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THE TERTIARY IGNEOUS INTRUSIONS
OF

GREEN LAKES AND ISABELLE LAKE VALLEYS,
BOULDER COUNTY, COLORADO.

By John Roberts Graham Jr., B. S.,

(Agricultural and Mechanical College of Texas, 1933.)

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Walter O. Thompson

August 20, 1934.

A thesis submitted to the faculty of the Graduate
School of the University of Colorado in partial fulfill-
ment of the requirements for the Degree of Master of
Science.

Department of Geology.

1934.

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thesis written by Mr. Ernest E. Wahlstrom on "The Geology of the Lake Albion Region" in 1933, which gives in excellent detail the petrology and mineralogy of the Camp Albion ore deposits.

Location and size of the area.

The area that is under consideration in this report covers approximately five and one half square miles and includes the greater portions of sections 12 and 13 of township 1 north, range 74 west; and sections 7 and 18 of township 1 north, range 73 west. Also the area includes the western half of section 17, the northern quarter of section 18, and the northeast corner of section 19, and the southwest corner of section 8, all of township 1 north, range 73 west.

The area reported upon occupies all of the Green Lakes Valley except its very head, Albion Valley in the vicinity of Camp Albion, part of the Isabelle - Brainard Lakes Valley, and part of the high ridge that is situated between Green Lakes and Isabelle

INTRODUCTION.

Purpose of the investigation.

This thesis is written for the purpose of presenting the geology in general, and especially the structural features of the two Tertiary (?) intrusions that outcrop within this area; to present a rather detailed topographic map of the area; and to enlarge upon the thesis written by Mr. Ernest E. Wahlstrom on "The Geology of the Lake Albion Region" in 1933, which gives in excellent detail the petrology and mineralogy of the Camp Albion ore deposits.

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Valleys. The area lies in the west - central part of Boulder county, Colorado, and approaches within, at the nearest point, one - fourth of a mile of the continental divide. Locally, this area is known as the "high country".

Methods of investigation.

In the field, mapping was done by means of a plane table and a telescopic alidade of the "scout" type. Pre - established bench marks, made by the 1912 survey of the watershed for the City of Boulder by Mann and Heentz, were used as a primary triangulation net. True north was established at night by sighting on Polaris and Delta Cassiopeia. The mean magnetic declination of the area is fourteen and one half degrees to the east, but the local magnetic declination is quite irregular due to the high iron content of the country rock. Hence, the plane table was oriented at each new station by taking a back sight on the previous station. Secondary traverses were run to make a check on closure and elevations. Observations of the strike and dip of joints and contacts were made entirely with the Brunton compass.

In the laboratory, hand specimens collected in the field were examined, and thin - sections made from these hand specimens were studied under the polarizing microscope.

Acknowledgements.

The author is greatly indebted to Mr. Robert C. Breed of Ann Arbor, Michigan who so obligingly served as instrument man during the mapping. Also the author is indebted to Dr. R. D. George and to Prof. A. B. Sperry, who suggested this investigation and who supervised the field work; to Mr. Ernest E. Wahlstrom who supervised the laboratory work; and to Dr. Henrik B. Stenzel of the Bureau of Economic Geology, State of Texas, for advice and suggestions in the application of the structural theories. The author also wishes to thank Dr. R. D. Crawford, Dr. A. C. Walton, and Mr. E. N. Goddard of the United States Geological Survey for their interest and kind suggestions.

PHYSICAL CONDITIONS.

Relief and Topography.

The area lies within one of the most rugged portions of the Front Range of the Rocky Mountains. Over half of the area, as shown on the map, is located in deep "U" shaped glacial valleys, while the remainder composes high ridges and flanks of mountains.

There are two glacial valleys, both of which trend in an east - west direction, and both terminate in glacial cirques just off of the western border of the map. The northernmost of these valleys, Isabelle Valley, is about one - quarter of a mile wide at the foot of Lake Isabelle. This part of the valley is a hanging bench with a series of lateral hanging benches on the southern side of Lake Isabelle. In the valley just above Lake Isabelle there is another hanging bench whose floor is about two hundred feet above the level of the lake. The lip of the hanging bench in which Lake Isabelle is located forms a natural dam which, combined with a small artificial dam, impounds the waters of the lake. This lip forms the crest of a steep 150 foot wall, and the valley from the base of this wall to the east becomes broader, mostly on the side that is south of the creek, to reach a width of about one - half mile, and continues to the east as a typical glacial valley for some two and a half miles past

Long Lake to the lower end of Brainard Lake. Peat bogs are much in evidence along the floor of the valley between Lake Isabelle and Long Lake. Everywhere along this valley from its head to the lower end of Brainard Lake the south wall is very much steeper than the north wall. In places, the south wall is a sheer cliff. Slopes of 1,500 feet vertically per 1,000 feet horizontally were noted. The elevation of the upper part of the valley that was mapped is 11,350 feet, and the lower part, below Lake Isabelle is 10,950 feet.

The other valley, Green Lakes Valley, is separated from Isabelle Valley by the Niwot - Navajo Ridge. Green Lakes Valley terminates to the east into Albion Valley. Like Isabelle Valley, this valley is a typical product of glaciation. It begins in a cirque on the continental divide between Arickaree and Navajo Peaks. The valley is essentially a series of hanging benches. At the foot of the Third Green Lake, the valley is approximately 1,500 feet wide. At this point, the northern flank of the bench is a sheer cliff about 800 feet high, and the southern flank is the steep north face of Mount Albion, which rises 1,500 feet above the surface of the lake. The elevation of the upper limits of Green Lakes Valley is just over 12,000 feet. The valley is very narrow at its head, but broadens to the east, until at Camp Albion it is about one - half mile wide.

At Camp Albion the valley has an elevation of 11,000 feet. The valley continues from Camp Albion to the south - east, and is known as Albion Valley. It loses its "U" shaped form just below the lower end of Lake Albion, indicating that this present valley which connects Camp Albion and Silver Lake is not of glacial origin.

Between Isabelle and Green Lakes Valleys there is a high, narrow, rather flat - topped ridge that is non - glaciated at its top. The ridge forms one of the most peculiar topographic features of the area. It begins, at its western extremity, at the top of Navajo Peak, whose elevation is 13,400 feet, and continues for over five miles to its eastern extremity which is a broad, dome - shaped mountain with rather gentle slopes. This mountain, which has an elevation of 11,453 feet, is named Bald Mountain on the Rocky Mountain National Park sheet of the United States Geological Survey, but locally it is known as Mount Niwot. This ridge crosses the entire map. The extreme western part, as shown on the map, is a narrow, saw - toothed, sharp ridge, increasing in elevation rather rapidly to the west as it nears its western extremity at the top of Navajo Peak. The elevation of this ridge on the western margin of the map is just under 13,000 feet. This is the highest point included in the area that was mapped with the plane table. Except for the rugged western part, as

mentioned above, this ridge is remarkably smooth on top, and averages a little over a quarter of a mile in width, ever widening to the east. The average elevation of this ridge across the map is a little over 12,000 feet, which is accordant with the elevation of the pronounced flat plateau which hangs so prominently between Mount Albion and Kiowa Peak.

There are five prominent mountain peaks within the immediate vicinity of the area. The highest is Navajo Peak, with an elevation of 13,400 feet, which is the western terminus of the above mentioned ridge. The next highest elevation is Arickaree Peak, elevation 13,147 feet, which is located just off of the south - west corner of the map. Both Navajo and Arickaree Peaks are extremely rugged alpine peaks, who owe their steep sides and jagged ridges to the agents of glaciation. Both of these peaks are located on the continental divide and are connected by a sharp ridge which forms the rim of the cirque at the head of Green Lakes Valley. Mount Albion, elevation 13,004 feet, is shown on the map. The broken contours indicate that this peak was not mapped with the plane table, but from an enlargement of the map of the region published by the United States Geological Survey. Although this peak is named Kiowa Peak on the Geological Survey map and in Mr. Wahlstrom's thesis, the local name is Mount Albion, and because it is so prominent a feature on

the sky - line as seen from Camp Albion, the author proposes to call this mountain Mount Albion instead of Kiowa Peak. The fourth important peak in the vicinity is the one that is shown on the Geological Survey map as Mount Albion, elevation 12,596 feet, but since this peak can not be seen from Camp Albion, the author proposes to call it by its local name of Kiowa Peak. The fifth peak is Mount Niwot, elevation 11,453 feet, which is located several miles to the east.

