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

By

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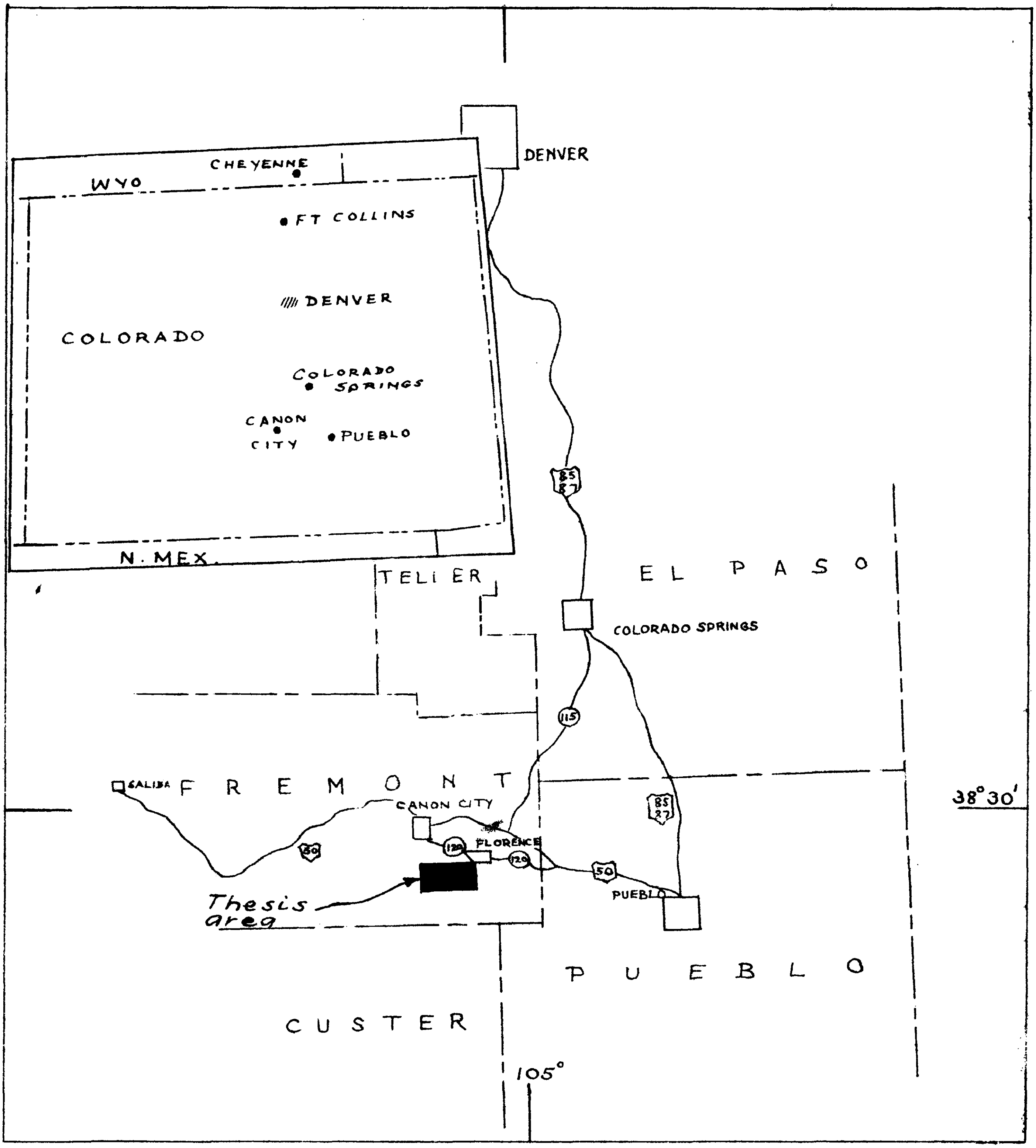
ABSTRACT

The area covered in this paper includes a portion of the foothills which lie along the eastern margin of the Wet Mountains, Fremont County, Colorado. This is a part of the southern extremity of the Canon City embayment. There is moderate relief in some parts of the area and this is influenced by the structure and variable resistance of the sedimentary deposits. The sediments dip at low angles to the east and give rise to hogback ridges as a result of differential erosion. The structure is complicated by folds and large faults trending northwest-southeast.

The sedimentary section ranges from the Dakota formation of Upper Cretaceous age to the Dawson arkosic conglomerate of late Upper Cretaceous and basal Tertiary age. The Dakota beds are in fault contact with the pre-Cambrian rocks.

PLATE I



LOCATION MAP
OF THESIS AREA

AJIT KUMAR GANGULI

INTRODUCTION

Location of the Area

The area mapped, about 30 square miles in size, lies in the eastern foothills of the Wet Mountains between latitudes 38°20' to 38°24' north and longitudes 105°6' to 105°15' west. It extends westward from a little south of Florence to State Highway 143. The southern boundary extends a little south of where Highway 143 enters the San Isabel National Forest. The eastern boundary is marked by State Highway 67. Plate I shows the location of the area and the highways which serve it. Plate 6 gives the location by township and range and the areal geology of the area studied.

Accessibility

The area can be easily reached by means of Highways 143, 267, and 275. These are connected by several graded dirt roads which pass through the small mining centers of Rockvale, Chandler, and Coal Creek. These are well-maintained and can be used throughout the year. There are some roads maintained by the ranchers of the area, which are hardly passable during wet periods. Plate 6 shows the road system including the trails.

Purpose of Investigation

The investigation was undertaken in partial fulfillment of the requirements for the degree of Master of Science at the Colorado School of Mines. The field work connected with it is an integral part of a program initiated by the Graduate Committee of the Department of Geology to map in detail the sedimentary rocks along the eastern margin of the Front range and to publish a complete report on the area.

This is an excellent area for the study of intricate structures, major thrust faulting, and also very tight folding.

Method of Investigation

The field work was started in the latter part of July, 1950, and was completed early in September, 1950. To familiarize himself with the stratigraphy of the area, the writer measured with Brunton compass and tape several sections south of the Florence water intake and west of the town of Wetmore. In the assigned area, sections X-X', Y-Y', and Z-Z', as shown in Plate 4, were measured in the North Cow creek, and Chandler creek areas, west and south of Chandler, in sections 21 and 34, between T. 20 S. to R. 70 W. and T. 19 S. to R. 69 W. respectively. The section X-X' represents a stratigraphic column from the bottom sand of the Dakota formation to the top of the Timpas limestone formation.

Reconnaissance work was done in the field to obtain the regional picture of the major fold and fault pattern of the Canyon City embayment.

There are three main problems in the area: (1) the complicated major thrust faults, with minor faultings, (2) the thinning of the Pierre shale, and (3) distinguishing the Trinidad sandstone from the "Laramie" formation.

The final step consisted of detailed mapping of each individual formation on areal photographs. Solution of the main problems which developed during the detailing of the area, required considerable time in the field. The first problem was to study the complex structural fabric of the area. The solution of the first problem by the writer appears in the section on structural geology and also in the map showing the general structural fabric of the area. The second problem was to determine the reason of the thinning of Pierre shale. This is discussed in the section on Stratigraphy under the sub-heading of Pierre shale. The third problem was to differentiate Trinidad sandstone from the overlying "Laramie" and the underlying Pierre formations. A discussion of this appears also in the section on Stratigraphy.

