GENESIS OF DEPOSITS OF DOLOMITE & MAGNESITE IN GRENVILLE & CHATHAM TOWNSHIPS, QUE.

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THE GENESIS

OF

THE DEPOSITS OF DOLOMITE AND MAGNESITE

IN

GRENVILLE AND CHATHAM TOWNSHIPS, QUEBEC.

Presented as a thesis in fulfillment of the requirements for the degree of Master of Science.

McGill University
April 1923.

Geo.W.Bain.

Frontispiece

Calcite Dolomite Magnesite



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PREFACE

The following work is intended to show the origin, extent and economic possibilities of a deposit of magnesite in Grenville township in the Province of Quebec. It includes a brief account of the general geology and structural features of the region as well as an advisory statement to guide the operators in the future development of the deposits and a caution to the buyers in selecting their supplies.

Since magnesite is rarely discussed in any textbook or reference book on ore deposits a lengthy outline of previous work on the magnesite deposits of the world has been included. The multiple interpretations of the facts connected with the deposits elsewhere has shown the author that, although he has sought to be impartial and to pursue a course free from preconceived opinions, it is quite possible that other views concerning the deposits may be held. Therefore for the benefit of future students, both the positive and negative evidence as well as the apparently unrelated details have been included in this thesis.

ACKNOWLEDGEMENTS.

In the preparation of this thesis the author has received invaluable assistance from the members of the staff of the Department of Geology both at McGill and Columbia Universities.

For assistance and encouragement in the early stages when the results obtained were discouraging and wholly negative, Dr. Adams and Mr. Graham of McGill University rendered invaluable assistance in helping to plan an outline of procedure and future study.

The petrographical and chemical studies of the contact zones, and more especially the problem of the origin of the biotite gneisses, were carried on in the laboratories of Columbia University under the guidance of Professor Chas. P. Berkey and Mr. R. J. Colony; to Prof. Berkey and Mr. Colony the writer owes many of the suggestions which led to the interpretation of the complex and unusual changes which took place in these ancient metamorphic rocks.

The directors of the North American Magnesite Company did all that they could to advance the study of their deposits and allowed free access to the assay records.

In assembling the facts and preparing reasonable and coherent conclusions, Prof. Berkey and Mr. Colony have offered many valuable suggestions and helpful criticisms which have enabled the author to present the problem and conclusions in their present form.

INTRODUCTION

The subject of this thesis was suggested to the writer by a lecture delivered at McGill University in 1921 by Mr.John A. Dresser.Mr.Dresser mentioned the fact that the magnesite deposits seemed to be associated with highly serpentinized peridotite and pyroxenite dykes.

During the month of October of the same year the writer accompanied by Dr.H.C.Cooke,Acting Professor of Geology at McGill University,visited the Scottish Canadian Magnesite Quarry.The quarry was small and the geological structure too complicated and obscure to present conditions favourable towards a detailed study.

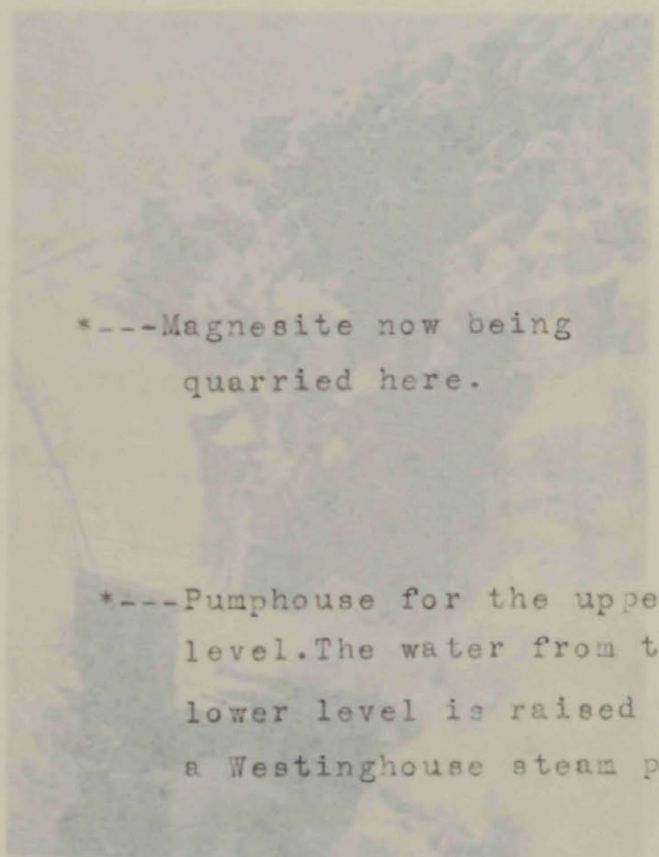
Later in the same season dolomite and magnesite were reported from the Limestone Chute on the West River.This locality was visited by Dr.Cooke and found to present conditions very favourable for a study which might throw light on the origin of the magnesite deposits.During a period when the river was low the writer visited the locality and collected specimens to study the relationships of the dolomites and the associated intrusives outcropping on the banks and in the bed of the stream.

Analyses showed that the rock was not magnesite but dolomite and although the structural features and quantitative relationships were worked out in considerable detail,the origin of the magnesite was almost as obscure as when the study was started.

Through the co-operation of the directors of the North American Magnesite Co.and especially Mr.Patterson,the writer was enabled to spend some time at their quarry at White Rock Lake.A large part of the country was covered with snow but the outcrops on the surrounding hills and in the quarry itself were sufficient to convince the writer that the same conditions prevailed as at the Limestone Chute.The author was given free access to analyses

Plate I.