The topographic similarity between Kiowa Peak and Mount Albion is to be noted. Their features are almost identical, and they are separated by a remarkably flat plateau, which is one - half to three - quarters of a mile wide. This plateau is accordant in its elevation with the Niwot - Navajo ridge located on the north side of Green Lakes Valley.

It is evident therefore, that after the last of the Tertiary (?) intrusions were formed in the area, the region was reduced to a gently rolling peneplain, the present remainents of which are now known as the Flat - top Peneplain. This peneplain now forms ridges and mountain tops and cuts all rock formations. The present topography is due to post - peneplain glaciation. of time between the two periods of glaciation than the time elapsed since the last Drainage. the ice.

Green Lakes Valley drains through five glacial lakes, which are numbered from "First" at the head

of the valley to "Fifth", which is located just west of Lake Albion, into Lake Albion, whose outlet, Albion Creek, flows southeast into Silver Lake at the headwaters of North Boulder Creek.

Isabelle Valley drains through Long and Brainard Lakes into South St. Verain Creek, which flows to the northeast.

Although all of the lakes are of glacial origin, Isabelle, Albion, Little Albion, the Fifth, Fourth, and Third Green Lakes have had their capacity increased by artificial dams. The water from these lakes is used for part of the water supply for the City of Boulder and for irrigation purposes, except the water from Isabelle Lake, which is used for irrigation alone.

Glaciation.

Glaciation has been by far the most important agent in the formation of the present topography of the area. There have been at least two stages of Pleistocene or younger glaciation, as evidenced by the fact that some of the glacial material in the vicinity is much more weathered than the glacial drift that is deposited on top of it. This indicates a longer period of time between the two periods of glaciation than the time elapsed since the last retreat of the ice.

A remarkable feature of Green Lakes Valley is

that it consists of a series of five hanging or tandem benches, formed by advances of the ice. The tandem benches have the appearance of being separate cirques, and may be called by the very appropriate name of "cyclopean stairs".

There is nothing remaining of the glacier that formed Green Lakes Valley, but Isabelle Glacier, now a small alpine or cliff glacier, may be the dying remnant of the powerful glacier that gouged out Isabelle Valley.

Prior to the last stage of glaciation it is evident that Green Lakes Valley drained not into Silver Lake, but continued east past the site of University Camp and over the course now occupied by Como Creek, as is shown by the fact that east of Camp Albion the original glacial valley is filled with glacial debris and a prominent perched moraine controls the topography in sections 21, 22, and 27 of township 1 north, range 73 west. Como Creek, as it flows across this perched moraine, occupies a very shallow valley, while about a mile below University Camp it flows through a deep gorge cut into hard schist. It is evident that this deep valley was not formed by the present Como Creek, but by the ancient stream that drained the original Green Lakes and Albion Valleys.

to the lack of vegetation and rough terrain, are excellent.

However, in many places the bed rock is obscured by

Vegetation.

Most of the area is above timberline where nothing grows except a few lichens and grass where the rock decay has been sufficient to produce a poor type of soil. However, in the lower parts of the valleys and up their walls to an elevation of about 10,750 feet the lodgepole pine (*Pinus murrayana*) grows wherever the glacial debris is fine enough to allow it to take root. Grass is thick in the peat bogs, and numerous arctic - alpine flowers are found.

Climate.

The climate is typical of the alpine zone. The precipitation is heavy, probably amounting to more than thirty inches per year. Light summer showers occur almost every day between June and mid - August. Snow flurries are common, even in mid - summer. In the winter and spring there is a heavy snowfall. The wind blows a great deal of the time, generally from the west, and gales commonly reach unheard of velocities. The mean temperature is very low. Frost is not at all uncommon at night even in mid - summer. The mean annual temperature is only slightly above freezing.

Exposures.

Exposures of bed rock, due to the lack of vegetation and rough terrain, are excellent. However, in many places the bed rock is obscured by

enormous piles of talus and rock slides. Below Camp Albion glacial debris is prevalent and hides much of the geology. In the flat valleys over the entire area peat bogs are common.

Culture.

The area may be reached over several different routes. Access is gained to Camp Albion by means of a very poor wagon road, some four and a half miles long, branching off of the Maxwell Road near University Camp. This wagon road passes through the abandoned settlement of Hills Mill, above University Camp.

An excellent new fire prevention road, built by the Civilian Conservation Corps, leads from the crossing of the Maxwell Road with North Boulder Creek past Silver Lake and directly into Camp Albion. Thanks are due to Lieutenant Veezey, U. S. Army, the commanding officer of Camp S. P. 1 - C., that built this road, for allowing the author its use.

Isabelle Lake may be reached by driving to Brainard Lake and thence hiking to the west over a foot trail. This trail continues to the west from Isabelle Lake over the continental divide into Crater Lake and the village of Monarch.

Nederland is the most important town in the region. It is a mining and tourist town of about 200 people. It is located about twelve miles southeast of Camp Albion.

Ward is a small mining town with a population of about 100, and is located seven miles east of Lake Isabelle.

An excellent gravel road connects Nederland and Ward. Daily stages connect both Ward and Nederland with Boulder.

University Camp, or Science Lodge, the summer geology and biology camp of the University of Colorado, is located just off of the Maxwell Road, two miles west of the junction of the Maxwell Road and the Ward - Nederland Highway. University Camp was the base from which the field work for this report was done.

All of the pre-Cambrian rocks are shown on the areal map as "Undifferentiated pre - Cambrian". There are several large gneissoid igneous dikes and a number of smaller granitic and pegmatitic dikes. These dikes are all intruded into the schists and gneisses of the Idaho Springs Formation. The dikes strike in a general northeast - southwest direction. This indicates that at the time these dikes were intruded, forces were acting from the southwest or northeast. The dip of these dikes is in all cases very steep. The larger dikes are 1,000 to 1,500 feet in width.

Structure of the Tertiary (?) intrusions.

The Tertiary (?) intrusions consist of two

GEOLOGIC STRUCTURAL CONDITIONS.

Introduction.

The structure of the area in general consists of two small stock like masses of Tertiary (?) age that are intruded into the pre - Cambrian granites and metamorphic rocks. The entire area is highly jointed, faulted, and fractured. The structure of the Tertiary (?) intrusions only will be considered in detail in this thesis, however a brief description of the structure of the pre - Cambrian rocks will be given.

Structure of the pre - Cambrian rocks.

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Structure of the Tertiary (?) intrusions.

The Tertiary (?) intrusions consist of two

stock - like masses of monzonite and several scattered dikes of "Birdseye" (latite) porphyry.

The two monzonite bodies have steep walled contacts that have no apparent relationship with the planes of schistosity of the Idaho Springs Formation into which they are intruded.

The monzonite in these two stock - like masses is relatively coarse grained. This indicates that the masses belong to a rather large intrusive body, because upon cooling, if the bodies were not rather large and deeply buried, the rock would be too fine grained to be classed as a monzonite.

One of these two intrusions extends from Lake Albion and a point just west of Little Lake Albion over the top of the Niwot - Navajo Ridge, and terminates on the northern slope of this ridge.

The areal outcrop of this intrusion covers about 400 acres. The other monzonite body is larger, and extends from the floor of Green Lakes Valley, over the Niwot - Navajo Ridge, across Isabelle Valley at Lake Isabelle, and extends east a little below Lake Isabelle. This intrusion continues past the northern boundary of the map. It is unfortunate that the author was unable to map the entire extent of this monzonite body. The author believes that these two monzonite bodies are cupolas from the same parent monzonite stock.

The reason for this is that both of the bodies are

practically identical in texture and composition, and are very similar to other such small monzonite bodies found in the vicinity, such as in the Arapahoe Valley west of Silver Lake and in the lower part of Isabelle Valley near Long Lake. The term stock is used to describe this postulated buried parent body of the existing monzonite outcrops by using daly's definition of a stock. That is, a stock is a discordant intrusive igneous body with all of the characteristics of a batholith, except that it is less than forty square miles in extent.

