

GEOLOGY OF THE AREA  
SOUTHWEST OF FLORENCE, FREMONT COUNTY, COLORADO

By

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Golden, Colorado

May, 1951

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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 Science.

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## CONTENTS

	Page
Abstract . . . . .	1
Introduction . . . . .	2
Location of the Area . . . . .	2
Accessibility . . . . .	2
Purpose of Investigation . . . . .	2
Methods of Investigation . . . . .	3
Acknowledgements . . . . .	4
Geography . . . . .	5
Relief . . . . .	5
Drainage . . . . .	5
Climate . . . . .	5
Vegetation . . . . .	6
Culture . . . . .	6
Geomorphology . . . . .	7
Stratigraphy . . . . .	9
General Statement . . . . .	9
Details of Stratigraphic Units . . . . .	10
Pre-Cambrian . . . . .	10
Mesozoic . . . . .	10
Upper Cretaceous . . . . .	10
Dakota . . . . .	10
Benton . . . . .	12
Niobrara . . . . .	14
Pierre . . . . .	15

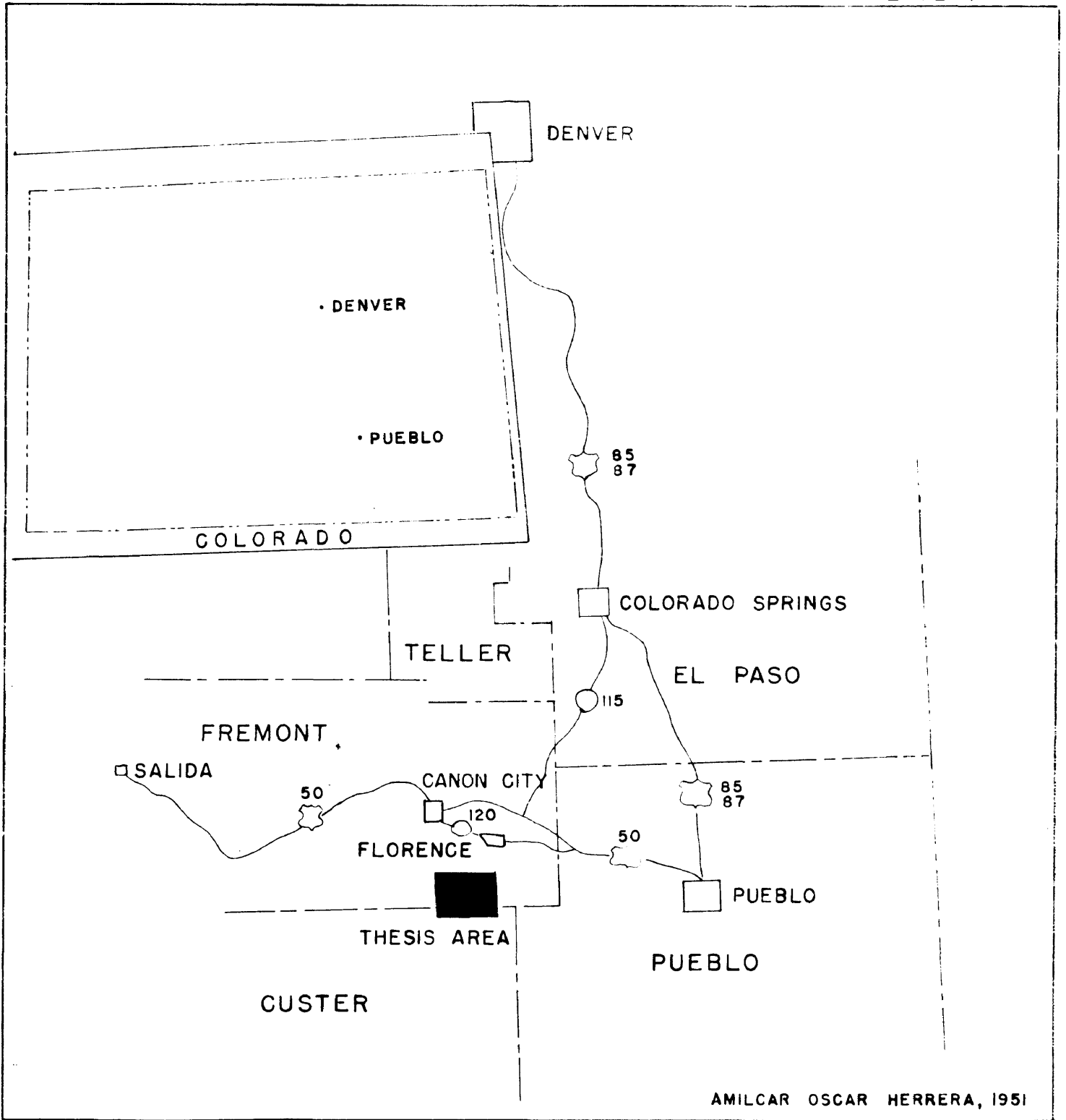
	Page
Trinidad . . . . .	17
"Laramie" . . . . .	18
Cenozoic . . . . .	20
Historical Geology . . . . .	21
Pre-Cambrian . . . . .	21
Paleozoic . . . . .	21
Mesozoic . . . . .	21
Structural Geology . . . . .	23
General Statement . . . . .	23
Faults . . . . .	23
Folds . . . . .	26
Economic Geology . . . . .	28
Coal . . . . .	28
Oil . . . . .	28
Clay . . . . .	28
Bibliography . . . . .	29

