NORTHEASTERN UNIVERSITY

GEOL OGY OF THE CALUMET, COLORADO, MINING DISTRICT

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for the degree
MASTER OF ARTS

DEPARTMENT OF GEOL OGY AND GEOGRAPHY

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Plate 1:
I. Areal sketch map of the Calumet region back cover
II. Geologic map of the Calumet district back cover
III. Geologic map of the Calumet Mine back cover
For the reader who wishes to get a general picture of the material covered in this report, a brief summary of the chapters is given below.

Chapter 2. Geomorphology and Physiography. — A north-south strip, about half a mile wide and underlain by sedimentary rocks, is characterized by parallel hogback ridges. To the west of this area the pre-Cambrian rocks have a topography of broad areas with knobs rising abruptly above. East of the outcrop of sedimentary rocks is a divide underlain by Tertiary granodiorite.

Chapter 3. Stratigraphic Succession. — The sedimentary formations of the Calumet district include the Cambrian (Renath quartzite); Ordovician (limitou limestone, Harding quartzite, and Freemont limestone), Devonian (Portheiq quartzite), Devonian-Mississippian ("Blue" limestone), and Pennsylvanian ("Weber" formation). The average thickness of all the formations is about 1250 feet. Approximately half of this is limestone, one-tenth quartzite, and the remainder shale and grit.

Chapter 4. Igneous Rocks. — The igneous rocks of the Calumet district are of three main types: (1) pre-Cambrian granite and gneiss; (2) Tertiary intrusive rocks, and (3) late Tertiary volcanics.

The pre-Cambrian rock is a very coarse-grained, white to pink granite and gneiss. It underlies the entire district and outcrops in the upland area on the western border.

The Tertiary intrusive rocks entered the region as a stock-like mass which outcrops over an area about 8 miles long and 4 miles wide. A smaller off-shooting stock and long finger-like, concordant extensions branch off from the main stock on its northeast side. These intrusions outcrop east of the Paleozoic formations. The rocks are mainly granodiorite — light to dark gray, fine to medium grained, and equigranular. Named plagioclase, augite, hornblende, and biotite occur as early minerals, and are surrounded and engulfed by quartz and orthoclase. Plagioclase has been recognized; along the outer border of the intrusive augite is more abundant than hornblende, and little orthoclase is present; in the central part, hornblende is more abundant than augite, and orthoclase in a prominent constituent. Local differentiation into and basic dikes is a common feature. The intrusive is believed to have reached its present position mainly by stoping.

Late Tertiary extrusives cover much of the surface at the southern end of the granodiorite stock. The extrusives occur both as flows and as pyroclastic deposits.

Chapter 5. Structural Geology. — The granodiorite intrusive was intruded along the axis of a syncline. The long dimension of the stock parallels the strike of the sedimentary rocks. The beds dip into the stock at an angle averaging about 25°. Numerous sills extend from the stock into the sedimentary rocks. Faults are present in the southern part of the Calumet district but are an unimportant structural feature.

Chapter 6. Contact Metamorphism. — The granodiorite stock which intruded the Paleozoic sediments of the Calumet district produced various contact effects around its borders. In most places this metamorphism was of little consequence, but in the vicinity of the Calumet mine all types of rock were altered to a varying degree. The sills at the mine were endemorphosed; the limestone were bleached and recrystallized usually to a coarse-grained, white marble, and at the mine they were intensively altered and impregnated with iron minerals; carbonaceous limestones of the "Weber" formation were transformed into graphite beds; the shale beds of the "Weber" were recrystallized and new minerals were developed; and some of the sandstones were recrystallized.

Chapter 7. Mineralogy. — Forty-three minerals were identified in the rocks of the Calumet district. This includes those found in the granodiorite, the contact zone, and the sedimentary beds. The occurrence of each of these minerals is described in some detail in the text.
Chapter 8. Economic Geology— Iron ore has been the only ore mined in the district to any extent, and production of this ceased in 1899. The deposit is of the contact metamorphic type. Magnetite is the predominant ore mineral, and occurs in a heavily silicated zone in the "Blue" limestone, usually "chinking in" between, or veining, blades of diopside. Besides iron ore, manganese, gold, and copper ores were once produced on a small scale.

The granodiorite makes a good building stone, and is being quarried at the present time. Marble has been quarried to be used as a flux. Several small graphite pits have produced some graphite.

Chapter 9. Production and Mining History— The Calumet mine was operated between 1891 and 1900, and produced 220,761 gross tons of ore. The reserve is estimated at 840,000 tons of iron ore.

Chapter 10. Description of Mines— The Calumet mine is the only mine in the district that was extensively worked. It was worked for magnetite ore only, and both the open-pit and underground methods were used. The Iron King mine was worked for gold, iron-ore being mined incidentally. It is an open pit. A mine was opened in a manganese deposit in the north-central part of sec. 3, T.6N., R.26E. Several other small mines operated for a short time. Numerous pits have been dug and several shafts have been sunk in search for ore.
INTRODUCTION

The Calumet mining district is located in eastern Chaffee County, Colo., in longitude 105°59' and latitude 38°37'. As shown in fig. 1, the Calumet district lies within the area surveyed with respect to the New Mexico principal meridian and base line, but reconnaissance work extended northward into the area surveyed with respect to the 6th meridian and base line (See Pl. 1).

The district lies within the range of hills which separate the south end of South Park, on the east, from the Arkansas valley on the west. These hills are the extension southward of the Mosquito Range. The district is located two miles east of the town of Turret (Fig. 2), and eight miles northeast of Salida. During the last two decades of the 19th century the Calumet district was a busy mining camp. Calumet City, within the district, was at one time a town of several hundred population. Now one shack is all that remains of the town. In 1933 a secondary road afforded the only means of getting into the district. A small railroad served the camp when mining was carried on extensively. This railroad has been abandoned since 1900.

Iron ore was the chief economic product taken from the Calumet district. Manganese ore and graphite were shipped in limited quantities, as was also marmarized limestone which was used as flux in the smelting of iron ore at Pueblo, Colo. Quarrying of granodiorite for building and monumental stone was until recently conducted on a large scale. Some gold and silver was taken from within the Calumet district, as well as from the granite area just to the west of the district.

No geologic report dealing with this district has been published. R.C. Hills wrote, in 1892, a short report on the Calumet mine, in which he described the ore body and the methods of mining. This manuscript was made available through the kindness of the Colorado Fuel and Iron Company.

The field study on which this report is based was carried on at the suggestion of B.S. Butler, who, with E.N. Goddard, did reconnaissance mapping in this area during 1931. Between three and four weeks of the latter part of the summer of 1933 were spent in the district, mapping the formations and studying the structure and the relations of the Tertiary intrusive to the sediments. Laboratory investigation has consisted chiefly in the study of thin sections of the many types of rocks.

A detailed study was made of only a few square miles centering about the Calumet mine. A less detailed study, however, was made of a much larger area, embracing about 64 square miles in the northwest corner of Fremont County and the
adjacent parts of Park and Chaffee Counties. As used in this report, the term "the Calumet district" includes the area shown on the geologic map of the Calumet district (Pl. II). The map covers about four square miles, and includes the entire width of the outcrop of the sedimentary formations, the eastern margin of the pre-Cambrian granite, and the western border of the Tertiary granodiorite.

ACKNOWLEDGMENTS

The study of the Calumet district was made possible through a research fund of Northwestern University. Mr. C. H. Bahr, Jr., Chairman of the Department of Geology and Geography of Northwestern University, was with the writers in the field during the entire period of field study. He directed the work and contributed most to the results obtained. He aided in the laboratory study and gave many valuable suggestions in the writing of this paper. The writers are pleased to acknowledge his many valuable contributions, without which the work could not have been completed in the time available.

Mr. E. Schlosser, mining engineer, of Barret, Colo., rendered invaluable aid in preparing the writers to use his claim maps of the district, in pointing out locations in the field, and in permitting the use of his drawing instruments at his home. The writers are extremely grateful to Mr. Schlosser for his help.

Mr. H. H. Mills, graduate student in geology at Northwestern University, helped in making thin sections of the rocks and offered many valuable suggestions in the study of the minerals under the microscope.

Mr. Julian G. Johnson, Professor of Geology at the Colorado School of Mines, was helpful in identifying fossils, and in lending unpublished notes on the Trout Creek area, the sedimentary sequence of which is similar to that in the Calumet district.

Mr. J. A. Stone, geologist for the Colorado Fuel and Iron Company, furnished production figures of iron ore shipped from the district, an unpublished description of the Calumet Mine by H. C. H. Mills, and analyses of the ore. The writers are grateful to Mr. Stone for the use of this material.

The writers are indebted to the late Professor J. A. Stark of Northwestern University for carefully reading the manuscript, offering valuable suggestions.

Miss Alfreda L. Catlett, graduate student at Northwestern University, gave much help in preparing the maps, and Mr. C. B. Millington, graduate student at Northwestern University, helped with the photographic work.

CHAPTER II

TOPOGRAPHY AND GEOLOGIC

The Calumet district may be divided, on the basis of the underlying rock, into three physiographic divisions. These divisions have not been named, but are referred to by the type of rock which outcrops in each division. Pre-Cambrian granite outcrops along the western edge of the district; Paleozoic sedimentary rocks outcrop in a narrow north-south strip east of the granite; and a stock of Tertiary granodiorite lies east of the sediments. The topography of each of these divisions is distinctive.

AREAL UNDERLAIN BY SEDIMENTARY FORMATIONS

The most noticeable feature of the topography of the area underlain by sedimentary formations is the hogback ridges which result from dipping beds of unequal resistance (Figs. 3). Three such ridges are more or less continuous for several miles north and one mile south of the Calumet mine. They correspond to the outcrops of Nodding sandstone, Parting quartzite, and the "Weber" formation, all of which dip eastward at an angle of about 25°. Another ridge roughly parallel to the ones named above is due to the thickening of a sill just south of the Calumet
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tinct, ridge.
In a general way the larger valleys within the area of sedimentary rocks parallel the hogback ridges, with smaller valleys entering the larger ones at right angles. However, the area is so narrow that streams flowing from the divide to the east out through the ridge almost without regard to structure.

(Picture Omitted)

Fig. 5— View looking north from hill just west of the Calumet Mine. The Part-
ing hogback is in the right middle distance, and the dip slope of the Harding sand-
stone is just beyond. Pre-Cambrian rocks form the irregular topography in the left background.

AREA UNDERLAIN BY PRE-CAMBRIAN ROCKS

The topography developed on the pre-Cambrian crystalline rocks, which lie to the west of the sedimentary formations, is characterized by rounded knobs which rise abruptly above the general level, and a lack of longitudinal and par-
allel ridges. The knobs, two of which are so prominent that they were used as triangulation points in mapping the area, are remnants left rising above an erosion level. They have been rounded by long exposure to weathering. The broad, more or less level upland surfaces, --elevation about 8,900 feet (Figs. 4,5, and 6) were probably developed in middle or late Tertiary time, as they are at a greater eleva-
tion than the high terraces along the Arkansas River which have been assigned a late Tertiary age.

Valleys have been cut back into the upland surfaces, and they have steep, canyon-like walls, and end abruptly at their heads. Tributaries to the main valleys are short, and they also have very steep walls.

(Picture Omitted)

Fig. 6— View from Harding Hogback looking west. In the foreground is the erosion surface developed on pre-Cambrian rocks. "Swatch Range is in the distance.

(Picture Omitted)

Fig. 8— View from a hill just west of Midway, at the south end of the district, looking north. The level area in the foreground is underlain with tuff and lime-
stone, and hogback ridges rise in the distance.

Fig. 6.— View looking south from west slope of Greentop Mountain. Note the wide park-like area in the foreground,—elevation about 8,500 feet.

AREA UNDERLAIN BY GRANODIORITE

The granodiorite intrusion is elongated in a north-south direction, and it forms the divide between streams flowing eastward into South Park and those flowing westward directly into the Arkansas River. The crest is not very rugged, but a few peaks, as Cameron Mountain, rise considerably above the general level of the divide.

Broad, flat areas have been developed along the divide at an elevation of about 10,500 feet (fig. 7). These broad flats have very little slope in any direction, but they end abruptly on their north and south sides against walls of bare rock. They could, no doubt, be correlated with an erosion level of other parts of the Southern Rockies, but insufficient data is at hand to make this correlation.

Topographic forms which closely resemble those developed in granite, have been developed in the granodiorite. Knobs and steep walls of bare rock are common, but they are less conspicuous than the granite knobs to the west because they are often hidden among trees (fig. 8). Valleys cut in the granodiorite have more nearly a V-shaped profile and a more nearly uniform gradient than those in the granite area.

REJUVENATION

A third period of base-leveling was begun after the valleys had been cut about 200 feet below the erosion surface on the pre-Cambrian rocks. The streams had reached the stage when they had begun to cut laterally rather than vertically, and floodplains were formed with widths varying from a few yards up to several hundred yards, depending on the type of rock in which the stream was cutting. In recent time the streams have rejuvenated and have cut narrow channels several feet deep in the flood plains (fig. 9). The rejuvenation is believed to have been caused not by a general uplift of the region, but by a rather sudden lowering of the main streams. This lowering could have been brought about by the streams which drain this area finding themselves suddenly again able to erode in their upper reaches as a result of having removed most of the accumulated material nearer their mouths. Since the last Glacial epoch, during which the channel of the Arkansas River was filled with sediments, the river has been cutting down at a rapid rate. This rapid down-cutting has caused rejuvenation of all tributary streams, and it may be that this rejuvenation has only recently been felt in the Calumet district, six miles east of the Arkansas valley.