Discussion of theories to determine directional forces.

The original plan of the author in making this investigation was to attempt to apply the theoretical methods of Hans Cloos of Bonn (Breslau), Germany[#] to determine the direction from which the two monzonite bodies were intruded, or the direction of the regional forces that existed during the time of intrusion. There are two theoretical methods used by Cloos to determine the direction of forces that existed during the time of intrusion. The first and best known of these methods is that of determining the direction of forces by means of "flow structure", or to use the American terminology, rather than the German,

[#] - The author obtained the information used in this thesis on the methods of Cloos by personal communication with Dr. Henrik B. Stenzel of the Bureau of Economic Geology, State of Texas. Dr. Stenzel was the assistant of Cloos at the time these methods were worked out and first applied.

"flow texture". The second method of determining the direction of forces is to assign all joints to three classes, thus classing them as "Q", "S", or "L" joints. The direction of forces is obtained by compiling data on the orientation of the joints of the different joint classes, and the relationship of these three joint classes.

The following paragraphs contain brief summaries of these two methods, and the conclusions of the author when these theoretical methods were applied to the monzonite bodies in the area that was investigated.

Cloos' theory of flow texture.

The theory of flow texture, assuming it to be valid which is in disagreement with some authors, is based on the fact that directions of greatest and least pressure can be determined by the orientation of flow indicators that are present in all coarse grained igneous rocks. Such flow indicators are foreign inclusions (xenoliths and schollen), all early crystallization products, schlieren, and minerals that are arranged in chains or parallel rows. These flow indicators, based on the theory of the rotational strain ellipsoid, tend to have their greatest dimension in the direction of least pressure, or the direction of greatest tension. Subsequently, these flow indicators have their

smallest dimension in the direction that is parallel to the direction of greatest pressure or least tension. Theoretically, directional stresses cause all flow indicators to rotate from their original orientation and to assume a new orientation conforming with the law of the rotational strain ellipsoid. This causes the flow indicators, especially tabular and elongated minerals and crystals, to assume a parallel arrangement.

The author applied this theoretical method during the process of the field work. A great many observations were made on the strike, dip, and pitch of the dark minerals in the monzonite. These dark minerals in the monzonite are the only flow indicators present that afford a means of determining the orientation of the flow texture throughout the entire part of both of the monzonite bodies. These dark minerals consist mostly of pyroxenes, and are equidimensional to a great extent. The fact that the dark minerals are equidimensional means that little or no crystal orientation, or flow texture, has developed to an appreciable extent in the monzonite bodies. In isolated localities within the monzonite bodies, especially around the margins and near the contacts, these pyroxene crystals and grains are in parallel rows or streaks, providing good evidence of

flow - textural orientation. In some differentiated phases of the monzonite large feldspar grains and crystals form excellent indicators of flow in themselves, but their orientation is so irregular that data obtained from them is not reliable.

This method of determining the directional forces by means of flow texture worked well only in isolated localities, especially near the margins, of the monzonite bodies. In accordance with the theory, observable flow texture exists near the contacts and is parallel to the contacts. The theory states that near a contact local forces are superior to regional forces. Such a condition is quite common in all igneous intrusions, but since this orientation of flow indicators parallel to the contact is caused by the physical reaction or "drag" of the solidifying magma, in its last stages of mobility, with the country rock, this is not a criterion upon which the orientation of directional forces can be based.

Flow texture must be observed away from the margins of an intrusion in order to establish the direction of the forces. Indicators of directional flow are practically nonexistent within the centers of the bodies. In several places within these monzonite bodies evidences of flow do exist to a vary limited extent, but the orientation of these

indicators is extremely irregular and varied. To attempt to use any data obtained from observations of flow texture to determine the direction from which the monzonite bodies were intruded is speculation.

Cloos' theory of joint systems and orientation.

The second theoretical method of Cloos for determining the direction of forces is by the orientation of the "Q", "S", and "L" joints.

This classification of joint systems was, like the theory of flow texture, worked out by Hans Cloos at Bonn, Germany. The following table is the joint classification of Cloos in comparison with the generally accepted English and American classification.

Cloos' classification.	English equivalent.
1. Quer-Klüfte, or "Q" joints.	Master or tension joints.
2. Spalt-Klüfte, or "S" joints.	Secondary or compression joints.
3. Lager-Klüfte, or "L" joints.	Horizontal joints or "sheet structure".

The quer - klüfte or "Q" joints are the master joints. They may be distinguished from the other joints by certain characteristics. Usually the "Q" joints are long, straight, usually covered with slickensides, and accompanied by dikes. These

joints accompany normal faults and may also be termed tension joints. Theoretically, the "Q" joints are at right angles to the direction of flow structure or texture, and are parallel to the direction of greatest pressure.

The spalt - klüfte or "S" joints are of secondary importance to the "Q" joints. They may be termed "split" joints. The "S" joints are much shorter and more irregular than the "Q" joints. They are due primarily to compression, therefore they strike at right angles to the "Q" joints, are parallel to the direction of flow texture, and strike at right angles to the direction of greatest pressure. "S" joints rarely have slickensided and are seldom associated with dikes.

The lager - klüfte or "L" joints are horizontal joints that are due mainly to sheet structure, caused by "unloading" or the removal of overlying rocks by erosion. In igneous intrusions, "L" joints may form at right angles to the direction from which the intrusion came from the depths of the earth. Invariably, if any appreciable amount of the intrusion has been removed by erosion, secondary "L" joints due to "unloading" will form. Such a condition is very confusing, making it practically impossible to use the "L" joints as a criteria for determining directional forces.

Such a condition exists in the monzonite bodies discussed in this report, therefore the "L" joints are neglected in this paper.

If the method of determining the direction of forces by the flow texture method is not possible, or to make a check of the findings of the flow texture observations, the "Q", "S", "L" classification can be utilized. This classification is important since the theory of Cloos states that the "Q" or master joints are parallel to the direction of greatest pressure and the "S" joints are at right angles to the direction of greatest pressure.

Field observations on joint orientation.

A number of observations were taken in the field on the strike of joints. 146 observations were made on joints classed by the author as "Q" joints. 82 observations were made on joints classes as "S" joints. The fact that the "S" joints are by definition not as prominent as the "Q" joints accounts for the fact that a smaller number of observations were made on joints of the "S" class. Observations made on joints of questionable classification are not included in this report.

A percentage table of the direction of the strike of the "Q" and "S" joints follows:

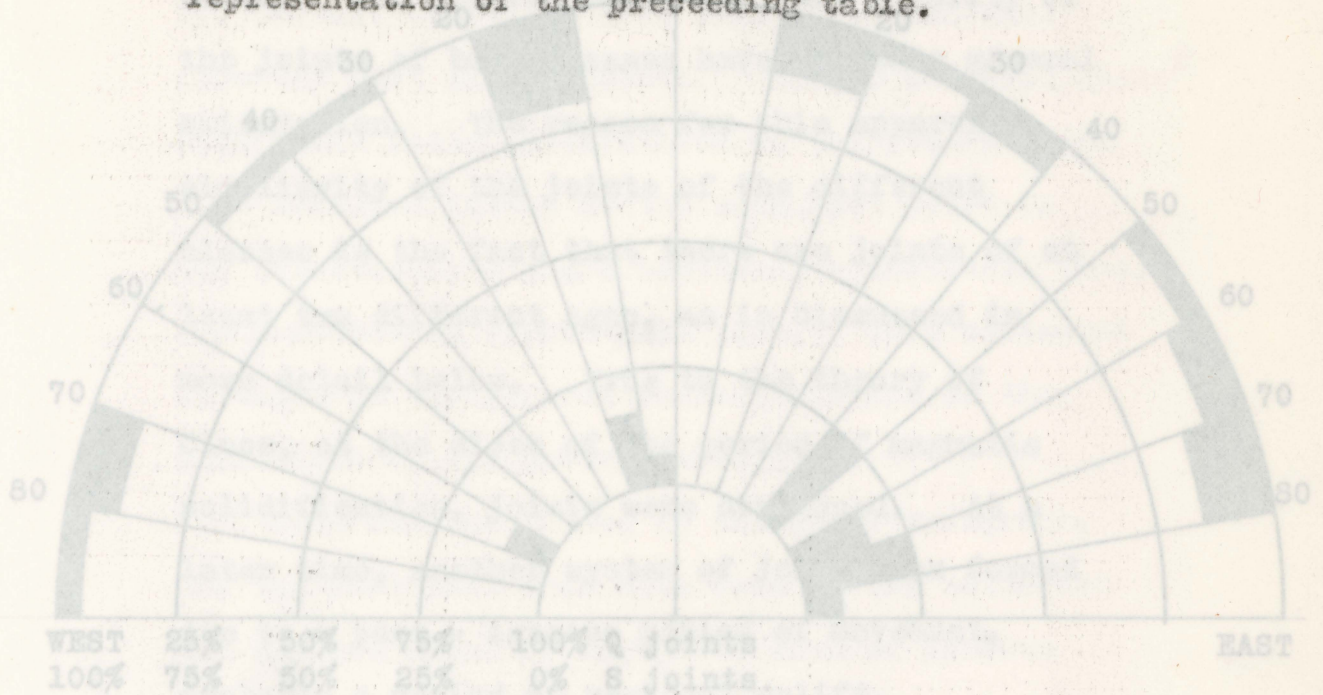
(Figures in parentheses indicate the actual number of joints.)