PLATES

I.	Location map . . . . .	page 1a
II.	Areal geologic map . . . . .	pocket
III.	General Stratigraphic Column . . . . .	pocket
IV.	Detailed Stratigraphic Column of "Laramie" Formation . . . . .	pocket
V.	Cross sections . . . . .	pocket

## ABSTRACT

The area discussed in this paper lies in the eastern foothills of the Wet Mountains of Colorado on the eastern flank of the Florence-Canon City syncline. The igneous and metamorphic rocks are pre-Cambrian in age and the sedimentary section is Upper Cretaceous. Generally the sediments dip at low angles, but near the contact with the pre-Cambrian complex, the structure is complicated by reverse faults, trending northwest-southeast, that overturn the sediments and place the pre-Cambrian rocks in contact with different formations from Dakota to "Laramie."



LOCATION MAP OF THE THESIS AREA

AMILCAR OSCAR HERRERA, 1951

INTRODUCTION

Location of the Area

The area mapped in this report comprises about thirty-four square miles of the eastern foothills of the Front Range of Colorado. It lies southwest of Florence in Fremont County and northwest of Wetmore in Custer County. It is bounded on the west by the pre-Cambrian rocks of the mountain front and on the east by State Highway 67. The southern boundary is about one mile south of the southern boundary of Fremont County. To the north the area ends three miles south of Florence. Plate I shows the location of the area and the highway which serves it. Plate II gives the location by township and range and the geology of the area studied.

Accessibility

The only paved roads in the area under consideration are Highways 67 and 276. The private roads in the western part of the area must be used with caution in wet weather. Plate II shows the road system.

Purpose of the Investigation

This investigation and the subsequent report were undertaken as a part of the requirements for the degree of Master of Science at the Colorado School of Mines. They are also part of a larger program initiated by the Graduate Committee of the Department of Geology of the Colorado School of Mines. This program will include the detailed mapping of all the sedimentary rocks along the eastern margin of the Front Range and the

publishing of a complete report on the area.

The area mapped by the writer is interesting, for it shows clearly the structural relationship between the pre-Cambrian complex of the Front Range and the sediments of the eastern foothills.

### Methods of Investigation

The field work for this report was started late in July, 1950, and was completed early in September of the same year. The first step was to establish the general stratigraphic and structural characteristics of the area. Various sections were measured northwest of Wetmore and in the northwest corner of the area, after which field reconnaissance work was carried out to locate the major folds and fault pattern of the area. The next part of the work consisted of detailed mapping of each individual formation on aerial photographs. In detailing the area two geologic problems developed. The first was the fault system occurring in the western boundary of the area. The solution of this problem required considerable time in the field, mainly due to the lack of good outcrops. The writer's solution of this problem appears in the section on structural geology. The second problem was the determination of the boundaries of the Trinidad sandstone. A discussion of these boundaries appears in the section on stratigraphy.

An aerial geological map was prepared upon the completion of the detailed work. The details that were plotted on the aerial photographs in the field were traced directly onto the map contained in the appendix of this report. Orientation of the photographs was controlled by enlarging the scale of the Canon City quadrangle map to meet the scale of the aerial photographs. Section lines, roads and drainage features were used as ground controls.

The information given in this report is primarily that gained from the field work. It is not intended by the writer to present all of the literature available on this area. An effort has been made to conform with previous studies made by graduate students in the neighboring areas.

Acknowledgments

The writer is indebted to the members of the faculty of the Department of Geology, Colorado School of Mines, for their time and helpful suggestions in carrying out this work. In particular Drs. Truman H. Kuhn, the writer's faculty advisor in this assignment, and Robert H. Carpenter have been very helpful in supervising the field investigations and criticizing this thesis. The writer is indebted also to Drs. F. M. Van Tuyl, J. H. Johnson, L. W. Le Roy, W. R. Wagner and W. D. Mateer for numerous helpful suggestions in connection with the preparation of this report.

## GEOGRAPHY

### Relief

In the area under consideration the foothill section shows a low to moderate relief that rises abruptly to the west along the mountain front. The predominantly flat surface on the section covered by sediments is a reflection of the soft shaly bedrock of the Pierre formation, which dips gently eastward into the Denver Basin. The upper sandstone members of the "Laramie" formation form prominent cliffs at the east section of the foothill area. Minor relief features are the hogbacks formed near the west boundary of the foothill section by the Dakota formation, the Greenhorn limestone and the Carlile sandstone of the Benton group, and the Timpas limestone of the Niobrara group.

### Drainage

The Canon City area is drained mainly by the east-west flowing Arkansas River. There are many tributary creeks spread in a network throughout Fremont County. The area studied is drained from south to north by the Mineral, Newlin, First Alkali, Second Alkali, Coal, South Oak, and Oak Creeks. These are consequent creeks and have many small insequent tributaries. Only in the northwest corner of the area are there subsequent creeks following the strike of the upturned formations.

