CONTENTS

LIST OF ILLUSTRATIONS

[Presented before the Society January 26, 1929]

GEOLOGIC HISTORY OF THE FRONT RANGE, COLORADO[1]

T. S. Lovering[2]

INTRODUCTION

The geologic history of the Front Range of Colorado that is presented here is based on the interpretation of data gathered during three years of field work, and on the large amount of literature dealing with the geology of the Range. The assembling of these data into a continuous history from pre-Cambrian time to the present is an attempt to give a properly proportioned picture of the geology of the region and has been both an aid to, and a check on, the solving of economic and related geologic problems. The field work, done for the U. S. Geological Survey in co-operation with the Colorado Metal Mining Fund, consisted largely of a detailed study of the Montezuma quadrangle supplemented by a reconnaissance of the Fraser quadrangle and many visits to other areas from Cripple Creek to Laramie. The information gained has been so helpful in the solution of hitherto obscure or puzzling features that a fairly well connected account of the historical geology can now be presented. Probably the most important features of the paper are a consistent correlation of the pre-Cambrian rocks, a summarizing of the paleogeography of the Paleozoic and Mesozoic, and new tentative solutions of the Laramie problem and the problem of Tertiary peneplains.

---

[1]Published by permission of the Director of the U. S. Geol. Survey and the Colorado Metal Mining Fund.

[2]Associate Geologist, U. S. Geological Survey.

An exhaustive account with thorough discussions of the many problems and with due credit to previous workers would form a volume of considerable size. To keep this paper within reasonable limits, therefore, it is presented essentially as a summary and the reader's general acquaintance with the regional geologic problems is assumed. Lack of space prohibits the repetition of local details described in published reports. These reports are already listed in the Bibliography of North America[3] and only the most important sources of information used in preparing the paper are given in the selected bibliography at the end of the paper. At this place I wish gratefully to acknowledge my indebtedness to all who have contributed to the geology of Colorado.

General Geology of the Front Range

The Front Range of Colorado, as considered in this paper, is an elongate dome extending from Canon City northward into Wyoming, where it disappears a short distance northeast of Laramie. Geologically it consists of a long narrow mass of pre-Cambrian rocks practically surrounded by up-turned Paleozoic and Mesozoic formations. All these formations are intruded in some places by Tertiary igneous rocks, and in others are partly covered by Tertiary sedimentary or volcanic rocks which frequently overlap the beveled edges of the earlier sediments.

The pre-Cambrian geology is a complex problem of regional metamorphism and batholithic intrusion sharply separated from that of later eras, whereas the divisions between the successive later eras are relatively obscure. This paper is accordingly divided into two main parts, pre-Cambrian and Cambrian to present.

[3] Nickels, J. M., Geologic literature of North America, U. S. Geol. Survey Bulls. 746, 747. Bibliography of North American literature, U. S. Geol. Survey Bulls. 731, 758, 784, 802.

PART I.

PRE-CAMBRIAN HISTORY OF THE FRONT RANGE

Introduction.—In their summary of the pre-Cambrian geology of North America, Van Hise and Leith[4] state that the pre-Cambrian rocks of Colorado fall into four main groups:

1. A complex of gneisses and schists, the oldest rocks of the mountains.
2. A complex of basic igneous rocks, now for the most part changed to greenstone, schists and gneisses.
3. A series of quartzites, slates, schists and conglomerates all of undoubted sedimentary origin.
4. Massive igneous rocks, chiefly granitic, occurring in large and small bodies, cutting the gneisses and sediments in some places, and elsewhere showing by their comparatively unmetamorphosed condition that they presumably form the most recent of the four categories mentioned.

This generalized picture is helpful in studying the pre-Cambrian rocks of the Front Range, as the intricate relations of the many formations are confusing. This is illustrated by the results of the careful study in the heart of the Front Range by Ball,[5] who distinguished nine different pre-Cambrian formations whose relative ages from oldest to youngest are as follows:

1. Idaho Springs formation (schists and crystalline rocks of sedimentary origin.)
2. Hornblende gneiss (mashed diabase).
3. Quartz monzonite gneiss.
4. Gneissoid granite.
5. Pre-Cambrian quartz monzonite.
6. Quartz-bearing diorite and hornblendites.
7. Rosalie granite.
8. Silver Plume granite.