Whatever the cause for rejuvenation, the streams in the Calumet district, almost without exception, have cut below their floodplains.
CHAPTER III

STRATIGRAPHIC SUCCESSION

The sedimentary formations of the Calumet district are Paleozoic in age, and outcrop in a narrow strip between the pre-Cambrian crystalline rocks on the west and the Tertiary granodiorite stock on the east. The dip of the Paleozoic beds is to the east at angles averaging about 25°. The thicknesses of the formations vary considerably, but the average thickness of all combined is about 1260 feet. About half of this is limestone, one-tenth quartzite, and the remainder shales and grits (fig. 10).

PALEOZOIC ROCKS

CAMBRIAN

Sawatch Quartzite

General Description

A thin bed of quartzite lies on the peneplained pre-Cambrian crystalline rocks and dips eastward with this surface beneath the overlying Paleozoic sediments. The rock is similar in character and in stratigraphic position to the Sawatch quartzite of central and south-western Colorado. In the Trout Creek area, fifteen miles to the north of the Calumet district, the formation is missing, but in the Leadville area, about 45 miles north of the district, it reaches a maximum thickness of 180 feet.2 There are few outcrops of the formation in the Calumet district, but "float" from it is common along the pre-Cambrian contact. Exact measurements were difficult to obtain, but the thickness is known to vary from about five feet to about twenty-five feet.

Lithologic Character

The rock is a granular, vitreous quartzite, with a thin conglomerate bed at its base. Bedding is indistinct, but three sets of joints cause the rock to break up into cubic blocks. The rock is gray to brownish in its lower portions. The round pebbles in the conglomerate are almost all of white quartz.

Relation to Underlying and Overlying Rocks

The contact of the Sawatch quartzite with the pre-Cambrian rocks is fairly regular and dips to the east at an angle of about 25°, paralleling the dip of the overlying formations. An unconformity separates this formation from the overlying Manitou limestone, and the lithologic break between the two is sharp. Whether or not the unconformity is erosional could not be determined because of the scarcity of exposures, but the varying thickness of the quartzite in


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Pliocene

"Webb" formation

Limestones and argillaceous beds of maroon color, with occasional interbedded shales and graywackes.

"Blue" formation

Limestones and dolomitic limestones with occasional interbedded shales and graywackes.

Fremont formation

Limestones and dolomitic limestones with occasional interbedded shales and graywackes.

Eocene

"Three Crosses" formation

Limestones and dolomitic limestones with occasional interbedded shales and graywackes.

Oligocene

"Gray" formation

Limestones and dolomitic limestones with occasional interbedded shales and graywackes.

Figure 10: Generalized section of the rocks in the Calumet district.
the Calumet district, and the absence of the formation in the Trout Creek area,1 fifteen miles to the north, are suggestive of a period of erosion before the Manitou was laid down.

Age and Correlation

No fossils were collected from the Sawatch quartzite in the Calumet district, but fossils from the same formation in the Weston Pass mining district, about 30 miles to the north, indicate an Upper Cambrian age.2

ORDOVICIAN

Manitou Limestone

General Description

A dolomitic limestone, Lower Ordovician in age, and having an average thickness of about 120 feet, overlies the Cambrian Sawatch quartzite. Its outcrop is marked by a depressed belt between the pre-Cambrian area to the west and the Harding hogback ridge to the east. In the Calumet district the Manitou limestone has been locally much metamorphosed by contact action of the sills, so that its character varies greatly from place to place within the district. Where the formation has not been metamorphosed or mineralized it is a massively bedded, buff dolomite.

Lithologic Character

A typical description of the formation, unchanged by contact action, must be taken outside the Calumet district. Dr. J. Harlan Johnson has made a detailed study of the Lower Paleozoic rocks in the Trout Creek area, fifteen miles to the north, and his description, in part, of the Manitou limestone follows:

The formation is 607 feet thick. The lower 117 feet is a highly silicified, light gray to white limestone with abundant nodules and streaks of chert. In the upper 290 feet the rock is dark gray to gray on weathered surfaces, and brownish pink when fresh. Silicification is absent, chert nodules are smaller, and the rock appears to be a dolomite. It tends toward massive bedding.1

In the Calumet district the Manitou limestone, where not metamorphosed, is similar in character to the Manitou limestone in the Trout Creek area.

The formation within the Calumet district is in many places a white marble, having been metamorphosed by silt intruding within or near the formation. The marble is not schistose, as is commonly the case with the metamorphosed Precambrian limestones, but is more massive and coarsely granular. At only one place, the west side of Convert Hill (See Fl. 1), was iron oxide found developed in the formation, and there only a small amount is present. Light colored silicates, however, are rather abundant in certain areas.

Relations to Underlying and Overlying Rocks

The Manitou limestone lies between two very siliceous formations — the Sawatch quartzite below and the Harding sandstone above. In each case the lithologic break is abrupt, not transitional. Marine conditions were established in this area in Lower Ordovician time, and after a long period of limestone accumulation, sedimentary conditions were suddenly changed, so that sandstone was deposited on the limestone. No unconformity exists between the Manitou limestone and the Harding sandstone.

Age and Correlation

The Manitou limestone formation has been recognized in Colorado in a number of widely separated areas — in the Gunnison-Athabasite-Crested Butte region, the Pueblo region, the Pike's Peak region, the Leadville-Alma region, and in southeastern Colorado. The type locality of the formation is in the Colorado-Springs quadrangle. In all of these areas the formation is thought to be Beekmantown, Lower Ordovician, in age. The Manitou limestone of the Calumet district is correlated, on the basis of lithology and stratigraphic position, with the Manitou limestone of other areas in Colorado.

Harding Sandstone

General Description

The Harding sandstone is a ridgemaker along most of its outcrop. It is a well indurated, reddish-brown sandstone — almost a quartzite. In the Calumet district it forms a prominent ridge. Though only about 70 feet thick, its outcrop is wide, because it not only caps a ridge but it also forms a long dip slope.

Lithologic Character

The rock is reddish-brown, is thinly bedded, and is well jointed (fig. 11). The lower half of the formation is darker and more thinly bedded than the upper half. The upper half is light brown, vitreous, and is thicker bedded than the lower half. Two sets of vertical joints (fig. 12), which strike N. 60° E. and N. 10° W., are well developed. The rock is hard and very resistant to erosion. Although one sill was found within the formation, and others above and below it, the sandstone has been little affected by contact metamorphism.

(Figure omitted)

Fig. 11—Cliff of Harding Sandstone a quarter of a mile southwest of the Calumet mine.

(Figure omitted)

Fig. 12.—Vertical jointing of the Harding sandstone in a stream bed just west of the Parting Hogback.

Relations to Underlying and Overlying Rocks

The Harding sandstone overlies conformably the Manitou limestone, and is in turn overlain conformably by the Fremont limestones. The actual contacts were not seen, but the uniformity in thickness of the Harding sandstone and Fremont limestone throughout the Calumet district is proof against the erosion of either before deposition of younger beds on them.

Age and Correlation

Harding sandstone occurs in a number of widely separated areas in Colorado — in the Pikes Peak and Canon City areas, in the Sangre de Cristo Mountains, and in southeastern Colorado. Its age has been determined as early Trenton or late Black River (Middle Ordovician). This age was established by Walcott, who studied the fauna from the Harding sandstone near Canon City. Associated with the invertebrate fauna of this formation he found and described fish "plates" or "scales" belonging to several species. Sihre and Johnson have more recently called attention to fish horizons in the Ordovician and Devonian of Colorado. A fish "scale" similar to those described by Walcott from the Harding sandstone near Canon City occurs also in the Harding sandstone of the Calumet district. On the basis of the fossils found in the Harding sandstone, lithology, and the stratigraphic position, the writers have correlated the formation with the Harding sandstone of other areas in Colorado.

General Description

The Fremont limestone in the Calumet district is a massively bedded, succheloidal, dolomitic limestone. It is buff to gray when fresh, and on exposed surfaces is brown. Its thickness averages 270 feet.

Lithologic Character

The following section of the Fremont limestone on the west side of the Parting Hogback gives a fairly good description of the formation within the Calumet district:

<table>
<thead>
<tr>
<th>Section of Fremont limestone on west side of Parting Hogback</th>
</tr>
</thead>
<tbody>
<tr>
<td>White, schistose, soft crumbly limestone</td>
</tr>
<tr>
<td>Dense, blue, resistant, massive but jointed</td>
</tr>
<tr>
<td>limestone. About middle a band bleached and maromized</td>
</tr>
<tr>
<td>Highly maromized limestone, Some beds, about 11 feet thick,</td>
</tr>
<tr>
<td>are blue in color but schisto-</td>
</tr>
<tr>
<td>tone and soft</td>
</tr>
<tr>
<td>Diorite sill separated by beds 1 to 4 feet thick,</td>
</tr>
<tr>
<td>of highly maromized limestone.</td>
</tr>
<tr>
<td>Maromized limestone, lower 25 feet is massive</td>
</tr>
<tr>
<td>and is less maromized than the upper 10 feet.36</td>
</tr>
</tbody>
</table>

In places the entire formation has been maromized or highly altered; in other places little or no change has taken place. Several small marble quarries were begun in the formation, but were soon abandoned (fig. 18).

Relations to Underlying and Overlying Rocks

The Fremont limestone lies between two resistant formations — the Harding sandstone beneath and the Parting quartzite above. The limestone, therefore, outcrops in a low area between two hogback ridges formed by the more resistant formations. No unconformity separates the Fremont limestone from the underlying Harding sandstone. Though the lithologic break is abrupt, deposition was continuous from Harding time into Fremont time. After the deposition of the Fremont limestone, a long period elapsed before the Parting quartzite was laid down. Thus there is both a lithologic and a time break between the two formations.

Age and Correlation

The Fremont limestone, where not altered by igneous activity, contains a fair abundance of fossils, corals being most numerous. A correlation of the Fremont limestone in the Calumet district with the Fremont limestone in other areas in Colorado (Upper Ordovician) was made on the basis of the fossils, lithology, and stratigraphic position.

DEVONIAN

Parting Quartzite

General Description

The Parting quartzite of Upper Devonian age is a white to purplish quartzite and averages about 25 feet in thickness. It is more resistant to erosion than the rocks immediately above or below it, and it commonly forms small hogback ridges. The formation is thicker in the northern end of the Calumet district, where it is exposed in many outcrops. Toward the south the formation becomes thinner, and can be traced only by its "float".

Lithologic Character

The rock is a true quartzite, varies from white to purplish in color, and is very resistant to erosion. The basal portion is darker than the upper portion, is more thinly bedded, and is less vitreous.

Relations to Underlying and Overlying Rocks

An unconformity, involving all of the Silurian and the Lower and Middle Devonian periods, separates the Parting from the underlying Fremont. The relation of the Parting quartzite to the limestone above in the Calumet district is not well understood. In the Weston Pass mining district, 10 miles southeast of Leadville, Colorado, the Parting quartzite is grouped with the Dyer dolomite to form the Chaffee formation (Devonian). But in the Calumet district the Dyer dolomite is inseparable from the Leadville limestone, and the two were grouped together to form the "Blue" limestone. This left the Parting quartzite of the Calumet district a distinct lithologic unit, and in this report it has been given the rank of a formation. But probably deposition was continuous in this area until the Dyer dolomite had been deposited.

Age and Correlation

The Parting quartzite in the Calumet district has been correlated with the Parting quartzite (Upper Devonian) of the Weston Pass and Trout Creek districts on the basis of lithology and stratigraphic position.
DEVONIAN - MISSISSIPPIAN

"Blue" Limestone

General Description

The writers have used the term "Blue" limestone to include all the limestone in the Calumet district lying beneath the "Weber" formation and above the Parting quartzite. The lower part of the limestone belongs to the Dyer dolomite formation, of Upper Devonian age, and the upper part to the Leadville limestone formation, of early Mississippian age. But inasmuch as beds of sandstone, which mark the base of the Leadville limestone in the Weston Pass district, were found at only one place within the Calumet district, it was impossible to draw the dividing line in the Calumet district between the Dyer dolomite and the Leadville limestone. Thus the "Blue" limestone as used in this report includes the Dyer dolomite and the Leadville limestone.

The "Blue" limestone averages 285 feet in thickness, is buff to gray in color where not altered by igneous intrusions, and is massively bedded. Its area of outcrop is marked by a belt of subdued topography, but the rock is exposed in many places.

Lithologic Character

The "Blue" limestone varies in its lithologic character along the strike as well as from the base upward. For half a mile north and south from the Calumet mine the limestone is white to grayish in color, and is medium coarse to coarse-grained. Outside this area the limestone is darker in color, weathered buff, and is finer grained. The change is due mainly to the heating and mineralizing effects of sills. The thickest sill in the Calumet district, the Main Sill, occurs in the "Blue" limestone.

At one locality, half a mile south of the Calumet mine, a bed of brown, calcareous, hard sandstone, eight feet thick, occurs near the middle of the formation, and is believed to mark the base of the Leadville limestone. At no other place was this sandstone found. The limestone beds are massive (Fig. 14), in places silicified, in some other places brecciated. Black chert nodules are abundant in the upper part of the formation (Fig. 15).

