr>
<td>30 Denver</td>
<td>4.460 grs.</td>
<td>0.010 grs.</td>
<td>0.25%</td>
</tr>
<tr>
<td>31 Laramie</td>
<td>16.260 grs.</td>
<td>0.850 grs.</td>
<td>5.20%</td>
</tr>
<tr>
<td>32 Laramie</td>
<td>18.885 grs.</td>
<td>0.545 grs.</td>
<td>2.80%</td>
</tr>
<tr>
<td>33 Laramie</td>
<td>12.495 grs.</td>
<td>0.135 grs.</td>
<td>1.08%</td>
</tr>
<tr>
<td>34 Laramie</td>
<td>14.288 grs.</td>
<td>0.432 grs.</td>
<td>3.00%</td>
</tr>
<tr>
<td>35 Laramie</td>
<td>10.632 grs.</td>
<td>0.018 grs.</td>
<td>0.10%</td>
</tr>
<tr>
<td>36 Laramie</td>
<td>13.415 grs.</td>
<td>0.025 grs.</td>
<td>0.18%</td>
</tr>
</tbody>
</table>
Listed below are the results of the microscopic examination on all heavy mineral separations examined.

Derby Dome Samples

Sample Number 1.

Magnetite - black color grains; some show good crystals. Composes about 60 per cent of sample. Magnetism strong.
Barite - dull yellow color; soft; and translucent. About 30 per cent of the mineral content.
Garnet - pink color; transparent; angular fragments. Shows some conchohal fracture.
Biotite - good tabular prisms; also few small flakes.
Feldspar - few white to gray color grains.
Topaz - few colorless; well formed crystals.
Ilmenite - few rounded; black color fragments; metallic luster.
Tourmaline - black color; broken; opaque crystals; few fragments.

Sample Number 1-1.

Magnetite - about 50 per cent of the mineral content. Uniform grains with a few good crystal prisms and pyramids.
Topaz - Many fragments with a few crystals. Colorless to light brown. About 30 per cent of mineral content.
Biotite - good hexagonal prisms.
Garnet - reddish brown color; opaque fragments. Few pieces; pink color; transparent.
Barite - pale yellow color; uneven size; irregular grains. Occurs with magnetite.
Feldspar - small amount; massive grains.
Tourmaline - dark brown to black color; few broken crystals.

Sample Number 2.

Magnetite - abundance - about 50 per cent. Uniform; well rounded; black color; slight limonite coating on grains.
Topaz - rather abundant - about 30 per cent. Colorless to brown; angular to well rounded fragments. Few small crystals.
Olivine - few well formed orthorhombic crystals; prismatic habit; few broken fragments; light shade of green and transparent.

Biotite - good tabular hexagonal prisms; few flakes.
Carnet - pink to red color; transparent; angular grains.

Tourmaline - black color; prismatic crystals.
Feldspar - few pieces of feldspar; possible orthoclase. Altered.

Ilmenite - few small grains; jet black color.
Chert - dark gray color; transparent to translucent; and well rounded.
Unknown - blue-green color; angular; opaque grains.

Sample Number 4.

Magnetite - total number of grains in entire heavy minerals -- 11. About 90 per cent are magnetite coated with limonite.

Topaz - one broken crystal of colorless topaz.

Sample Number 5.

Magnetite - black color; well rounded to subangular shape; uniform size. About 40 per cent.
Limonite - irregular shape; brown color; and about 40 per cent of mineral content.

Topaz - few small prismatic crystals.
Tourmaline - black color; opaque; small number of grains.

Biotite - hexagonal tabular prisms.
Olivine - few dark green color; transparent crystals.
Ilmenite - few grains; black color.
Chert - black color; glassy; angular shape.
Unknown - blue transparent; angular grains.

Sample Number 6.

Magnetite - small amount of heavy minerals; Magnetite makes up about 99 per cent. Coated with barite.

Hornblende - dark green color; few cleavage faces. Small amount present.
Barite - occurs as coating and pieces on the magnetite.
Sample Number 29.

Magnetite - very fine grains; uniform size; and makes up about 50 per cent of minerals.
Topaz - golden to colorless grains and crystals. Usually transparent and irregular size.
Muscovite - silver gray color; flakes.
Biotite - small flakes; some hexagonal prisms.
Tourmaline - broken crystals; black color; and opaque.
Barite - pale yellow color; irregular shape; and small grains.
Chert - black; glassy grains.
Garnet - pink to red color; angular; uniform size; transparent grains.
Ilmenite - jet black color; irregular shape.