The North American Magnesite Quarry.



*---Magnesite now being quarried here.

*---Pumphouse for the upper level. The water from the lower level is raised with a Westinghouse steam pump.

North American Magnesite Quarry.

The operators encounter great difficulties in trying to quarry magnesite during the winter. Large quantities of snow and water must be handled. The water in the pipe lines frequently freezes in a climate which occasionally reaches -50F.

of magnesite and other useful data in the possession of the operators. This information along with the personal help of Mr.Patterson was of great assistance in the study of the occurence of the magnesite and the structural features of thedistrict.

HISTORY OF THE DEPOSITS.

Previous to 1914 the world derived the major part of its supply of magnesite from Veitsch in the Province of Styria,Austria, and from the Island of Eubea on the east coast of Greece.Toward the close of that year the supply from Austria was cut off entirely and most of the Greecian magnesite was required by England and France.As a result,the United States and Canada were no longer able to obtain foreign magnesite;this led to a renewed examination of, and search for domestic deposits of the material.Several such were opened up and worked successfully in the United States and in Canada the magnesite occurring in the County of Argenteuil,Province of Quebec was found to be of commercial value.

The deposits are situated in Grenville township,about eight miles from Calumet station,on the Canadian Pacific Railway. There are no good roads in this locality and transportation difficulties at first appeared so great that people were unwilling to expend much capital in the developement of this prospect.

Magnesite was first discovered in this district in bowlders near White Rock Lake in 1900 by the Rev.W.P.Boshart.The material of these bowlders,Boshart observed,was more glistening than the ordinary Grenville Limestone,so he sent a specimen to the Department of Mines,Ottawa,for analysis.The sample proved to be almost pure carbonate of magnesia,and to be of commercial value if present in sufficient quantities.

During the summer of the same year Boshart and McAllister found numerous boulders and outcrops of rock which gave promise of being magnesite of commercial grade.As a result of their summers work they beleived that they had a mineral deposit,which if developed would be a prosperous mine rivalling that at Veitsch;so the

partners procured options on most of the land on which they knew that magnesite occured.Trial shipments were made to various consumers of the material and favourable reports obtained but at that time the transportation difficulties were too great and the returns too small.

The next attempt to work the quarries was in 1907 when Mr.T.J.Waters organized the Canadian Magnesite Co.and opened a quarry on the north half of Lot 18,Range XI of Grenville Township and later on Lot 15 Range IX of the same township.A limestone kiln was erected on the property and calcined rock hauled by waggon or sleighs to Calumet.

The next attempt to work the work some other deposits was in 1914 when the North American Magnesite Co.took over these deposits and some others and has continued to ship crude and calcined magnesite until the present.

During 1915 Mr.S.Melkman organised the Scottish Canadian Magnesite Co.and opened a quarry on Lots 15 Range X and XI of Grenville Township.A light narrow-gauge railway connects this quarry with the Canadian Pacific Railway at Magnesite Station.Shipments are made only during the summer months.

Numerous other quarries have contributed to the output of district but the major part has come from the open pits of the North American Magnesite Co.and the Scottish Canadian Magnesite Co.

In 1917 Wilson[1] estimated that the deposits contained 686,000 tons of crude magnesite containing less than 12% of lime and suitable for the manufacture of firebrick,refractory materials,etc.In addition there are about 483,700 tons of magnesite dolomite containing more than 12% of lime and suitable for the manufacture of artificial stone for building purposes.Since this estimate was made more magnesite has been discovered;on the other hand much has been removed and also much of the lower grade material is no longer mer-

1. Memoir 92 C.G.S.

chantable now that the purer material from Austria is again available.It would seem as though the reserves had not changed appreciably.

SUMMARY OF CONCLUSIONS

The observations of the occurrence of magnesite and dolomite both asa mineral and as a rock seem to indicate the following conditions of formation and to point to conclusions given below:-

1. Deposits of dolomite and magnesite of this type can be expected only in the Grenville Crystalline Limestone.
2. The deposits are closely associated with paragneisses rich in ferromagnesian minerals and which have been contact metamorphosed and hydrothermally altered by Laurentian Granite and Syenite magmas.
3. The deposits occur only beneath impervious dykes of Buckingham or early Laurentian age, and on the crests of anticlines or for a short distance down their flanks and plunge. Magnesite deposits are more likely to occur where combinations of the above structures exist.
4. The silicates increase in depth so that the deposits cannot be expected to continue to great depths.
5. Dolomite is finer grained than calcite. Magnesite is finer grained than dolomite. Dolomite occurs as small grains replacing calcite volume for volume. Magnesite occurs as small grains replacing dolomite volume for volume. The replacement shows a eutectic structure.
6. If the rocks are considered in small units the dolomite must completely replace the calcite before the magnesite can replace the dolomite.
7. Some beds have been more completely replaced than others. This may have been due to catalysers but is more probably due to greater porosity in the replaced bed.
8. The rocks consist of definite carbonates calcite and dol-

omite,or dolomite and magnesite,rather than isomorphous mixtures of calcium and magnesium carbonates.

9.The occurrence of the two carbonates dolomite and magnesite rather than isomorphous mixtures of calcium and magnesium carbonates lowers the value of the material as a refractory brick since the calcined dolomite is apt to crumble or be fluxed leaving behind an incoherent mass of grains of magnesia.