Age and Correlation

The "Blue" limestone is made up of two formations — the Dyer dolomite and the Leadville limestone. The Dyer dolomite is Upper Devonian in age and the Leadville limestone is early Mississippian in age. Both formations have been recognized in the Trout Creek area, 18 miles to the north, and they can be traced, though not as separate units, into the Calumet district.

Fig. 14.— Typical, unaltered "Blue" limestone exposed in a hill just west of Midway, at the south end of the Calumet district.

Fig. 15.— Typical upper "Blue" limestone at the south end of the Calumet district.
A series of beds composed of grits, sandstones, shale, and limestones, overlying the "blue" limestone, has been designated the "Weber" formation. These beds occur stratigraphically at the same horizon as the Weber (Pennsylvanian) in the Leadville area. It is mainly on this basis that a correlation was made.

The formation varies greatly in thickness in the Calumet district. On Porphyry Hill, a half mile north of Calumet mine, the thickness is less than 185 feet. About one mile south of the Calumet mine the thickness is over 2,200 feet. Many of the beds in the "Weber" formation are resistant to erosion, and the formation commonly outcrops in a steep slope.

**Lithologic Character**

Beds of grit, sandstones, sandy and carbonaceous shale, graphite, and limestone make up the formation. The lower portion of the formation is more shaly and carbonaceous than the upper portion. Two, and possibly more, graphite horizons occur in the lower half of the formation. The lower graphite bed is within a few feet of the base of the formation, and the upper graphite bed is about 150 feet above the first. Each graphite bed is about three feet in thickness, and both beds have been mined in a number of places within the Calumet district.

The grit and sandstone beds are lenticular in character and are commonly cross-bedded. The grains are firmly cemented making the rock very resistant to erosion. Jointing is well developed in the sandstone beds (fig. 16).

Limestone beds occur at several horizons in the "Weber" formation. In general the limestone is drab gray in color, dense, massive, fine-grained, and hard. One bed, about 25 feet in thickness, occurs between the two graphite horizons, and another bed, 60 feet or more in thickness occurs about 400 feet above the first. These two beds were seen at several widely separated localities, so, presumably, they are persistent beds. Other limestone beds, which may be only lenses, were observed at a few places. One such bed, which outcrops on Bald Hill at the north end of the district, has been highly mineralized, and a small contact metamorphic deposit of magnetite has been worked.

At least two diorite sills are known to occur in the "Weber" formation on the west side of the Greentop Mountain. In the thicker sill, which is 67 feet thick and lies 1,000 feet above the base of the formation, a quarry for building stone was begun but soon abandoned.

**Relations to Underlying and Overlying Rocks**

There is a distinct break in lithology between the basal "Weber" formation and the underlying "blue" limestone. Marine conditions, which prevailed during the time when the "blue" limestone was being deposited, gave way to swampy and shallow water conditions. Whether there was an erosional interval in this area after the formation of the "blue" limestone and before the beginning of deposition of the "Weber" is not known. Key horizons which might be traced to determine such a break are not present in the "blue" limestone.

The "Weber" beds, as do all the formations, dip toward the granodiorite stock. The stock cuts across the strike of the sedimentary formations and cuts off the "Weber" formation nearer its base at the north end of the district (fig. 46). This explains why the formation is thickest near the south end of the district.

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(Picture Omitted)

Fig. 16.- Massive, jointed "Weber" beds near top of formation. South end of Greentop Mountain.

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Age and Correlation

The beds of this area which make up the "Weber" formation, Pennsylvanian in age, have been so placed because they are lithologically and stratigraphically similar to the Weber of the Leadville area. Further study would, no doubt, cause division of the formation into members with a more definite age assigned to each member. Gould has made a thorough study of the "Weber" formation in the Salt Creek area, a few miles north of Front Creek pass, and divided the formation into various members. The writers spent insufficient time in the Calumet area studying rock from a stratigraphic viewpoint to permit such a division being made.

CHAPTER IV

IGNEOUS ROCKS

The igneous rocks of the Calumet district are of three main types: (1) pre-Cambrian granite and gneiss, (2) Tertiary intrusive rocks, and (3) late Tertiary volcanics. The Tertiary intrusive rocks affected the mineralization in the district and are the only ones studied in detail.

PRE - CAMBRIAN ROCKS

Crystalline rocks of pre-Cambrian age lie west and southwest of the Calumet district. They are mainly coarse-grained and porphyritic granites, probably of Pikes Peak age, schist which the granite intruded, and dike and pegmatites which cut the other two. Granite forms much the greater part of the rock. It is everywhere very coarse-grained, with orthoclase phenocrysts up to an inch in diameter. It is usually highly gneissoid, the feldspar phenocrysts (porphyroblasts) occurring as elongated, deformed pods between seams of muscovite and ferromagnesian minerals (fig. 17). Its color is light gray to faintly pink. Coarse-grained pegmatites and quartz veins are numerous.

(Picture Omitted)

Fig. 17.— Porphyritic, pre-Cambrian granite gneiss, half a mile north of Hetehite.

(Picture Omitted)

Fig. 18.— View looking south from Calumet Hill. Greentop Mountain is in the middle distance. Beds dip to the east. The quarry in the foreground is in granite which is directly in line with the strike of the "Weber" on Greentop Mountain and on the central hill.

The main mass of the Cretaceous intrusive rocks is a stock which has broken through the Paleozoic formations and sent out dikes at various horizons. The stock outcrops over an area of about 37 square miles northeast, east, and southeast of the Calumet mine. Much of the stock lies in the northwest corner of Cook County, but the stock extends into the adjacent part of Lake and Iroquois counties. There is also a small, disconnected mass, part of which may be a stock (see p. 17), called the Main sill, which extends from the Calumet mine southeast to the vicinity of the Iron King mine. The intrusive rocks are in contact with sedimentary rocks on all sides, except near the southern end of the main stock where volcanic flows overlap.

The Cretaceous intrusive rocks are mainly granodiorite, but there is much local differentiation in the main mass.

The main Cretaceous stock is an elongated mass, about eight miles long and four miles wide at the surface, with the long direction about paralleling the strike of the formations. The sedimentary rocks on the west side of the stock dip easterly into the intrusive at an average angle of 20 to 30°. On the east, according to reconnaissance work by Butler and Goddard, the prevailing dip is to the west. Thus it appears that the granodioritic magma broke through the bottom of a syncline.

Undoubtedly the intrusive is mainly a stock. This is strongly supported by field evidence. As shown on Plate II, the "Chez" formation on Greenway Mountain and the hill just to the north, strikes north-northwest directly into the granodiorite at the quarry [fig. 18]. Some of the beds have been completely cut off by the granodiorite. Also, at the south end of the stock, in the NE. cor. of sec. 23, T. 60 N., R. 16 E., the "Weber" formation, striking northeast and dipping steeply to the southwest, appears to be cut off against the intrusive. There is no evidence of marked coming up of the sediments at any place, as would be necessary were the intrusive a laccolith, but instead the formations dip into the intrusive.

Although probably most of the magma entered the district as a discordant mass, dikes are an important feature in the Calumet district, and there are a few dikes. These small intrusive bodies were found cutting every formation except the thin quartzite (fig. 19).

The relations of the Main sill, which forms a ridge east of the way from the Calumet mine to the Iron King mine, are in some doubt. The writers believe that in its south-central part the magma entered as a small stock-like offshoot from the main mass to the east; whereas to the north, and on the western side, the magma expanded as a sill in the "Blue" limestone. The Main sill is definitely a sill at its outcrop across Fleming Creek from the Calumet mine where the igneous rock is seen in a deep gully to rest concordantly on the "Blue" limestone. Northeast from this outcrop the sill thinns out and was not traceable north of Graphic Hill. The Main sill has been eroded off to the west to such an extent that its former extension as a sill in that direction is not so obvious. But in the east-central part of sec. 24, T. 61 N., R. 9 E., a mesoic structure parallel to the bedding of the underlying "Blue" limestone strongly suggests that the intrusive extended on up dip to the west as a discordant sheet.

1. It was first thought that the beds tended to dip more steeply on the west side as the intrusive was approached, but this is not borne out by the recorded dips. However, the dip, and also the strike, becomes more variable as the stock is approached and frequently the dip is 40 or more. Some of the steep dips are associated with faults east of the Iron King mine.

The stock-like nature of the Rain Sill in its south-central part is suggested by its contact relations with the intruded limestone. The limestone bed at the surface on the west side of the intrusive dips directly into the igneous rock with no change in dip. Here the intrusive a sill at this point, the igneous should rest upon this bed as the limestone is followed down-dip underground. However, in the NE cor. of sec. 2, T.50 N., R. 9 W., an inclined tunnel has been driven toward at the contact of the "Blue" limestone and the granodiorite, and instead of continuing downward below the igneous rock in sill relationships, the limestone is cut out by massive granodiorite a short distance from the surface. The sketch (fig. 20) and picture (fig. 21) indicate the manner in which the limestone was cut off by the intruding magma. Evidently here the magma stopped its way upward, fingering-out up dip into the limestone. The proposed structural relations of the Rain Sill are shown in the accompanying sketches (figs. 22 and 23).

(Figure Omitted)

Fig. 19.--- View looking north along strike of formations from north end of Calumet Hill. A sill of granodiorite supports the low hill in the foreground, outcropping between limestone beds (white).

This "fingering-out" of a discordant intrusive into a sill which gradually thins out and terminates, the writers believe, may also be the general structure of the northwestern extension of the main stock. The outcrop of the main granodiorite intrusive bands westward from the quarry in the NW 1/4 of sec. 30, T.51 N., R. 9 W., and then continues northward along Corundum Knob and Graphite Hill (Pl. 11). In the last two localities and also to the north in sec. 22, T.51 N., R. 9 W., the granodiorite exhibits excellent flow structure (figs. 24 and 26), the flow planes are parallel to the dip and strike of the country rock, and seem to indicate a general contemporaneous magma flow parallel to the bedding. According to Schlosser,1 well drillings through the granodiorite in sec. 22, T.51 N., R.9 W. encountered limestone at a depth of about 100 feet. These two facts indicate that the main mass of granodiorite, as in the case of the Rain Sill, also terminates to the north and northwest in a long, gradually thinning sheet.

(Figure Omitted)

Fig. 21.--- View of north wall of tunnel in sec. 2, T.50 N., R.9 W. The rock outlined in red is the remains of a limestone bed which is completely cut off a few feet to the right of the picture. The surrounding rock is granodiorite. The irregular border of the limestone and the isolated inclusion suggest assimilation of the limestone by the magma.

(Figure Omitted)

Fig. 24.--- Two phases of the granodiorite. The specimen on the left exhibits the trachyholoclute texture of the border phase of the intrusive, and that on the right the central, massive phase. (Specimens are 2 inches long).

1. Schlosser, F. J., Personal communication, 1933.
Fig 20. — Sketch of position in south wall of tunnel in sec. 8, T.99S., R.30 E. The conglomerite intruding the limestone from the east has cut it off wherever by denudation.
Fig. 32. — Sketch showing possible relations near south end of Main Sill.

Fig. 33. — North-south cross-section of Main Sill showing probable relations.
MACROSCOPIC DESCRIPTION

The granodiorite is light to dark gray and fine-to medium-grained. It is generally equigranular, rarely porphyryic. Near the outer edge of the mass, especially at the west and north margins, the rock has a tuffshaped structure (see figs. 24 and 29). This gives way to a massive structure toward the center of the intrusive. The rock is sometimes shocked by inclined joint planes (figs. 25).

The granodiorite commonly weathers into rounded knobs rising above the general level of the surface (figs. 26). The rock breaks down into a brownish gray very similar to the weathering of the Pikes Peak granite. On flat or rolling topography, the weathered zone extends down several feet.

Inclusions, rarely over a few inches in diameter, are abundant in the granodiorite (see pps. 27 and 46). They are of two general types: (1) Basic fragments up to one-sixteenth inch in diameter like the cavities. The inclusions show a parallel arrangement in some places, as is shown in fig. 27. More commonly, however, they show no definite arrangement whatever.

Aplites, granitic dikes, pegmatites, and basic dikes cut the granodiorite. The aplites and granite dikes occur as stringers, subparallel dikes, and irregular masses up to 100 feet in diameter. The rock is white to light gray, fine-grained, and commonly porphyryic. The contact of the dikes with the intruded rock is sharp; the larger masses of acidic material grade near their margins into the granodiorite. The acidic masses are more resistant to erosion than the granodiorite and are frequently marked by elevated areas.

Pegmatites occur in the granodiorite and in the country rock near the border, but they are rare. A white pegmatite with large biotite crystals occurs on top of Corunna Hill. Another outcrop east of Calumet Hill.

Only two basic differentiates, probably dikes, were mapped, both of them fine-grained and very dark-colored. The basic differentiates are probably less numerous than the acid differentiates, but owing to their more rapid weathering and less distinctive color they are more easily overlooked.

Numerous small sills and dikes from 1 to 10 feet in thickness occur in the Calumet district, usually in the Fremont or "Blue" limestones, and less frequently in the Manitou limestones. A sill, two feet thick, was found in the Harding sandstone on eighth of a mile south of the Calumet mine, and a dike cuts the Harting quartzite in sec. 22, T. 33 N., R. 9 E. These sills and dikes are dark-colored, dense rocks, with scattered phenocrysts of feldspar and pyrite in an euhedral groundmass. The intrusions have sharp contacts with the country rock and frequently show chilling at the borders.

(Figure omitted)

Fig. 25.-- Sheet jointing in granodiorite at quarry just east of Calumet mine.