### Climate

The climate of the region is semi-arid. The average mean temperature for the summer is 72 degrees F., and the average mean temperature for the winter is 42 degrees F. The average annual precipitation is about thirteen

inches, the greatest monthly precipitation being in October and the least in November.

### Vegetation

Vegetation, which is scarce in the plain section, is that generally characterizing the foothills of the Rocky Mountains between the altitudes of 5000 and 7000 feet above sea level. Among the most common trees are the pinon pine (Pinus edulus), the western yellow pine (Pinus ponderosa), the Rocky Mountain red cedar, and the juniper, which grows abundantly on dry rocky ridges. Cottonwoods grow along water courses, but are uncommon in the area mapped. Some types of cacti are abundant. Grasses and wild flowers are scarce.

### Culture

The most important industries of the region are agriculture and coal mining. In the area studied the only important economic product is coal. There are several coal mines in the zone covered, but most of them are now abandoned. Only the Double Dick mine is producing coal at the present time.

## GEOMORPHOLOGY

The area mapped in this report is in the transition zone between the Front Range of Colorado and the Great Plains, which is known as the foothills belt. The Colorado Front Range is a name applied to the easternmost portion of the Rocky Mountains between the Arkansas River to the south and the Cache La Poudre River near the Wyoming boundary. South of the Arkansas River the front follows the Wet Mountains. The core of both ranges is crystalline. The Sangre de Cristo Range on the west and the Wet Mountains on the east form the boundary of the Wet Mountain Valley.

The Canon City embayment area is a structurally depressed area along the Arkansas River. West of Canon City is the Intermediate basin, through which the Arkansas River flows and which is called the Royal Gorge Plateau. Remnants of two erosion surfaces which occur in this plateau are known as Webster Park, south of the Arkansas River, and Eight Mile Park, north of the river. Webster Park is a low surface about 6000 feet in elevation with extensive flat areas dissected into broad valleys of later erosion cycle. This erosion surface is developed largely on upturned Mesozoic beds. The Eight Mile erosion surface forms a rough upland of about 7000 feet in elevation developed on the crystalline rocks.

The foothills section of the area is a belt of sedimentary rocks, of Upper Mesozoic age in the area under consideration, folded, faulted, and upturned against the mountain front. The most important topographic features in this section are the hogback ridges produced by differential erosion of the upturned beds near the contact with the pre-Cambrian complex, and the prominent cliffs formed by the sandstone members of the "Laramie" formation

on the eastern part of the area. The zone under consideration can thus be divided, topographically, into three units: (a) a narrow belt parallel to the mountain front composed of parallel valleys and ridges, (b) a central flat area of gentle dips, (c) an eastern section characterized by steep cliffs produced by the dissection of the "Laramie" and Trinidad formations.

In the first zone, the valley and ridges are better developed in the southeastern portion of the area, where the Dakota formation and the Benton and Niobrara groups outcrop. The sandstone members of the Dakota formation are prominent hogback-forming. The Greenhorn and Carlile members of the Benton group and the Timpas limestone of the Niobrara group form minor hogbacks. In the central portion of the area the pre-Cambrian comes into contact, due to reverse faulting, with Pierre, "Laramie," and Trinidad beds. The valley and ridges belt is less prominent in this part of the area, as the sandstones of the Trinidad and "Laramie" are poorly consolidated and, therefore, easily eroded. In the central zone the topography is controlled by the gently dipping "Laramie" formation.

STRATIGRAPHY

General Statement

The exposed formations of the area considered in this report are confined exclusively to the sedimentary rocks of Upper Cretaceous age. The pre-Cambrian gneisses and schists which form the mountain front on the western margin of the area will be referred to briefly here, as their relationship to the sedimentary section is primarily one of structural nature. These Upper Cretaceous formations rest on a major reverse fault contact with the pre-Cambrian.

The oldest sedimentary formation present in the zone is the Dakota formation of basal Upper Cretaceous age. The Benton formation rests conformably on the Dakota formation. It is composed of three members: Graneros shale, Greenhorn limestone, and Carlile shale and sandstone in ascending order. The lower member of the Niobrara formation, the Timpas limestone, rests unconformably on the top member of the Benton formation and is overlain by the Apishapa shale, the upper member of the Niobrara formation. Resting conformably on the Apishapa shale is the Pierre shale. The Trinidad sandstone lies conformably on the Pierre shale. This formation is correlated with the Trinidad of the Raton Mesa region and with the Fox Hills formations to the north, although there are discrepancies with respect to its exact age. Lying conformably on the Trinidad sandstone is the "Laramie" formation, the coal-bearing formation of the Canon City coal field. This formation is correlated with the "Laramie" elsewhere in the Denver Basin, but its correlation with beds outside this area is still controversial. Resting conformably on the "Laramie" formation are beds of undetermined age, that the writer has named in this report as beds "A".

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## DETAILS OF STRATIGRAPHIC UNITS

### Pre-Cambrian

At the contact of the sediments with the pre-Cambrian rocks, pink coarse granites with associated pegmatites and quartz veins are exposed. Further west, younger gneisses and schists also are exposed. T. S. Lovering (13) has suggested an Algonkian age for this complex.