An areal geologic map was prepared in connection with the detailed work. The details that were plotted on the areal photographs in the field were traced onto the areal geologic map prepared on a reduced scale. Orientation of the photographs was controlled by enlarging the scale of the Canon City Quadrangle to correspond to the scale of the areal photographs. Section lines, permanent roads, and main drainage features were used as ground controls. Use of them eliminates error to a great extent. An areal geologic map was prepared on a reduced scale of nearly 2000 feet to an inch from the base above. This report presents information primarily gained from the field work. The writer has endeavored to correlate his work with previous work done by graduate students in the neighboring areas and an effort has also been made to consult all of the literature available on this area.

Acknowledgments

Before starting on the field work, (several publications on this region were reviewed) the publications of J. W. Bartram (1), N. M. Fenneman (4), T. S. Lovering (11), and R. L. Heaton (7), and Vanderwilt, Van Tuyl et al (13) were reviewed. These were very helpful in the correlation of the geologic formations and structures in and around the thesis area.

The writer gratefully acknowledges the assistance of members of the staff of the Department of Geology, Colorado School of Mines, who have given valuable guidance in carrying out this work. In particular, Drs. Truman H. Kuhn (the writer's faculty adviser) and Robert H. Carpenter have been very helpful in supervising the field investigations and criticising this thesis. The writer is indebted also to Drs. F. M. Van Tuyl, J. H. Johnson, L. W. LeRoy, W. R. Wagner, and Professor W. D. Mateer for numerous helpful suggestions in connection with the preparation of the report.

GEOGRAPHY

Relief

The relief of the area is subdued in the foothills section rising abruptly to the west along the mountain front.

Drainage

To the north, the area is drained by the generally eastward-flowing Arkansas River. Many creeks drain into the Arkansas River throughout Fremont County and the assigned area is drained mainly by Sand Creek, Fawn Hollow Creek, North Cow Creek, Chandler Creek, and Oak Creek. Irrigation ditches are maintained by the ranchers. There is one spring near the crest of a tight anticline exposing the Dakota formation. The rivers exhibit typical youthful characteristics in the foothills area but upon emerging onto the plains, several meanders are evident which indicate that a condition of grade has been attained. Many of the smaller, intermittent streams, which are of the subsequent type, flow in strike valleys between successive ridges. These intermittent streams show locally a trellis drainage pattern.

Climate and Vegetation

The climate of the region is semi-arid. The average annual rainfall is about fourteen inches, the heavier precipitation occurring during the spring and early summer. There are occasional flash floods that carry much debris including many large boulders and cobbles from the mountain front causing much damage to roads and irrigation systems. Temperatures in the foothills belt are somewhat lower in the summer than those of the plains section to the east.

The vegetation is scarce in the plains section. Presence of a few trees along the creeks and irrigation ditches is notable. A remarkable vegetational pattern has developed on the various outcrops of different geologic formation. A certain type of scrub cedar (Juniper), shows a peculiar affinity for the soils derived from the Timpas limestone. The vegetational pattern has helped in following the formational boundaries. Fig. 4 shows the typical vegetational pattern developed on the Timpas limestone.

Culture

The most important industries of the region are agriculture and coal mining. Cultivation of grain is common in the plains and the foothills area and cherries are harvested from orchards located for the most part on soils derived from the Niobrara formation. There are several coal mining towns in the area, such as Chandler, Rockvale, Coal Creek, some of these are being abandoned at present. The coal of the area is a high-grade coking coal.

GEOLOGY

Geomorphology

The Colorado Front Range is a name applied to the mountains between

THE COLORADO FRONT RANGE IS A NAME APPLIED TO THE MOUNTAINS BETWEEN the Arkansas River to the south and the Cache La Poudre River near the Wyoming boundary. South of the Arkansas River, the mountain front is offset to the west and follows the Wet Mountains. Both ranges are in the easternmost crystalline belt of the Rocky Mountains. In the mountains south of the Arkansas River, a peneplain is developed which is a little lower and less perfect than to the north. The conspicuous ranges, Sangre De Cristo on the west and Wet Mountains on the east, bear the same relation to the intervening Wet MountainsValley as the ranges farther north bear to South Park. The Wet Mountains culminate in Greenhorn Mountain (12,230 ft.) which is analogous to Pikes Peak, a great monadnock of the Front Range. However, the former is broader and less high.

The structurally depressed area along the Arkansas Valley is known as the Canon City Embayment area. The Intermediate basin, eight or ten miles in width just west of Canon City through which the Arkansas River flows, is called the Royal Gorge plateau. Parts of two erosion surfaces are to be observed in this plateau. These are known as (a) Webster Park, south of the Arkansas River, a low surface 6100 feet in elevation with extensive flat areas dissected into broad valleys of a later erosion cycle and (b) Eight Mile Park, north of the river, a rough upland 6,800 feet in elevation developed on the crystalline rocks and containing Fremont Peak, which has the appearance of a monadnock. The former surface is developed largely on upturned Mesozoic sedimentary rocks. W. E. Powers has grouped the known terrace remnants of the area into seven groups.

In the area discussed, the plains section exhibits a very low relief with the exception of topographic features related to the Laramie formation, which forms hills due to differential erosion and also to faulting. The very nearly flat surface reflects the soft shaly bedrock of the Pierre formation, which dips gently eastward into the Denver Basin. The foothills section of the area is a part of a belt of sedimentary beds, folded and upturned against the mountain slopes of the Front Range and Wet Mountains. The hogback ridges are the most characteristic features of the topography of this area. They are due to differential erosion of upturned beds of variable resistance. The resulting topography of long parallel valleys and ridges shows the direct influence of geologic structure.

The first hogback encountered after entering the area from the east is that formed by the Carlile sandstone in conjunction with the Timpas limestone (Fig. 1). Two hogbacks are developed on the Dakota formation. The latter are by far the most prominent relief features of the area examined. The last major relief in the area is represented as a ridge formed by the Laramie sandstone formation. This is the highest ridge in the region, giving a relief of about 200-250 feet. The Laramie formation develops a synclinal trough with low dips. All the hogbacks trend approximately north-south (Fig. 2). The mountain front consisting of pre-Cambrian rocks exhibit very irregular and dissected topography and rises abruptly to the west above the foothills.

STRATIGRAPHY

General Statement

Work was concentrated, in the area assigned, on the sedimentary rocks ranging in age from Upper Cretaceous to Cenozoic. There are two divisions among the pre-Cambrian rocks: (1) Pike's Peak granite, which is younger, and (2) Injection gneisses and schists, which are older. Resting on a major overthrust fault contact with the pre-Cambrian is the Dakota group of formations. The age of this group was designated by early writers as basal Upper Cretaceous. The Benton group consisting of Graneros shale, Greenhorn limestone, and Carlile sandstone and shale overlies and rests conformably on the Dakota group. The Timpas limestone, basal member of the Niobrara formation, rests disconformably upon the Carlile member of the Benton group and is overlain by the Apishapa shale, the top member of the Niobrara group. Overlying the Apishapa is the Pierre shale, which is the oil-producing formation in the Florence oil field.

The Trinidad sandstone overlies the Pierre shale conformably. From the Canyon City embayment southward, the Fox Hills sandstone is thought to be represented by the Trinidad sandstone, although J. B. Reeside contends that the Trinidad sandstone is older than the Milliken sandstone, which constitutes a major part of the Fox Hills in northern Colorado. Overlying the Trinidad sandstone is the coal-bearing "Laramie" formation. The "Laramie" has been the subject of a long controversy. Resting disconformably on the "Laramie" formation is the arkosic conglomerate of the Dawson formation. This constitutes the topmost consolidated formation in the assigned area. It occupies the synclinal trough in the north central portion of the area studied, the deepest portion of the Canyon City embayment. Nussbaum is present in outlying areas.