(Figure omitted)

Fig. 26.-- Weathering of granodiorite, Sec. 25, T. 33 N., R. 9 E. Note slabby weathering. The slabs parallel flow lines in the rock and dip east parallel to the dip of the sediments.

(2) Inclusions, probably originally rich in calcite or dolomite as they are now largely represented by cavities, showing faintly basic borders. Dolomite crystals up to one-sixteenth inch in diameter like the cavities. The inclusions show a parallel arrangement in some places, as is shown in fig. 27. More commonly, however, they show no definite arrangement whatever.

(Figure omitted)

Fig. 27a.-- Parallel arrangement of inclusions in granodiorite, sec. 14, T. 33 N., R. 9 E.

-21-
The following description of the microscopic character of the granodiorite intrusive is based on a study of fifty thin sections made from specimens which were thought to be typical of phases of the granodiorite stock and its dikes. A more thorough study of the stock is to be desired, for it would undoubtedly bring to light prevailing intrusive which could not be shown from this cursory study. In the description the following types are distinguished: (1) typical granodiorite, (2) differentiates - aplites, granitic dikes, and porphyries, basic differentiates, and pegmatites, and (3) small dikes and dikes.

**Tonal Granodiorite**

**Texture**

The typical granodiorite is holocrystalline, equigranular, and fine-grained, with the grains averaging less than 1 mm in diameter. Subhedral crystals of sodium plagioclase are surrounded and embayed by irregular masses of quartz and orthoclase - hypidiomorphic texture (Fig. 28). Not only do quartz and orthoclase encroach the early minerals, but plagioclase occurs within the boundaries of earlier-formed plagioclase.

Primary gneissic structure is well developed in the granodiorite on the west side of the Bain Hill and on the borders of the stock in the region north of the Cabinet mine. (See Fig. 15). This structure (Fig. 28) is due mainly to the parallel orientation of biotite, augite, and hornblende during intrusion. To a less degree the plagioclases also tend to be oriented with their long directions parallel to the flow lines.

**Composition**

The typical granodiorite, as it occurs on Cameron Mountain and at the Mount Cross quarry at the southern end of the stock, is composed of 45 to 50 percent plagioclase, 15 to 16 percent orthoclase, 10 to 25 percent quartz, and 5 to 10 percent biotite, 4 to 7 percent hornblende, about 1 percent augite, about 1 percent magnetite, somewhat less than 1 percent tianite, and a small percentage of apatite. Augite is more abundant than hornblende in the granodiorite at various places in the Cabinet district (See p. 24). The following minor accessory minerals occur in varying amounts: urailite, green biotite, chlorite, sericite, epidote, carbonate, kaolin, and antigorite.

The minerals of the granodiorite may conveniently be divided into three groups with respect to their relative times of formation. The primary minerals, plagioclase, hornblende, augite, titaniferous augite, biotite, epidote, sericite, and tianite, are definitely early. They occur in subhedral to euhedral crystals, and are frequently corroded and surrounded by the later minerals. Orthoclase, and quartz are never in euhedral crystals, and magnetite is rarely subhedral. These three minerals occur in irregular masses, surrounding and embaying the earlier formed minerals, and are definitely later than the others. Lastly, hydrothermal alteration of the primary minerals has produced varying amounts of urailite, green biotite, chlorite, sericite, epidote, carbonate, kaolin, and antigorite.

The plagioclase is almost invariably zoned (Figs. 28 and 30). The central zone is a solid leucodiorite, averaging a bluish, and the zones become more acid outward until the outer zone is a leucodiorite. In some instances two centers of zoning occur in the same crystals. The plagioclase is usually altered to a moderate degree to a fine-grained, brownish mass of carbonate, epidote, and sericite (possibly paragonite). This alteration is, in many crystals, selectively zoned, with the inner zone, or one of the intermediate zones, altered, whereas the other zones are only slightly altered. The plagioclase may be deeply corroded, with only a shell remaining (Fig. 31).

(Figure omitted)

**Fig. 28.** Texture of granodiorite from Cameron Mountain. Note corroded border of sodium plagioclase. The subhedral white and dark material in the slide is quartz. Crossed nioles, X 50.

---22---
Green hornblende is a common constituent of the Caluset Mountain and Mount Cross granite gneissites. It is frequently schistose, but in nearly all of the crystals there are centers of augite (Fig. 23). Most of the hornblende may have been formed earlier augite by reaction with the liquid magma (See p. 24). Some of it may also be hydrothermally altered augite, but hydrothermal alteration has affected the plagioclase and biotite only moderately and so was probably only of minor importance in altering the augite to hornblende. The hornblende shows alteration to chlorite.

Augite is much more abundant than hornblende in the granodiorite at the quarry southeast of the Caluset mine, in the Main Sill, and in the region north of the Caluset mine. Here too the augite tends to go over to hornblende, but apparently the process was stopped before it had gone very far. Some of the pyroxene exhibits schiller structure. The association of intergrown augite, biotite, and magnetite is pronounced in some of the slides (Figs. 33 and 34). Possibly the magnetite is a "releasen" mineral from the reaction of augite with the liquid in the formation of biotite. The augite has altered, probably hydrothermally, to omphite, biotite, chlorite, antigorite, and quartz.

Hornblende with augite centers. Biotite and hornblende show alteration to chlorite. A, augite; B, biotite; C, chlorite; H, hornblende. Without analyzer, x 33.

Association of augite (A), biotite (B), and Magnetite (M). Without analyzer, x 16.
Citrine augite was found in a specimen from sec. 22, T.61 N., R.9 E.,
it exhibits pink to white pleochroism, a small extinction angle, and alteration to
chlorite.

Biotite occurs commonly throughout the granodiorite. Usually it appears
primary, possessing crystal outline. In some instances, however, it appears to be
denary or hydrothermal, and in such cases is usually associated with augite (see
p. 23). The biotite shows alteration to green biotite and chlorite (fig. 32). The
green biotite is usually partly altered to chlorite.

Citrine is always present in the granodiorite, occurring both in irregular
masses and in diamond-shape forms.

Apatite is present throughout all the sections in small elongated prisms
included in other minerals.

Orthoclase, filling the spaces between, and surrounding and corroding
earlier minerals, is a chief constituent in the Cameron Mountain and Mount Cross
quarry granodiorites (fig. 31). In the Calumet district and to the north, however,
it is much less abundant, and even rare in some specimens. Some of the rock here
is a diorite or quartz-diorite. The orthoclase is usually altered along cleavage
planes and fractures to kaolin with some sericite.

Quartz, like orthoclase, corrodes the earlier minerals (fig. 28), some-
times sending verruculous tongues into plagioclase. Quartz is never cataclastic. It is
generally abundant, but again like orthoclase it diminishes in amount in the rocks
in the Calumet area, although not to as great an extent.

Plagioclase is abundant in all the slides, averaging 1 to 1.5 per cent. It
occurs in irregular grains, commonly with verruculous arms extending into other
minerals, and may be mostly a symplectic mineral. Most of the magnetite apparently
was soluble in the silicate solution until the very last stages of crystallization.

Notable Variations

Two notable variations in the composition of the granodiorite have been
noticed from the study of thin sections. The writers believe that they are closely
related in origin. First, in some localities the percentage of augite increases
above the normal amount and the percentage of hornblende correspondingly diminishes;
this is noticeable especially in specimens collected along the western and north-
western borders of the intrusive — for example, at the quarry southwest of the Cal-
umet mine, in general in the Main Hill, on Corvus Knob, on Graphite Hill, at Cal-
umet City, and in sec. 22, T.61 N., R.9 E. Secondly, in the same localities, ortho-
close becomes less abundant — practically absent in some of the slides — with a
corresponding increase in the amount of plagioclase. In the following the writers
suggest two alternate hypotheses to explain this variation:

1. According to the reaction principle, there is a definite series of min-
erals which tend to form in an igneous melt. This series is shown in Table 1.

<table>
<thead>
<tr>
<th>Reaction Series in Alk-alkaline Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>olivine</td>
</tr>
<tr>
<td>enstatite</td>
</tr>
<tr>
<td>pyroxene</td>
</tr>
<tr>
<td>calcic plagioclase</td>
</tr>
<tr>
<td>alkali-calcic plagioclase</td>
</tr>
<tr>
<td>amphibole</td>
</tr>
<tr>
<td>alkali-calcic plagioclase</td>
</tr>
<tr>
<td>biotite</td>
</tr>
<tr>
<td>potash feldspar</td>
</tr>
<tr>
<td>muscovite</td>
</tr>
<tr>
<td>quartz</td>
</tr>
</tbody>
</table>

177-196, 1922.
If a melt were of a composition such that any one of the minerals in the left ("discontinuous") series would form, then at a certain high temperature, olivine would crystallize out. With slow cooling and generally favorable circumstances the olivine would react with the residual solution and would finally be recrystallized as pyroxene at a lower temperature, and so on down the series. With rapid cooling, however, a pyroxene melt, for example, might be carried below the reaction temperature before crystallization began, and then pyroxene crystals would grow in the supercooled melt without the reaction and formation of hornblende. The same general principle applies also to the right ("continuous") wing of the series. Examples of definite interaction between early formed crystals and the surrounding liquid are numerous in the granodiorite. Quartz and orthoclase replace albite-albite plagioclase, and quartz-coal plagioclase as pyroxene replaces the more basic plagioclase. The writers believe that the varying ratios of angle hornblende and orthoclase-plagioclase may be explained by this principle.

The ratio of augite to hornblende is high and that of orthoclase to plagioclase is low in the Main sill, near the western contact of the stock and the "Weber" formation, and in the long sill-like extension of the main stock to the northeast. In these border regions the magma would cool more rapidly than toward the center. Here we might expect to find the minerals that occur high in both series - augite and plagioclase. This statement assumes that the temperature dropped so rapidly as to pass below the reaction temperature before much reaction could take place. Toward the center of the mass, however, a slower rate of cooling would allow the augite that was formed early to be altered mostly or entirely into hornblende. Similarly, the plagioclase would react with the more siliceous liquid to form considerable orthoclase (or anorthoclase). This explanation is thus based on temperature controls. Probably other factors assisted, such as diffusion of the more basic material toward the outside in "border crystallization". The more acid material might thus at the same time be forced inward as the outside tended for the acid matter originally present. Some of the acid material also moved outward into the country rock, and much acid material in the Calumet district was forced out as dikes.

(2) The alternative hypothesis explains the variation on the basis of a difference in composition of the magma near the border from that in the central part of the intrusive. The magma was intruded into the Paleozoic formations, which in this district are largely limestones. On the borders of the intrusive, where the magma was in contact with the limestone, assimilation may have proceeded rapidly enough to make this border phase of the magma approximately more calcic than the central part. Since the magma was thus more calcic on the border, more basic plagioclase was formed, and augite, which is more generally associated with calcic rocks than with hornblende, crystallized out more profusely there than in the center, less calcic magma. The fact that large augite crystals were formed in places in the enclaved sills at the Calumet mine (See p. 59 is interesting in this connection.

These two conceptions of the manner in which the variation was produced are offered only as possible explanations. The apparent angle-hornblende reaction strongly suggests that the "reaction principle" was an important factor, but whether in this small intrusive, which is coarse-grained to the border, temperature differences were as effective as postulated may be open to question. Perhaps both factors were important during crystallization, but the writers believe that the second postulate is the more plausible.

Differentiates

Aplites, granitic dikes, and porphyry of pargasites, and basic dikes cut the granodiorite. The acid dikes at the surface probably far outnumber the basic. The relation in age between the acid and basic dikes was not determined.

Aplites

The aplites are usually small resistant dikes, with a fine-grained, sugary-glassy texture. They are composed almost entirely of altered orthoclase and quartz with some microcline and titanite. Ferrumagnesium minerals are absent.

Granitic Dikes

Here are included a large part of the light-colored dikes, usually larger in size than the aplites, variable in composition, and not as even granular in texture. One of the dikes, 100 feet east of Corundum knob, is composed largely of alteration with orthoclase, quartz, and augite.
Another, near Calumet City, is composed almost entirely of intergrown quartz and orthoclase and microcline. A large, plug-like mass of granitic material, 75 feet across, also near Calumet City, is composed almost entirely of orthoclase, with quartz and plagioclase. About half a mile south of the Mount Cross quarry occurs a body of acid rock in the granodiorite, probably a dike, which, although in general equigranular, contains abundant phenocrysts of green hornblende in a matrix of orthoclase and plagioclase, a little quartz, and abundant titanite and magnetite.

**Acid Porphyries**

The acid porphyries are probably about as abundant as the granitic dikes. In the SW. cor. of sec. 22, T.51 N., R.6 E., a large acid dike, 40 feet wide and striking N. 65° E. forms a low ridge across the country. Zoned andesine and biotite phenocrysts along with some hornblende phenocrysts and a few phenocrysts of quartz lie in a fine-grained, holocrystalline, porphyro-hornblende of feldspar and quartz (fig. 38).

At the quarry southeast of the Calumet mine, a porphyry dike several feet across outcrops, consisting mostly of plagioclase phenocrysts in a fine groundmass of small plagioclase crystals with some apatite, magnetite, and hornblende. Another porphyry dike, three-quarters of a mile south of the Mount Cross quarry, consists of large phenocrysts of orthoclase with some plagioclase, quartz, and biotite in a very finely crystalline groundmass of feldspar and quartz. Numerous other examples might be cited.