[4] Van Hise, C. R., and Leith, C. K., Pre-Cambrian Geology of North America, U. S. Geol. Survey, Bull. 360, p. 824, 1909.

[5] Spurr, J. E., Garrey, G. H., and Ball, S. H., Economic Geology of the Georgetown Quadrangle. U. S. Geol. Survey, Prof. Paper 63, pp. 37-66, 1908.

9. Pegmatite and associated granite and granite porphyry.

The complexity of the relations of these formations is evident from Ball's statement on page 91 that "in a distance of one mile * * * six formations alternate seventy-six times, or at the rate of one every seventy feet."

Broadly speaking, however, the pre-Cambrian rocks of the Front Range comprise a thick series of schists and injection gneisses intruded by a succession of batholithic and stock-like masses of granite and closely related rocks. In spite of some marked differences, most of the intrusives are so related structurally and petrographically that they are believed to belong to one great period of batholithic invasion.

The pre-Cambrian quartz monzonite, the quartz-bearing diorite, and the "Rosalie" granite of the Georgetown quadrangle are believed by the writer to be part of the Pikes Peak granite batholith. The relations of the quartz monzonite-gneiss, the gneissoid granite, and the injection gneiss facies of the Idaho Springs formation, to the Pikes Peak granite, suggest the early intrusive activity, attending the slow formation of a granite batholith. The Silver Plume granite is correlated with the Mount Olympus granite and the granite of Coal Creek, but these intrusives are later than the main period of batholithic invasion.

Pre-Cambrian Formations

Idaho Springs formation.—The Idaho Springs formation appears to be the oldest rock unit in the region. Its less altered facies consist chiefly of quartz-biotite schists, biotite-sillimanite schists, and quartz schists or gneisses. Occasional masses of lime silicates intergrown with garnet and magnetite suggest the metamorphism of limy beds. The quartz schists and gneisses are undoubtedly metamorphosed shaly sediments. The thickness of these sediments has been estimated by Clarence King as not less than 25,000 feet and none who have studied the region in detail have been able to give a more accurate figure.

Although no earlier formations are known in the Front Range, a microscopic study of the quartz gneiss gives an interesting insight into the source of these very ancient sediments. The gneiss consists largely of quartz and contains only small amounts of feldspar and biotite. The individual quartz crystals contain numerous parallel lines of fluid inclusions, but the parallelism is not related to schistosity and has random orientations in different grains, proving that it is an original structure and not caused by deep-seated metamorphism. Under high magnification, Brownian movement can be seen in many of the fluid inclusions, where minute cubic salt crystals have been hammering vainly against the walls of their cells. Fluid inclusions containing salt crystals are found only in rocks formed at high temperatures and pressures, and the quartz imprisoning these minute liquid inclusions probably formed in a granitic magma. Thus the quartz gneiss gives us a clue to one of the most remote periods in the earth's history, reaching far back of the time when the Idaho Springs formation was deposited. These high temperature quartz grains probably record the formation of a granite far below the surface, its subsequent uplift, its slow uncovering as erosion wore away the overlying rocks, its disintegration at the surface and the transportation of this detrital material to a sea which washed the quartz sand almost free from the minerals with which it had been associated in the granite. No remnant of the land mass which supplied the sediments of the Idaho Springs formation is known in the Front Range of Colorado.

The simple types of schist mentioned above do not make up all of the Idaho Springs formation, but only represent those portions of it which have escaped the more severe metamorphism that characterizes large areas of it. Injection gneiss is developed on a grand scale and some areas of the schist have been so thoroughly injected by granitic material that they are easily mistaken for granite gneiss.

Hornblende gneiss.—So far as my observations have gone, hornblende gneiss is everywhere younger than the Idaho

Springs formation and older than any of the other pre-Cambrian formations of the Front Range. This agrees with the relations described by Ball in the Georgetown quadrangle. The hornblende gneiss is extensively developed along the western side of the range from South Park to Estes Park, and there are also many small areas of it on the eastern side of the divide. It intrudes the Idaho Springs formation, and its linear outcrop and parallelism with the schistosity of that formation suggests that it was intruded in the form of great sills between the beds of the Idaho Springs sediments. It is also possible that portions of the hornblende gneiss represent intercalated surface flows, but no structures such as ellipsoids or pillow structure have been observed. This formation is characterized by the same degree of metamorphism which is found in the Idaho Springs formation; granulation of the feldspars is usual, quartz grains are commonly found crushed, and *lit par lit* intrusion of later aplite and pegmatite has converted large masses into contorted injection gneiss often indistinguishable from the injection gneiss of the Idaho Springs formation.