Direction.	"Q" Joints.	"S" Joints.
West - N 80 W	6% (9)	---
N 79 W - N 70 W	12% (18)	---
N 69 W - N 60 W	---	10% (8)
N 59 W - N 50 W	---	---
N 49 W - N 40 W	3% (4)	---
N 39 W - N 30 W	3% (4)	---
N 29 W - N 20 W	---	---
N 19 W - N 10 W	18% (26)	15% (12)
N 9 W - North.	---	5% (4)
North - N 10 E	---	---
N 11 E - N 20 E	12% (18)	---
N 21 E - N 30 E	3% (4)	---
N 31 E - N 40 E	9% (13)	---
N 41 E - N 50 E	---	25% (21)
N 51 E - N 60 E	6% (9)	---
N 61 E - N 70 E	13% (19)	15% (12)
N 71 E - N 80 E	15% (22)	25% (21)
N 81 E - East.	---	5% (4)
TOTAL	100% (146)	100% (82)

NOTE:- For convenience in determining the directions of orientation of the "Q" and "S" joint systems, all joints of each system were grouped into divisions of ten degrees. The actual number of joints was transferred to percentages in order to afford a more even basis of comparison,

since more observations were made on the "Q" joints than were made on the "S" joints.

See the following page for a graphic representation of the preceeding table.

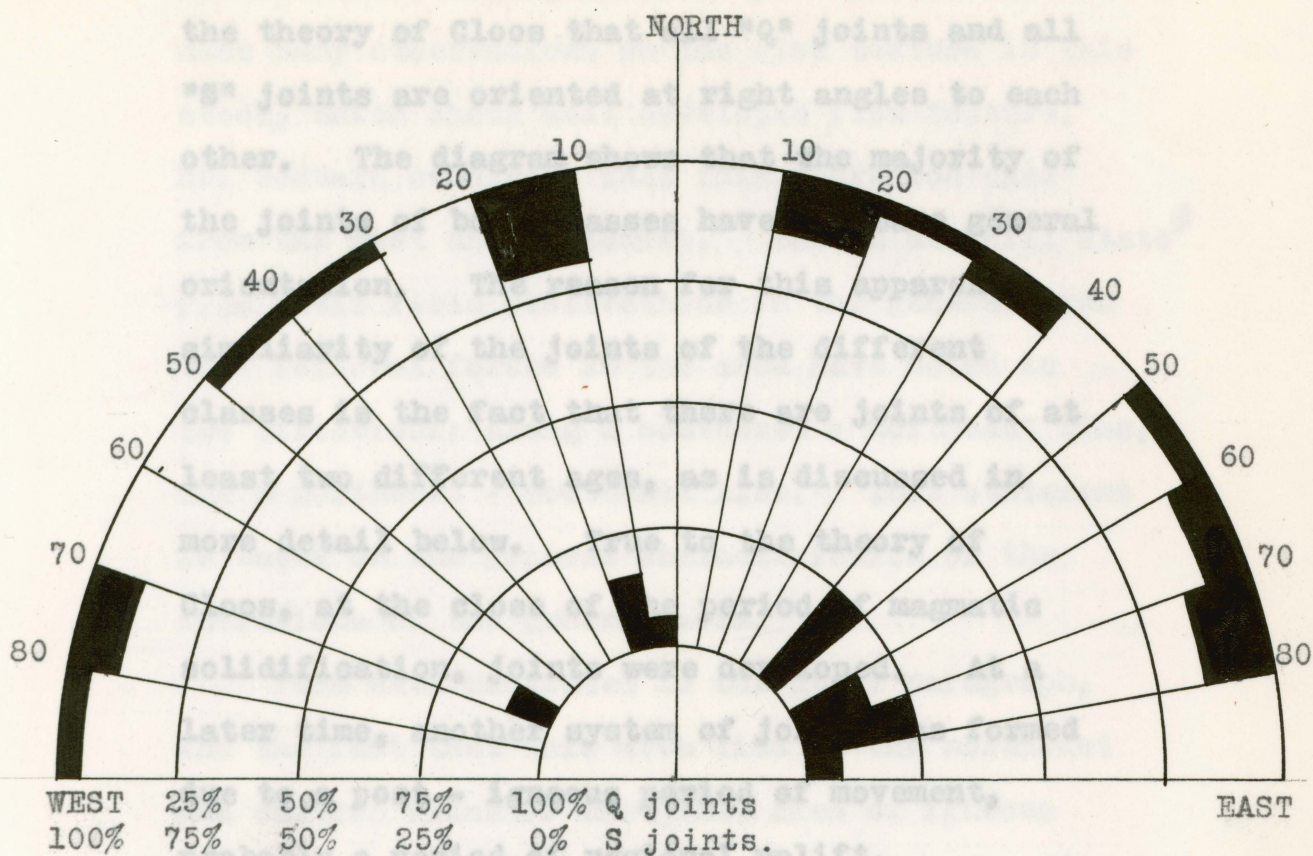


ORIENTATION OF JOINT SYSTEMS.

"Q" joints plotted on the outer margin.

"S" joints plotted on the inner margin.

Number of joints expressed in percentages.



ORIENTATION OF JOINT SYSTEMS.

"Q" joints plotted on the outer margin.

"S" joints plotted on the inner margin.

Number of joints expressed in percentages.

There are many "Q" joints striking in an approximate north-south direction. Also there are many "S" joints striking in an approximate east-west direction. The author observed in the field that none of these joints extended beyond the limits of the monzonite bodies. In agreement with the theory of Glos, this orientation indicates that the greatest directional force during the period of magmatic solidification was along the line east-west, north by north and south by south.

There is a Tertiary stock at Jamestown, about 15 miles east of these two monzonite bodies, that is very similar to them. The Jamestown stock

The preceeding table and the graphic representation of the table do not appear to conform with the theory of Cloos that all "Q" joints and all "S" joints are oriented at right angles to each other. The diagram shows that the majority of the joints of both classes have the same general orientation. The reason for this apparent similiarity of the joints of the different classes is the fact that there are joints of at least two different ages, as is discussed in more detail below. True to the theory of Cloos, at the close of the period of magmatic solidification, joints were developed. At a later time, another system of joints was formed due to a post - igneous period of movement, probably a period of regional uplift.

There are many "Q" joints striking in an approximate east and west direction. Also there are "S" joints at right angles to them. (North 10 to 20 degrees west.) The author observed in the field that none of these joints extended beyond the limits of the monzonite bodies. In agreement with the theory of Cloos, this orientation indicates that the greatest directional force during the period of magmatic solidification was along the line east by north and west by south.