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**Picture Omitted**

| Fig. 38 | Hornblende (H), biotite (B), feldspar (F), and corroded quartz (Q) phenocrysts in a fine-grained groundmass. Without analyzer, x 16.
---

**Picture Omitted**

| Fig. 39 | Micropegmatitic texture in pegmatite. The white is quartz, and black is orthoclase. Crossed nicols, x 16.

---

**Feldspars**

The small white pegmatite dikes, 3 to 4 feet wide, were mapped, one cutting the "Scher" formation between the main hill and the main stock, and the other cutting the granodiorite on Corundum Hill. From the thin sections it appears to consist almost entirely of quartz and orthoclase intergrown (fig. 36), and large flakes of biotite up to three-quarters of an inch across. A very little muscovite also is present.

**Basic Dikes**

The basic dikes, like the acid, are variable in composition, but none is extremely basic. The two that were found cut the granodiorite. They are fine-grained and granular with plagioclase (labradorite) predominating. The plagiooclase occurs in two generations, the first as euhedral crystals which have been cracked and altered, the second as euhedral masses surrounding and encasing the earlier minerals. Aegirine, biotite, and magnetite are the important dark minerals in a dike just south of the quarry southeast of the Calumet mine, whereas hornblende and biotite are important in a dike northeast of Calumet City. Especially the plagioclase and biotite are bent and broken, indicating movement after crystallization (fig. 37).

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**Picture Omitted**

| Fig. 37 | Deformed biotite in a basic dike. Without analyzer, x 50.

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26
**Fig. 38.** Large plagioclase phenocrysts, and trachytic texture in second generation plagioclase. Without analyser, x 50.

**Differentiation in outlying areas**

**Small Sills and Dikes**

The many small sills and a few dikes cutting the Talcocozo formations in the Calumet district are of the same general character. They are here classified as andesite porphyry.

Contains, large andesine phenocrysts, with a maximum diameter of 3 mm., are imbedded in a crystalline, very fine-grained, flinty matrix. The matrix is composed mostly of small laths of second generation plagioclase exhibiting trachytic texture, especially as roses of small crystals bending around the large phenocrysts (ill. 36). Generations of plagioclase are conceded. Pyrite is absent, usually in irregular masses with vermicular arms extending into hornblende and through the groundmass. In some instances the pyrite exhibits cadbic outlines. Green hornblende is the predominating ferromagnesian mineral. Some biotite is present. Apatite and mesasite, especially the latter, are abundant. Carbonate is an important alteration product occurring in small patches and in veins in plagioclase, and throughout the groundmass associated with sericite. Quartz is present in only very small amounts.

**Differentiation in outlying areas**

Both acid and basic dikes, believed to be of the same age as the granodiorite, cut the pre-Cambrian granites and schists, and are thought to be responsible for the concentration of ores in the Curvet area, just west of the Calumet district.

**PHYSICAL CHARACTER OF THE GRANODIORITE MAGMA**

A study of the granodiorite intrusive in the field as well as in the laboratory should shed some light on problems concerning the character of the magma, its depths of intrusion, and the manner in which it was intruded. Several relations were observed in the field from which inferences may be drawn. These latter are to be considered only inferences and sharply distinguished from observed relations.

**Observed Relations to Country Rock**

The intrusive is mainly a discordant mass with its long axis about parallel to the axis of a syncline, approximately in whose center it has been intruded. It forms a notable edentum into the country rock in the vicinity of the quarry southeast of the Calumet mine. The intrusion, on its northeast border, is probably sill-like; trachytic texture has been developed, with the flow lines paralleling the bedding planes of the country rock. Numerous sills occur, but none exhibits great lateral extent. The main sill, which is over 600 feet thick at the Calumet mine, thins out and disappears a few hundred yards to the north, and it exhibits flow structure as it thins. Although some of the sills show moderate chilling at their borders, neither the main stock nor the main sill exhibits any such tendency. The fine to medium-grained texture prevails right up to the contact with the country rock. Cracks developed in the intrusive, and are filled usually with calcic material. Some of these dikes have sharp boundaries, and some are gradational into the country rock.

Inclusions are numerous in the granodiorite, and these are found more abundantly near the border of the intrusive. One large inclusion, however, or "Window" sandstone occurs at the eastern foot of Canon Mountain in the S., S. E. of sec. 31, T. 51 N., R. 10 E. Based on information gathered on a reconnaissance trip into this area, the inclusion is 500 to 600 yards long by 100 to 200 yards wide. All the other inclusions that were found are not more than a few inches across, and are of two general types as already mentioned (p. 51). One type is partly an open vein and contains dolomite crystals. It may have been originally dolomite. The most common type is dark-colored, basic, and crystalline (probably recrystallized). This latter type -
Appears in three forms which are gradational into one another: (1) The fragment is recrystallised but has sharp boundaries and has been changed little in composition (Fig. 39); (2) The fragment has an irregular contact, and has been imprecated by granodiorite (Fig. 40); (3) The fragment appears only as a ghost, having been almost entirely assimilated (Fig. 41).

Differentiation has occurred both as a variation in the composition of the granodiorite and on dikes of acid and basic material. Erosion of the plagiodolase with later corrosion is a constant feature, and reversal of zoning was noted in one case. Syngentic replacement of the limestone has taken place at the borders.

(Picture Omitted)

Fig. 39.— Sharply defined inclusion in granodiorite, showing very little assimilation around its borders.

(Picture Omitted)

Fig. 40.— Contact between an inclusion and granodiorite. The inclusion has been markedly imprecated with the magma, and assimilated around the border.

(Picture Omitted)

Fig. 41.— An almost completely assimilated inclusion. Only a ghost remains of the original fragment. (The inclusion is the dark area in left center).

Inferences as to Character of Magma

From the preceding facts, we may draw some inferences as to the character of the magma.

Viscosity

The viscosity of the magma must have been relatively high. This is indicated, in the first place, by the rapid thinning of the Bain Sill. Had there been a low viscosity, we would expect a greater linear extent of this large mass of material. The fact that it apparently broke through the strata in the central-southern part of the Bain Sill and thickened greatly, rather than extending itself laterally, suggests that the magma was rather viscous. In the second place, the numerous basic inclusions, most of which probably were heavier than the magma, did not sink. Probably they are a late accession of the magma and had not time to sink to the bottom; but the fact remains that there are many basic inclusions suspended in the rock.

Also, where assimilation has been important, there is no evidence of a streaming upward of the schlieren from the inclusion indicating that it was sinking. In the third place, the presence of many already formed crystals in the melt as it was intruded would increase the viscosity of a granodiorite melt. Such crystals were abundant in the magma as it was intruded into the border regions, at least, is suggested by the alignment of the crystals parallel to the direction of flow. Another evidence is seen in the broken and bent crystals of the basic dikes, which, having been bent during intrusion, must have been present before intrusion.

The magma, however, was a liquid of a not very high viscosity since the feldspars show zoning and reversal of zoning indicating a turbulent liquid.
Temperature

The temperature of the magma as it entered the region can only be surmised. If it had not begun to crystallize, it was probably about 1000°C or less hotter than when crystallization began. It would seem that it began crystallizing, however, somewhere between 1500°C (the upper limit of stability for plagioclase) and 800°C (the lower limit for augite). These are the two important early minerals in the granodiorite. As the magma cooled, silicates reacted with the residual liquid to form green hornblende, which is formed below 600°C, and biotite crystallized out, which dissociates at 600°C. Thus, the final solidification probably took place below 600°C.

Assimilation

It is interesting to speculate on the degree to which assimilation has proceeded for this is vitally connected with any theory dealing with the method of intrusion of the magma.

The magma, being intermediately acid, was of a type favorable to assimilation. The country rock that the magma passed through after it broke through the pro-cambrian, and before it reached the "tebor", was largely limestone. The limestone was probably not sufficiently digestible. The local intense pyroclastization in the limestone suggests that the magma was capable of assimilating this country rock and the coarse-grained texture of the granodiorite at the contact with the country rock indicates that the latter was probably at a high temperature during the intrusion, which would be favorable to assimilation.

That some assimilation went on is indicated by (1), the rounding of the inclusions and their gradual disappearance, (2), engulfment of the intrusive into the country rock, and (3), the presence of labradorite-endesine feldspar rather than andesine-oligoclase in a magma as rich in orthoclase and quartz as this, which means a high calcium content that would be expected if such limestone was assimilated. This last evidence is purely speculative, for we know nothing of the composition of the magma before intrusion.

In conclusion, then, it may be said that conditions were generally favorable rather than unfavorable for assimilation on a fairly large scale. The inclusions found near the wall of the stock were probably caught in the magma not long before its solidification. As they are assimilated to some extent at this late stage, might not assimilation on a much larger scale have been accomplished at an earlier stage when the magma was hotter and more fluid.

Inferences as to Depth of Intrusion

Since the intrusive is fine- to medium-grained throughout, we can from this postulate a medium depth of probably two to four miles below the surface for the granodiorite at its time of intrusion. If the depth is calculated from the probable overburden at time of intrusion, figures comparable to these are arrived at. Probably all the Paleozoic formations, including the Harum formation, covered this area once, since they outcrop to the south, north, and east of this region; and much of this may have overlain the district at the time of intrusion. This represents a probable thickness of 10 to 15 thousand feet of rocks. It must be emphasized that little is known for sure concerning the overburden at time of intrusion.

The stock may not have had a very much greater vertical extent than at present. This based on the evidence furnished by what is thought to be a large roof pendant in sect. 31, T. 51 N., R.10 E. (See p. 37).


2. These figures are mostly from Bowen, N. L., Geologic thermometry, in Fairbend's, W. O. et al., The laboratory investigation of ores, McGraw-Hill Book Co., N.Y., 1928, pp. 172-199.
Inferences as to Method of Intrusion

The possibility that considerable stowing has taken place in the Columet region as the granodiorite was intruded, has been discussed (see p. 29). The writers believe that it has been important in making room for the granodiorite. The rock that was there originally had to go somewhere. The rocks do not appear to have been moved up, since they dip into the intrusive, and have been clearly cut out in some places. If they were shoved aside and compressed, there does not seem to be much evidence for it. Local steepening of dip and a few minor rolls occur, but these do not seem to at all adequately take care of the displaced rocks.

Whether or not stowing is considered as important, one other point is to be considered.

The coincidence of the intrusion of the granodiorite along the axis of the syncline may be only a coincidence, but it suggests some connection between the intrusion and the structure. There are two methods of approach: (1), the syncline was formed after the intrusion, and (2), the structure was present when the magma was intruded, localising and directing the intrusion.

(1) That the beds may have been bowed down into the magma by withdrawal of some of the magma after intrusion suggests itself as a possibility. This does not seem likely, however, in this case, since we are dealing with a small, discordant intrusive. Where this is thought to have occurred, the intrusive masses are very large and mostly concordant.

(2) If the syncline was already present, with the beds dipping about 25° toward the center, then at the axis of the syncline these Paleozoic limestones would lie at a position more than a mile below a corresponding stratigraphic horizon 2½ to 3 miles out on the flanks of the syncline. These limestones rest on the ancient rises Peak granite, which because of its character, would probably not be so easily topped as limestones by the granodioritic magma. Also, we might expect fractures, or at least weaknesses along the axis of the syncline.

If this stock is a subaerial intrusion rising above the main surface of a batholithic roof, its presence might possibly be due to a local intensity of stowing due to the presence of a more easily stowed rock or to more fractures, or both.

With this syncline's sending the beds along its axis farther down into the lithosphere, a rising batholith, meeting the limestone beds first along the axis, would have tended to expand upward locally in this more easily stowed rock. The main batholith may have already been in a sluggish condition, due to its near approach to the surface, and so did little rising after the stock was formed. A sketch (fig. 42) indicates the postulated condition.

This idea is of course only a suggestion, but it seems to the writer to account for the facts better than any other proposal.

AGE

The intrusive stock cuts all the sedimentary formations which crop up in the region. It thus is later than the youngest formation outcropping in the area, the "Webber" (Pennsylvanian), and is believed to be early Tertiary in age. The belief is based on the fact that it is similar in composition to other intrusions in south-central Colorado. It appears highly probable that the rock was intruded during the late Tertiary orogeny when there was much igneous activity.

Tectonic Type and Data

General Description

A small area north and south of Hikesy, and an area of several square miles at the south end of the granodiorite stock, are covered with volcanic tuff and lava flows. The rock is light in weight and usually light in color, although it contains large biotite crystals. The flows overlie the tuff wherever the two are found together. The flow is more dense than the tuff, is usually brown in color, and is resistant to erosion.

The tuff characteristically forms low, round hills, though it occurs in valley flats mixed with alluvium.
The age of the volcanics is probably late Tertiary. The rock is clearly later than the granodiorite, which it overlies, and the tuff occurs in valleys which were probably developed in late Tertiary time.

CHAPTER V

STRUCTURAL GEOLOGY

The main structural features of the Calumet district are simple. The sedimentary formations lie on a peneplaned surface of the pre-Cambrian granite, and dip east at angles varying from 20 to 25°. An intrusive stock, Tertiary in age, has cut off the formations a short distance down their dip, and has sent off sills at various horizons between and in the formations (fig. 46). (For structural relations of the intrusive, see p. 19). Faulting is of minor importance in the district.

The prevailing strike of the sedimentary formations is NSE or NNE, but locally this direction is departed from as much as 45 degrees. In general the dip is to the east at an angle averaging about 25°, but the angle of dip is variable, and there is even local reversal of dip (fig. 46).