Sample Number 30.

Magnetite - well rounded to subangular grains. Makes up about 95 per cent of the minerals present.
Feldspar - dull gray white color; some being altered.
Barite - occurs as small pieces cemented to the magnetite.
Muscovite - small amount of silver gray mica.

Known Denver Formation

Sample Number 31.

Magnetite - small prisms and pyramids; many broken fragments. Barite cemented to grains. Abundance - about 90 per cent.
Topaz - colorless; crystals; broken fragments; angular to subangular in shape. Usually transparent.
Barite - dull pale yellow color; angular shape; found on the magnetite grains.
Biotite - several good hexagonal tabular prisms.
Olivine - long prismatic crystals; light green color.

Sample Number 32.

Magnetite - uniform size; subangular shape; black color; coated with barite. Abundance - about 50 per cent.
Topaz - colorless to brown; angular to subangular; few long prismatic crystals. Rather abundant - about 30 per cent.

Olivine - transparent; green color; mostly long prismatic crystals. Few grains present.

Biotite - good hexagonal prisms; few small flakes.

Feldspar - few pieces; altered; white color.

Garnet - angular; pink color; transparent; and uneven in size.

Ilmenite - angular to subangular; black color; and opaque.

Tourmaline - black color; opaque; few good crystals; many fragments.

Sample Number 33.

Magnetite - black opaque; few crystals; many fragments; subangular. Abundance - about 90 per cent.

Biotite - few good hexagonal tabular prisms.

Topaz - yellow color; transparent; crystals; and rounded grains.

Tourmaline - black color; opaque; good crystals along with fragments. Makes up about 3 per cent of sample.

Olivine - green color; transparent; long prismatic crystals.

Muscovite - occurs as small thin sheets.

Garnet - reddish brown color; opaque; and irregular shape.

Ilmenite - black color; angular; and fairly abundant, about 3 per cent.

Barite - as coating and pieces on magnetite. Few free.


Unknown - blue green color; transparent crystal.

Sample Number 34.

Magnetite - black color; uniform size; angular to subangular shape. Abundance - about 85 per cent.

Biotite - hexagonal prisms.

Barite - dull yellow color; angular; fine pieces.

Topaz - few colorless grains and crystals; transparent.

Hornblende - good cleavage faces; dark green color.

Tourmaline - black color; opaque; and uneven shape.

Zircon - brown opaque crystal; shows good termination.
Known Laramie Formation

**Sample Number 35.**

- Magnetite - uniform size; angular shape; black color.
- Tourmaline - black color; opaque; few good crystals; many fragments.
- Topaz - yellow brown color; few grains. Transparent.
- Biotite - few hexagonal prisms.

**Sample Number 36.**

- Magnetite - trace.
- Muscovite - small thin sheets of silver gray mica.

**Summary**

The writer concludes that correlating the Derby exposures with some formation of known age, by means of heavy mineral content, is of little value in this case. As shown in the above results, the percentage of heavy minerals did not check. Heavy mineral correlation can be used only if the samples come from a known part of a formation. The heavy mineral content shows only that the same mineral assemblage is the same for all Derby dome samples. This suggests that all exposures in the Derby area are parts of the same formation.
Insoluble Residue Determination

An insoluble residue determination was made on all samples which contained any appreciable amount of calcium carbonate. The results, giving the percentage of calcium carbonate content, are tabulated below.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Original Weight</th>
<th>Final Weight</th>
<th>Percentage of CaCO₃ content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Derby</td>
<td>9.67 grs.</td>
<td>6.08 grs.</td>
<td>37%</td>
</tr>
<tr>
<td>1-1</td>
<td>7.55</td>
<td>4.50</td>
<td>41%</td>
</tr>
<tr>
<td>2</td>
<td>8.84</td>
<td>5.51</td>
<td>38%</td>
</tr>
<tr>
<td>4</td>
<td>8.07</td>
<td>4.69</td>
<td>42%</td>
</tr>
<tr>
<td>5</td>
<td>7.02</td>
<td>3.85</td>
<td>45%</td>
</tr>
<tr>
<td>6</td>
<td>7.18</td>
<td>3.18</td>
<td>56%</td>
</tr>
<tr>
<td>29</td>
<td>9.69</td>
<td>6.15</td>
<td>37%</td>
</tr>
<tr>
<td>30</td>
<td>8.41</td>
<td>4.20</td>
<td>50%</td>
</tr>
<tr>
<td>31 Denver</td>
<td>9.26</td>
<td>5.75</td>
<td>38%</td>
</tr>
<tr>
<td>32</td>
<td>8.73</td>
<td>4.82</td>
<td>45%</td>
</tr>
<tr>
<td>33</td>
<td>6.29</td>
<td>3.68</td>
<td>42%</td>
</tr>
<tr>
<td>34</td>
<td>8.79</td>
<td>4.76</td>
<td>46%</td>
</tr>
</tbody>
</table>