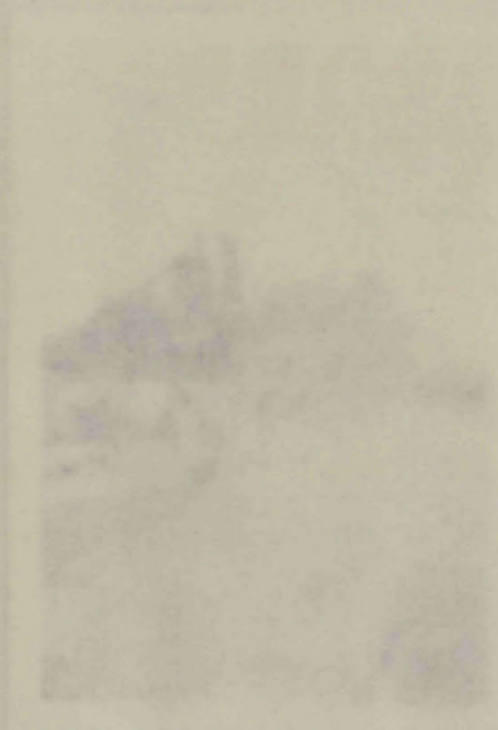
10 The magnesia bearing waters seem to have been given off by a granite magma during its final stages of consolidation.

11.The dolomites when free from sulphides should furnish anexcellent material for the manufacture of artificial building stone.The magnesite containing less than 5% of calcium carbonate and low in silica should furnish an excellent fire-brick for steel furnaces.

Plate II.



Scottish Canadian Magnesite calcining plant.



North American Magnesite Keystone kiln.



North American Magnesite Quarry at White Rock Lake.







PROPERTIES,PREPARATION AND USES OF MAGNESITE

Magnesite is a rhombohedral carbonate of magnesia containing 47.6% of MgO and 52.4% of CO_2.In a hand specimen it is distinguished from calcite by its higher specific gravity,3 to 3.12 as compared with 2.72,for carbonate of lime,and also by its hardness 3.5 to 5 as compared with 3 for calcite.Pure magnesite is white or pearly white in colour but it is usually stained gray or brown by ferrous and ferric iron.

Chemically magnesite is less active than calcite or dolomite.It is not decomposed by cold concentrated hydrochloric and and sulphuric acids but effervesces freely when the acids are heated. Magnesite gives up its CO_2 at a temperature below 600°C,while calcite retains its CO_2at temperatures up to 875°C.The magnesia produced by burning the carbonate is very refractory having a melting point at about 2500°C.Unlike lime it does not combine readily with silica to form silicates;it is further unlike lime in that when dead burned it will not take up water or carbon dioxide to form hydroxides and and carbonates.Thus magnesia,as the calcined product is called,is relatively inert.It is hard and massive and is readily distinguished from dolomite by its pinkish tint while the dolomite is white.

Magnesite is marketed in four forms:-

1. Crude magnesite.
2. Caustic calcined.
3. Dead burned.
4. Clinker.

Crude magnesite is the term applied to the product as as it comes from the mines.The impurities are removed as far as possible by cobbing,but some serpentine,quartz,dolomite,diopside and sulphides of iron,copper,lead,and zinc still remain.

Caustic calcined magnesite is produced by heating the crude magnesite to a red heat or about 1100°C.This material still retains from 2 to 4% of CO_2;it slakes in contact with water and

and takes up CO_2 from the atmosphere.

Dead burned magnesite is produced by calcining at a white heat or about 1700°C. The calcined product contains less than one percent of CO_2. It does not slake in water and does not absorb CO_2 from the atmosphere.

Clinkered magnesite is produced from crushed magnesite by partial fusion with iron oxide-usually hammerscale from the rolling mills, which serves as a binder and as aflux during the process The fusion is carried out in rotary cement kilns burning powdered coal. The product of this fusion is a brownish material composed of pebbles about three quarters of an inch in diameter.

The chief use of magnesite is as a refractory material in the metallurgical industries. Its high melting point and relative chemical inertness render it particularly suited for this purpose. Only dead burned magnesite of the highest grade can be used in this industry. Magnesite is used in the manufacture of oxychloride or Sorel cement. As a flooring material, Sorel cement is superior to ordinary cement in that it has a very low coefficient of expansion and will take a high polish. The cement is made of a mixture of finely powdered magnesite and magnesium chloride. When wet with a a solution of magnesium chloride it sets and forms a hard vitreous mass. The magnesium carbonate gives up its CO_2 at a lower temperature than other common carbonates and for this reason it has been used in the manufacture of carbon dioxide gas.

Other uses of magnesite depend upon the magnesium content of the mineral rather than upon its physical properties. Some of the more important uses are: magnesium bisulphide used in the manufacture of pulp and paper, metallic magnesium, magnesium chloride, cold water paint and several other products of the chemical industry. In addition it is used along with other materials in the manufacture of medicinal

and toilet sundries.These take a very small percentage of the output and require freedom from certain impurities which are not so objectionable in the material for the metallurgical industries.

THEORIES REGARDING THE ORIGIN OF MAGNESITE

Magnesite has been mined and used for nearly a century. During this period,and more especially in recent years,many valuable contributions have been made to our knowledge of the genesis of deposits in various parts of the world.Up to the present four main types have been recognised:-

1. Magnesite as a sedimentary rock.
2. Magnesite as an alteration of serpentine.
3. Magnesite as a vein filling.
4. Magnesite as a replacement of limestone.