There is a Tertiary stock at Jamestown, about 15 miles east of these two monzonite bodies, that is very similar to them. The Jamestown stock

has been worked out by Mr. E. N. Goddard of the United States Geological Survey. Mr. Goddard made many observations on the flow texture in this stock, which shows well developed flow texture. Mr. Goddard concludes that this intrusion came from the west and southwest. Bastin and Hill state[#] from their field observations in the general area that regional forces in the area have acted in two directions; along a southwest - northeast line, and a northwest - southeast line. This statement is based on the general characteristics of the intrusions of the general area.

From data mentioned in the above paragraph, and the fact that this area lies on the northeast and eastern flank of the great area of igneous activity of North Central Colorado, it is concluded that the two monzonite bodies in this area, like the Tertiary stock at Jamestown, were intruded from the depths while regional forces acted from the west and southwest.

The "Q" and "S" joints that are grouped in orientations that do not conform with the data listed in arriving at the above conclusion can be

- The Economic Geology of Gilpin county, and adjacent parts of Clear Creek and Boulder counties, Colorado. U. S. G. S. Professional Paper # 94, page 62.

are due to "unloading" rather than directional forces, and hence give no data that can be used

terated as joints that are due to later regional movements. The majority of these joints are not limited to the monzonite bodies, but extend past the contacts into the older country rocks. Individual joints of these groups can be traced directly from the monzonite bodies into the schist of the Idaho Springs Formation. The "Q" joints in this group strike in a north by west direction and the "S" joints are truly at right angles, striking east by north. This data lead to the conclusion that post intrusion movements existed, with the direction of greatest force along north by west and south by east lines.

All joints not accounted for in the above discussion probably owe their orientation to local movements, probably later faulting.

The chief basis of distinction between the "Q" and "S" joints is that the "Q" joints are tension joints with a high angle of dip, and "S" joints are compression joints with a low angle of dip. The average dip of the observed "Q" joints is 78 degrees, the maximum dip is 90 degrees, and the minimum dip is 65 degrees. The average dip of the observed "S" joints is 44 degrees, the maximum dip is 71 degrees, and the minimum dip is 18 degrees.

The "L" joints have been entirely neglected. They are due to "unloading" rather than directional forces, and hence give no data that can be used

to arrive at conclusions as to the directional forces that have existed.

General structure of the area.

Contacts of the monzonite bodies with the country rocks are steep everywhere they could be observed. Contacts are sharp in some cases, being bound by fault planes. In other cases the contact is irregular, assuming a lit - par - lit structure with the schists of the Idaho Springs Formation. Unfortunately, in many places the exact contact is obscured by overburden of talus, glacial drift and debris, and in the valleys by deposits of peat.

Several faults were mapped, the location of which may be found on the map. It is impossible to map all the faults in the area. Due to the relatively homogeneous character of the monzonite, numerous structures that appear to be joints are possibly faults with a comparative large displacement. All of the joints may be said to be faults, with very small displacements, varying from a fraction of an inch to several feet in their displacement.

There are three dikes of "Birdseye" porphyry, which is younger in age than the monzonite. A small dike that strikes north and south is located in Isabelle Valley just below Lake Isabelle. A larger dike of this porphyry, striking in a

general east and west direction is found in Green Lakes Valley. This dike is offset by a fault that strikes in a north and south direction. The displacement of the dike by this fault is approximately two hundred and fifty feet. Another dike of this porphyry is located south of the Second Green Lake. This dike strikes northeast and southwest.

All of the above mentioned dikes have a dip of approximately ninety degrees.

In the east face of the cliff of the small hanging bench just above the Second Green Lake there is another outcrop of the "Birdseye" porphyry. This outcrop strikes north thirty degrees east, and dips twenty degrees to the west. This outcrop is an igneous sheet, which can be extended into the porphyry sheet that outcrops on the steep north face of Albion Peak. (See figure 4.) The term igneous sheet is used to describe this structure on the basis that a sill - like body intruded into igneous rocks is an igneous sheet.[#] The fact that this intrusion, which has an average thickness of less than ten feet, is very flat lying accounts for the very large amount of "Birdseye" porphyry talus that is found everywhere in Green Lakes Valley, far down Albion

[#] - Classroom discussion with Mr. Wahlstrom.

Valley, and in glacial drift as far east as Hills' Mill near University Camp. It is improbable that the existing vertical dikes of this porphyry could have been the source for such a great amount of porphyry talus.

Conclusions as to Geologic Structure.

It has been shown that the flow texture theory of Cloos for the determination of the direction of forces that existed at the time of magmatic solidification does not apply to these two monzonite bodies. However, Cloos' theory of determining directional forces by means of the orientation of joint systems does apply. It is not the intention of the author to try to disprove the flow texture theory of Cloos as many geologists are attempting to prove. It is the belief of the author that while the theory works to perfection in many cases similar to the intrusions in this area, it does not exist universally as advocated by the followers of Cloos. There is definite evidence to show that flow texture does not exist within the monzonite bodies of this area. There are several reasons why flow texture is not found in these bodies. It is possible that the magma was highly fluid and was completely emplaced before early crystalline products were developed, thus eliminating the

possibility of these products being flow indicators. The fact that elongated minerals are rare in the monzonite is an important feature in making it difficult to detect flow texture, if it exists. Also, it is possible that directional forces strong enough to cause orientation of flow indicators were non-existent or very weak until the magma was almost completely solidified. The forces that formed the initial joint systems must necessarily have acted after the magma was completely, or practically solidified.

varieties in this thesis, so they will be neglected in this report. For the same reason, the petrology in general of the area will not be discussed in great detail.

Pre - Cambrian Rocks.

The Idaho Springs Formation.

All of the pre - Cambrian rocks are shown on the map as "Undifferentiated pre - Cambrian". The pre - Cambrian rocks that outcrop over the greatest part of the area belong to the Idaho Springs Formation, and consist of schists and gneiss. This formation is the regional country rock. These metamorphic rocks have a rather uniform steep dip, and strike in a general northwest direction. This gives the rocks the appearance of being upturned sediments. These

rocks were probably PETROLOGY. The

Introduction.

The rocks of this area fall into two classes, as mentioned before, the pre - Cambrian country rocks, and rocks that were intruded into the pre - Cambrian country rock during the early Tertiary (?). Also, there are ore deposits of Tertiary (?) age and glacial and peat deposits of Pleistocene and Recent times. The ore deposits of the Camp Albion area were treated by Mr. Wahlstrom in his thesis, so they will be neglected in this report. For the same reason, the petrology in general of the area will not be discussed in great detail. Pre - Cambrian Rocks.

The Idaho Springs Formation.

All of the pre - Cambrian rocks are shown on the map as "Undifferentiated pre - Cambrian". The pre - Cambrian rocks that outcrop over the greatest part of the area belong to the Idaho Springs Formation, and consist of schists and gneiss. This formation is the regional country rock. These metamorphic rocks have a rather uniform steep dip, and strike in a general northwest direction. This gives the rocks the appearance of being upturned sediments. These

rocks were probably originally sediments. The Idaho Springs Formation can roughly be classified as biotite - sillimanite gneiss and schist.

Other Pre - Cambrian Rocks.

Other pre - Cambrian rocks are igneous intrusions, most of which are rather large dikes that are intruded directly into the metamorphic rocks. Mr. Wahlstrom has identified these rocks as gneissoid quartz monzonite, biotite granite, and pegmatites. The author did not examine either the biotite granite or the pegmatites in detail, but two thin sections of the gneissoid quartz monzonite were examined. Locally this rock is massive rather than gneissoid, and could, from the appearance of the hand specimen, be called a quartz monzonite porphyry because some of the feldspar grains are large enough, in contrast to the remainder of the rock, to be classes as phenocrysts. The ground mass of this rock is gray and fine - grained. The phenocrysts vary in size from one tenth to one half of an inch in diameter. For the most part, these phenocrysts are equidimensional. They are composed of both quartz and feldspar. In thin section, the feldspar phenocrysts showed albite twinning. Some of the phenocrysts show a positive optical character with extinction angles that average

twelve degrees on the section normal to the 001 and 010 crystal faces. This data indicated that the feldspar is andesine. Minerals in the ground mass that were detected by the microscope were biotite grading into phlogopite, quartz, andesine, and accessory titanite, black iron ore, and a few scattered grains of zircon.