The mineral content of the insoluble residues is listed below:

Sample Number 1.

Quartz - subangular to round; uniform size; colorless to smoky; transparent to translucent. Abundance - about 90 per cent.

Chert - several black pieces; angular shape.
Topaz - colorless; transparent; and basal cleavage present.
Glaucnite - light green color; pebbles; well rounded.
Garnet - pink color; transparent; angular grains.
Magnetite - black color; magnetic; uniform size.
Muscovite - very small amount.
Tourmaline - black color; opaque; and a few good crystals along with fragments.
Barite - pale yellow color; irregular shape.
Jasper - one piece of red jasper.
Feldspar - light gray color; badly altered.

Sample Number 1-1.

Quartz - medium to fine grains; subangular; transparent; slight iron staining.
Abundance - about 90 per cent.
Feldspar - badly altered.
Biotite - well formed hexagonal prisms.
Magnetite - well rounded to subangular; uniform size.
Topaz - colorless to brown; fragments and prismatic crystals; transparent.
Garnet - few pink color; angular; transparent grains.
Tourmaline - few pieces; black color.

Sample Number 2.

Biotite - good hexagonal prisms; black color.
Feldspar - white color; few grains.
Magnetite - magnetic; uniform size; subangular; black color.
Quartz - rounded to subangular; colorless to smoky; few grains of secondary quartz.
Abundance - about 85 per cent.
Muscovite - thin flakes; small; yellow brown color.
Topaz - colorless to brown; crystals along with fragments.
Chert - black color; glassy material.
Jasper - few small grains of red quartz.

Sample Number 4.

Quartz - very fine grains; angular to round; uniform. Grains are stained with iron in some cases.
Muscovite - few small flakes.
Jasper - two small pieces of red quartz.
Magnetite - small; uniform size.
Gypsum - small amount of nail-head crystals of selenite; colorless to milky.
**Sample Number 5.**

Quartz - angular; some show marked degree of rounding; colorless. Abundance - about 95 per cent.

Biotite - small flakes.
Muscovite - small; thin silver gray color grains.
Feldspar - badly altered; pale gray color; massive.
Topaz - colorless to light brown; few good crystals.
Talc - few small pieces.
Magnetite - uniform size; subangular shape; black color.
Limonite - some yellow-brown color grains present.

**Sample Number 6.**

Quartz - very fine grains; often stained yellow.
Abundance - about 95 per cent.
Organic matter - plant remains.

**Sample Number 29.**

Quartz - mostly angular; occasional well rounded grains. Abundance - about 99 per cent.
Ilmenite - opaque; black color; irregular grains.
Barite - dull yellow color; massive; and angular.
Topaz - light yellow color; good crystal.
Jasper - red color; conchoidal fracture.
Biotite - small black flakes.

**Sample Number 30.**

Quartz - colorless; some grains stained by iron; angular to subangular shape. Fine grain and uniform shape.
Muscovite - thin tabular sheets.
Limonite - present as coating on magnetite.
Magnetite - few small rounded to subangular grains.
Ilmenite - angular; irregular shape masses.

**Sample Number 31.**

Feldspar - very few grains of dull white color.
Quartz - angular; coarse grains; some iron staining.
Abundance - about 85 per cent.
Magnetite - small subangular grains.
Biotite - well formed hexagonal prisms.
Muscovite - thin tabular sheets.
Actinolite - green color; bladed masses.
Unknown - reddish pink color; angular grain.
Sample Number 32.
Quartz - colorless; sometimes stained by iron; subangular; uneven form. Percentage about 85 per cent.
Biotite - good hexagonal tabular prisms.
Muscovite - thin plates.
Olivine - prismatic crystals; light green color. Some transparent.
Tourmaline - black color; opaque; few good crystals; others broken. Irregular shape.
Magnetite - uniform size; well rounded to angular shape.