The abundance of hornblende, biotite, and labradorite, together with the presence of moderate amounts of quartz, augite, and magnetite, as revealed by a microscopic study of the formation, suggests that it represents a much metamorphosed quartz diorite. It formed in large part before schistosity was developed in the Idaho Springs formation, although the earlier sediments may have been locally converted into schists before the last masses of diorite had formed.

The Idaho Springs formation and the hornblende gneiss correspond to numbers 1 and 2 of the general groups summarized by Van Hise and Leith and should accordingly be followed by schistose sediments. As the hornblende gneiss is both overlain and underlain by the sediments of the Idaho Springs formation, the overlying part of the Idaho Springs formation may represent number 3 of the succession given by Van Hise and Leith. Further study may indicate a decided break between the schists underlying the hornblende gneiss and those above, but none has yet been found.

Quartz monzonite gneiss.—Following the sediments of group 3 of Van Hise and Leith there is an extensive series of granitic intrusives. The earliest rock known to be later than the hornblende gneiss is the quartz monzonite gneiss of the Georgetown quadrangle. This rock is unimportant areally and has been observed in few places outside of a small region south of Georgetown. It contains inclusions of both Idaho Springs formation and hornblende gneiss. These inclusions are parallel to the gneissic structure developed in the quartz monzonite gneiss. Very commonly they fade into the enclosing rock and one can find all gradations from distinct inclusions of schist to shadowy areas of biotite-rich quartz monzonite gneiss that represent almost completely assimilated schist fragments. A thin lens of schist frequently tails off into lines of biotite indistinguishable from those in the surrounding gneiss which are apparently unrelated to any inclusions. *Lit par lit* injection of schist and hornblende gneiss inclusions by the quartz monzonite magma is always evident and it is difficult to escape the conclusion that assimilation, resulting from extreme development of *lit par lit* injection, played an important part in the formation of the gneiss. The assimilation and intimate injection of schistose country rock must have helped develop a strong primary gneissic structure in the quartz monzonite magma and this was intensified by continued flowage of the magma under pressure during its crystallization, for both quartz and feldspars are decidedly granulated.

The facts just presented indicate that the intrusion of this early quartz monzonite was deep-seated, that the Idaho Springs formation and the quartz diorite had already been converted into schist and hornblende gneiss, and that locally at least some of it was being changed into injection gneiss. Thus between the formation of the original equivalent of hornblende gneiss and the quartz monzonite gneiss there may have been a long time interval during which folding and schistosity were developed. As an alternative hypothesis, it is suggested that the schist developed very shortly before the intrusion of the quartz monzonite magma, and was caused by regional compression and the hot emanations from the magma. The development of schistosity would thus slightly precede *lit par lit* injection and might be closely followed by the intrusion of small or large masses of the magma itself. Such masses would take advantage of the newly formed schistose structure, forming sheets parallel to the foliation, and would themselves be early enough to develop orthogneissic structure.

Granite gneiss.—Granite gneiss is said by Ball to be older than the quartz monzonite gneiss, but I have been unable to find satisfactory evidence of this relation. Where the schists have been highly injected and metamorphosed it is easy to find specimens that do not differ appreciably in composition or appearance from the quartz monzonite gneiss. Inclusions of this sort are present in the granite gneiss, but I have not found any which were unquestionably quartz monzonite gneiss. The foregoing is not intended as controversial, but simply to indicate the difficulty of unraveling some of the relations between the early rocks, and as a caution to those who study them in the future.