An anticlinal fold one mile southwest of Hinsley has caused the Manitou limestones to outcrop between outcrops of Harding sandstone. "Rolls" in the Harding sandstone are reflected in the dip slope developed on the formation. These "rolls" interrupt the otherwise uniform eastward dip, producing small anticlines which plunge down-dip, and open like a fan in that direction. They may be due to lateral compression, or to sills of varying thicknesses pushing up beneath.

The most extensive faulting in the district occurred about one mile south of the Calumet mine (See fig. 46). The vertical displacement, with the downdrop side on the west, has let the "Weber" formation down, and subsequent erosion has left small areas of "Weber" shale surrounded by "Blue" limestones. The Iron King mine is located near one of these faults. Other mineralized zones just east of the Iron King mine are located near faults.

The time relations of the faulting to the intrusions was not carefully studied. Apparently some of the fault zones are mineralized, but on the other hand, some of the sills end abruptly at the faults.

Two of the faults south of the Calumet mine strike northwest, and one strikes northeast. These directions correspond roughly to the strike of the sedimentary formations, which, as has already been stated, varies greatly. The displacement of these faults is vertical. A fault three miles north of the Calumet mine strikes nearly east, and has a horizontal displacement of 1,000 feet. The fault cuts entirely across the outcrop of sedimentary formations, and dies out in the granodiorite on the east and in the pre-Cambrian rocks on the west. No mineralisation has taken place along this fault.

South of Cameron Mountain faulting has taken place in the patch of "Weber" which lies on the granodiorite stock. As only a reconnaissance trip was made into this area, the details of the faulting are not known.

The apparent thickness of the "Weber" formation is variable along the strike, being less than 200 feet just north of the Calumet mine, and more than 2,000 feet a mile south of the mine. This variation in thickness is due to the formation's being cut off at varying distances from its base by the granodiorite stock. This is shown in A and B, fig. 46.

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FIG. 43  - Section meeting along the south sides of pits 58 and 57.

Key:
- W: Wapakoneta sandstone on La Porte limestone
- DP: Bunker limestone on Pierre shale
- DT: Tight marl fissured by lower intrusive or granodiorite

Pits 58 and 57. Scale: 1 inch = 800 feet.
Fig. 45.—Sketch map showing how the granodiorite stock cuts diagonally across the sedimentary formations, thus permitting a greater thickness of the "Weber" formations toward the south.

Structure section along line A-A'.

Legend for A-A' and B-B'.

Structure section along line B-B'.

"Blue" Is.
Fig. 46... Structure section along the line L1, Plate II.
Horizontal scale 1 inch = 600 feet.
Relief not to scale.
Ch. Harding sandstone; C. Frueauf limestone;
In, Wanting and/or; TBB, "Blue" limestone; Br.
Robey Formation; Jr, granite-granodiorite.
CHAPTER VI

CONTACT METAMORPHISM

The granodiorite stock which intruded the Paleozoic sediments of the Cal-
umet district produced various contact effects around its borders. In most places,
this metamorphism was of little consequence, but in the vicinity of the Calumet mine
all types of rock were altered to a varying degree. The sills at the mine were en-
domorphed; the limestones were bleached and recrystallized usually to a coarse-
grained, white marble, and at the mine were intensely altered; carbonaceous lime-
stones of the "Weber" formation were transformed into graphitic beds; the shale beds
of the "Weber" were recrystallized and new minerals were developed; and some of the
sandstones were recrystallized.

METAMORPHISM OF THE SILL

The limestone at the Calumet mine was intruded by at least five sills.
There may be more present, but if so, they were indistinguishable from the intensely altered limestones. The large upper sill and the main sill are granodioritic in com-
position, but the smaller ones contain less orthoclase, and should be classed as dior-
ite, or where they contain more quartz, as quartz-diorite. The two larger bodies
have been little altered, but the small sills in the mine have been so intensely
metamorphosed that they usually could not be traced with any certainty across the
open pits.

Bleaching of the diorite is the most notable effect. The large, uppermost
sill at the mine (See Pl. III) is a very dark-colored rock on the southern edge of
the south open cut. As it is traced northward through the mine, however, it rapidly
changes to a light gray rock with a greenish tint, resembling the surrounding altered
limestone, and it is traceable with certainty for only a short distance. The original
sill was composed mostly of plagioclase, hornblende, and biotite (fig. 47). The
bleached phase (fig. 48) contains no hornblende or biotite, but instead is rich in
epidote, calcite, and bladed diopside, and contains a little actinolite. The epidote
occurs as large crystals, and the calcite as irregular masses and veins. The plag-
AOCLase is only moderately altered to calcite and epidote. The bleaching has been
produced by the complete destruction of the hornblende and biotite. It would seem
that much iron has left the sill, perhaps helping to form magnetite and epidote in the
limestone at the expense of the biotite and hornblende in the sill.

Characteristically augite is an abundant endosomatic mineral in the sills,
and some fibrous tremolite is usually present. The augite commonly occurs as large,
peloblastic crystals (figs. 49 and 50).

--- Picture Omitted ---

Fig. 47.— Dark sill not endomorphosed, composed of hornblende (H), biotite (B),
and plagioclase (P). Analyzer cut, x 50.

--- Picture Omitted ---

Fig. 48.— Bleached phase of dark sill, composed of plagioclase (P), epidote (E),
diopside (D), and calcite. Without analyzer, x 50.
At one point, at the contact between a limestone inclusion and the diorite, the hornblende instead of being altered, was segregated at the contact (fig. 51).

METAMORPHISM OF THE LIMESTONE

One of the most striking features of the Calumet district is the widespread metamorphization of the limestones and dolomites (fig. 52). This has probably been accomplished mostly by the heat and pressure attending the intrusion of the granodiorite. Bleaching and coarse recrystallization are general. (See fig. 53, and compare this texture with that of the unmetamorphosed, fine-grained, dense limestone in fig. 50). In some places, however, a fine-grained marble has been developed with schistose structure (fig. 54); and frequently the beds have been selectively bleached, producing a banded marble with alternating bluish-gray and white bands (figs. 55 and 56).

At a few places the "Blue" limestone has been metamorphosed one step further. Solutions from the intrusive entered the already metamorphosed limestone and by metasomatic replacement at high temperature the limestones were altered. Three examples of this are described below.

In the NE ¼ of the SW ¼ of sec. 34, T.51 N., R.9 W., diopside has developed profusely in the metamorphosed "Blue" limestone over a small area (fig. 56). A very little pyrite came in later.

Fig. 51.-- Hornblende segregated at the contact of diorite (upper left), and limestone (lower right). Without analyzer, x 25.

Fig. 52.-- Specimen of metamorphosed "Blue" limestone (right) beside a specimen of the unmetamorphosed "Blue" limestone.

Fig. 53.-- Thin section of metamorphosed "Blue" limestone shown in fig. 52. The central crystal is 8 mm. across. Crossed nicols, x 50.
Fig. 54. — Schistose marbled Fremont limestone on the west side of Parting Hogback.

Fig. 55. — Marmorized Fremont dolomite, showing selective bleaching of bands.

Fig. 56. — Blades of diopside replacing the fine-grained "Blue" limestone. Crossed nicols, x 50.

In the SW. 1/4 of sec. 35, T.51 N., R.9 E., in the vicinity of the abandoned manganese mine, a silicate (tremolite?) streaks the "Blue" limestone with bunches of fine, long, white fibers (figs. 57 and 58).

The most intense silication took place in the limestone at the Calumet mine. Here diopside, epidote, garnet, brown and green biotite, tremolite, and actinolite replace the former carbonate; and magnetite, hematite, pyrite, and chalcopyrite vein and replace both the silicates and the carbonate (see p. 42). Diopside is the most abundant of the silicates (fig. 56). It occurs usually as light, greenish-gray spheroidal masses as large as eight inches in diameter, composed of radiating blades (fig. 57). Frequently entire beds, from a fraction of an inch to several feet in thickness are made up almost entirely of this mineral. Epidote occurs usually as disseminated grains throughout the limestone, or in beds composed almost entirely of granular epidote, or as dense masses along joints and fractures. It is of a clear, dark-green color, and often shows a peculiar zoning in thin sections (fig. 50). Figs. 59 and 60 illustrate the manner in which it has replaced the limestone. Garnet is of secondary importance, but in small patches here and there it is the principal mineral. Biotite is irregularly distributed and only in places, mixed in with the ore, is it important. Tremolite, occurring in fine fibers, and actinolite are not abundant.

Fig. 57. — Fibrous, white silicate streaking "Blue" limestone.

Fig. 58. — Thin section of silicate shown in fig. 57. Crossed nicols, x 16. (Small circles are bubbles on slide.)
Fig. 59.—Epidote almost completely replacing calcite of the original limestone. Without analyzer, x 50.

METAMORPHISM OF THE "WEBER" CARBONACEOUS LIMESTONES

Carbonaceous limestones near the base of the "Weber" formation have been altered, by the heat and pressure accompanying the intrusion, to impure graphite. Calcite is the main impurity, and occurs in veins and in small segregated masses throughout the graphite (fig. 51). The calcite is characteristically in needles with their long axes perpendicular to the walls of the veins and extinguishing in series, causing a block wave to pass down the vein as the stage is rotated.

Fig. 60.—Fine-grained epidote thoroughly disseminated throughout the limestone, which is here coarsely crystalline calcite. Without analyzer, x 50.

METAMORPHISM OF THE SHALE BODIES OF THE "WEBER"

Some of the shale bodies of the "Weber" formation along Graphite Hill and Comanche Knob show noticeably the effects of the near-by intrusion. They have been hardened, and sillimanite, mostly of the variety fibrolite (fig. 60), andalusite, and cordierite(? are developed. Possibly, also, some of the plagioclase present is a result of the metasomatism. However, plagioclase occurs as a primary constituent in the "Weber" gneiss, and it is difficult to tell whether or not some of it is secondary. The rock is shot through with pyrite (fig. 60), which occurs as veinlets and as a replacement of the ground-mass. The groundmass is mostly recrystallized quartz.

METAMORPHISM OF SANDSTONES

Most of the sandstones of the "Weber" formation have been entirely recrystallized near the border of the intrusive. The light-colored sandstones are fine, even-grained, and composed almost entirely of quartz grains with altered contacts, and muscovite. There is also a little plagioclase and orthoclase. The darker gneiss contain much biotite, but the quartz is also entirely recrystallized.

CHAPTER VII

MINERALOGY

LIST OF MINERALS

Forty-three minerals were identified in the rocks of the Calumet district. This includes those found in the granodiorite, the contact zone, and the sedimentary beds. There follows an alphabetical list of the minerals.

Fig. 61.—Calcite veining graphite. Without analyzer, x 50.
Minerals of the Calumet District

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actinolite</td>
<td>Present in very small amounts in the endomorphosed sills at the Calumet Mine. It is light green and fibrous.</td>
</tr>
<tr>
<td>Andesine</td>
<td>Present everywhere in the granodiorite intrusive and sills, except in some of the differentiates. It usually occurs as the outer border of the sodal plagioclases.</td>
</tr>
<tr>
<td>Andalusite</td>
<td>Found in minor amounts in the metamorphosed “Weber” shaly beds along Corundum Hill and Graphite Hill.</td>
</tr>
<tr>
<td>Antigorite</td>
<td>Occurs in minor amounts in the granodiorite as an alteration of augite.</td>
</tr>
<tr>
<td>Apatite</td>
<td>Widely distributed in all phases of the intrusive and in small amounts in the silicified limestone at the Calumet mine. It is always in small, well-formed prisms.</td>
</tr>
<tr>
<td>Augite</td>
<td>An abundant primary constituent of the granodiorite, especially at the northeast edge; and is also present as an endomorphic mineral in large euhedral crystals.</td>
</tr>
<tr>
<td>Biotite</td>
<td>Occurs as a primary constituent of the granodiorite, probably as a deuteritic mineral, and as a hydrothermal alteration product of augite. It also occurs in the pyrometamorphically replaced limestone in the Calumet mine.</td>
</tr>
<tr>
<td>Calcite</td>
<td>A common hydrothermal alteration product of biotite in the granodiorite, and is present in the silicified limestone of the Calumet mine.</td>
</tr>
<tr>
<td>Chlorite</td>
<td>Makes up the greater part of the monzonite limestone, the Precambrian limestone, and the “Blue” limestone; with impurities it forms beds several feet in thickness in the “Weber” formation, and occurs in veins in the graphite of the “Weber”. It also occurs in the ore body as large euhedral crystals, filling in between the magnesite and calcite and often including grains of magnesite. It is present in small quantities in the intrusive rocks.</td>
</tr>
<tr>
<td>Chalcopyrite</td>
<td>Occurs in very small quantities and was found at only a few places in the district. Scattered grains are associated with magnesite and pyrite at the Calumet mine, and with pyrite in the quartz-calcite veins in the granodiorite.</td>
</tr>
<tr>
<td>Chert</td>
<td>A common alteration product, in the intrusive, of augite, titanic-ferric augite, brown biotite, green biotite, and hornblende.</td>
</tr>
<tr>
<td>Corundum</td>
<td>Thought to be present in the metamorphosed “Weber” shaly beds.</td>
</tr>
<tr>
<td>Cuarzite</td>
<td>Reported from the metamorphosed “Weber” sandstone on Corundum Hill.</td>
</tr>
<tr>
<td>Garnet</td>
<td>Present in small amounts in the silicified limestone in and near the Calumet mine.</td>
</tr>
<tr>
<td>Gold</td>
<td>Was mined from quartz-calcite veins in the main sill, and from a mineralized fault zone in the lower “Weber” beds.</td>
</tr>
</tbody>
</table>
Graphite occurs in two beds in the lower "Weber" formation. Each bed has a thickness of about three feet.