Sample Number 33.
Quartz - well rounded; colorless grains. Uniform size. Abundance - about 80 per cent.
Magnetite - subangular shape; uniform size; strongly magnetic.
Topaz - prismatic crystals; few broken fragments; colorless to brown.
Muscovite - thin tabular plates.
Glauconite - well rounded grains; light green color.

Sample Number 34.
Quartz - coarse; few rounded grains. Slight iron staining.
Magnetite - strongly magnetic; uniform size; subangular shape.
Biotite - few hexagonal tabular plates.
Topaz - few colorless crystals.
Limonite - some masses of yellow-brown color grains.

Summary

The writer is of the opinion that from the above results, the formation at Derby dome may possibly be part of the Denver formation. The basis of this reasoning is that several sandstones at Derby dome have a very high content of calcium carbonate. They correspond to the high lime content sandstone members of the Denver formation.
CONCLUSIONS

In summary, there are certain important features of the strata of the Derby dome area which may be of value for correlation purposes. These are: (1) small sink-hole depressions; (2) the presence of sandstone boulders, from five to seven feet in diameter, embedded in soft loosely consolidated sandstone; (3) a sandstone layer made up of nodules joined together to form a bed of uniform thickness; (4) very gentle dips; (5) certain characteristic minerals; (6) a similar assemblage of heavy minerals in all samples from the Derby dome area; (7) the existence of samples containing a high percentage of calcium carbonate; (8) plant remains found in some places lying perpendicular to the bedding plane; and (9) petrified wood in some areas.

All of the above features are characteristic of the Denver formation. Such constituents as hornblende, olivine, and obsidian found in the Derby and known Denver samples adds to the belief of the writer that the Derby sediments may represent the Denver formation.

Other characteristics observed, which would possibly place the Derby dome exposures in the Laramie formation, are: (1) chert is present in several Derby dome samples; (2) the mineral content consists mostly of quartz grains and some impurities; (3) impure lignitic material is interbedded with some shales; (4) plant remains are similar to those of the Laramie group; and (5) the samples examined from Derby
dome and Laramie formations are low in heavy minerals.

The writer believes that since chert is found in both the Denver and Laramie formations, it should not be used as a definite criterion for correlating with the Laramie formation. The heavy mineral content may differ unless samples come from the same stratigraphic horizon of a given formation. The plant remains are so much alike in the Denver and Laramie formations that they cannot be definitely distinguished from one another. The mineral assemblage, except for andesitic debris, are too similar to be distinguishable.

Because of the results of the heavy mineral determination of the Derby dome samples and from the fact that the exposures in the area have no measurable dips, the writer is of the opinion that most of the outcrops in the Derby area are part of the same formation.

The writer concludes from the results of the field and the laboratory examinations of the exposures at Derby dome and the outlying areas of known Denver and Laramie formations that the surface formation at Derby dome is part of the Denver formation. The writer is also of the opinion, because of the similarity in the results of the Denver, Laramie, and Derby exposures, that the Denver formation, as known today in the Plains area, is actually part of the Laramie group.
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Parker, B. H.