In the following pages,typical examples of each of these types of deposit will be described so as to simplify a discussion of the deposit which is being studied in greater detail.

MAGNESITE AND HYDROMAGNESITE AS A SEDIMENTARY ROCK.

Carbonate of magnesia occurs as a sedimentary rock at Atlin,B.C.,and in Kern Co.,California.

ATLIN,B.C.

The deposit lies in a basin and is about six to eight feet thick over an area of eighteen acres.Here the material is not magnesite but hydromagnesite in a white powdery form.

The following are results of analyses of the slightly impure material as sampled:-

SiO_2	1.86	0.90	0.54
Al_2O_3	0.67	0.10	0.17
Fe_2O_3	0.15	0.09	0.11
FeO	0.60	0.45	0.64
CaO	0.04	0.82	0.68
MgO	41.13	42.35	42.19
CO_2	35.98	36.10	36.17
H_2O	18.02	18.95	19.05
H_2O (Subt.)	1.92	1.61	1.35
	100.45	99.76	99.55

The deposits have not the tufaceous structure of spring deposits nor do they lie on top of ferro-magnesian rocks from which they could have derived their magnesia.They probably represent a lake deposit which has become exposed owing to the drying up of the water.

KERN CO.,CALIFORNIA,U,S. A.

The deposits are situated in the Mohave Desert of Central California.Outcrops are few and the geology has been worked out from exposures in prospecting pits and on ridges of hard limestone which resist erosion.

The ore bodies show a distinct bedded structure,and are interstratified with clays and clay shales forming a member of a series of cherty limestones which outcrop in ledges nearby.The magnesite beds and interstratified clay seams are soft,so that surface exposures are rare.The succession of strata is variable and is different

1.Summary Report of C.G.S.,1915. Annual Report of C.G.S.,1899.

2.Bulletin 355 U.S.G.S.

for different pits but a log taken from a shaft on one property will serve to illustrate the general characteristics.

Material	Description	Thickness
Cherty layer	Carbonaceous, lenticular	6"
Clay	"	4"
Magnesite	Hard, white	5"
Clay	Gray coloured	3"
Magnesite	White	6"
Clay	Dark gray	4"
Magnesite	White	4"
Clay and magnesite	Mixed	8"
Magnesite	Clear white, massive	1'6"
Clay	Brown	4"
Magnesite	White	1'0"
Clay	Greenish	3"
Magnesite	Compact, white	10"
Clay	Large body	

The strata are badly distorted and lenticular in the thicker parts. Slip planes are rather common and where these occur the bedding becomes rather indistinct. The strike taken in the shaft of one prospect was N 15°W and the dip E 60°N. while 300 feet to the northwest the strike was N.60°W. and the dip S.45°W.

The magnesite is fine grained and breaks with a conchoidal fracture. On exposure to the atmosphere and rain it crumbles to an earthy powder. The composition is given by the following analyses:-

SiO_2	9.64	8.51	5.03	4.75
Al_2O_3 Fe_2O_3	2.46	2.94	1.40	0.76
CaO	4.25	3.36	1.56	Tr.
MgO	37.19	38.32	42.78	44.20
CO_2	40.70	40.12	45.78	47.32
Undetermined	5.76	6.75	2.45	2.97

When the mineral composition is calculated from these analyses it is found that there is insufficient CO_2 to combine with the MgO to form $MgCO_3$. Evidently some of the magnesia is present as $Mg(OH)_2$ in the hydromagnesite molecule $MgCO_3, Mg(OH)_2$. Thus to a limited extent the deposit has much the same mineral composition as that occuring at Atlin, B.C.

The lime content at Atlin and in Kern Co. is remarkably low for sediments, unless sedimentation took place under extraord-

inary conditions.The beds of shale clay and magnesite have the characteristics of lake deposits and point to the formation of the magnesite by a chemical precipitation and subsequent dehydration during the metamorphism of the beds.

The lakes in which the precipitation took place are supposed to have been filled with brines rich in sodium carbonates and other soluble carbonates.Spring waters rich in magnesium salts possibly magnesium sulphate,flowed into the lake;reaction took place between the sodium carbonate of the brines and the magnesium sulphates of the springs to produce relatively insoluble magnesium carbonate and hydroxide and soluble sodium sulphate.Since calcium carbonate,calcium sulphate,sodium carbonate and sodium sulphate are many more times soluble than magnesium carbonate,they would remain in solution allowing a relatively pure precipitate of magnesium carbonate to form.

Sedimentation of a later date has buried the deposits and preserved them from erosion.

MAGNESITE AS AN ALTERATION OF SERPENTINE.

Magnesite derived from serpentine rocks accurs in several countries and widely separated areas.The magnesium carbonate of these deposits is exceedingly fine grained,having the appearance of unglazed porcelain;it has a conchoidal fracture,a specific gravity above three and a hardness of five.

The mineral occurs in veins cutting serpentines from which the magnesia was evidently derived by the decomposition of the silicate in the presence of water containing an excess of CO_2.The chemical reaction taking place on its formation may be expressed as follows:-

$$H_4Mg_3Si_2O_9+3CO_2 = 3MgCO_3+2H_2O+2SiO_2$$

The magnesium carbonate is deposited in veins as magnesite and the silica carried away in solution;some silica is deposited as opal.

The chief deposits of this type are in Eubea,Greece;and in California,U.S.A.Deposits of lesser importance are found in Victoria,Australia;Mysore and Salem,India;Reinosa,Spain;Transvaal, South Africa;and Maryland,U.S.A.