### Mesozoic

#### Upper Cretaceous

##### Dakota

Location of Exposure: The Dakota formation is well exposed in the southeast corner of the area under consideration. A complete section is shown along the road which connects State Highway 67 with the Florence water intake located 3 miles west of Wetmore.

History: The Dakota formation was first described and named by F. E. Meek and F. V. Hayden (16). The type locality is Dakota, Nebraska. The term has been widely used over large areas of the western states, but recently, the strict correctness of its application has been questioned. At present the United States Geological Survey has restricted its use to the rocks located east of the Front Range. The rocks located in approximately the same stratigraphic position in areas west of the Front Range are tentatively named Dakota (?) formation.

Thickness: The total thickness of the Dakota group as determined by a Brunton-tape traverse is 350 feet. Thicknesses of the individual members,

are shown in Plate III.

Lithology: In the area under consideration the Dakota formation can be divided in three members as follow: a lower sandstone, a middle shale and an upper sandstone.

The lower member is an extremely resistant medium to coarse grained sandstone with lenticular conglomerate at the base. Crossbedding occurs very commonly near the base of this sandstone member. The color varies from light buff to brown. The middle shale member is composed of black to dark brown fissile shale, grading to harder sandy shale at the top. The exposures of this member are in general very poor. The shales are always covered by debris from the sandstone members. The sandstones being more resistant to the erosion than the shale form prominent hogbacks, whereas the shale member is always indicated by the presence of a longitudinal depression between such hogbacks.

The upper sandstone member of the Dakota formation exhibits remarkable changes in hardness in short distances. In some places it is very hard, almost quartzitic in appearance, and in other places argillaceous and relatively soft. This member contains some beds of fire clay.

Stratigraphic Relationship: The Dakota formation, in this area, is separated from the pre-Cambrian by a major fault. The upper contact with the Graneros shale is not well exposed but is indicated by the dip slope of the top sandstone member of the Dakota.

The Dakota formation was deposited by an advancing sea during early Cretaceous time. The sandstone members poorly sorted and composed of angular grains, indicate a near shore environment. The middle shale member indicates a temporary change in the depth of the basin of deposition.

Paleontology and Age: No fossils were found by the writer in the

Dakota formation. The age of this formation is considered to be Upper Cretaceous.

Correlation: The Dakota formation is correlated with beds of the same name elsewhere east of the Front Range.

#### Benton Formation

Location of Exposures: The three members of the Benton formation — Graneros, Greenhorn and Carlile in ascending order — are poorly exposed in the area under consideration. The best exposures are located along the road which connects State Highway 67 with the Florence water intake in the southeastern corner of the area.

History: The Benton formation was named by Meek and Hayden (16). The type locality is Fort Benton, on the Missouri River, about 40 miles below Great Falls, Montana. However, the stratigraphic limits of the formation are based largely on sections along the Missouri River in northern Nebraska where the Benton formation rests on Dakota sandstone and is overlain by Niobrara limestone. The subdivisions used in this report, Graneros shale, Greenhorn limestone and Carlile shale and sandstone were described by Gilbert in 1896 (5). The type section is along the Arkansas River, about 40 miles southeast of Florence.

Thickness: The thickness of this formation as measured with a Brunton-tape traverse is between 365 and 385 feet. The general stratigraphic column (Plate III) shows the thickness of the individual formations.

#### Lithology of members

Graneros Shale: The lower member of the Benton formation, Graneros shale, consists of hard, brittle, bluish-gray shale. It is a typical valley-forming member and is usually covered by vegetation. The lack of good exposures makes it impossible to give a detailed description.

Greenhorn Limestone: The Greenhorn limestone is the middle member of the Benton formation and, together with the Carlile sandstone, forms a prominent hogback. It consists of pale bluish-gray to white compact, fine-grained, slabby limestone. There are interbedded streaks of dark gray limy shale. In this limestone the writer found abundant remains of a characteristic fossil, Inoceramus labiatus.

Carlile Shale and Sandstone: The lower portion of the Carlile member is composed of dark gray shale, and the upper, of a yellow to brownish sandstone. The contact between the shale and the sandstone is gradational.

Stratigraphic Relationships: The contact of the Benton with the Dakota is gradational forming a transition zone about 5 feet thick. The contact with the basal member of the Niobrara formation is disconformable. According to J. H. Johnson (9) the Benton-Niobrara contact is separated by a diastem. The only evidence of this diastem in the area studied is the slightly wavy contact between the Benton and Niobrara formations.

Environment of Deposition: During Benton time eastern Colorado was covered by a great Cordilleran sea which extended over a wide area in the Rocky Mountain and Great Plains area. In this fluctuating sea of variable depth, the sediments of the Benton formation, mostly fine-grained, were deposited. At the close of Benton time a decrease in the depth of the basin is indicated by the deposition of the coarser-grained Carlile sandstone.

Paleontology and Age: The only fossils found by the writer in this formation were specimens of Inoceramus labiatus in the Greenhorn limestone member. According to studies of the United States Geological Survey as recorded in the Pueblo folio (4) the most characteristic fossil of the Benton formation is Inoceramus labiatus.