Waldschmidt, W. A.
APPENDIX
**DRILLER'S LOG OF EMAN OIL CORPORATION'S #1 WELL**

S E Section of Section 28  
Township 3 South, Range 64, Adams  
County, Colorado

<table>
<thead>
<tr>
<th>Depth</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>60'</td>
<td>Alluvium</td>
</tr>
<tr>
<td>67</td>
<td>Coal and shale</td>
</tr>
<tr>
<td>150</td>
<td>Soapstone</td>
</tr>
<tr>
<td>154</td>
<td>Lime</td>
</tr>
<tr>
<td>198</td>
<td>Shale</td>
</tr>
<tr>
<td>200</td>
<td>Coal</td>
</tr>
<tr>
<td>228</td>
<td>Black shale</td>
</tr>
<tr>
<td>280</td>
<td>Gray slate</td>
</tr>
<tr>
<td>293</td>
<td>Lime</td>
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<td>Sand</td>
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<td>Black slate</td>
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<td>804</td>
<td>Brown sand</td>
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<tr>
<td>860</td>
<td>Brown shale</td>
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<td>Iron</td>
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<td>1575</td>
<td>Lime</td>
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<td>Sand</td>
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<tr>
<td>1583</td>
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<tr>
<td>1665</td>
<td>Sand</td>
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<tr>
<td>1735</td>
<td>Sandy lime</td>
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<tr>
<td>1780</td>
<td>Sandy shale</td>
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<tr>
<td>1795</td>
<td>Shale</td>
</tr>
<tr>
<td>1819</td>
<td>&quot;Calcite and wax&quot;</td>
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</table>
Center of S W 1/4 of Section 2
Township 3 South, Range 66 West,
Adams County, Colorado

Elevation 5425

0 - 12 Soil
12 - 40 Hard coarse sand
40 - 95 Coal
95 - 105 Coal
105 - 420 Dark brown sandy shale
420 - 440 Water sand
440 - 530 Sandstone—very hard
530 - 600 Dark gray shale
600 - 640 Shaley sand about 95% sand
640 - 680 Dark gray shale
680 - 715 Sand
715 - 760 Sandy black shale with gumbo
760 - 795 Hard sand water
795 - 815 Shale
815 - 825 Gumbo
825 - 840 Sandy shale
840 - 875 Water sand—Water filled to within 200 feet of top. This virtually is quicksand.
875 - 890 Sandy shale

(At this point, the well set for several weeks, then started to produce water from same when a good showing of natural gas showed up in the water whenever the bailer was run—gas would also bring sand from bottom and bridge 300 feet up in pipe; 6¾" casing set at 760. Because of the gas, it was decided to underrean pipe and drill well on deeper in hopes of securing sufficient gas in Milliken sand for fuel on big well.)
890 - 1004 Broken shale gray light
1004 - 1034 Water sand
1034 - 1168 Blue shale
1168 - 1215 Sandy shale
1215 - 1225 Blue shale
1225 - 1251 Sand
1251 - 1275 Dark shale with lime shells sticky (probable top of Pierre). Samples taken here identified as Pierre shale by Waldschmidt.

1275 - 1280 Hard sand
1280 - 1375 Black shale with lime shells with the streaks containing quite a bit of wax, very sticky.

(Shale at 1315 feet identified as Pierre by Waldschmidt).

(N.B. The above log, to 890 deep, was taken by Charles T. Lupton, before his death. The balance of the log, from 890 on to 1375, was obtained by J. W. Clayton, while the well was being drilled. Down to this depth, 1375, this log is taken from the water well, drilled by national machine tools. Balance of log is driller's log with rotary tools).