DETAILS OF STRATIGRAPHIC UNITS

Pre-Cambrian

The basement rock was studied only near the contact with the sediments. At the contact of the sediments with the pre-Cambrian, mostly pink, coarse granites with associated pegmatites and quartz veins are exposed. These are younger in age than the gneisses and schists to the west which they intrude. Both S. F. Emmous (3) and T. S. Lovering (11) have suggested Algonkian as the age of this complex; however, there is disagreement as to its exact age. The general strike of the metamorphics is to the north. The basement complex seems to have been eroded almost to a plane surface prior to deposition of the sediments.

Mesozoic

Upper Cretaceous

Dakota

Location of typical exposures: Though the Dakota is persistent along the fault contact with the pre-Cambrian, at no place is it completely exposed. The top and the bottom sandstone members form two typical hogback ridges.

In the shallow depression between the two prominent hogbacks developed upon the sandstone members, the middle shale member occurs. Both the top and bottom contacts of the middle shale are to some extent covered by rock debris derived from the sandstone of the Dakota group. Two sections were measured. One (X-X') is along North Cow Creek in the assigned area and another to the south of the area. This formation is faulted and tightly folded in the area where section X-X' was measured. Plate 4 shows the detailed section measured in this formation.

History: F. B. Meek and F. V. Hayden (12) named the Dakota group at the type locality at Dakota, Nebraska. This terminology has been widely used in the western United States; in recent years, questions have arisen as to the validity of its wide use. The United States Geological survey now restricts the use of the term "Dakota Group" to the rocks east of the Front Range whereas the rocks stratigraphically in the same position to the west of the Front Range are called "Dakota formation."

The writer uses the name "Dakota formation" to include the top sandstone member, the middle shale member, and the bottom sandstone member.

Thickness: The thickness of this formation is variable in the area. The reasons are the variation in the thickness of the middle shale member and also the pinching effect due to faulting. The thickness of this formation ranges from 110 to 280 feet. The general stratigraphic column (Plate 2) shows the average thickness of this formation.

Lithology: The lower sandstone member is probably not the same as the Lakota described by Darton (2). This lower member forms a prominent hogback. It is a coarse to conglomeratic sandstone in places near the base, varying in color from light buff to brown. There are lenses of conglomerate in the lower portion. The basal sandstone beds are locally cross-bedded. The conglomerate contains chert pebbles, which are cemented with silica. The intermediate member, referred to as the middle shale member, was reported by T. W. Stanton in 1905 to contain fossil leaves at several localities. The top part of the middle shale grades from a softer shale into a brown sandy shale, and is usually harder than the lower part of the middle shale. This is exposed in creeks which cut the Dakota hogbacks. The top sandstone member of the Dakota formation contains fire clay which has been mined near the State Penitentiary. The hardness of this top sandstone member is variable. This is argillaceous in some parts, forming a very pronounced ridge in some parts whereas this ridge is very low in other parts of the area.

Stratigraphic relationships: The Dakota formation rests on a major fault contact with pre-Cambrian. Stratigraphically, the fault is not always at the same level in the Dakota. The upper contact with the Graneros shale is conformable though not clearly exposed. It may be clearly recognized by the dip slope formed by the top sand member, which is resistant.

Environment of Deposition: The sediments of the Dakota formation indicate a changing environment. The bottom sandstone which is locally cross-bedded indicates fluviatile or near-shore deposition. The middle shale was probably formed in a fresh or brackish-water environment as indicated by the fossils associated with it. The top sand member is probably a near-shore marine deposit.

Paleontology and Age: No fossils were found in the Dakota formation in the assigned area but elsewhere in this portion of Colorado occasional fossils have been collected from the formation. It is considered by most writers to be Upper Cretaceous in age.

Correlation: According to Lee (9), the middle shale member is equivalent to the Purgatoire formation of southeastern Colorado and the top sandstone member is equivalent to the Muddy in northern Colorado and Wyoming.

Benton

Location of typical exposure: The Benton group consists of three members designated in ascending order as Graneros, Greenhorn, and Carlile. This group is rather poorly exposed along the eastern edge of the foothills section of the area. Two good exposures were located -- one in the northern portion of the area in a cut of Highway 143 and another in the middle of the tight anticline in the middle of the area (Fig. 3).

<u>History</u>: The name, Benton group, was given by Meek and Hayden (12) to a series of beds exposing at Fort Benton near Great Falls, Montana. In 1896, G. K. Gilbert first used the names of the sub-divisions while describing the formation in southeastern Colorado. The names of the sub-divisions used in this report conform with those used by the other graduate students working on the current mapping program.

<u>Thickness</u>: The total thickness of this group in the area surveyed, as determined by Brunton-tape traverse, is about 430 feet. The general stratigraphic column (Plate II) shows the thickness of the individual members and their formational relationships.

<u>Lithology</u>: The lower member of the group is the Graneros shale. It is a soft, black, fissile, calcareous, silty shale. It is not possible to give a detailed description of this member because it is not well exposed. Because of its softness, it forms valleys. The middle member is known as the Greenhorn limestone. This consists of several harder limestone horizons interbedded with grayish silty shales. These limestones form low ridges as they approach the stream beds. Fig. 3 shows a typical exposure of a limestone horizon of the Greenhorn member. The top member of the Benton group is known as the Carlile. G. K. Gilbert (6) first named it from Carlile Spring and

Carlile Station 21 miles south of Pueblo, Colorado. This member is composed of calcareous, dark gray shales in the lower and middle parts grading upward to brownish argillacious sandstone. An unusually good exposure is shown in the anticline in Fig. 4.

Stratigraphic relationships: The Benton contact with the Dakota, is gradational. The individual three members, Graneros, Greenhorn, Carlile, are conformable to each other. The upper contact of the Carlile with the Timpas limestone member of the Niobrara group, is disconformable. This contact is well exposed (Fig. 6). J. H. Johnson (8) expresses the belief that the Benton-Timpas contact is separated by a diastem. His conclusion is based on overlap conditions, lithic variation, faunal diversity, and differences in thickness obtained at various areas along the Front Range.

Environment of Deposition: The Benton group was deposited by a fluctuating sea of variable depth. In the closing stages, of Benton time, the depositional basin became shallower for a short time, which explains the change from Greenhorn limestone to the argillacious sandstone of the Carlile.

Paleontology and Age: No fossils were found in the area in the Graneros shale member. The Greenhorn limestone member contains numerous specimens of Inoceramus labiatus. A few fragments of fossils were found in the Carlile member in the area. Benton fossils from studies by the United States Geological survey as recorded in the

Pueblo folio (16) include Inoceramus deformis and Inoceramus labiatus. The Benton group is Upper Cretaceous in age.

Correlation: The Benton group with its three members is correlated with beds of the same name in Wyoming and southeastern Colorado, on the basis of fossils and lithology as well.

Niobrara

Location of typical exposures: Only the basal portion of the Niobrara is well exposed because of the hard limestone in this member. Typical exposures occur on the limbs of the syncline and of the tight anticline in the area. Low ridges are also formed in the northwest part of the area by the limestone member.

History: The Niobrara group was first named by Meek and Hayden (12). The Timpas and Apishapa members were subdivided first by Gilbert (6) while the type locality for the Timpas is near Timpas Creek, that for the Apishapa, is along the Apishapa River. The above two locations are in the Arkansas Valley in southeastern Colorado.

Thickness: The thickness of both Timpas and Apishapa members is given in the general stratigraphic column in Plate 2. The total thickness of the Niobrara is 364 feet.