Granite gneiss is widely distributed throughout the Front Range, but rarely covers areas of more than a few square miles. The granite gneiss seldom has the grain size typical of the average granite. Most of it is fine grained but grades into coarse grained facies in several places, indicating that it is a metamorphosed aplite with local pegmatitic phases. In several places the granite gneiss forms small cross-breaking intrusions, but usually occurs as sill-like bodies which may follow the schistosity of the older rocks for miles. As in the quartz monzonite gneiss, evidence of assimilation and injection of the schistose country rocks is common. Unlike the quartz monzonite gneiss, however, the evidence of assimilation and *lit par lit* injection is usually confined to the borders of granite gneiss masses. Horizons of injection gneiss in the Idaho Springs formation are commonly associated with pegmatitic facies of the granite gneiss

The quartz-bearing diorite and the quartz monzonite, as Ball[6] has shown, are genetically related and grade into one another in some places. It is therefore confusing to try to separate them into distinct formations when considering the Front Range as a whole.

The Rosalie granite, mapped by Ball in the Georgetown quadrangle, has been traced southward through the Platte Canyon quadrangle into the Pikes Peak quadrangle and found to be continuous with Pikes Peak granite as mapped by Cross and Mathews.[7] As the latter name has priority, it is here used to designate this granite throughout the Front Range. The quartz monzonite was separated from the Pikes Peak granite by Ball, who believed it distinctly younger. The typical coarse-grained, pink Pikes Peak granite contrasts strongly with much of the gray, slightly gneissic, quartz monzonite and these two rocks on the whole are easily distinguished from each other; but complete gradations from one into the other can be found at several places from the vicinity of Summit Lake southwest into Bruno Gulch. The gneissic structure of the undoubted quartz monzonite in this region is caused largely by the parallel arrangement of the feldspars and biotite and to a less extent by the imperfectly assimilated stringers of schist. Where schist inclusions and biotite are minor constituents, the quartz monzonite assumes the pink color of the Pikes Peak granite and, where flow structure is not evident, it becomes indistinguishable from the granite. The perfect gradation from one rock to the other indicates that the two are facies of a single rock mass, and their distribution indicates that the quartz monzonite is the border facies of the larger granite mass. It need not be considered, therefore, as a separate formation in the discussion of the regional geology.

The Pikes Peak granite batholith was a deep-seated intrusion and was probably the chief factor in developing injection gneiss in the older formations. Around the large mass

---

[6]Op. cit. p. 56.

[7]Cross, Whitman, U. S. Geol. Survey Atlas, Pikes Peak Folio (7), 1894.

the metamorphic aureole is so widespread that it is difficult to trace the relation between them. A brief description of the schists bordering a small mass of Pikes Peak granite at Bruno Gulch may help to understand the more profound effects of the great batholith itself. Around the border of the stock at Bruno Gulch, the Idaho Springs formation is greatly altered for a distance of several hundred feet. As one approaches the granite the normal quartz-biotite-sillimanite schist of the region grades into a finely layered injection gneiss in which about one-half of the rock consists of quartz and feldspar laminae between layers of biotite. The next change observed is the segregation of some of the quartz and feldspar into knots about one-half inch in diameter scattered sparingly through the rock. As the granite mass is more closely approached these knots become more and more conspicuous and most of them are sharply angular after the habit of microcline crystals; indeed many of them consist of single microcline crystals containing small inclusions of quartz. Close to the granite these feldspar metacrysts become so abundant that the rock more nearly resembles a gneissic porphyritic granite than a schist and, in fact, it was mapped by Ball as a granite gneiss. The white, highly quartzose aplites instrumental in forming the injection gneiss are essentially parallel to the schistosity and are earlier than the cross-breaking siliceous aplites which vein the schists. Both are earlier than the feldspar metacrysts. The areal relations of the granite and the zone of granitization in the schists show clearly that the changes in the schist have been induced by the granite.

Similar metamorphism is well shown at the southern end of the granite mass of Coal Creek, a few miles northwest of Golden. Fuller[8] has described the progressive increase in metamorphism of the schists bordering the granites of Estes Park and believes that the granites in this region have affected the schists for several miles from their contacts.

[8] Fuller, M. B., General features of the pre-Cambrian structure along the Big Thompson River in Colorado, Jour. Geol., Vol. 32, pp. 49-63, 1924.