Tertiary (?) Rocks.

The second class of rocks includes those that are found in the Tertiary (?) intrusions. These intrusions are composed of monzonite, "Birdseye" porphyry, and pyroxenite.

Monzonite.

In the hand specimen the monzonite is a light gray, phaneric igneous rock. It is in general massive, and in the field has joints at almost exact right angles to each other. The monzonite varies in texture. Near the contacts it is rather fine grained and slightly porphyritic, with a development of flow texture. This rock was observed to become much coarser towards the center of the intrusions, until near the center its texture is in some places almost as coarse as that of a pegmatite. The finer grained phases are somewhat porphyritic, having small feldspar phenocrysts that are oriented parallel to each

other. These phenocrysts are elongated and have an average length of less than three fourths of an inch, but some were observed that had lengths of about three inches and widths of about an inch. About seventy five percent of the rock by volume is feldspar. Black ferro - magnesium minerals and small crystals of brownish - yellow titanite were observed in the hand specimens.

Several thin sections were made of the monzonite specimens. There is a marked difference in the size of the grains depending on whether the specimen was taken from a point near the contact or towards the center of the intrusion. The mineral content of these thin sections is identical in all cases, the only difference being in the size of the grains, as mentioned above. The minerals found in the thin sections of the monzonite are andesine, black iron ore, diopside, titanite, hornblende, and zircon.

The thin sections showed about seventy five percent of the rock by volume is plagioclase feldspar. Albite twinning is quite well developed. The feldspar grains upon which observations of extinction angles were made had extinction angles that average from twelve to twenty two degrees. In the cases where it was possible to obtain the optical character of the plagioclase, it was found

in all cases to be positive. This leads to the conclusion that the feldspar content of the monzonite is, except in local differentiated phases, andesine. The remainder of the monzonite is composed of ferro - magnesium minerals, both amphibole and pyroxene in about equal proportions. The pyroxene minerals are anisotropic and biaxial. Their optical character is positive, are colored a pale green, and are non - pleochroic. The birefringence is about .028, and the relief is medium high. The extinction angle varies from thirty five to thirty eight degrees. From the above data the mineral is determined to be diopside. The amphibole is anisotropic, biaxial, pleochroic, green to greenish yellow. The birefringence is .016 and the extinction angle is eighteen degrees, classing the mineral as hornblende. The following accessory minerals were found in the monzonite. Titanite occurs in irregular grains, geniculate crystals, and occasionally in acute rhomb crystals. The titanite in thin section is anisotropic, colorless, biaxial, and has extremely high relief and birefringence. Small irregular grains of black iron ore are scattered throughout the monzonite. Occasional small grains of apatite are found. The apatite is uniaxial and has a birefringence that is lower than that of quartz. Small zircon grains were noted, but these are very rare.

"Birdseye" porphyry.

This rock is a latite porphyry. The term "Birdseye" is used purely for convenience in distinguishing this rock from the pre - Cambrian gneissoid quartz monzonite.

This porphyry is younger than the monzonite, because dikes composed of it are found within the monzonite. It occurs in several small sized dikes and in a sheet on the north cliff of Albion Peak. In the hand specimen this porphyry may be described as having small to medium sized irregular phenocrysts of plagioclase feldspar, enclosed in a fine to medium grained, dark gray to black groundmass. In thin section the following minerals were noted: albite, orthoclase, black iron ore, hedenbergite, diopside, hornblende, and apatite. The phenocrysts are of two types. The first type have carlsbad twinning, are small, and are not as abundant as the phenocrysts of the second type. These phenocrysts were determined to be orthoclase. The second type are much larger than the first type, and show well developed albite twinning. The index of refraction of this type is higher than that of orthoclase, but is less than that of Canada balsam. The extinction angles on the sections normal to the 001 and 010 crystal faces varies from five to twelve degrees, measured from the cleavage traces. From this data, this type of

phenocryst is classed as albite.

The matrix is composed of small grains of orthoclase showing carlsbad twinning, and a greenish gray, non - pleochroic pyroxene. The interference color of this pyroxene is bright blue to green of the third order, and its extinction angle is thirty eight to forty degrees, measured from the cleavage traces, thus classing this mineral as diopside. Another weakly pleochroic, optically positive, green pyroxene that has a high relief, a birefringence of .015 and extinction angles that vary from forty two to fifty two degrees was found. This mineral was classified as hedenbergite. There appear to be transitions between the pure diopside and the pure hedenbergite. There is a small amount of green amphibole, pleochroic light yellowish - green to dark olive green, with high relief and bright second order interference colors, and with an extinction angle of twelve degrees. This mineral is classified as hornblende. Small masses and needles of a uniaxial, colorless mineral with a very low birefringence was observed, scattered throughout the groundmass. This mineral was identified as apatite. Numerous small grains of black iron ore are present.

Although the "Birdseye" porphyry has the general appearance of being quite basic, the thin

section investigations show that it has a high percentage of acid feldspar. Therefore, regardless of its dark color, and due to the fact that it is quartz free, the rock may be classed as a latite porphyry. The name "Birdseye" has been applied by Mr. A. B. Sperry because of the appearance of the weathered rock.

Pyroxenite.

The pyroxenite is found in several places that are too small to map, within the monzonite bodies. Also, a large mass, and an east and west trending dike, about ten feet wide, are located at the lower end of Lake Isabelle. This rock appears as a black, fine grained, igneous rock. It is difficult to tell from the hand specimen if the rock contains a higher percentage of amphibole or pyroxene, even though hornblende crystals can be seen with the naked eye.

The hand specimen shows a few very small scattered grains of a light mineral, probably a plagioclase feldspar, and scattered grains of quartz.

Both of these minerals occupy an extremely small percentage by volume of the rock. Unfortunately, neither of these two minerals appeared in the thin section of this rock. It is possible that they were not present at all in the part of the rock from which the thin section was made, or

due to the rather brittle nature of the rock and the difficulty of making a thin section, these two minerals were plucked out during the process of making the section.

The following is a microscopic description of the pyroxenite. A green, non - pleochroic pyroxene with well developed cleavage and high relief, a birefringence of a second order blue - indigo, and an extinction angle of thirty five to thirty eight degrees, measured from the cleavage traces, was observed. This mineral was classified as hedenbergite. Apatite, optically negative, colorless, with low birefringence and an absence of cleavage was noted. Another pyroxene, colored pale green, biaxial, non - pleochroic, with a relief higher than apatite, a birefringence of .032, and an extinction angle varying from thirty five to forty degrees, measured from the cleavage traces, was observed. This mineral is classified as diopside. The amphibole in the rock is colored dark green to greenish brown, and is pleochroic, being pale greenish brown in the X direction and dark olive green in the Z direction. It has medium relief, and has a birefringence of .022. An extinction angle of eight degrees was measured. This mineral is classified as basaltic hornblende. One lath shaped flake of biotite completely enclosed in diopside was noted.

Percentage volume of the minerals in this rock was obtained by using a calibrated eyepiece in the microscope. This procedure gave the following results:

Hedenbergite-----	30%.
Apatite-----	15%.
Black iron ore-----	4%.
Basaltic hornblende-----	20%.
Diopside-----	30%.
Biotite-----	1%.
Total-----	100%.

From the above table it is seen that there is sixty percent of pyroxene to twenty percent of hornblende, so the rock should be called a pyroxenite rather than a hornblendite as it has been called by some in the past. This pyroxenite mass appears to be due to differentiation or recrystallization which took place during the later stages of the monzonite intrusion. Mr. E. N. Goddard believes that this pyroxenite mass is a recrystallized inclusion of the Idaho Springs Formation.

The Paleozoic and Mesozoic history of the general region is imperfectly known. During a great part of these times erosion was an active geologic agent. Parts of the general region were land during the Carboniferous as shown by

the Mountain HISTORICAL GEOLOGY.

A brief resume of the geologic history of the area and the surrounding region is as follows:

Pre - Cambrian.

The earliest known formations to have occupied this area were thick sediments which were regionally metamorphosed during the pre - Cambrian to form the schists of the present Idaho Springs Formation. Their present mineral composition is indicative that they were originally sediments of a rather shaley nature.