1375 - 1440 Shale shells
1440 - 1472 Sticky shale
1472 - 1503 Shale
1503 - 1547 Broken lime and shale
1547 - 1585 Hard sandy shale and lime
1585 - 1602 Shale lime shells
1602 - 1620 Broken sandy lime
1620 - 1686 Sandy shale
1686 - 1690 Sandy lime
1690 - 1691 Lime
1691 - 1750 Shale lime shells
1750 - 1753 Hard lime
1753 - 1756 Sandy lime
1756 - 1766 Broken sandy shale
1766 - 1789 Sandy shale
1789 - 1809 Shale shells
1809 - 1814 Lime shells
1814 - 1869 Shale shells
1869 - 1928 Shale shells
1928 - 1935 Shale shells
1935 - 1945 Shale shells
1945 - 1995 Shale shells
1995 - 2005 Shale and sand
2005 - 2015 Shale and sand
2015 - 2048 Shale and sand
2048 - 2054 Sand gas (Estimated 2 to 3 million cubic feet)
2054 - 2070 Sandy shale gas
2070 - 2085 Shale shells sand gas
2085 - 2105 Shale shells gas
2105 - 2127 Sandy shale - some gas still showing
2127 - 2137 Shale shells - " " " "
2137 - 2160 Shale broken sand - some gas still showing
2160 - 2175 Shale and sand - " " " "
2175 - 2195 Shale and sand - " " " "
2195 - 2264 Shale and shells - " " " "
2264 - 2270 Sand Gas (Estimated 2,000,000 cubic feet)
2270 - 2280 Sandy shale - Some gas still showing
2280 - 2298 Sandy shale - Bentonite " "
2298 - 2312 Shale shells - some gas still showing
2312 - 2325 Shale shells - " " " "
2325 - 2350 Sandy shale - " " " "
2350 - 2360 Sandy shale - " " " "
2360 - 2375 Sand and shells - " " " "
2375 - 2394 Broken sand and shells
2394 - 2402 Sandy shale - " " " "
2402 - 2412 Shale shells - some gas still showing
2412 - 2450 Sandy shale - " " " "
2450 - 2494 Shale and shells - " " " "
2494 - 2515 Shale and shells - " " " "
2515 - 2550 Hard shells - " " " "
2550 - 2556 Pyrites of iron - " " " "
2556 - 2562 Sand and shells - " " " "
2562 - 2602 Shale and shells - " " " "
2602 - 2620 Sand (showing of oil and gas. Oil estimated
2620 - 2830 Sandy shale (Gas estimated 3 to 4 million cu.ft.)
2830 - 2836 Hard sand
2836 - 2855 Sandy shale
2855 - 2879 Sticky shale (Bentonite)
2879 - 2895 Sandy shale
2895 - 2944 Broken sand and shells
2944 - 2969 Sandy shale
2969 - 3002 Shale and shells
3002 - 3127 Sandy shale
3127 - 3155 Shale
3155 - 3270 Sandy shale
3270 - 3275 Shale shells
3275 - 3285 Shale sand shells
3285 - 3306 Shale shells
3306 - 3699 Sandy shale
3699 - 3711 Shale
3711 - 3785 Sandy shale (75% sand)
3785 - 3796 Bentonite
3796 - 3875 Shale and sand
3875 - 3905 Shale (Brown sand)
3905 - 3962 Sandy shale
3962 - 3980 Shale Bentonite
3980 - 4124 Brown sandy shale
4124 - 4138 Shale Bentonite
4138 - 4143 Brown sandy shale
4143 - 4149 Sand showing light green oil and gas
4149 - 4286 Sandy shale
4286 - 4298 Shale Bentonite
4298 - 4331 Sandy shale (Brown sand)
4331 - 4362 Sticky shale (Bentonite)
4362 - 4366 Bentonite
Hand (Brown) Home oil showing  
Brown gray shale. Slightly sand and gritty. Few sand fragments.

Dark gray shale. Slightly sand and gritty. Few sand fragments.

Dark gray shale. Slightly sand and gritty. Still gritty.

Dark gray shale. Slightly sand and gritty. Few sand fragments.

Shale rather hard and compact. Still gritty.

Dark gray shale. Similar to above. Occasional limy fragment. Little pyrite. Very small amount of grit and sand. Sand is about 0.20 to 0.30 mm. Majority of grit is 0.30 mm.

Dark gray shale. Similar to above.

Dark gray sandy shale. Little increase in sand. Similar to above. Shale shows very slight lime content.

Dark gray sandy limy shale - similar to above. Not very limy.

Dark gray sandy limy shale - similar to above. Not very limy.

Dark gray sandy limy shale. Decrease in sand content.

Dark gray sandy shale (3). Shale similar to above. Sand very fine and somewhat shaley. Gray sand (1)

Gray sand. Similar to above.

Dark gray sandy shale - very lightly limy.

Examination of samples from the Baxter No. 1 well, from 12 to 4,368 feet, has been completed. On the basis of characteristics of the samples, it has been possible to determine certain formation contacts and to predict the depth to other formations. These determinations and predictions are as follows:

- Base of Laramie - Top of Fox Hills: 380 feet
- Base of Fox Hills - Top of Pierre: 1034 feet
- Top of Hygiene (in Pierre section): 1995 feet
- Base of Niobrara: 3205 feet
- Top of Niobrara (predicted) between 5100 & 5300 feet
- Top of Muddy; First sand of Dakota series (Predicted) between 6100 and 6300 feet

It is possible that any of the depths given above may be incorrect as much as 100 feet because of single samples representing many feet of section and because of mixing of sampler during drilling. The top of the Fox Hills (380 feet) is based on samples from the Baxter well, whereas, on information from the water well only a short distance from the Baxter well, the top of the Fox Hills could be placed at approximately 420 feet.

Similarly, the base of the Fox Hills as determined from the Baxter well is at 1034, whereas, on the water well information, it could be placed at 1040 feet or 1220 feet.