Correlation: The Benton formation is correlated, on the basis of

fossils and lithology, with beds of the same name in Wyoming and Colorado.

### Niobrara Formation

Location of Exposures: The exposures of this formation in the area under consideration are very poor. Only the basal member, the Timpas limestone, which forms a minor hogbacks, presents good exposures in the northwestern and southwestern corners of the area studied. The upper member, the Apishapa shale, exhibits only a few scattered exposures, none of them complete.

History: The Niobrara formation was named by Meek and Hayden (16). The subdivision into two members, Timpas limestone at the base and Apishapa shale at the top, was first established by Gilbert (5); in some reports on eastern Colorado this formation has been treated as a group. The type locality for the Timpas limestone is near Timpas Creek, that for the Apishapa is near the Apishapa River. Both localities are in the Arkansas Valley in southeastern Colorado.

Thickness: The thickness was measured with a Brunton-tape traverse at the northwestern corner of the area. Due to the lack of good exposures, particularly in the shale member, the result is only approximate. The total thickness was found to be about 460 feet. In the general stratigraphic column (Plate III) the thicknesses of the individual members are shown.

### Lithology

Timpas Limestone: This member consists of a basal white to creamy, fine-grained, limestone. In the upper part of the Timpas, the limestone alternates with thin beds of calcareous shale. The limestone has a conchoidal fracture, and a well-developed joint pattern.

Apishapa Shale: This member consists of grayish-blue shales, with some interbedded grayish-blue limestone.

Stratigraphic Relationships: The Niobrara lies disconformably on the

on the Carlile member of the Benton formation. The upper contact with the Pierre shale is gradational.

Paleontology and Age: The writer found accumulations of Inoceramus deformis in the Timpas member. The most characteristic fossil of the Apishapa member is Ostrea congesta which has not been found by the writer in the area studied. Both members are highly foraminiferal. The age of the formation is Upper Cretaceous.

Environment of Deposition: The fine-grained character of the sediments and the absence of sandstone members tend to indicate that the formation was deposited in a deeper sea than the preceding Benton formation. However, the thick Inoceramus deformis shells, indicative of shallow-water environment, would rather point to the presence of a borderland at the old stage of erosion.

Correlation: The Niobrara formation has been correlated with beds of the same name elsewhere in the Great Plains region on the basis of fossil relationships and lithology.

### Pierre Shale

Location of Exposures: There are no complete exposures of the Pierre shale in the area under consideration. Along the eastern boundary of the mapped zone good exposures of the uppermost portion of the Pierre occur (Fig. 1 - 2).

History: The Pierre shale was first named and described by Meek and Hayden (16). The type locality is Fort Pierre, South Dakota.

Thickness: It is impossible to measure the true thickness of the Pierre shale in the studied zone due to the lack of good exposures. A traverse was made in section 3 in the northwestern corner of the mapped area, and the thickness was found to be between 1100 and 1200 feet. Evidently this

is not the true thickness of the Pierre, because according to Lavington and Thomason, this shale is 4000 feet thick near Florence. Apparently the Pierre shale has been affected by a reverse fault which is responsible for cutting down its thickness. This point will be considered in detail in the section on structure.

Lithology: Only the top of the Pierre shale can be studied in the area under consideration. It consists of soft, dark gray, sandy shale grading upward into the Trinidad sandstone. The exact location of the boundary between these two formations will be considered in the section on the Trinidad sandstone. The Pierre shale has been divided in five recognizable sections in the Arkansas Valley. These are the Barren section at the base, above which appear successively the Rusty, Tepee, Cone-in-Cone, and transition sections.

In most places at least three of those divisions are recognizable, the Barren, Rusty and Tepee sections.

Stratigraphic Relationship: The Pierre shale rests conformably and with a gradational zone on the Apishapa member of the Niobrara formation. The contact with the overlying Trinidad sandstone is conformable and gradational.

Paleontology and Age: No fossils have been found by the writer in the Pierre shale, but numerous fossils have been found at different horizons in nearby localities. The age of this formation is Upper Cretaceous.

Environment of Deposition: The Pierre shale was deposited under shallow-water marine conditions.

Correlation: The Pierre shale is correlated with beds of the same name, elsewhere over the eastern slope of the Front Range.

### Trinidad Formation

Location of Exposures: There are good exposures of the Trinidad sandstone along the eastern limit of the mapped zone. A complete section can be found along State Highway 276 in section 17. Figures 3 and 4 show exposures of the Trinidad formation.

History: The Trinidad sandstone was first named and described by R. C. Hills in 1899 (16), as the Trinidad formation. The type locality is at Trinidad, Las Animas County, Colorado. N. H. Darton in 1905 (16) considered Trinidad sandstone as the upper member of the Fox Hills formation in eastern Colorado. There is no general agreement in regard to the exact age of the Trinidad sandstone, but according to its stratigraphic position, it is generally considered the equivalent of the Fox Hills formations. In the zone under consideration the similarity of this sandstone with the one holding the same stratigraphic position in the Raton Mesa region was first pointed out by Stevenson in 1874 (11). The name Trinidad sandstone was first used in the Canon City field by W. T. Lee and F. H. Knowlton in 1917 (11).