Later, but still in pre - Cambrian time, quartz monzonites, granites, and pegmatites were intruded into the crystalline rocks of the Idaho Springs Formation. These intrusions have since undergone enough metamorphism to now have a gneissoid structure and texture.

Paleozoic and Mesozoic.

There is no evidence in the area itself to give any hint as to the geologic conditions that prevailed during the Paleozoic and Mesozoic times. The Paleozoic and Mesozoic history of the general region is imperfectly known. During a great part of these times erosion was an active geologic agent. Parts of the general region were land during the Carboniferous as shown by

the Fountain Sandstone (Pennsylvanian) resting in an erosional unconformity on the pre - Cambrian rocks. Erosion and sedimentation both took place during the Paleozoic and Mesozoic, but the former greatly overbalanced the later. Land existed during the early mesozoic as shown by the Upper Cretaceous Dakota Sandstone resting in an erosional unconformity on the pre - Cambrian rocks. The Cretaceous in general seems to have been a period of submergence, because the late Cretaceous sediments that now exist on the eastern flank of the mountains do not become coarser towards the mountains, indicating that these sediments probably originally extended over the present "high country".

Tertiary.

A series of uplifts, caused by compression along an east and west line began in the early part of the Tertiary (?) prior to the formation of the Tertiary (?) intrusions. This series of uplifts resulted in faulting and fracturing and the later intrusion of the monzonite bodies. This was the first renewal of vulcanism since the pre - Cambrian. Following this period of vulcanism there was a period of widespread and intensive faulting, as is shown by the many faults that displace all of the Tertiary (?)

intrusions. After this period of faulting there was a long period of erosion, which formed a gently sloping peneplain. Next, there was a period of late Tertiary uplifts, which seem to have had no pronounced effect upon the local structure of the area. Regionally, these uplifts formed a new peneplain, located at a lower level than the early Tertiary peneplain.

Quaternary.

The Pleistocene and Recent times, although unimportant from a structural and tectonic standpoint, are highly important from a physiographic viewpoint. During this period, at least two advances of alpine and cliff glaciers resulted in the formation of the present topography.

of the area is the lakes. Many more feet of water can be stored in these lakes for drinking and irrigation purposes. Due to the heavy winter snowfall, these lakes are always filled to capacity by the end of the spring thaws. By proper storage management, the water impounded in these lakes becomes a highly important water reserve to the City of Boulder and the land immediately to the east of Boulder.

ECONOMIC CONSIDERATIONS.

The most important economic geologic feature in the area is the mineralized zone at Camp Albion, in which are located several mines. These mines are not treated in this report. Mineralization is to be noted in several isolated spots along the monzonite - pre - Cambrian contacts, but except for the limited zone at Camp Albion, none of the mineralization seems to be of economic importance.

The monzonite has the qualities of a good building and monumental stone, but because of the location of the monzonite masses, it is not economically valuable at present.

The most important general economic feature of the area is the lakes. Many acre feet of water can be stored in these lakes for drinking and irrigation purposes. Due to the heavy winter snowfall, these lakes are always filled to capacity by the end of the spring thaws. By proper storage management, the water impounded in these lakes becomes a highly important water reserve to the City of Boulder and the land immediately to the east of Boulder.

BIBLIOGRAPHY.

"The Geology of the Lake Albion Region, Boulder county, Colorado" by E. E. Wahlstrom, University of Colorado, 1931.

"The Economic Geology of Gilpin county, and Adjacent Parts of Clear Creek and Boulder counties, Colorado" by E. S. Bastin and J. M. Hill. U. S. G. S. Professional Paper No. 94.

"Igneous Rocks and the Depths of the Earth" by R. A. Daly.

"The Elements of Optical Mineralogy" by A. N. Winchell.

"Essentials for the Microscopical Determination of Rock - forming Minerals and Rocks" by Albert Johannsen.

"Minerals in Rock Sections" by L. McI. Luquer.

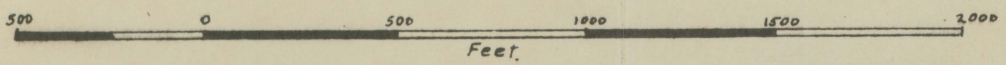
"Field Geology" by F. H. Lahee.

"The Geology of the Science Lodge Region, Colorado" by J. R. Graham Jr., University of Colorado, 1932.

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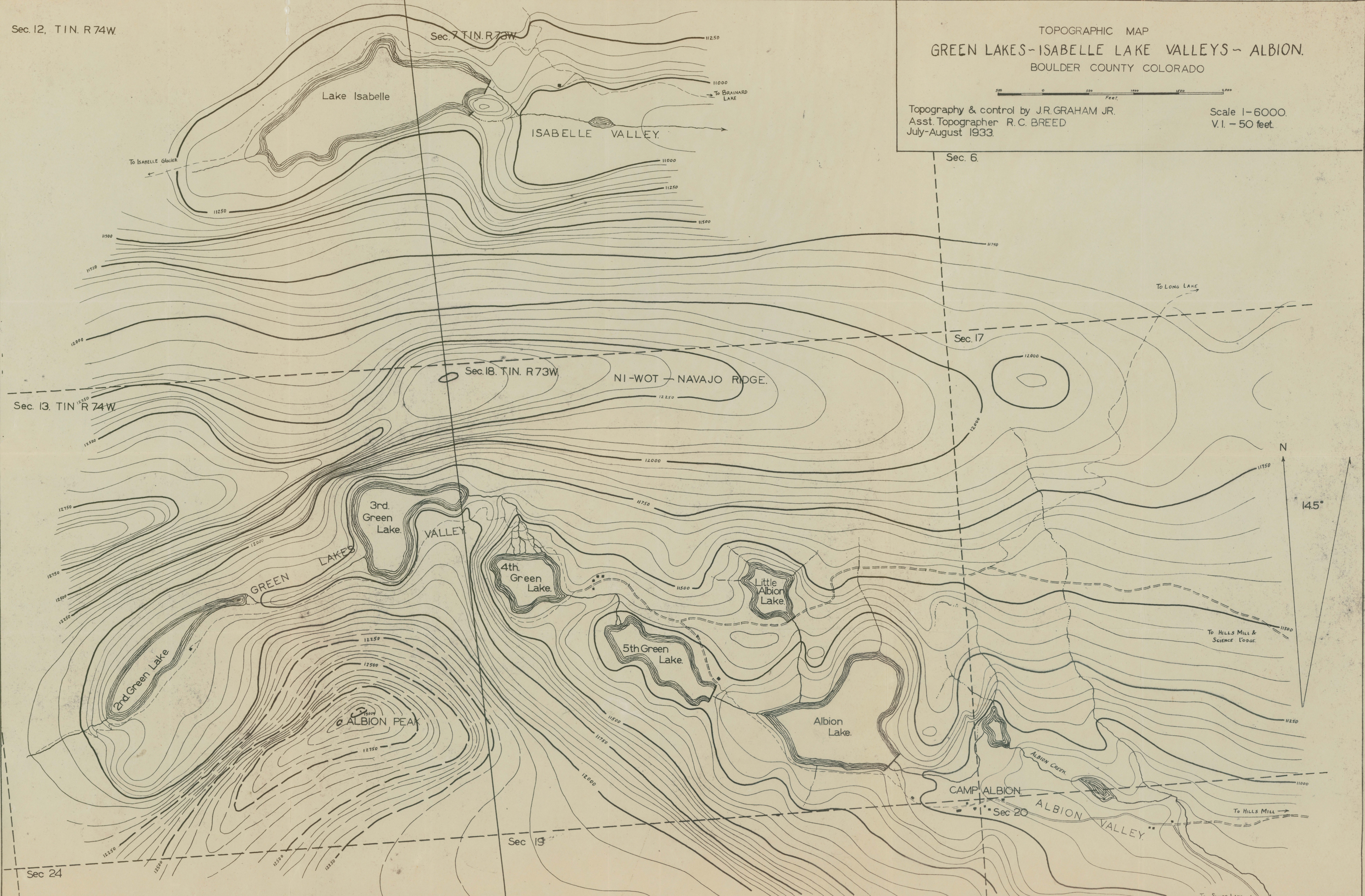
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TOPOGRAPHIC MAP
GREEN LAKES-ISABELLE LAKE VALLEYS - ALBION.
BOULDER COUNTY COLORADO