Magnetite is present in small amounts in the Calumet mine and is sufficient quantity to be classed as an ore in the Iron King mine.

Malachite is a rather common alteration product of orthoclase in the granodiorite.

Labradorite as the inside zone of plagioclase is ubiquitous in the granodiorite.

Limonite is widely distributed in both the sedimentary and igneous rocks where weathering has taken place. It is most abundant in those rocks rich in sulphides and oxides of iron.

Magnetite is abundant in the contact zone as a replacement mineral in the limestone. It is associated at the Calumet mine with pyrite, epidote and diopside, it typically occurs in bands which parallel the bedding of the limestone, and in these bands it has completely replaced the limestone.

Malachite is present in very small quantities as an alteration product of chalcopyrite. It occurs as a stain in the quartz-carbonate veins in the granodiorite sill.

Magnetosiderite is an important constituent of the protore at the manganese mine.

Muscovite is rare, but occurs in some of the acid dikes cutting the granodiorite, where it is intergrown with orthoclase.

Magnetite is abundant in some of the "Weber" beds, and is a very important mineral in the pre-Cambrian gneisses.

Orthoclase occurs abundantly in the granodiorite in irregular masses; surrounding and corroding the earlier minerals.

Magnetite is thought to be present in the silicified limestone at the Calumet mine.

Pyrite occurs in small amounts in veins and in irregular masses in the magnetite ore, and is abundant as an introduced mineral in the "Weber" metamorphosed sandstones.

Pyroxyline occurs as an alteration product from rhodochrosite in the north-central part of sec. 14, T.50 N., R.9 E. The mineral occurs in the "Blue" limestone above the Main Sill and is associated with siderite and calcite.

Quartz is the main constituent of the various sandstones, being recrystallised in the "Weber". It occurs in irregular masses in the granodiorite, and as phenocrysts in some of the porphyry dikes. It is a late mineral at the Calumet mine, having crystallised in vugs and along open joints.

Rhodochrosite is thought to be the main protore for the manganese ore, occurring in veins as a low temperature effect of the intrusive.

Siderite is a common alteration product of orthoclase and often of plagioclase.

Siderite is present at the manganese mine, veined with pyrolusite.

Siliquinite has been abundantly developed in the "Weber" shaly sandstones near the intrusive. It is mostly of the variety fibrolite.

Silver may occur at the Iron King mine. The ore shipped from there contained silver which may have been native metal.

Siliquinite has been doubtfully identified from the granodiorite in sec. 52, T.51 N., R.9 E.

Siliquinite, often in euhedral, diamond-shaped crystals, is an abundant primary constituent of the granodiorite.

Siliquinite is only of minor importance in the endomorphosed sills and silicified limestones at the Calumet mine.

Airgun in small amounts was identified in the "Weber" gneite.
The Clilucet district of Colorado is known chiefly for its deposit of magnetite. This deposit, however, is small, and during the period of mining operations only about 228,000 tons of ore were shipped. There has been no production of magnetite in the district since 1899.

Several other metallic and non-metallic products were shipped in small quantities from the district. A list of these includes precious metals, manganese ore, quartzoidite for building stone, marble for ornamental stone and for flux, and graphite. These have never been produced on a large scale, and in the summer of 1933 all quarrying and mining operations within the Clilucet district had ceased.

Iron ore forms the chief ore of the Clilucet district, and has been the one most extensively mined. Mining of the ore began in 1881 and continued with few interruptions until 1899. The mining was done by the Colorado Fuel and Iron Company, and operations were centered on the west side of Clilucet Hill, located in the SW 1/4, sec. 26 and the adjacent parts of secs 7, 34, and 35, T. 16 N., R. 9 W. During the period of mining operations a small railroad served to haul the ore from the mine down Fleming Creek valley to the junction with the Denver and Rio Grande Railway.

General Geology

Country Rock

The magnetic ore-body occurs in the upper two-thirds of the "Blue" limestone which has been separated from the lower third by the Main Sill (See Pl. III). The Weber formation directly overlies the "Blue" limestone, but at the mine the hanging wall is formed mostly by an upper sill, about 50 feet in thickness, which separates the two sedimentary formations. Three small, bleached sills (See p. 35); and perhaps others, cut the limestone between the upper, fifty-foot sill and the Main Sill.

Structure

The beds in general show the prevailing strike and dip of the district (E. 15° N. with a 260 dip to the east), but some minor irregularities in the form of crumple and rolls occur, perhaps partly the result of blasting. It should be mentioned, however, that the bedding is often obscure where the alteration has been intense, and the relations are not clear. Numerous slickensided surfaces indicate faults, generally with only slight displacement. At the north end of the north open cut a fault with a three-foot displacement is easily distinguishable (Fig. 63). The fault dips 40° to the east, with the downthrow side on the east.

The footwall of the ore is usually metamorphosed, altered limestone; but in the north open cut the footwall is formed by a small, bleached sill. The hanging wall is formed by the upper sill in most places, otherwise by altered limestone. As shown on Pl. III, the upper sill is in general confined to the "Weber" formation, but at the mine it becomes discordant and cuts down into the "Blue" limestone. The observations were made only at the surface and the relations may be different underground.

Metamorphism

The metamorphism of the country rock coincident with the intrusion has been discussed (See p. 37). The limestones have been metamorphosed and altered and the sills endomorphosed.

ORE DEPOSITS

Mineralogy of the Primary Ore Minerals and Gangue

The primary ore minerals include the following: magnetite, hematite(?), pyrite, and chalcopyrite. The gangue is composed of calcite, diopside, epidote,
Fig. 63.— Strings of fibrolite in the “Weber” shaly sandstone. The abundant black material is pyrite. Without analyser, x 50.

Fig. 65.— Fault at north end of north open cut. Note crumple in the upper right part of the picture.

Fig. 66.— Replacement of recrystallized limestone by magnetite. Without analyser, x 50.

garnet, green and brown biotite, apatite, tremolite, and actinolite, all of which occur mostly as alteration of the original limestone. Plagioclase, anatase, titanite, quartz, and hornblende are found in the altered sills.

From an examination of the ore specimens and thin sections the paragenesis seems to be:

1. Calcite.
2. Diopside, epidote, garnet, and green and brown biotite — not distinguished as to relative ages.
3. Magnetite and hematite(?).
4. Pyrite and chalcopyrite.
5. Calcite and quartz.

Calcite occurs both as a primary constituent of the original recrystallized limestone, and as a late deposit in veins.

The silicates replaced the limestone. This replacement has been practically complete in some places, but usually calcite is still present. Radiating blades of diopside occur commonly intergrown with much calcite which secondarily has been recrystallized to crystals an inch or two in diameter. The epidote usually occurs in small grains replacing carbonate (see figs. 59 and 60, p. 39), or as larger crystals along joints.

The magnetite occurs in two ways: (1) as a fine-grained, dense replacement of the only slightly silicified limestone, probably guided by small fractures (fig. 64), and (2) as crystals from a small fraction of an inch to three-eights of an inch across in veins and replacement bands, usually in the more completely silicified rock. The magnetite characteristically veins and "chinks in" between the blades of the diopside, and is thus definitely later than this silicate (figs. 65 and 66).

Muscovite, quartz, usually in elongated prisms, occurs in fractures and veins, and is a late precipitate.

in the metallurgical treatment of the ore, the silicates are undesirable, and the calcite beneficial.1

Analysis of the Ore

The following analyses of the ore are the best obtainable:2

---

2. Furnished by the courtesy of the Colorado Fuel and Iron Co., Pueblo, Colo., and J. B. Stone, geologist for the company.
Typical analysis of eight cars shipped in 1897.

<table>
<thead>
<tr>
<th></th>
<th>per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>64.9</td>
</tr>
<tr>
<td>Silica</td>
<td>10.6</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Average of 240 cars shipped in 1894.

<table>
<thead>
<tr>
<th></th>
<th>per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>45.7</td>
</tr>
<tr>
<td>Silica</td>
<td>19.0</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.52</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.017</td>
</tr>
</tbody>
</table>

The last analysis of the ore shows it to be deteriorating greatly in value. This was apparently due not so much to a lower grade ore at depth, but to a different type of mining which permitted less exclusion of gangue (See p. 50). Sulfur, relative to the iron content, is greater in the last ore which was mined at lower levels.

(Picture Omitted)

**Fig. 65.**—Magnetite replacing diopside. Without analyzer, x 50.

(Picture Omitted)

**Fig. 66.**—Magnetite veining, and "chinking in" between, blades of diopside.

(Picture Omitted)

**Fig. 67.**—Bands of magnetite and diopside alternating. Note large radiating rosettes of diopside in upper center of picture.

**Form of Ore Body**

Since the ore replaces a definite series of beds in the limestone, it has a linear extent parallel to the strike, and dips with the beds into the hills. The thickness of the ore-body is 40 to 50 feet, and an inclined adit has continued in the ore down the dip for 1800 feet. The ore-body has a width of about 500 feet. The ore occurs usually as bands parallel to the bedding, from a fraction of an inch to three or four inches in thickness, separated by light-green silicated limestone. The original bedding is thus often well preserved (fig. 67).

**Secondary Alteration of Ore**

The secondary alteration of the ore has been slight, but of some importance. Pyrite and chalcopyrite have been oxidized at the surface to limonite, the sulphur having been removed in solution. This produced an ore lower in sulphur near the surface, and thus made this ore more desirable. The increasing sulphur content at depth was one of the main factors causing discontinuance of mining.
Study of the Primary Ore

The ore is of the contact metamorphic (pyrometasomatic) type. Its occurrence at the contact of the intrusion, the type of country rock in which the ore occurs, the form of ore-body and texture of ore, and the association of minerals are definite evidence on this point. It is the same type of deposit, and closely resembles, the Cornwall, the magnetite deposit, the Iron Springs, Utah, iron-ore deposits, and several other well known districts in this country and abroad.

The introduction of the iron is thought to have been a late effect of the intrusion. That the iron came from the intrusive is indicated by (1), the location of the magnetite near the intrusive, (2), the abundant magnetite and ferromagnetite minerals still in the granodiorite, giving evidence of a potential source, (3), the destruction of the iron minerals in the sills associated with the ore, suggesting that iron has been transferred from the sills into the limestone, and (4), the inability of the limestone to furnish the iron. That the deposition of the magnetite was a late effect of the intrusion is indicated by (1), the endomorphism of the sills, (2), the general homogeneity of the granodiorite mass, indicating no particular segregation of magnetite at the contact, and (3), the fact that the magnetite was introduced after the limestone was silicified. Furthermore, the deposition of the magnetite may be considered not only as a "late effect" of the intrusion, as was probably also the silicification of the limestone, but also as a separate process rather distinct from the earlier metasomatism which produced the silicates. Wherever the magnetite is associated with the silicates it occurs in veins or masses replacing the mineral along lines of weakness between the blades, or in veins cross-cutting the fibers (Fig. 60). There is no indication of the magnetite's having been intergrown with the silicates. Thus the crystallization of the magnetite seems to be a distinctly later process than the pyrometasomatism which produced the silicates, for they seem to have been in all cases completely crystallized before the magnetite entered. Probably as the silicates cooled, cracks developed in them, and the iron-bearing solutions took advantage of these cracks, using them as passage-ways and replacing the silicates along the borders and along cleavage planes. The ore minerals themselves, therefore, might be considered as a high temperature vein and replacement deposit, their connection with the contact metamorphic minerals being simply that the gneiss minerals were greatly fractured after formation allowing the iron-bearing solutions to thoroughly penetrate and replace them. Had not these fractures been present, the solutions might have moved on along main channels and have deposited where fractures did occur.

The means by which the iron was transferred from the intrusive into the limestone is still much in the realm of hypothetical reflections. Leith and Harder suggest that, in the case of the Iron Springs, Utah deposit, the iron may have been carried as ferrous chloride in an aqueous solution above the critical temperature of water. By a breaking down of the water, the iron was oxidized and precipitated as magnetite. They suggest this equation as a plausible reaction:

\[ 3 \text{FeO(OH)} + 4 \text{H}_2 \text{O} = 3 \text{Fe} \text{O}_3 + 4 \text{H}_2 \text{O} \]

This has been found empirically to happen above 500°C, which temperature does not seem unlikely in the case of the Calumet deposits. The BO1 which could have dissolved the magnetite after its formation would have been easily neutralized by the limestone.


1. Leith, C. M., and Harder, R. C., Ore Deposits, p. 77.
The localization of the ore at the particular place at which it occurs seems logical when all points are considered. The ore occurs in a limestone which is noted for its replacement deposits; the ore-body lies only 600 yards horizontally from the westward expanse of the main stock, and only about 50 feet stratigraphically above the Main Hill where the sill is 600 feet thick; a 50-foot upper sill, which is normally in the "Weber" formation, here cuts downward into the limestone. In other places was found to exist in the Calumet district at all comparable to this as a favorable locus for ore deposits.

MALAMANDER DIME

A small amount of manganese ore has been shipped from the Calumet district. It was taken from a mine in the north-central part of sec. 2, T.56S., R.9 W. The ore occurs in the "Blue" limestone above the Main Hill. Rhodochrosite and siderite probably deposited in low temperature veins in the limestone have weathered to pyrolusite and limonite. A study of the rock under the microscope showed pyrolusite occurring in dendritic forms and the siderite in crystallized grains. The rock containing pyrolusite, even in small amounts, is dark brown to black. The extent of the ore deposit is not known.