Late pre-Cambrian granites.—Throughout the Front Range there are moderately large masses of granite, including the Cripple Creek granite of the Pikes Peak quadrangle, the Silver Plume granite of the Georgetown quadrangle, the granite of Coal Creek in the Blackhawk quadrangle, and the Mount Olympus granite of the Estes Park region, which bear a strong lithologic resemblance to one another and are distinctly later than the Pikes Peak granite. These late pre-Cambrian granites show a decided tendency to follow faults and cross fractures in the schists and gneisses in contrast to the marked habit of parallelism to the schistosity shown by the older intrusives. Gneissic structures are rarely observed in the late granites, but in some places, as in Geneva Gulch at the mouth of Smelter Gulch, there is a well marked orthogneissic structure developed. The lithology of the late granites is very similar and the marked flow structure of the feldspars, the unoriented biotite crystals and the much finer-grained texture readily distinguish them from the Pikes Peak granite. Most of the inclusions of schist are angular and show sharp contacts with the granite. Assimilation was evidently a less important factor during the formation of these granites than in the formation of the Pikes Peak granite. These facts indicate that there was a time interval between the formation of the two kinds of granite. However, there are no sediments known which are younger than the Pikes Peak granite and older than the Silver Plume granite, and it therefore seems best to consider both granites as belonging to the same general period of batholithic intrusion.

At many places along the eastern edge of the Front Range, there is a series of quartzites and quartz schists which has commonly been considered younger than the Idaho Springs formation and later than the granites of the Silver Plume type. The late pre-Cambrian granite of Coal Creek definitely intrudes this series. The schistosity and bedding of the quartzites are parallel to the so-called older mica schists and there is a perfect gradation between them. In

Estes Park, Fuller concluded that there was no appreciable difference in the age of the quartzites and the underlying mica schists into which they grade, and I have not found any evidence for separating these quartzites and quartz mica schists from the Idaho Springs formation.

Summary of pre-Cambrian.—Before considering the Paleozoic and later periods, it may be well to summarize the pre-Cambrian history as interpreted from the observations given above.

The most remote event which we can infer is the formation of a granitic mass and its subsequent uplift and erosion. This ancient granitic highland was in part the source of the thick series of shales and sandstones that originally made up the greater part of the Idaho Springs formation. The thickness and wide areal extent of the shaly sediments suggests that they were marine. Into this series of shales and sandstones great masses of diorite were intruded parallel to the bedding, and it is possible that some of the dioritic magma reached the surface in the form of andesitic flows while the sediments were accumulating, and became interbedded with them.

Uplift, accompanied by strong folding, followed the deposition of the sediments, and ushered in a period of intense intrusive activity which culminated in the formation of the Pikes Peak batholith and its related granite masses. Into the crumpling mass of sediments many bodies of diorite, monzonite, and granite were injected. Under the conditions which prevailed, characteristic of the zone of flowage, the heat and emanations from these intrusives converted the sediments into schists and gneisses. Continued diastrophism accompanied the invasion of much larger masses of granitic magma, and many of the earlier intrusives were converted into gneisses during its slow solidification. The granite masses which were formed at this time are the largest found in the Front Range and the intrusive activity as well as the metamorphic processes waned markedly after their formation.

At some later time, after the Pikes Peak granite had solidified, another series of granite invasions occurred. These are the latest pre-Cambrian rocks known and include the Cripple Creek granite, the Silver Plume granite, the granite of Coal Creek, the Mount Olympus granite, and their associated pegmatites. The fact that they were intruded in the zone of fracture instead of the zone of flowage, and after the Pikes Peak batholith had solidified, implies a considerable lapse of time, but they still may be regarded as representing the last major stage of the batholithic cycle.

The formation of these later granites was probably accompanied by uplift and was certainly followed by a long period of erosion which probably left the Front Range as a highland bordered by nearly level lowlands to the east and west in the later part of the Algonkian. This Front Range highland probably persisted through the remainder of pre-Cambrian time and possibly through Paleozoic time as well.