Lithology: The lower member of the Niobrara is the Timpas limestone. The Timpas is a whitish, slightly argillaceous limestone interbedded with thin calcareous shales. Wherever it crops out, it forms low ridges. Some calcite crystals occur along fractures and joint planes. A very prominent joint pattern is developed in it. The upper member of the Niobrara is the Apishapa. This consists of grayish-blue shales interstratified with soft grayish-blue limestone in the lower part. The shaly beds of the lower part of the Apishapa weathers to thin white, papery shale fragments and the upper part tends to disintegrate more thoroughly into a light orange colored soil. Fig. 7 shows an Apishapa ridge in the middle of the syncline.

Stratigraphic relationships: The Niobrara lies disconformably on the Benton group, as is indicated by a gently undulating surface separating the two groups. The upper contact is not gradational with the Pierre shale because of faulting.

Paleontology and Age: The Timpas limestone has abundant remains of Inoceramus deformis. Ostrea congesta is the characteristic fossil of both the Timpas and Apishapa members. A prolific fauna of foraminifera occurs in the shaly layers of the Timpas and throughout the Apishapa. The Niobrara formation is Upper Cretaceous in age.

Environment of Deposition: This is definitely a marine deposit. Inoceramus deformis shells in the Timpas limestone indicates a shallow sea. Abundant micro-fossils in the Apishapa indicate definitely a shallow sea during its deposition.

Correlation: The Niobrara group is highly fossiliferous. Its two members have been correlated with the Niobrara members elsewhere in the Great Plains region on the basis of lithology and fossil relationships.

Pierre

<u>Location of typical exposures</u>: In this region, good exposures of the Pierre shale are limited. The better exposures appear in cuts along Highway 67. A typical exposure of the basal shales may be found in a gully in the southern portion of the area.

<u>History</u>: Meek and Hayden were responsible for naming the Pierre formation from the type locality at Fort Pierre, South Dakota.

<u>Thickness</u>: Accurate thicknesses of this formation are impossible to obtain in the area studied. A traverse was made and the thickness was determined to be between 1200 and 1250 feet. However, it is apparent that this is not the true thickness of the Pierre, for there is evidence of reverse faulting and of folding culminated by erosion, which seem to be responsible for cutting down its thickness. According to Lavington and Thomason, the Pierre is 4000 feet thick near Florence.

<u>Lithology</u>: The Pierre is a thick mass of shale, which varies in color from lead-gray to black. Scattered exposures through the section show a more sandy shale above the basal beds. This formation is divided into five recognizable zones in the Arkansas Valley and as far north as Perry Park. These are the Barren zone at the base, above which appear successively the Rusty, Tepee, Cone-in-Cone, and Transition zones.

In most places, three divisions, known as the Barren Zone, Rusty, and Tepee, of the Pierre are readily recognized. A few fairly well developed fine-grained sandstones crop out at various positions in the Transition zone.

Stratigraphic relationships: The Pierre lies conformably and gradationally on the Niobrara formation. The Pierre is overlain by the Fox Hills formation in central and northern Colorado, according to Lovering and Goddard (10), but from the Canon City embayment southward, the Fox Hills sandstone is represented by the Trinidad sandstone.

Environment of Deposition: The condition under which the Pierre was deposited was a shallow-water marine environment. Because of the increase in proportion of sandy material above the base of the formation, there is indication of an uplift in the highlands supplying the sediments or a shallower sea.

Age and Correlation: The Pierre is Upper Cretaceous in age. It is correlated with the Pierre formation in other areas by various workers.

Trinidad

Location of typical exposures: A good exposure of this sandstone was found in section 3, in the extreme southwestern part of the area. It also outcrops near the town of Coal Creek. Fig. 9 shows a typical exposure of this sandstone.

<u>History</u>: The lithologic similarity of Trinidad sandstone to the sandstone holding the same stratigraphic position in the Raton Mesa region was pointed out by Stevenson. From the Canon City embayment northward, the Trinidad sandstone is represented as Fox Hills sandstone. Some fossil plants in this formation helped in the correlation.

<u>Thickness</u>: The thickness of this formation is about 85 feet in the area worked by the writer.

<u>Lithology</u>: The Trinidad is composed mostly of gray or brown sandstone with gray shale partings.

<u>Stratigraphic relationships</u>: The lower contact with the underlying Pierre shale is transitional. For mapping purposes, the boundary between the two formations in most places is placed arbitrarily at the bottom of the lowest sandstone facies in the Pierre.

<u>Paleontology and Age</u>: Some fossils (9) were found in the area near Coal Creek. These were both of microscopic and macroscopic forms. The age of this formation is Upper Cretaceous.

<u>Environment of Deposition</u>: Because of the presence of coal beds in the top portion of this formation, this must have formed in a brackish to a fresh-water environment.

<u>Correlation</u>: Trinidad of this area is correlated with the Fox Hills sandstone to the north and with the Trinidad of the Raton Mesa region to the south because of lithologic similarities, stratigraphic position

and fossils.

"Laramie"

Location of typical exposures: This formation is typically a cliff-former in the area. Fig. 10 shows a typical cliff formed by the "Laramie".

History: The name "Laramie" is used for this formation, though it has been the subject of a long controversy. During the year 1874, Stevenson announced that the coal measures of the Canon City area contained marine fossils of Cretaceous age.

Thickness: The thickness of the "Laramie" is about 1282 feet in this area, but is variable and decreases northward.

Lithology: The upper part of the "Laramie" consists of a massive sandstone about 500 feet thick in the western part of the area. It thins toward the east, probably because the top was eroded away previous to the deposition of the younger beds. In the eastern part of the area, it forms a cliff 200 to 250 feet high, which is localled known as the "rim rock." The coal-bearing beds are separated into two groups by a sandstone called the "Rockvale sandstone" considered by earlier workers to be of marine origin. Generally, the principal constituents of the "Laramie" are gray sandstones, lignitic shales, and gray claystones.

Stratigraphic relationships: It lies conformably upon the Trinidad sandstone and is overlain by the Dawson arkosic conglomerate in the northern portion of the assigned area.

Paleontology and Age: According to Lee and Knowlton (9) several fossils are found in the "Laramie" in this area. The upper coal group has yielded a large flora. The names of a few fossils are given below:

Rosselinites lapideus Knowlton

Halymenites major Lesquereux

Halymenites striatus Lesquereux

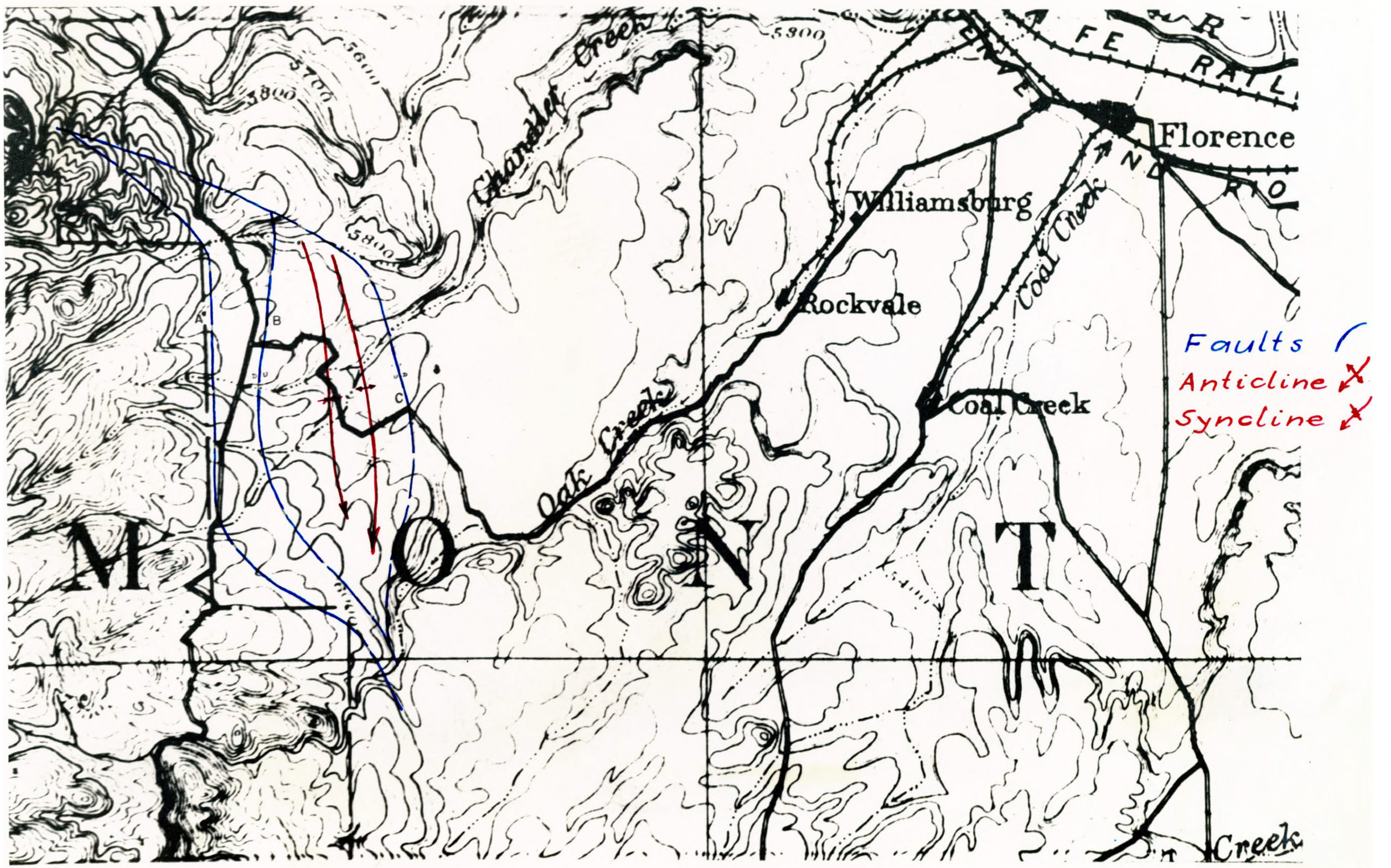
Chondrites bulbosus Lesquereux

Alos, there is the presence of Halymenites, a problematic fossil of probable marine habitat, near the top of the coal-bearing rocks. The flora has been identified and described by Lee and Knowlton in their professional paper published by the United States Geological Survey. With the kind permission of the Survey, the writer has included in this report some reproductions of pictures of fossils characteristic of the formation in this area figured by Lee and Knowlton. This formation is Upper Cretaceous in age.

Environment of Deposition: These strata were possibly deposited in a brackish to a near-shore marine environment of an oscillating Cretaceous sea.

Correlation: This formation is correlated with the "Laramie" elsewhere in eastern Colorado, by earlier worksers on the basis of lithology and fossil indications. There is vigorous controversy whether this formation should be called "Laramie" or not.

PLATE V



GENERAL STRUCTURAL FABRIC

STRUCTURAL GEOLOGY

General Statement

The Front Range-Wet Mountain area appears to be a geanticline. Folding and faulting are common structural features along the eastern margin of the Wet Mountains in the assigned area. The major structural feature of the eastern margin of the Wet Mountains is the monoclinal dip of the foothills belt eastward into the Canon City embayment. Because of faulting, the sediments are upturned against the pre-Cambrian. The monoclinal trend has been modified by a series of steeply dipping folds and pronounced faulting of the foothills. The anticlinal folds show steep dips on both sides, whereas the synclinal folds show a steep dip only on the eastern side. In the area studied, these folds trend nearly north-south. Plate 5 shows the structural fabric of the area.

Folds

The drag-fold type is generally well-developed only in the shaly sections and possibly result from adjustments in the incompetent layers to stresses incident to the major folding. This type of drag folding is evident in the Graneros, Greenhorn, and Carlile shale in proximity to the major faults in the area studied. This type of drag folding may reasonably be due to contortion during regional arching. The syncline along the western edge of the area is asymmetric with steep dips on the eastern limb and low on the western (Plate VI). Itsplunge is about

20 degrees to the south. The adjacent anticline to the east also plunges to the south and on the north it gradually opens out separating the two limbs. Both limbs of the anticline are steep. The influence of the structure is reflected in the topography. The Benton, Niobrara, Pierre, Trinidad, and "Laramie" show conformable monoclinal dips to the east and gradually flatten out toward the plains. There is a minor synclinal trough in the "Laramie" formation and the arkosic conglomerate of the Dawson.

Faults

In the area under discussion, there are three longitudinal faults. Faulting and folding are closely allied and the trend of the faults is nearly parallel to the axes of the folds.

Fault "A" (Plate V) is located at the contact of the pre-Cambrian and the Dakota in the northern portion of the area and brings the basement into contact with the younger formations, ranging from Graneros up to the "Laramie" in the southern extremity of the area. There is a sudden change of dips in the younger sediments along the basement contact. These are evidences in favor of faulting. Locally, the lower portion of the Dakota is in contact with the basement, whereas, at other places, the upper portion of the Dakota is in contact. This indicates that the Dakota is in contact with the basement stratigraphically at different positions locally. The dip of the fault "A" surface could not be determined. However, the dip of this fault "A" is presumed to be high because of surface trace. This fault "A" is the result possibly of the failure of the theoretical Wet Mountain arch.

The fault designated as "B" (Plate V) is sinuous in trace. Plate V shows the writer's interpretation of the structural pattern of the area. The solid black lines indicate clean-cut evidence of faulting as shown by the displacement of beds and also by the discontinuity of beds. The dashed lines indicate possible extensions of faults. The slickenside faces where this fault "B" transects the formations is indicative of faulting. The discontinuity of beds was the only criterion for locating the surface trace of the faults in this part of the area because of poor exposure.

Fault C (Plate V) is a large reverse fault. This fault is believed to form the contact between the Apishapa and the Pierre formations. Immediately south of the area, this fault appears to dip to the west, decreasing the true thickness of Pierre markedly. Within the area, the thickness of Pierre is about 1200 feet. The true thickness of the Pierre in the relatively undisturbed area south of Florence is approximately 4000 feet. The stratigraphic throw of the fault is believed to be at least 1000 feet.

In addition to the faults mentioned above, there are occasional transverse faults of minor throw in the area.

The solid black lines show clear-cut evidence of faulting. The dashed lines indicate possible extensions of faults. The bottom sand member of the Dakota group locally exposed often shows well-developed slickensides even where there is no appreciable displacement.

Summary of Structure

In the area the major structural trend is approximately north-south with some deviation to the northwest and locally southwest.

During post-Cretaceous time, uplift accomplished possibly in part by arching took place in the pre-Cambrian rocks to the west. Lateral pressures developed because of compressional forces causing elongation in the vertical direction and overriding thrust faults. The strain ellipsoid shown in the text represents shear fractures developed due to compression.