GOLD ORE

A small amount of gold has been taken from mines in the Calumet district. So far as is known no placer mining has been done, though many placer claims have been staked.

Some placer ore occurs in quartz-calcite veins in the granodiorite sills. Several shafts were sunk in the Main Hill in the NW 1/4 of sec. 35, T.56 N., R.9 E., and a small amount of gold was taken out. A long tunnel was driven for gold in the Anacoda claim just to the north. In addition to quartz and calcite, chalcopyrite and pyrite are also present in the ore, and the weathering of these to limonite and malachite has caused staining along the veins.

Another type of gold ore is that taken from the iron King mine, located in the NW 1/4 of sec. 35, T.56 N., R.9 E. There the gold is associated with hematite ore in altered limestone, and occurs along a fault zone.

Considerable gold has been taken from quartz veins in the pre-Cambrian granite just west of the Calumet district. The quartz veins are associated with dikes which are thought to be related to the granodiorite intrusive.

COPPER ORE

No copper ore occurs in the Calumet district, but mention should be made of the occurrence of copper deposits on the east side of the granodiorite about four miles east of the Calumet mines. There the minerals are chalcopyrite and malachite, and they occur in the sandy shale beds of the "Weber" formation. Much prospecting for copper ore has been done, but no deposit rich enough to be mined at a profit has been discovered.

HOT SPRING DEPOSITS

A claim has been staked about half a mile southwest of Midway for the purpose of quarrying ornamental stone. The rock to be quarried is a colorless hot springs deposit. A pit about six feet deep and several feet across was dug, but little or no stone has been hauled away. The rock is pure white in color and has a peculiar, wavy texture, but as it was deposited in beds one foot or less in thickness, this probably will prevent its use as an ornamental stone. The structure is typically that of hot springs, and the very irregular bedding will probably prevent its being quarried.

GRANODIORITE

Granodiorite has been quarried within the Calumet district, and in the area just east of the district. Much money has been invested in quarrying projects. In the unear of 1903 much of the greater part of the quarrying and polishing equipment was idle.

The rock takes a fine polish and possesses all the properties of a good building stone. Excellent sites for quarries are also numerous, there being many exposures of the rock in vertical walls which are easily accessible. At such local—
otions the rock in the faces of the walls is fresh, and the over-burden and the weathered zone above is usually thin. Such sites are usually selected in preference to a level surface, as the rock is commonly weathered for several feet below a surface on which erosion is not active.

Jointing (fig. 26, p. 21) in the rock aids the quarrymen in obtaining rectangular blocks by blasting. The joint planes, crossing at nearly right angles, are at a sufficient distance apart to permit large blocks being obtained if desired. Rarely is the jointing such as to interfere with quarrying, and there are many quarry sites where the jointing will aid rather than hinder quarrying.

Inclusions in the granodiorite, called "mats" by the quarrymen, are, as would be expected, not evenly distributed throughout the rock. (See figs. 27, 30, 40, and 41.) Areas where they are numerous are avoided. The "mats" are usually composed of f erro-capsesion minerals which weather rather easily, staining the stone and destroying the polish.

The future of the quarrying industry in the Calumet district and adjacent areas can not be predicted, but it is believed that once the good qualities of the rock are more widely known the rock will be in demand as a building stone as well as an ornamental stone. There is a large quantity of the rock which can be quarried, and as the area is only a few miles from a shipping point, it could be shipped in greater amounts when economic conditions improve. Roads have already been built to several quarries, and the Ute Trail highway, from which the roads branch, is now being widened and otherwise improved (1933).

MARBLE

Many quarries were opened in the marmorized Frement and "Blue" limestones within the Calumet district. Most of the quarries were abandoned soon after they were opened, and at present all quarrying of the rock has stopped. The marmorized rock is freer from impurities than that which is not marmorized, and consequently it makes a better block. Most of the marble shipped from the district was for use as a flux in the Colorado Fuel and Iron Company's steel mills at Pueblo.

Quarrying of the marble in the Calumet district is not likely to be done on a large scale. Although the marble makes an excellent flux, it will not be quarried for that purpose unless a railroad is built into the district, which is unlikely. The stone possesses some very desirable qualities which make it an ornamental stone. It has a pleasing color, being either pure white or having white and dark bands alternating, and, in the case of the marmorized "Blue" limestone, the texture and structure are good for ornamental stone. The bedding in the marmorized "Blue" limestone is massive, and the texture is medium- to coarse-grained. The rock takes a good polish; its tensile strength is not known, but it is great enough to permit the rock's being used as an ornamental stone.

The marmorized Frement limestone, as a whole, is quite different from the marmorized "Blue" limestone. It commonly has a schistose structure, and is very soft. This structure would prevent its use either as a building stone or as an ornamental stone.

Another factor should be borne in mind in any consideration of quarrying the marble of the Calumet district. The formations which have been changed locally to marble are soft and have been stripped from the underlying more resistant formations. They outcrop, therefore, almost directly beneath the more resistant formations which hold up the ridges. Quarrying down the dip of the formations would soon carry the
CHAPTER IX
PRODUCTION AND MINING HISTORY

The Calumet iron mine, owned by the Colorado Fuel and Iron Company, was opened in 1881 and operated until 1999. The production during those years was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1882</td>
<td>14,308</td>
</tr>
<tr>
<td>1883</td>
<td>22,060</td>
</tr>
<tr>
<td>1884</td>
<td>10,483</td>
</tr>
<tr>
<td>1885</td>
<td>2,902</td>
</tr>
<tr>
<td>1886</td>
<td>12,123</td>
</tr>
<tr>
<td>1887</td>
<td>5,660</td>
</tr>
<tr>
<td>1888</td>
<td>5,312</td>
</tr>
<tr>
<td>1889</td>
<td>14,308</td>
</tr>
<tr>
<td>1890</td>
<td>9,528</td>
</tr>
<tr>
<td>1891</td>
<td>5,319</td>
</tr>
<tr>
<td>1892</td>
<td>228,781</td>
</tr>
</tbody>
</table>

The ore produced at the Calumet mine in the early years of operation was high in iron, but the ore also contained considerable sulphur. In later years the quality of the ore deteriorated greatly. More and more pyrite was encountered as mining was pushed farther and farther away from the weathered zone. This was a major factor in the closing of the mine. Another important factor was the changing iron-square-set stoping, as practiced in the early days, to the open-stop system of mining that was used later. The open-stop method permitted less selecting and sorting of the ore underground. During the '90's some attempts were made to reduce the sulphur in the ore by roasting, but with very little success. In 1905 a little work was done at Calumet in an attempt to find whether any workable ore still remained in the mine. All the ore found, however, was high in sulphur and no further work has been done.

The Iron King mine, privately owned, was operated until the 1920's. It is located about one mile south of the Calumet mine, and was worked mainly for gold. The iron ore was mined incidentally and was dumped on the ground about the mine. It is said that this ore can be hauled profitably by truck to Calumet.

During the time of mining operations at the Calumet mine, a small town, Calumet, was in existence in a small park-like area about half a mile northeast of the mine. The town has been long deserted, and all traces of it except a small storage shack have disappeared.

The date when prospectors were first attracted to the Calumet district is not known, but gold mining in the granite area just to the west was carried on even before mining of iron ore was begun. Prospecting for and some mining of gold have been done within the Calumet district in more recent years. Many placer claims and some lode claims have been staked.

Prospecting for, and some mining of, other metals than gold have also been done. A manganese mine was started, but soon abandoned. It was relocated in 1933, but no mining has been done since.

A few ears of graphite, said to have been of good quality, were shipped from the district, but at present no graphite is being mined. Several quarries were
begun in the monumental Vermont and "Blue" limestones. Some of this stone was cut for ornamental uses, but it was mainly quarried to be used as a flux in the steel mills at Pueblo, Colorado. All quarrying of the stone for any use has been suspended. A quarry was opened several years previous to 1933 to obtain ornamental stone. The stone is a hot spring deposit, and is not very extensive. Gurnard is said to have been mined in small quantities.

Quarrying of gneissodiorite was until a few years ago a large industry in the gneissodiorite area. Hundreds of thousands of dollars were spent in quarrying and polishing equipment, and in building roads. But most of the investments proved unprofitable, and the cubic feet of stone shipped from the area was in no way comparable to the amount of money invested. At present there is no quarrying of this stone in the Calumet district, but just outside the district to the south quarrying on a small scale continues. The gneissodiorite, called "granite" by the quarrymen, takes a polish well and is a good building stone. The stone will be quarried on a large scale in the near future.

Mining of gold is continuing on a very small scale in the granite area just west of the Calumet district.

Mining on a very large scale or at any very great profit is not likely to be done again in the Calumet district. There are still about 600,000 tons of ore in the Calumet mine, but even with an increase in demand for iron, the cost of starting operations would be too great to mine the ore. Quarrying of the gneissodiorite for building stone, and of the limestone for flux, has a brighter future.

Discovery of rich ore is a possibility, and the Calumet district, instead of becoming completely deserted, may again become a prosperous quarrying and mining district.

CHAPTER X

DESCRIPTION OF MINES

The Calumet mine is the only mine in the district that was extensively worked. It was worked for magnetite ore only, and both the open-pit and underground methods were used. The iron mine, an open-pit, was worked for gold, iron ore being mined incidentally. A mine was opened in a manganese deposit in the NW 1/4 of sec. 2, T.60 N., R.10 E. Several other small mines were opened in the district, and some of them were operated for a short time. Numerous pits have been dug and several shafts have been sunk in search for ore.

CALUMET MINE

The Calumet mine is located on the west slope of Calumet Hill at an elevation of about 2,500 feet (barometric reading) (Fig. 68). The bottoms of the open pits are about 600 feet above the base of the hill, and the north of the upper tunnel is 200 feet lower. The ore was first mined from an open pit and hauled down the hillside on tramcars. The larger pit is about 350 feet long and 50 feet wide.

(Picture omitted)

Fig. 68. View of Calumet Mine, looking east across Fleming Creek.

The smaller pit, 200 feet north of the larger one, is only about 100 by 50 feet. The elongation in each case is parallel to the strike of the formations. The open-pit method of mining was stopped when the overburden became too great. Mining into the hill and down the dip of the beds caused the overburden to increase in thickness rapidly, and made it necessary to extend the workings underground. A tunnel was driven from the back wall of the large pit down the dip of the ore horizon. Other tunnels were driven later. As the tunnels have caved in, it was not safe to enter them to study the underground relations. But W. G. Hills in 1892, at that time geologist for the Colorado Fuel and Iron Company, wrote a description of the interior workings, and his description, in part, follows:

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The cross-out tunnel is about 600 feet long and intersects the lower or second level, which extends in both directions a distance of about 1,000 feet. The cross-out - which digs into the mountain at an angle of 40 degrees - has a thickness, normal to the plane of bedding, of from 40 to 50 feet, including an occasional "horse" of partly mineralised rock too poor in iron to pay for extraction. The method of working is quite simple, being in several respects a modification of the one employed for working inclined coal beds, the difference being, (1) instead of the ore being taken out the full thickness of the ore-body, it is stopped from two rooms one above the other, the lower room being worked out first; while a body of ore extending from "rib" to "rib" is left as a floor in working the upper room. (2) There are two chutes at the lower end of the room - the ore being loaded by hand - while large breaks are made in the "ribs" as such for the purpose of extracting the maximum quantity of ore as for promoting ventilation. Since the ground is quite firm, but little timbering is necessary, and this only on the levels - a great improvement over the old method of putting in square sets in six-foot tiers, which requires about 25 men and framed timbers for every 100 tons of ore removed. In mining, the larger pieces of ore roll to the bottom of the room, but much of the finer stuff has to be shoveled, then loaded on the mine-cars it is taken to a common point and dumped into an open chute, which extends on one side of the ladder-way to the lower level. This chute is provided with a sheet-iron lining on the bottom, and log traps to moderate the descending velocity. At the lower level the ore is loaded from the chute, and hauled in trips by mule power through the cross-out to the head of the tramway.

Little can be added to Hill's report, as developments underground later than 1892 are not known. The pits, dumps, and roads may still be plainly seen on the hillside, but the tunnels have covered badly near their mouths. A scrubby growth of trees is slowly hiding all traces of former activity in the area.

IRON KING MINE

The Iron King mine worked a mineralised fault zone for gold. It is an open pit about 50 feet deep with a nearly circular groundplan. A haulage tunnel driven from a point a short distance down the slope from the mine intersects the pit at about half its depth. A large pile of iron ore, mined incidentally to the gold, lies just west of the pit. The mine is located only a few hundred feet from the Turret road and is easily accessible.

HARDWOOD MINE

A deposit of manganese ore occurs in the Ni of the NW 1/4 of sec. 2, T.50 N., R.9 W., on the east side of a small valley. It was worked on a small scale, and incidentally, it was reclaimed in January, 1933 and called the Venture lode. In mining the manganese ore one shaft and three inclined tunnels were driven. The shaft is about 50 feet deep and connects with at least one of the tunnels. It was used to bring the ore to the surface. But from the inclined tunnels the ore was hauled out on cars by means of a windlass turned by a horse. The windlass is still at the mine. A cabin in fairly good condition stands 200 feet southeast of the mine, a road which may be travelled without great difficulty leads from the Turret road to the mine.

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