Although it has been a common practice to correlate the various pre-Cambrian formations of all North America with those of the Lake Superior region, such a correlation of widely separated regions is obviously unsatisfactory unless the ages of granitic and metamorphic rocks can be determined by analyses giving the lead-uranium ratio. In the absence of exact age determinations, the only available means of correlation is a comparison of the histories of the two regions, an obviously inexact method. The major events in the pre-Cambrian history of the Front Range are similar in sequence to the batholithic invasions of the Laurentian and Algoman revolutions of the Lake Superior region, which were separated by a long interval during which Lower and Middle Huronian sediments and basic lavas were formed. The Idaho Springs formation could thus be tentatively correlated with the Lower and Middle Huronian, the Pikes Peak granite assigned to the early Algoman, and the Silver Plume and associated granites to the late Algoman. All these formations would then be included in Algonkian as defined by the U. S. Geological Survey.

PART II

HISTORY OF THE FRONT RANGE FROM THE CAMBRIAN TO THE PRESENT

Introduction.—In reconstructing the history of the Front Range from the Cambrian to the present, the successive formations have been studied with special reference to the character of the lithology, the fossils, the amount of metamorphism and structural disturbance shown by the formation, and the areal relations of overlap to the thickness and character of sediment nearby.

On the basis of this study, a series of paleogeographic maps has been prepared, showing the areas covered by various rock systems just before the succeeding formation was deposited. These maps emphasize old areas of erosion much more than the usual paleogeographic maps which commonly show the maximum extent of a given sea.

These maps, figures 1 to 5, show that the area occupied by the present Front Range was relatively high throughout Paleozoic and Mesozoic time. Evidence is given which suggests that the Front Range highland, after sinking below the level of the sea in Pierre time, emerged and in places was wiped clean of post-Algonkian sediments before Laramie time. The Laramide revolution is shown to follow the deposition of the Denver formation.

In Tertiary time partial peneplains were developed in Eocene, Oligocene, and Miocene time. The earliest peneplain, the Flattop surface, is shown to be in large part a pre-Cretaceous peneplain laid bare by the removal of sediments and lavas.

The Quaternary glacial stages of the Front Range are correlated with the Kansan, Illinoian and Wisconsin glaciations of the plains.

PALEOZOIC AND MESOZOIC FORMATIONS

Cambrian.—Cambrian rocks are found on both sides of the Front Range near its southern end. The marine fossils give little indication of the climate, but sediments suggestive of glaciation, aridity, or extreme humidity are not found. The abundance of quartzite, with its even basal contact, suggests a shallow sea transgressing over a base-leveled surface. Nowhere is the Cambrian thick and it is definitely overlapped by Ordovician beds on both sides of the range.

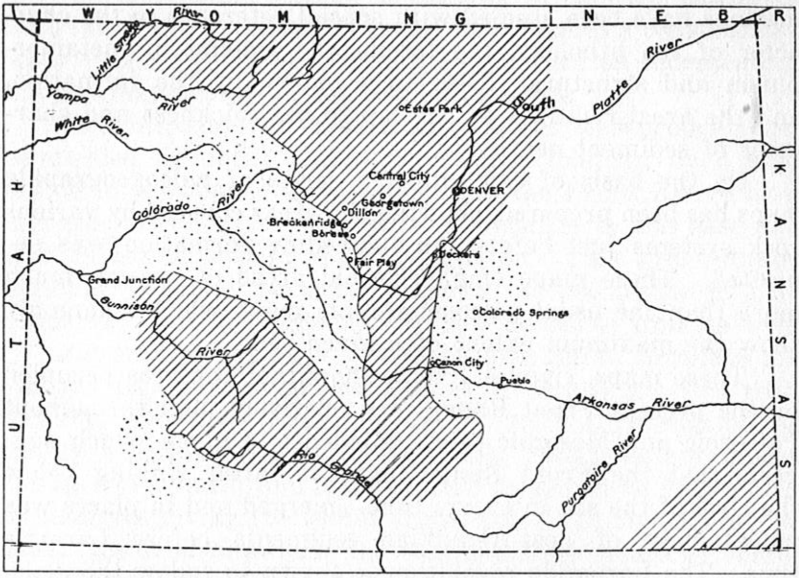

Fig. 1—Paleogeographic map of Cambrian and Ordovician rocks of Colorado.
Ruled area=highland at beginning of the Devonian.
Dotted areas, Cambrian and Ordovician rocks at beginning of the Devonian.