HISTORICAL GEOLOGY

General Statement

There is a great deal of literature on the geologic history of the Front Range and the adjoining foothills. This thesis is a result of field study which will be coordinated with other papers into a unit when the mapping program of the Department of Geology of the Colorado School of Mines is completed. That is why this discussion on historical geology will include only that which may be deduced from this field work. There are extensive discussions on the geologic history of the region by Lovering (11) and Heaton (7).

Pre-Cambrian

The pre-Cambrian metamorphic rocks immediately west of the area under discussion are primarily metasediments and granites. During the pre-Cambrian time, the area was wholly made up of crystalline rocks. They were eroded later to a nearly flat surface.

Paleozoic

No Paleozoic rocks are exposed in the area under discussion.

Mesozoic

No Triassic and Jurassic rocks are found in this area because of faulting.

The sediments of the Dakota group indicate a changing environment. The Bottom sandstone member is indicative of a fluviatile environment. The Fuson shale was probably formed in a brackish to a shallow-water marine environment. The top sandstone member is probably a near-shore marine deposit. Ostrea shells are associated with the Fuson shale. The Benton group was deposited by a fluctuating sea of variable depth. In the closing stages of Benton time, the depositional basin became shallower, as indicated by the change from Greenhorn limestone member to the argillaceous sandstone of the Carlile. The abundance of Inoceramus deformis, the Timpas limestone indicates a shallow-sea environment. The Apishapa beds are full of Ostrea congesta and belong to shallow-water marine environment. Pierre shales was deposited in a shallow sea. The Trinidad sandstone was deposited in a near-shore marine environment while the Laramie is of brackish to fresh-water origin. There is a Liatus between the "Laramie" and the Dawson arkose. The latter formation is entirely continental.

ECONOMIC GEOLOGY

Minerals

The minerals of the area are almost all non-metallic. Although there are several pegmatite dikes in the pre-Cambrian in the area, no quarries are being operated in the area.

Ground Water

The Arkansas river is draining the area immediately to the north. The natural source of water in this area is both the Arkansas river and also the ground water. There is a natural spring in the Dakota which outcrops in the middle of the anticline.

Coal

There are several coal mines in the area. All of them obtain their coal from the Laramie formation. These are mostly coking coals and are used for domestic and other purposes. The coal measures owe their preservation partly to the fact that they occupy the trough of a syncline. The occurrence of coal in this area was known as early as 1820, when this area was visited by Major Loug's party. In 1909, C. W. Washburne examined the coal beds of the Canon City area and followed the long-established custom of referring them to the "Laramie."

Oil and Gas

The Florence oil field (discovered in 1863) is the second oldest oil field in the United States. This field at present produces some high gravity oil. All wells produce from the fractures in the Pierre shale. Possibilities of finding oil below the Dakota group are extremely poor because of the lack of favorable traps.

There was no evidences of oil staining in the rocks of the area investigated by the writer. There is one structure which may be a possible oil trap. That is the small, tight anticline in the west-central part of the area. Whether this structure is extensive enough to contain petroleum in commercial quantities would have to be determined by drilling. The above structure is a high-dipping southward plunging anticline. The writer came into contact with no evidence suggesting that this structure had ever been drilled. The basal sands of the Dakota should be reached at about 200 feet on the apex of this structure.

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Fig. 1. A view of the escarpment formed by the "Laramie" near the town of Rockvale.

Fig. 2. A view of the Dakota exposures in the middle of the tight anticline southwest of the town of Chandler.

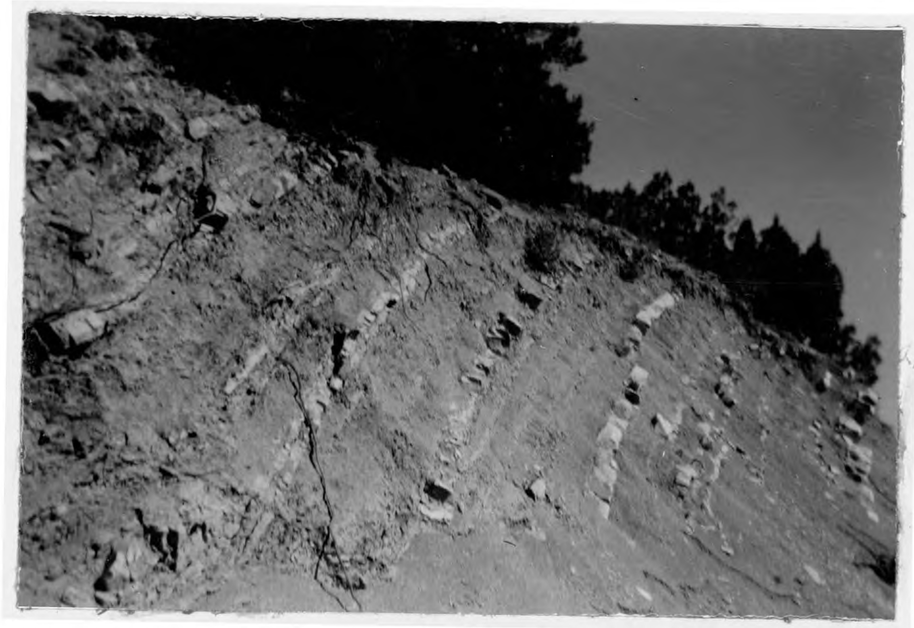


Fig. 3. Greenhorn exposed in a road cut in the northwest of the thesis area along Highway 143.

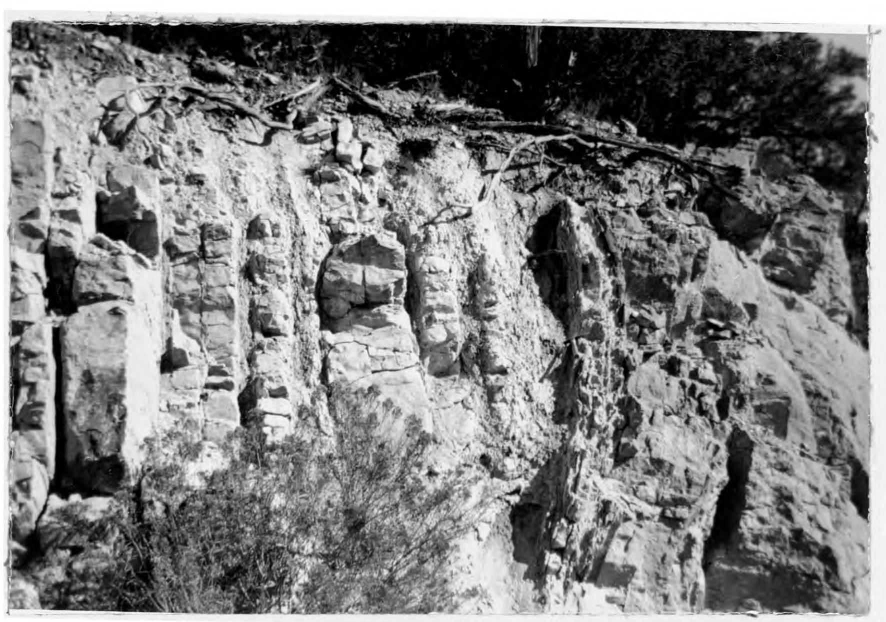


Fig. 4. A view of the Carlile member in a road cut in the northwest of the thesis area along Highway 143.

Fig. 5. Contact between the Timpas and the Apishapa marked by the "pick" and exposed widely in the extreme southwest of the thesis area.

Fig. 6. A typical exposure of the Timpas limestone in the western limb of the tight anticline one-half mile southwest of the town of Chandler.

Fig. 7. A view of the Apishapa ridge in the middle of the syncline southwest of Chandler.