Topography & control by J.R. GRAHAM JR.
Asst. Topographer R. C. BREED
July-August 1933

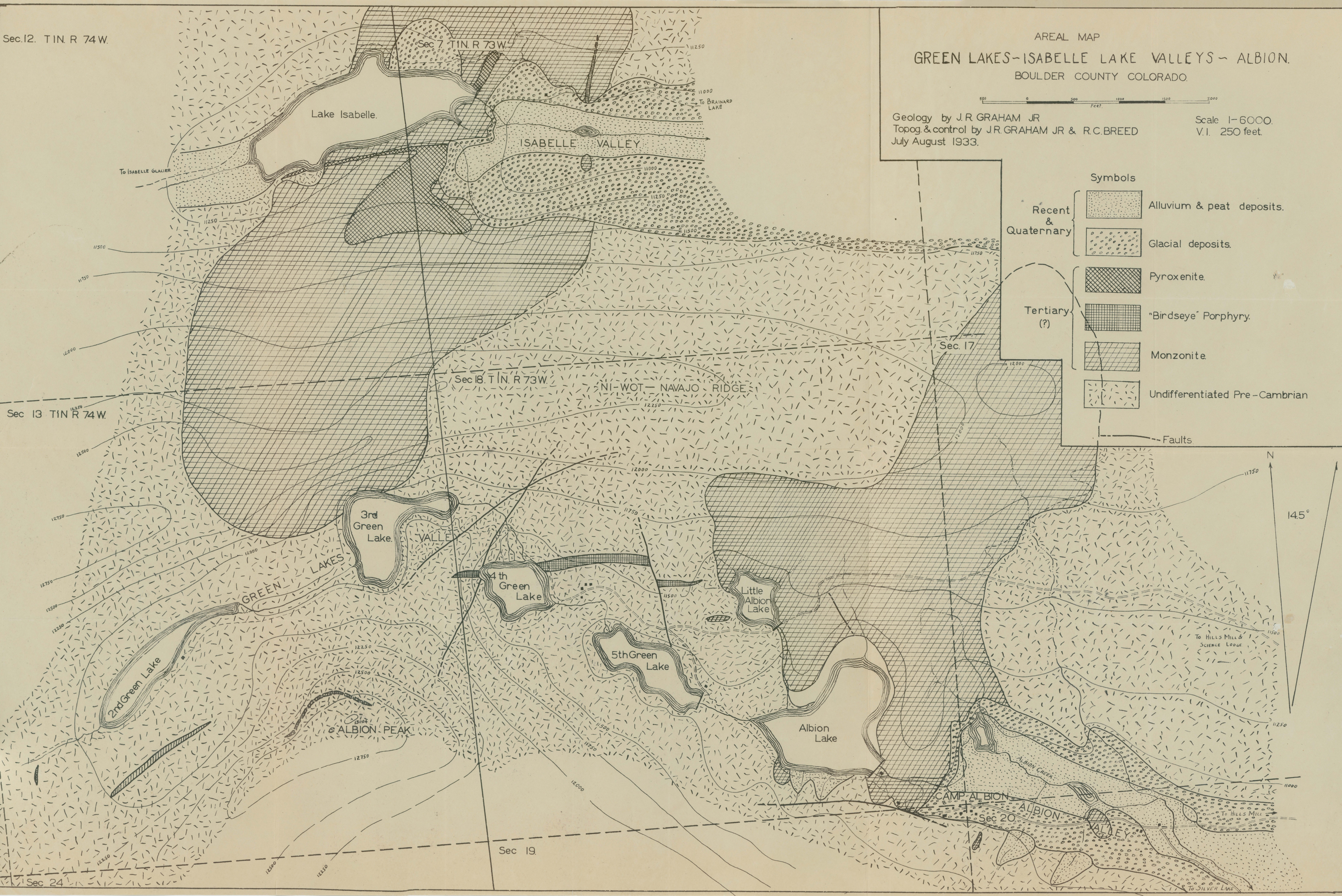
Scale 1-6000.
V.I. - 50 feet.



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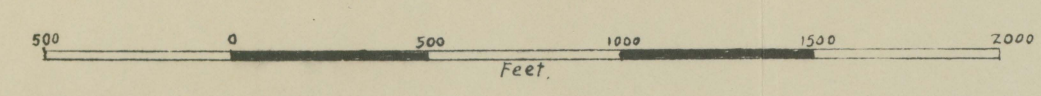
Sec. 12. T1N. R 74 W.



AREAL MAP

GREEN LAKES-ISABELLE LAKE VALLEYS - ALBION.

BOULDER COUNTY COLORADO.



Geology by J.R. GRAHAM JR
Topog. & control by J.R. GRAHAM JR & R.C. BREED
July August 1933.

Scale 1"=6000.
V.I. 250 feet.

Symbols

- | | | |
|---------------------------|--|-------------------------------|
| Recent
&
Quaternary | | Alluvium & peat deposits. |
| | | Glacial deposits. |
| Tertiary
(?) | | Pyroxenite. |
| | | "Birdseye" Porphyry. |
| | | Monzonite. |
| | | Undifferentiated Pre-Cambrian |
| | | Faults |

N
145°

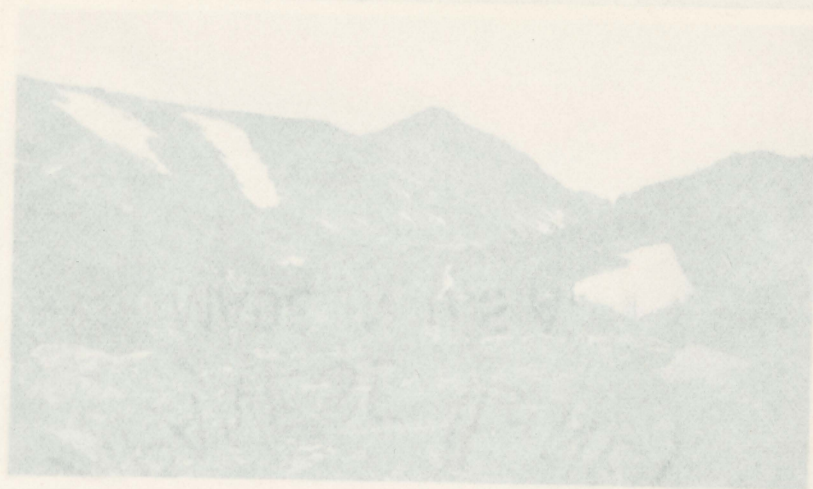


Figure 1.

Albion Valley in the foreground, the face of the hanging bench in which Lake Albion is located, and Mount Albion.



Figure 2.

Lake Isabelle, with the continental divide and Isabelle Glacier in the background.



Looking west along Navajo Ridge.

Figure 1.

Albion Valley in the foreground, the face of the hanging bench in which Lake Albion is located, and Mount Albion.



Figure 2.

Mount Albion (the peak in the cliff face is a "Birdseye" porphyry sheet), Green Lakes Valley, Navajo Lake Isabelle, with the continental divide and Isabelle Glacier in the background.



Figure 3.

Looking west along the Niwot - Navajo Ridge.



Figure 4.

Mount Albion (the white streak in the cliff face is a "Birdseye" porphyry sheet), Green Lakes Valley, Navajo Peak, and the Niwot - Navajo Ridge.



Figure 5.

Differentiated phase of the monzonite near
Lake Isabelle, showing flow texture.



Figure 6.

Contact of pyroxenite and monzonite near
Lake Isabelle.

Figure 8.

Small delta in the bed of Lake Isabelle.



Figure 7.

Junction of Albion Valley (right) and Arapahoe Valley, showing Arapahoe Glacier and Peaks, and (right) Kiowa Peak and part of the ancient plateau.



Figure 8.

Small delta in the bed of Lake Isabelle.

Date Due

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