On the southwestern side of the range the Ordovician beds overlap the Cambrian quartzites a nearly uniform distance of two or three miles. Near Red Cliff, however, the Cambrian quartzite is unusually thick and the Ordovician is very thin and sandy. Further west, the Cambrian beds are consistently present and do not show sudden variations in thickness. On the eastern side of the Front Range, however, the Cambrian beds are irregular in thickness and distribution.

These relations, which are duplicated in some measure in the succeeding systems, suggest that the Cambrian shoreline on the western side of the Front Range highland was essentially that marked by the Ordovician overlap, but that the eastern shoreline was obliterated by erosion following the uplift at the end of Upper Cambrian time. Although the boundary of the Cambrian is ragged and irregular in detail between Canon City and Colorado Springs, its general trend at the beginning of the Ordovician period can be found (fig. 1). The regularity of the western border indicates that the Front Range highland immediately to the east of this border probably remained above water throughout Cambrian time. Again, the relation of overlaps in succeeding formations suggests an intermittent, oscillating but progressive, sinking of a high area in the Front Range region. The hypothesis that the Cambrian sediments once completely covered the Front Range area is also tenable, but for the reasons given above, it seems improbable.

However, the Ordovician overlap has not been critically studied in many places on the western slope, and subsequent work may show relations indicating a larger vertical oscillation between the Cambrian and Ordovician than seems probable from the facts now at hand. There was probably an arm of the Cambrian sea extending north-northwest from Colorado Springs to the vicinity of Deckers, bordered on the west and north by land, also another embayment extending northward from Canon City. The shoreline on the west of the Front Range highland probably extended north-northwest from Howard to a point about 12 miles north of Fairplay, where it turned sharply to the northwest, as shown in figure 1.

Ordovician.—The Ordovician rocks have nearly the same distribution as the Cambrian and contain marine fossils which are poor climatic indicators. The sediments are not as sandy as the Cambrian and contain more limestone and shale. They are overlapped by Devonian and Pennsylvanian beds which transgress farther upon the Front Range highland. The Deckers embayment was probably deepened slightly during this period, since Ordovician beds overlap the Cambrian on Trout Creek southeast of Deckers. About ten miles southwest of Colorado Springs the Ordovician rocks thin and disappear, overlapped by Pennsylvanian beds, but within a short distance they reappear and gradually thicken to the west as the Canon City embayment is approached. They disappear rapidly west of Canon City and are overlapped by Pennsylvanian, Jurassic (?), and Cretaceous formations. Since the lower Ordovician beds disappear on the southeast front of the range, there is evidence that the Ordovician sea was shallower between the two embayments than elsewhere, and that the two troughs were becoming more accentuated. There is no appreciable thinning of the Ordovician beds north of Canon City for a distance of fifteen miles, where, at the head of the embayment, they are found as erosion remnants resting on granite. The western shore of the land mass followed that of the Cambrian sea but was in general a few miles farther to the east.

Silurian.—No Silurian sediments are known near the Front Range and it is safe to say that this region was not submerged during that period.

Devonian.—Devonian sediments are confined to the western side of the Front Range, as shown in figure 2. They contain marine fossils only. The sediments are sandy at the base, but for the most part are very limy or dolomitic and do not indicate proximity to a land mass undergoing active erosion. The lack of Devonian sediments on the eastern side of the range was probably due to non-deposition in this area. The Mississippian limestone in the Canon City embayment rests directly on the Ordovician.

Mississippian.—The Mississippian rocks are well represented west of the Front Range, and at the beginning of Pennsylvanian time their distribution there was practically the same as that of the underlying Devonian system.

Their extent on the eastern slope is uncertain, as only a few small areas of Mississippian rocks remained uneroded when Pennsylvanian sediments covered this side of the highland. Small areas were left in the Canon City embayment and in the Deckers embayment about 12 miles southwest of Castle Rock.