EUBEA,GREECE.[1]

The Greecian magnesite quarries are situated on the Island of Eubea which lies in the western part of the Aegean Sea and is separated from the mainland by the Canal d'Atalanti.

A belt of peridotite rocks,of Jurassic age,and largely altered to serpentine stretches across the island from east to west. The magnesite occurs in shear and fracture zones in both the peridotites and serpentines pointing to a double decomposition of the olivine according to the following reaction:-

$$H_2O+2Mg_2SiO_4+CO_2 = H_4Mg_3Si_2O_9+MgCO_3$$

$$H_4Mg_3Si_2O_9+3CO_2 = 2H_2O+2SiO_2+3MgCO_3$$

In places the magnesite veins become so numerous that they constitute

1. Economic Geology Vol.XVI, 1921.

Geological Map - Eubea, Greece.
(Economic Geology)

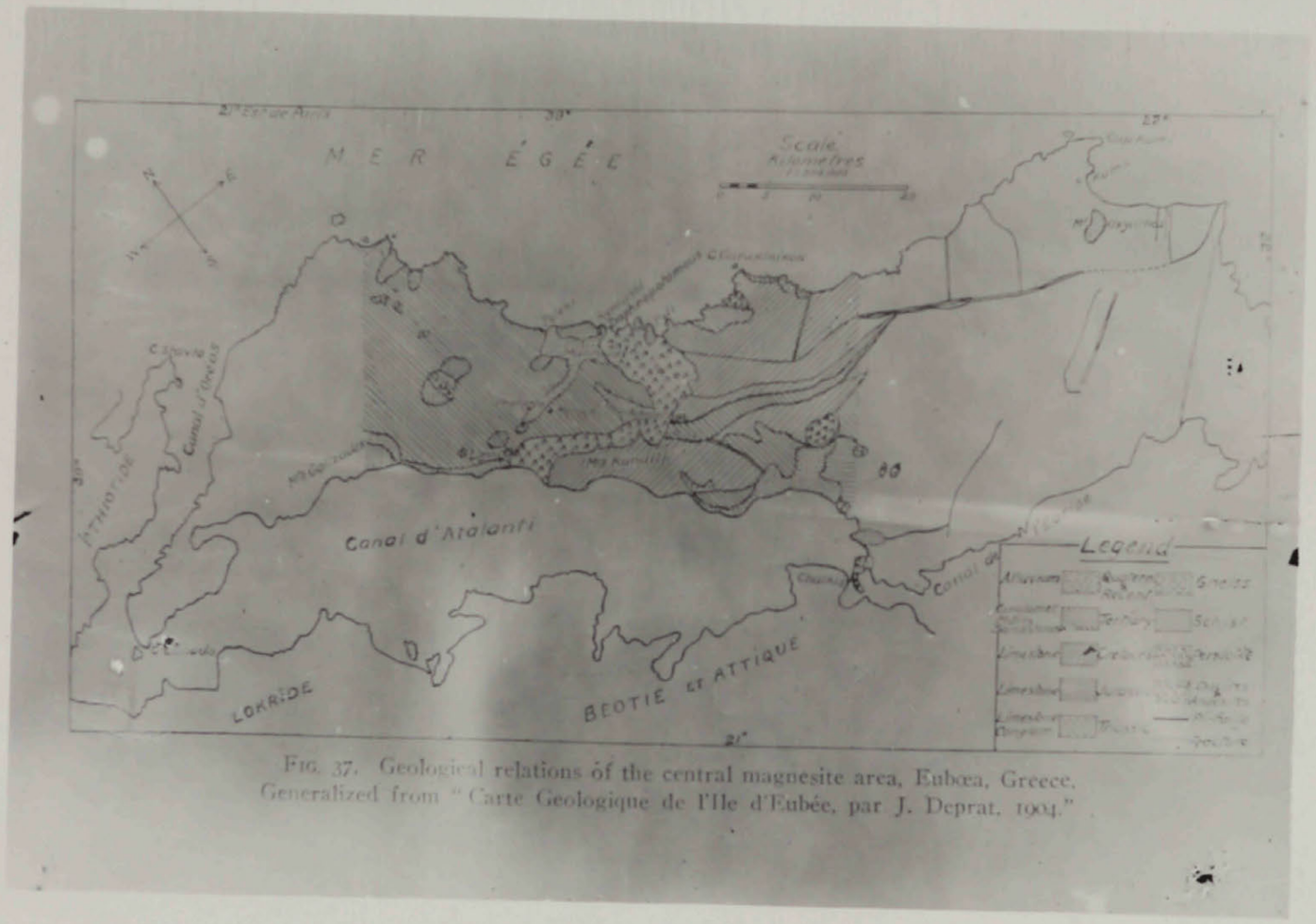
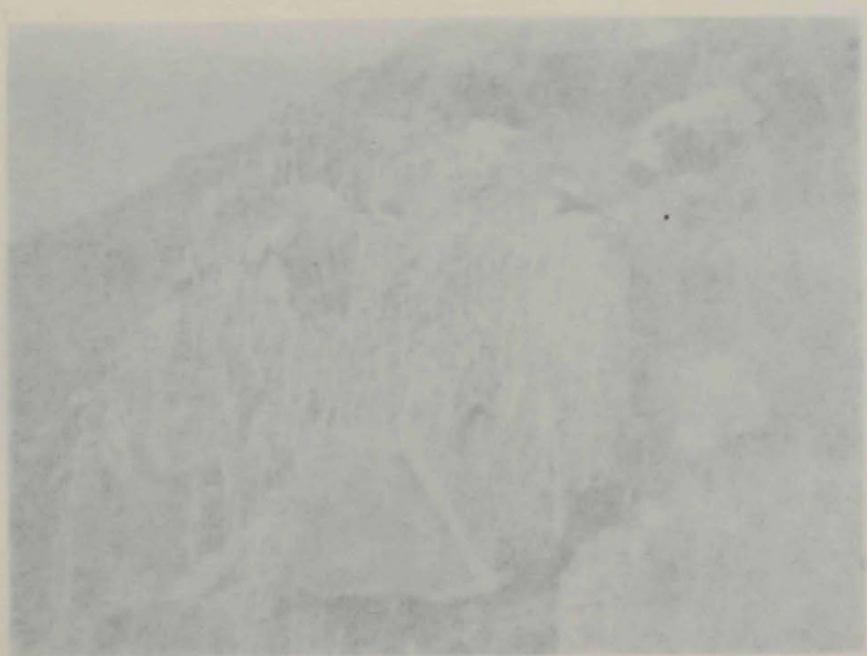