Thickness: The thickness of the Trinidad sandstone was measured on the section along Highway 276 and is about 70 feet.

Lithology: This formation is composed of yellow to light brown poorly consolidated massive sandstone. It contains, in the lower portion, numerous large yellow to brown sandy concretions sometimes more than 3 feet in diameter.

Stratigraphic Relationship: The lower contact with the Pierre shale is transitional. To locate the boundary between these two formations, the writer used criteria established by the Rocky Mountain Association of Petroleum Geologists (16) to differentiate between Pierre shale and Fox Hills formation. The boundary shall be considered as horizon below which the section is predominantly gray marine clay shales and sandy shales of Pierre

age and above which the section changes rapidly to a buff to brown sandstone containing numerous large gray to brown hard sandy concretions. This criterion is easily applied in the area mapped, because the transition from the typical Pierre shale to some alternated beds of shale and limestone and finally to pure sandstone is rather sharp. The boundary mapped by the writer was placed at the base of the transitional zone. The contact with the overlying "Laramie" is conformable.

Paleontology and Age: Great numbers of Halymenites major Lesquereux were found by Lee and Knowlton (11) in the area under consideration. The age of the Trinidad sandstone is Upper Cretaceous.

Environment of Deposition: The Trinidad sandstone was deposited in a shallow-water marine environment.

Correlation: The Trinidad sandstone of this area is correlated with the Fox Hills sandstone to the north and with the Trinidad sandstone of the Raton Mesa region to the south on the basis of fossils, lithology and stratigraphic position.

#### "Laramie" Formation

Location of Exposures: Most of the mapped area is covered by the "Laramie" formation, but in no place is completely exposed. However, in the eastern part of the area along the contact with the Trinidad sandstone there are good exposures of the basal part (Fig. 5). The upper part beds are well exposed in the western portion of the area, particularly in the northwestern corner.

History: The "Laramie" formation was first named and described by C. King in 1876 (16). The use of the name "Laramie" and the correlation of this formation have been the subject of a long controversy. The United States Geological Survey decided in 1910 to restrict the use of the term "Laramie" to the Denver Basin region.

Thickness: A detailed section of the "Laramie" formation is included in this report (Plate No. IV). Since there is no complete exposure in the area under consideration, the section represents an interpretation of data collected at several exposures within the area.

The section is therefore not intended to represent the exact composition of the formation at any particular place in the area, but to give a detailed picture of the approximate position of the different beds that compose the "Laramie" on the studied zone. In making the section some information has been taken from sections made at different mines of the area, and published by W. L. Lee and F. H. Knowlton in 1917 (11).

Lithology: The "Laramie" formation consists of gray massive poorly sorted, poorly consolidated sandstone, dark shale, coal beds and gray claystones. The upper sandstone is a prominent cliff-former and is locally known as the "rim rock." It forms cliffs 200 to 250 feet high in the eastern part of the area (Fig. 6 - 7). The coal beds are restricted to the lower half of the formation, and are separated in two groups by the massive "Rockvale sandstone." (Fig. 8) Detailed section is shown in Plate IV.

Stratigraphic relationship: The "Laramie" formation rests conformably on the Trinidad sandstone. The contact is located at the base of a coal bed, about 4 feet in thickness, that is locally called "Rockvale coal bed." The same coal bed has been used as a marker by Washborne, W. T. Lee and F. H. Knowlton (11) in early work near the zone.

A bed of conglomerate and conglomeratic sandstone lies conformably at the top of the "Laramie" formation, in the west portion of the area. The thickness of this bed varies from 2 or 3 feet up to 10 or 12, and in some places is overlain by a few feet of a gray massive sandstone very similar to the upper "Laramie" sandstone. This bed could belong either to the

"Laramie" formation or to a younger formation overlying it, but the writer did not find any evidence to prove either of these hypotheses. In this report these beds are named beds "A?"

Paleontology and Age: The "Laramie" is a highly fossiliferous formation. Fossil land plants are abundant and the skeletons of many of the last dinosaurs are very well preserved. In the zone under consideration abundant flora have been classified by earlier workers (11).

The writer found fossil tree trunks in the coal bed of the lower shale members. (Fig. 9). The trunks are silicified in the center and carbonized in the periphery. Those trees have not been classified by the writer.

The study of the fauna and flora of the "Laramie" formation has conclusively proved that its age is Upper Cretaceous.

Environment of Deposition: The paleontologic and lithologic evidences show that at the beginning of Laramie time the sea had largely retreated, leaving an area of swamps and low-lying land masses. The "Laramie" formation was deposited under a prevalent continental environment.

Correlation: This formation is correlated with the "Laramie" elsewhere in eastern Colorado. Correlation with other beds outside of the Denver Basin is still controversial.

#### Cenozoic

Part of the southern portion of the area, sections 31, 32 and 36, is covered by slightly consolidated gravels and silts of probably Pleistocene or late Tertiary age.

## HISTORICAL GEOLOGY

Pre-Cambrian

The wide areal extent and great thickness of the Idaho Springs formation, composed of pre-Cambrian metamorphosed sediments, indicate a period of depression and deposition of marine or continental sediments. Those rocks were uplifted, faulted, folded and metamorphosed during late pre-Cambrian time. During the same period the intrusion of the Pike's Peak granitic batholith took place. This intrusion resulted in the formation of injection gneisses and schists.