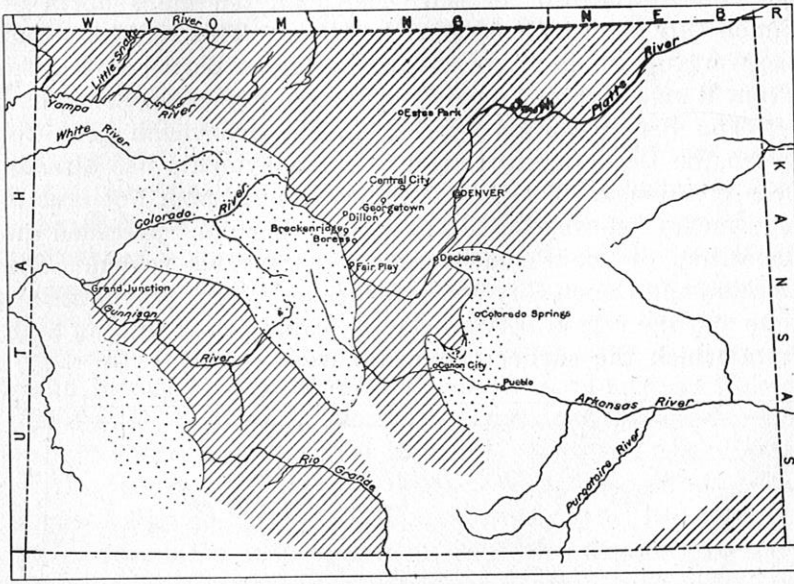

Fig. 2—Paleogeographic map of Devonian and Mississippian rocks of Colorado.
Ruled area=highland at beginning of the Pennsylvanian.
Dotted areas, Devonian and Mississippian rocks.

There is no decided break between the Devonian and Mississippian formations on the west side of the range. The Mississippian formations are decidedly limy at the base and pass up through shaly horizons into distinctly sandy beds. In many places these grade into the overlying Pennsylvanian grits and in others there is a sharp break between the two. The fossils in the Mississippian are all marine forms. The line of the Pennsylvanian overlap is a few miles east of the Ordovician shoreline on the west side of the Front Range highland, and suggests the slow submergence of this land mass. The Mississippian limestone in the Canon City and Deckers embayments is found as a very thin bed between the Ordovician and Pennsylvanian rocks, with evidence of erosional unconformities at both its upper and lower surfaces. It is worthy of note that the Mississippian limestone rests on much lower beds of the Ordovician ten miles north of Canon City than it does near the town.[9] This indicates that the warping which followed the Ordovician period raised the Front Range highland more than the country to the southeast.

The Pennsylvanian overlap of the Ordovician beds between the Deckers and Canon City embayments has already been mentioned. These facts indicate that important crustal movements followed the Mississippian epoch and preceded the deposition of the Pennsylvanian beds in this region. The Deckers and Canon City embayments were accentuated at this time and the region between the two was raised into an arch from which the earlier sediments were eroded.

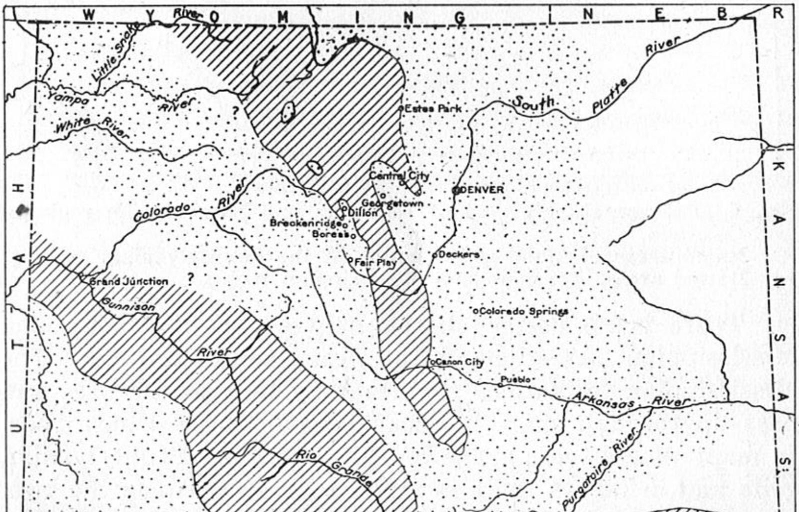

Fig. 3—Paleogeographic map of Pennsylvanian and Permian rocks of Colorado.
Ruled area=highland at beginning of the Triassic.
Dotted areas, Pennsylvanian and Permian rocks at beginning of the Triassic.

[9]Cross, Whitman, op. cit. p. 2.