FIG. 37. Geological relations of the central magnesite area, Eubœa, Greece. Generalized from "Carte Geologique de l'Ile d'Eubée, par J. Deprat, 1904."



Stockwork of Magnesite - California.
(Bull. U.S.G.S.)



Sheeted Zone with Magnesite - California.
(Bull. U.S.G.S.)





a magnesite rock with a few remnants of serpentine to show the original structure.Two processes have been at work:-

1.Solution of the silica and serpentine.

2.Concentration of the magnesite in veins and stock-works.

The deposits attain a depth of over 300 feet and cover a large rea.The maximum annual production of crude magnesite was 150,000 tons for 1914.Analyses of the material mined has given the following results:-

SiO_2	2.86	1.54
$Al_2O_3 + Fe_2O_3$	0.55	0.33
CaO	0.55	1.21
MgO	46.94	46.38
Ignition	51.10	49.84
Moisture	---	0.70

CALIFORNIA,U.S.A.[1]

The magnesite of California resembles that of Eubea in texture and its mode of occurence and origin seem to be similar. The mineral occurs in serpentinized rocks derived from peridotites and pyroxenites,which underlie an area of about 1000 square miles in the Coast Range Mts.of California.The peridoties belong to a series of batholithic intrusives of Cretaceous age which since consolidation have been greatly faulted and broken up.Solutions carrying CO_2have penetrated along these fractures and decomposed the enstatite and olivine,with the formation of first serpentine and later magnesite.The silica was carried away and the magnesium carbonate deposited in the space formerly occupied by the serpentine;since the carbonate occupied only four-fifths of the volume of the serpentine considerable shrinkage and additional fracturing must have taken place enabling the carbonated waters to carry out their work more completely.Serpentine in all stages of decomposition is found inthe brecciated zones and veins.

1.Bulletin 355 U.S.G.S
Bulletin 540 U.S.G.S.

The origin of the carbonated waters essential to the formation of this type of deposit is still a debatable question. Some geologists have shown that some of the deposits in serpentines were formed by ascending thermal waters given off by the consolidation of the deeper portions of the same magma while others believe that meteoric waters may have brought about the change. The nature of the alteration favours the view of the geologists supporting alteration by magmatic waters. In either case alteration and replacement of the serpentine and transportation of the magnesite and silica have played an important part. In the formation of the magnesite deposits, the silica has been held in the solution probably as soluble silicic acid and the magnesite has been precipitated as soon as the decrease in pressure would allow the excess of CO_2 to escape, thus giving a product relatively free from impurities.

A number of typical analyses are given below:-

SiO_2	0.41	0.51	0.23
Al_2O_3	0.28	1.98	0.04
Fe_2O_3	0.12	0.16	0.20
CaO	0.03	0.59	0.19
MgO	47.16	45.84	46.88
CO_2	51.88	50.80	51.57
	99.88	99.88	99.11

In 1915 the mines produced 30,500 tons of crude magnesite having a value of $274500.

MAGNESITE AS A VEIN FILLING

Magnesite as a vein filling is relatively unimportant from an economic point of view.The several deposits usually described as belonging to this class are not all veins but include many occurences forming a link between the fissure veins and the replacement deposits.

Near West Beach,New Brunswick,[1] magnesite occurs in a vein several feet wide cutting a gray chloritic schist.

Sir Wm.Logan desribes an occurence of magnesite in Bolton and Sutton Townships,[2] Quebec.At Bolton the magnesite forms a bedded deposit lying between steatite on one side and serpentine on the other.The bed resembles crystalline limestone and contains in addition to magnesite,the minerals dolomite,nickeliferous pyrrhotite and a nickeliferous silicate.An analysis gave the following:-

Insol.	8.03	45.90
$FeCO_3$	9.02	19.35
$CaCO_3$	0.00	0.00
$MgCO_3$	83.35	33.00
Al_2O_3	------	0.50
	100.40	98.70

In Sutton Township the magnesite forms a bed about a foot thick,lying between gray micaceous schists.

At Lac des Mille Lacs,Algoma,Ont.,[3] a blue ferruginous magnesite occurs in association with finely crystalline pyrite.

Magnesite as vein filling,has been reported from several localities in British Columbia[4] and the Yukon,[5] but published accounts of these occ urences are usually lacking in detail.

1.Report of Progress.1870-71.C.G.S.