Fig. 8. A typical exposure of the Trinidad Sandstone along the Oak Creek in the extreme south of the thesis area.

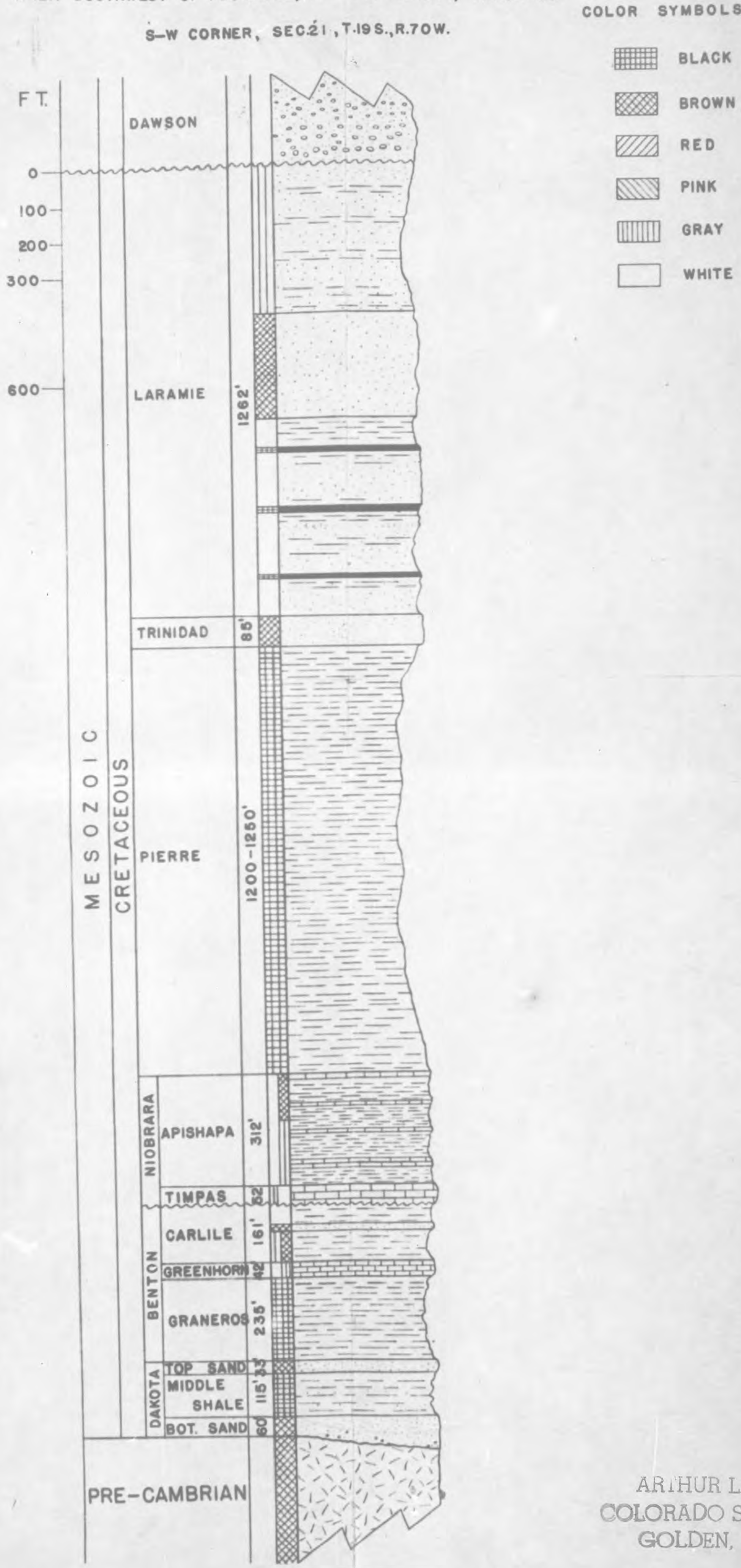
Fig. 9. A panoramic view of the cliff formed by the "Laramie", south of the town of Chandler.

GENERAL STRATIGRAPHIC COLUMN

PLATE II

AREA SOUTHWEST OF FLORENCE, FREMONT COUNTY, COLORADO

S-W CORNER, SEC.21, T.19S., R.70W.



AJIT KUMAR GANGULI
1950

DETAILED STRATIGRAPHIC COLUMN OF THE DAKOTA

PLATE III

AREA SOUTHWEST OF FLORENCE, FREMONT COUNTY, COLORADO
S-W CORNER, SEC33, T.19S., R.70 W.