Paleozoic Era

No Paleozoic rocks are exposed in the area under consideration.

Mesozoic Era

No Triassic and Jurassic rocks are exposed in the area studied.

The Dakota sandstone of Upper Cretaceous age was deposited in a changing environment and indicates the advances of the sea over a formerly emergent land. The shale member of this formation and its faunal contents point to a shallow-water marine environment. The sandstone members, poorly sorted and composed of angular grains, were probably deposited in a near-shore environment. During the Benton time immediately following the Dakota the submergence of the area continued, and a great Cordilleran sea extended over a wide area in the Rocky Mountains and Great Plains areas. The sediments deposited in the Benton sea, mostly fine-grained, indicate a deep-water marine environment. The deposition of the coarse-grained Carlile sandstone and the disconformity at the base of the Timpas limestone shows a retreat of the

seas at the close of Benton time.

During Niobrara time the presence of thick cells of Inoceramus deformatis indicates a shallow-water marine environment. The lack of clastic sediments in the Niobrara group points to a landmass at a late stage of erosion as source of the sediments. The Pierre shale was deposited in a shallow sea. The deposition of the coarse-grained Trinidad sandstone indicated a withdrawal of the seas that began at the close of the Pierre time.

During Laramie time the sea had largely retreated, leaving an area of swamps and low-lying land masses. The Laramie formation was deposited under a prevalent continental environment.

## STRUCTURAL GEOLOGY

### General Statement

The area under consideration is located on the southwest flank of the Florence-Canon City syncline, which is part of the Canon City Embayment. This syncline is a small basin, approximately triangular in shape, which is separated from the south end of the Denver Basin by a structural divide known as the Red Creek-Pike's Peak Arch or anticline. This structure plunges to the southwest from the pre-Cambrian granite of Mount Pittsburg. The east flank of the Florence-Canon City syncline is flat-lying and the west flank is steeper and in places overturned. The sediments of the western side of the syncline extend northward up to the northern limit of Fremont County. Beyond this line, the crystalline basement outcrops.

In the area under consideration the sedimentary formations of Upper Cretaceous Age, have been folded and faulted due to a compressive force acting from the west. As a result the sediments exhibit a reverse fault contact with the pre-Cambrian and are overturned along the western portion of the area. To the east of this contact zone is a large asymmetrical syncline with gently dipping flanks, the axis of which trend roughly parallel to the contact of the sediments with the pre-Cambrian rocks. The age of the tectonic movement which produced those structures is late Upper Cretaceous or Early Tertiary.

### Faults

The fault contact between the pre-Cambrian complex to the west and the sedimentary formations to the east (fault "A" in Plate V) is the most

important structural feature of the area under consideration. This fault which trends from N 30° W in the northwestern portion of the area to about N 50° W in the south portion brings the pre-Cambrian into contact with formations ranging in age from Dakota to Laramie, indicating a minimum stratigraphic throw of about 2600 feet at the point of maximum vertical separation. The lack of good exposures makes it impossible to determine accurately the position of the fault plane. However, there is field evidence which permits the approximate determination of the position of this plane. In the northwestern corner of the area the sediments dipping to the west are overturned and abruptly truncated against the pre-Cambrian. The position of the fault plane is not observable, but in some places along the creeks, small outcrops of the Carlile sandstone occur beneath the western edge of the pre-Cambrian rocks, indicating a reverse fault dipping to the west. In section 26, outcrops of the pre-Cambrian rocks overly the Pierre and Laramie formations indicating that the dip of the fault plane is flatter in this part of the area. To the southwest in the sections 36 and 6, the area is covered by gravels which make it impossible to observe the attitude of the beds. In the southeastern portion of the area studied the formations again outcrop, but there they are dipping to the north and northeast. The position of the sediments suggests that in this area the fault is a high angle fault with the pre-Cambrian rocks forming the upthrown block. In conclusion, in the writer's opinion, this fault is a reverse fault of variable dip. In the southern part of the area it is believed to be steeply dipping.

To the east and parallel to the above described fault is an oblique reverse fault dipping probably to the east (Fault "B" in Plate V). In the northwestern portion of the area this fault brings the top member of the "Laramie" into contact with the basal member of the same formation, indicating

a stratigraphic offset of about 1000 feet. To the southwest the stratigraphic offset decreases gradually, and in the northern portion of section 15 "Laramie" beds of the same stratigraphic position are in contact. There is no evidence of this fault south of the portion covered by gravels. In the writer's opinion, this fault probably is terminated by the fault first described (fault "A"). On the east side of the fault, the "Laramie" formation dips to the east, from 50 degrees on the northwest corner of the area to 3 or 4 degrees in the portion of the fault south of section 10. In the writer's opinion, the attitude of the "Laramie" was determined by the upward folding of the sediments near the contact with the pre-Cambrian, during the first part of the tectonic movement which produced the faults. On the east side of the fault the shale members of the "Laramie" formation show drag folding to the west, produced by the upward movement of the eastern block. The writer's interpretation of this fault is shown in Plate V.