2.Geology of Canada.1863.

3.Annual Report.1899.C.G.S.

MAGNESITE AS A REPLACEMENT OF LIMESTONE.

The most important deposits known,namely those at Veitsch are of the replacement type.Similar,but smaller,occurences are found in Stevens Co.,Washington,and in Argenteuil Co.,Quebec.The magnesium carbonate is coarsely crystalline,white in appearance,and usually has associated with it much pale green or yellowish serpentine.The magnesite occurs as a replacement of limestone,produced through the agency of magnesian thermal waters of magmatic origin.

The deposits of Austria have been worked and studied for over half a century.The result is that Austrian and German geologists have come to beleive that the ore bodies were formed by the replacement of limestones and possibly some other sediments through the agency of magnesia bearing solutions.[1] There is however some difference of opinion as to whether these solutions emanated from an acid or basic intrusive both of which occur in close association with the deposits.

At present similar doubt exists regarding the deposits in Quebec and Washington.

STYRIA,AUSTRIA.

As early as 1873 J.Rumph studied the magnesite rocks in the Austrian Alps and in a paper stated that the deposits seemed to be marine sediments,of Silurian age,and were deposited from saturated solutions of magnesium carbonate in warm waters.

In 1885 Foullon found epidote crystallized between the rhombohedra of magnesite,thereby showing that their present condition at least was not due to simple sedimentary processes.

Later in 1893 Kock recognized fossils characteristic of the Carboniferous period and definitely expressed the opinion that the deposits were of contact metamorphic origin;but did not state

1.Tsch.Met.und Petr.Mitt.Vol.XXVI 1907
Zeit.fur Prac.Geol.Vol.XXI.1913.

his reasons for this conclusion.Furthermore he mistook the sediments which were not magnesite for limestone whereas they are really dolomite.In this paper Kock did not discuss the chemical reactions that took place during the transformation.

In 1900Weinschenk mentioned the stocklike masses of magnesite in Liesing and pointed out their close relationship to the extensive talcose rocks of the region.Such formations he explained by the bringing in of pure magnesium compounds,as otherwise the dolomite stage would hardly have been passed.The pinolites Weinschenk beleives are impregnations of the"Tonscheiffer"in which most of the rock consists of flat rhombohedra of magnesite and the original Tonscheiffer was completely recrystallized.

In 1903 Kock and Redlich showed that the magnesite was formed by the replacement of limestone and that in this respect it was analogous to the deposits of ankerite and siderite in the same district.In 1905 Weinschenk explained the formation of the magnesite as due to the metamorphism of the limestone by metasomatic processes,the change being brought about by magnesia solutions emenating from granite laccoliths intruding granite,and limestones of Crboniferous age.

In 1907 Redlich showed that the limestone was first changed to dolomite and later to magnesite but was inclined to regard basic intrusives of Paleozoic age as having supplied the magnesia.

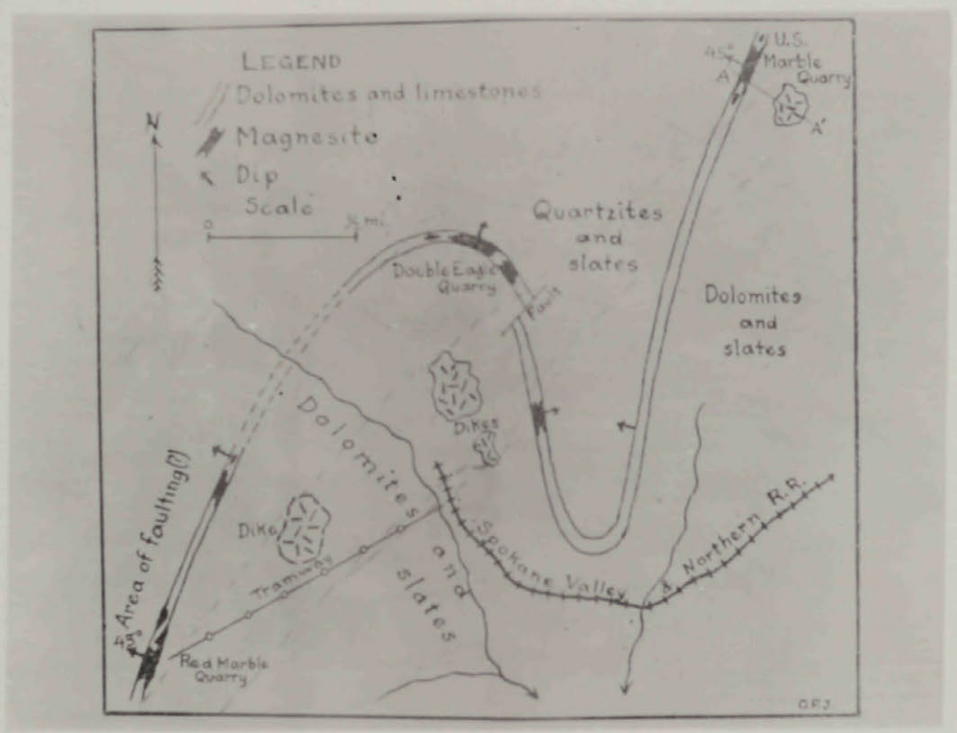
STEVENS CO.,WASHINGTON,U.S.A.[1]

The magnesite deposits of Stevens Co.are found in Chewelah Valley,fifty miles north of Spokane,Washingtom.