The top and base of Hygiene section are placed at 1995 and 3205 feet respectively in order to include the major
sandstone horizons. However, by including more sandy shale both higher and lower than the depths given, the top of the Hygiene could be placed at 1630 and the base at 3275 feet. Normally the Hygiene formation is between 1500 and 1600 feet thick. Therefore, on the basis of either 1995 to 3205 feet or 1640 to 3275 feet, the Baxter well is definitely through the Hygiene.

The base of the Hygiene (3205 feet) has been used to predict the depth to the Niobrara between 5100 and 5300 feet, and to the top of the Muddy (first sand of Dakota Series) between 6100 and 6300 feet. As soon as the exact top of the Niobrara is determined, more accurate predictions can be made as to the depth at which the top of the Muddy will be encountered.

Respectfully submitted,

MINERALOGICAL AND PETROGRAPHICAL LABORATORY

(signed) W. A. Waldschmidt
DRILLER'S LOG OF FITZSIMONS GENERAL HOSPITAL

Fitzsimons, Colorado
Township 3 South, Range 67 West
Adams County, Colorado

Elevation 5381

15'  Loam
36  Sand Gravel
40  Clay *
50  Brown shale
55  Blue shale
56' 6" Coal
64  Brown shale
69  Sandrock
84  Hard sand shale
99  Clay
167  Shale
169  Rock
283  Shale and clay
285  Sandrock
297  Clay
291  White sand
425  Clay and shale
430  Rock
440  Clay
452  Clay
460  Soft sand rock
575  Clay and shale
577  Rock
605  Soft sand rock
625  Clay
690  Shale (cave)
730  Sand rock (water)
790  Clay and shale
805  Hard sand rock
903  Sand rock (water)
927  Black shale
DRILLER'S LOG AURORA WELL

S E 1/4 S E 1/4 N W 1/4 of
Section 24
Township 3 South, Range 67 West
Adams County, Colorado

Elevation 5350 Topog.

100 Surface sand and gravel near top
126 Sand and gravel, water
182 Coal shale
216 Water in gravel
529 Soapstone and clay. Coal, shale and water "Scranton
coal", upper Laramie
810 Shale to the iron deposit
820 Water and gravel
830 Shale
1100 Lime shale water
1108 Lime shale water
1245 Shale and sand
1434 Shale, light colored
  Gas flow
1470 Shale, black
1474 Shales, black with shells
  Show of oil in shale
1540 Shale, brown
1550 Coal, Laramie
1680 Solid sand, carrying water
1690 Shale
1710 Sand, showing of oil
1740 Shale and limestone shells, Pierre
1850 Shale and limestone shells, Pierre
1950 Shale, shells, Pierre
  Showing of oil
2010 Shale and shells
2065 Oil sand
2122 Shale and shells
2220 Shale and shells
2400 Shale
2875 Shale, sandy, about 85 to 90% sand
2885 Hard lime
3020 Shale, sandy, about same % as above
3116 Shale becomes blue at 2900'. Shales blue sandy with
  hard shells 1" to 2" thick
3137 Shale, blue
3165 Shale, hard, blue-gray, considerable gas
3200 Shale soft, blue, gas
3212 Shale, limy hard, lighter in color, gas
3213 Shale, soft, scaly, black
3215 Shale, blue
3220 Shale, blue, gas
3240 Shale, gray, sandy, streaks of limestone
3250 Lime, hard
3260 Shale, gray
3270 Lime, hard
3280 Shale, gray
3292 Lime, hard
3295 Shale, gray
3300 Lime, hard
3305 Shale and gas
3320 Lime, hard
3328 Shale and gas
3340 Lime, hard
3350 Shale, gray, gas
3385 Lime
3375 Shale, blue
3390 Lime
3400 Shale, gas
3437 Lime
3460 Shale, sandy and gas
3474 Lime
3485 Shale, with oil
3492 Lime
3508 Shale
3525 Lime
3738 Shale
3742 Bentonite
3750 Shale, hard, gritty at base
3790 Shale, gray
MAGNETIC MAP OF DERBY DOME
COLORADO SCHOOL OF MINES
JANUARY 24, 1940
by
Brunnerfield, Manning,
Schottborn, Dissen,
Clark, Perelman,
Treated by:
Thomas