Another reverse fault, (fault "C" in Plate V) dipping to the west probably occurs in the northwestern corner of the area approximately along the contact of the Pierre with the Apishapa shale. No field evidence of this fault was found by the writer. The presence of this structure is assumed in order to explain the anomalous thickness of the Pierre in that part of the area. The information obtained from wells drilled for oil exploration in the Canon City embayment indicate that the Pierre shale is probably more than 4000 feet thick in the zone under consideration. In the writer's opinion, the best explanation of the reduction of the thickness of the Pierre shale is reverse faulting, but the possibility of other causes cannot be eliminated. Other possible causes would be different thickness due to original deposition, or erosion due to uplift before the deposition to the Trinidad sandstones. The gradational contact of the Pierre with the Trinidad on the eastern border of the area, and the uniformity of the thickness of the Pierre over large

areas make all explanations except faulting highly improbable.

A fault trending approximately N 60° E occurs in the southwestern corner of the area. The horizontal separation produced by the fault in the pre-Cambrian is about 1500 feet and decreases gradually when the fault cuts through the sedimentary formation and is only about 100 feet in the Timpas limestone. This fault probably dies out in the Pierre shale. No vertical separation can be detected.

The faults described above, seem to have been formed during a single period of tectonism as a result of a compressive force acting from the west. The sediments, highly disturbed along the western boundary of the area near the contact with the pre-Cambrian, and practically undisturbed on the eastern part, tends to corroborate this hypothesis. The formations were first folded by the compressive force, forming an asymmetric syncline with the axial plane trending at right angle to the direction of the force and with the west limb steeper than the east. As the compression became stronger, the formations are believed to have failed by rupture, producing the reverse faults described in this chapter. The transverse fault of the southeastern part of the area, probably represents a minor adjustment to the main structures.

The age of the tectonism is post beds "A" which are the youngest beds affected by this movement. As the beds "A" are Upper Cretaceous or early Tertiary this movement belongs undoubtedly to the Laramide orogeny.

### Folds

The main fold in the area studied is a large asymmetrical syncline which extends from north of the northern limit of the area studied to within 2 miles of the southern boundary of the mapped area. The dip on the western flank ranges from 3 degrees to 50 degrees and on the eastern flank from 4 degrees to 10 degrees. The axis of the syncline roughly parallels to the pre-Cambrian

contact and plunges 3 degrees to 6 degrees to the northeast. The western limb is truncated by the reverse faults described above, and the eastern flank dipping gently to the west extends through the eastern boundary of the area. To the southeast the syncline is covered by gravels.

In the southeastern corner of the area, an assymmetrical anticline occurs. The axis trends approximately N 50° E and the plunge is about 40 degrees to the northeast. The northwestern flank of this structure is truncated by faulting against the pre-Cambrian, and the southeast flank strikes parallel to those rocks. The transverse fault described in the section on faults, cuts through this fold near its axis. The anticline was probably produced by upward movement of the basement, but no field evidence has been found to confirm this hypothesis.

ECONOMIC GEOLOGY

The chief economic products of the area studied are non-metallic. A brief description of some of the important products is given below.

Coal

The occurrence of coal in the Canon City embayment was known as early as 1820 when the field was visited by Major Long's party. All the workable coal beds are located in the "Laramie" formation in the lower 600-700 feet of sandstone and carbonaceous shale. The "Laramie" coal is bituminous and high grade, and makes an excellent domestic fuel. It does not coke.

There are several old coal mines in the area mapped, but only the Double Dick mine is producing coal at present.

Oil

The Florence oil field, discovered in 1863, is the second oldest oil field in the United States. The Canon City pool, adjacent to the Florence pool, was discovered in 1927, and is now operated by the Continental Oil Company. All the wells produce high gravity oil from the Pierre shale. No evidence of oil in the rocks, or favorable traps, was found in the area studied.

Clay

Several formations, "Laramie," Trinidad, Benton and Dakota, yield clays of economic value, but these from the upper Dakota are the most valuable. They are used for the manufacture of refractory brick, crucibles, muffles, and furnaces.

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Fig. 1. View of interbedded sandstones and shales near top of Pierre shale. Southwestern corner of section 5.



Fig. 2. Close-up of Pierre shale shown in Fig. 1.



Fig. 3. View of Trinidad formation dipping to the west, west of fault "A". View taken looking south. Center of section 10.



Fig. 4. Local fault showing minor displacement in westerly dipping Trinidad formation, resulting from adjustment of beds following major displacement along fault "A". Center of section 10.



Fig. 5. Interbedded thin shales and sandy shales overlying one of the coal beds of the lower part of "Laramie" formation. Section 9, one mile west of Double Dick mine.



Fig. 6. General view of escarpment formed by the upper sandstones of the "Laramie" formation near the northern boundary of the area.



Fig. 7. View of escarpment formed by the upper sandstone of the "Laramie" formation near northern boundary of section 1.



Fig. 8. View of outcrop of the "Rockvale" sandstone of the "Laramie" formation near Rockvale, one mile north of the area studied.

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Fig. 9. Two views of fossil logs from the shales of the basal part of the "Laramie" formation. Center of logs is silicified, periphery is carbonized.