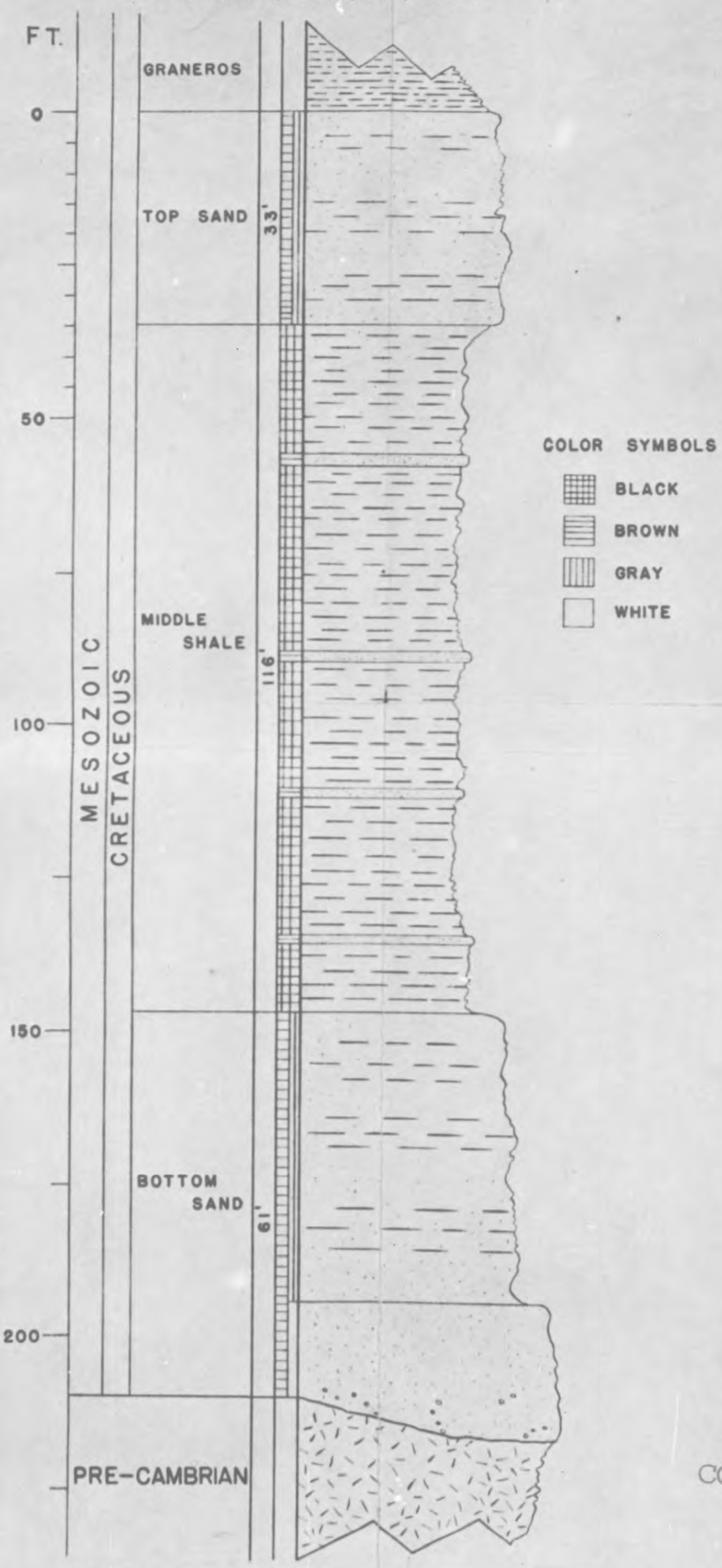


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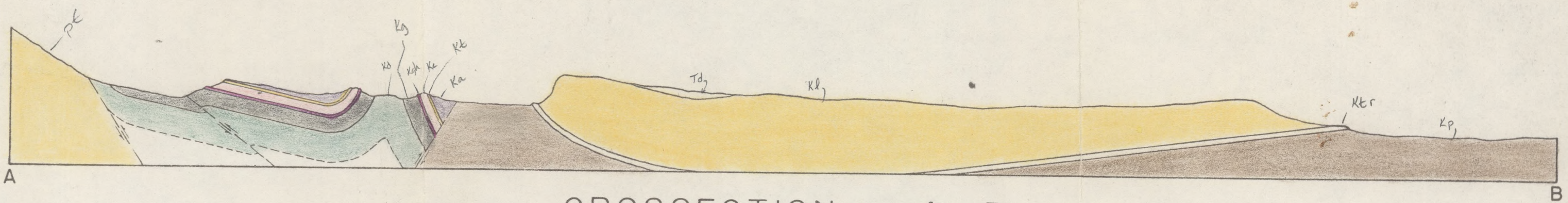
PLATE IV



CROSSECTION A–B

AREA SOUTHWEST OF FLORENCE, FREMONT COUNTY, COLORADO

TERTIARY
- DAWSON Td

CRETACEOUS
- LARAMIE Kl
- TRINIDAD Ktr
- PIERRE Kp
- APISHAPA Ka
- TIMPAS Ktp

CRETACEOUS
- CARLILE Kc
- GREENHORN Kgh
- GRANEROS Kg
- DAKOTA Kd

PRE–CAMBRIAN

HORIZONTAL & VERTICAL SCALE

1 0 1 2 3 4 5

THOUSANDS OF FEET

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1950

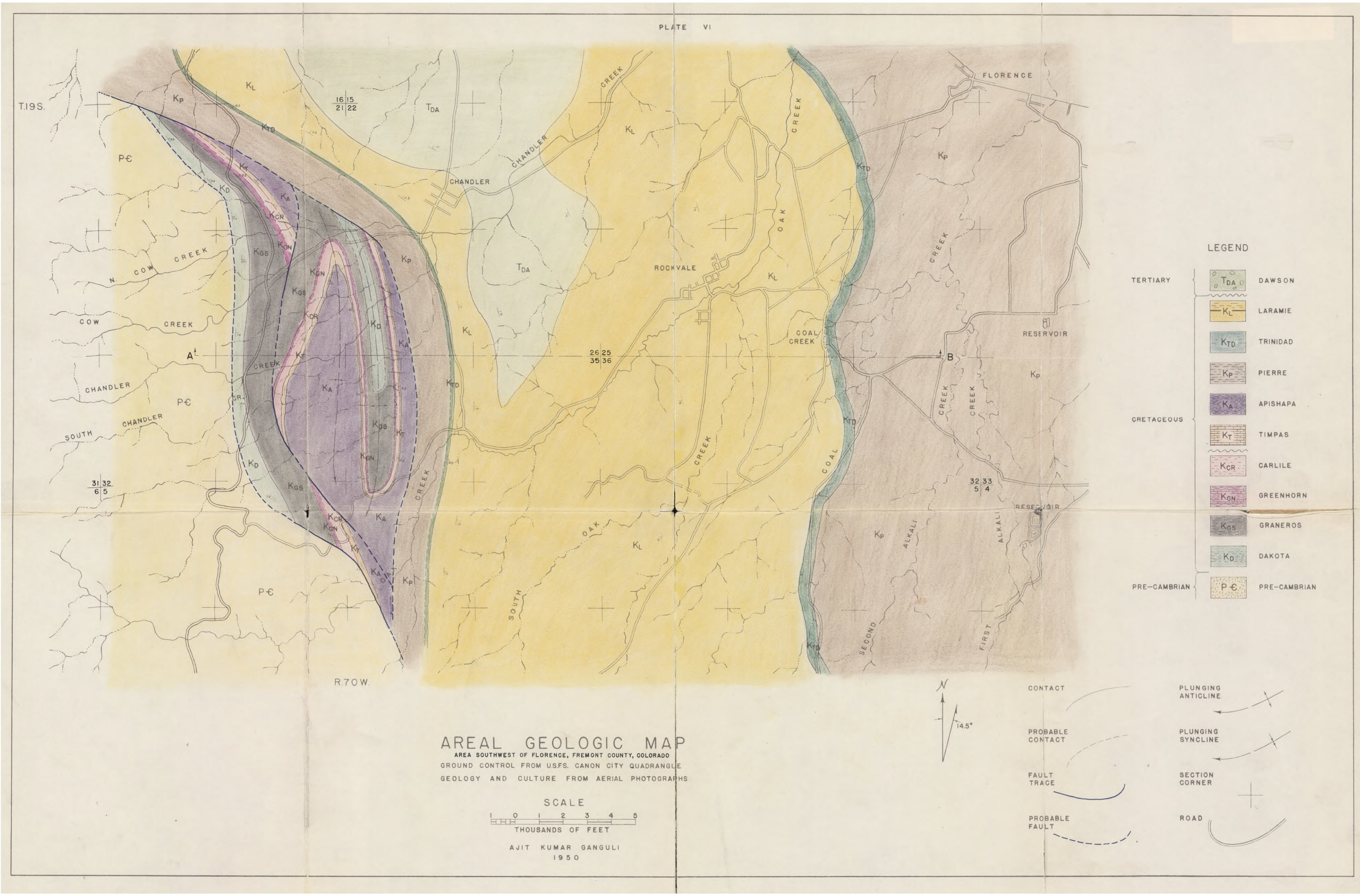
PLATE VI
AREAL GEOLOGIC MAP
AREA SOUTHWEST OF FLORENCE, FREMONT COUNTY, COLORADO
GROUND CONTROL FROM U.S.G.S. CANON CITY QUADRANGLE
GEOLOGY AND CULTURE FROM AERIAL PHOTOGRAPHS
SCALE
1 0 1 2 3 4 5
THOUSANDS OF FEET
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1950
LEGEND
TERTIARY
DAWSON
LARAMIE
TRINIDAD
PIERRE
CRETACEOUS
APISHAPA
TIMPAS
CARLILE
GREENHORN
GRANEROS
DAKOTA
PRE-CAMBRIAN
PRE-CAMBRIAN
CONTACT
PROBABLE CONTACT
FAULT TRACE
PROBABLE FAULT
PLUNGING ANTICLINE
PLUNGING SYNCLINE
SECTION CORNER
ROAD
N
14.5°
T.19S.
R.70W.
FLORENCE
CHANDLER
ROCKVALE
COAL CREEK
RESERVOIR
N. COW CREEK
COW CREEK
CHANDLER CREEK
SOUTH CHANDLER
OAK CREEK
SOUTH OAK CREEK
COAL CREEK
CHANDLER CREEK
SECOND ALKALI CREEK
FIRST ALKALI CREEK
A
B