The magnesite is of the crystalline variety and occurs together with dolomite in beds of Carboniferous age.In most localities the limestones are dolomitic but only near dykes do they ap-

1.Economic Geology Vol.XIII,1918.

Geological map - Chewelah Valley, Wash.
(Economic Geology).
(The author has sketched the probable zone along which the dykes occur in a more or less continuous manner).


LEGEND
Dolomites and limestones
Magnesite
Dip
Scale
½ mi.
N
U.S. Marble Quarry
45°
A
A'
Quartzites and slates
Double Eagle Quarry
Fault
Dolomites and slates
Dikes
Dikes
Dolomites and slates
Spokane Valley
Northern R.R.
Area of faulting(?)
45°
Tramway
Red Marble Quarry
G.F.J.

proach magnesite in composition.

The dykes are composed of a dark green hornblende which is largely altered to chlorite and serpentine.The feldspar is also highly changed and magnetite surrounds grains of pyrite from which it is probably derived.In the hand specimen the dykes appear quite fresh and are dark green in colour.The alteration which has taken place is believed to be hydrothermal.

Near the dykes the limestone is much distorted and contains a yellowish green pseudoserpentine,sometimes identified as ophicalcite.At no point does magnesite occur in contact with the dykes just beyond this serpentine zone.

Since the dykes show alteration similar to the limestone I thought that the change from limestone to magnesite took place long after their intrusion.It is believed however that the waters producing the alteration were directly affected by the presence of the dyke.

Although the geologist who studied these deposits did not recognise the fact,or if he did,failed to point it out,a glance at the geological map will show that the dykes occur in a zone and this zone intersects a series of plunging folds.The workable deposits of magnesite all occur farther down the plunge than their intersection with the dykes and more especially where the structure is such as to concentrate any solutions which might be rising from great depths.This structure will be emphasised in the detailed study of the Grenville deposits.

ARGENTEUIL CO.,QUEBEC.[1]

The magnesite deposits of Argenteuil Co.are situated about eight miles north of the town of Grenville on the north shore of the Ottawa River between Montreal and Ottawa.

The deposits are of early pre-Cambrian age and occur in a

1.Memoir 98,C.G.S.

metamorphosed group of sediments known as the Grenville Series. Associated with the magnesite are dolomites,garnet gneiss,biotite gneiss,feldspathic gneisses and serpentine.The serpentine occurs in the"limestone"as scattered grains or in large lenticles.

The magnesite was formed by the replacement of the limestone through the agency of magnesia-rich solutions which appear to have come from a series of basic peridotite and pyroxenite dykes which are found cutting the limestones.

RS NOTE:-This includes a summary of the knowledge up to the time the study was started.In the case of the Grenville deposit,for which the author has considerable additional information,and proposes some new details as to the origin of the solutions and the chemical reactions taking place,it must be stated that at the time the deposits were examined by Wilson they were not developed to a very great extent and as favourable conditions for study were not available as when the work was undertaken by the author.

Plate IIIa.



In the distance, on the left, are the Paleozoic plains. The small knobs and level fields in the centre of the photograph are underlain by Laurentian granite. A Monadnock of late pre-Cambrian granite is seen in the background.



Plate IIIa



The Pre-Cambrian Escarpment.

The photograph is taken from the narrow gauge railway connecting the magnesite quarries to the Canadian Pacific Railway at Magnesite Station. The Paleozoic-Pre-Cambrian contact does not lie at the base of the scarp but is off the photograph altogether i.e. the scarp has retreated a distance since its formation.



TOPOGRAPHY

The district in which the magnesite is found is situated on the border of the Laurentian Highlands and at an elevation of from four to five hundred feet above the Ottawa River.Lying as it does on the very edge of the uplands,Argenteuil County is intersected by many deep valleys cut by streams flowing southward.As a consequence the region presents a very hilly appearance but when viewed from the south side of the Ottawa River it is seen to be a dissected upland,which extends to the east,west and north for great distances. Only one hill rises above the even skyline of the peneplain and it extends from Brownsburg on the east to Magnesite Station on the west. This hill is a monadnock of Algoman granite.

From Lachute westward the Canadian Pacific Railway follows the edge of the highlands,which end abruptly in a southward facing scarp two hundred feet or more in height,and broken here and there by the valleys of the Rouge and West Rivers and other smaller streams. When the streams leave the highlands to flow out upon the Ottawa Valley they are characterized by rapids and waterfalls,which in many places are used for the developement of water power.

GENERAL GEOLOGY

The rocks of Argenteuil County are divided into five main groups according to their age.They are represented in the following geological column:-

Table of formations.

Quaternary	Champlain	Marine clays and sands.
	Glacial	Boulder clay,gravel,sand and loess.
	Unconformity.	
Paleozoic	Chazy	Limestone
	Beekmantown	Calciferous sandy dolomite
	Potsdam	Sandstone and quartzite.
	Unconformity.	
Algoman	Dykes	Trap
	Bosses	Quartz and orthoclase porphyry.
	Batholiths	Hornblende granite and syenite.
	Diabase dykes	
Laurentian	Batholiths	Granite and syenite.
	Dykes	Aegerite granite and pegmatite.
	Dykes	Peridotite and peroxenite.
Grenville	Grenville Series	Crystalline limestone. Skarn rocks Garnet gneiss Biotite gneiss

A straight line joining Lachute and Calumet separates the Paleozoic sediments to the south from the Pre-Cambrian complex to the north.The Pre-Cambrian escarpment lies along this line,so that both topographically and geologically the Pre-Cambrian and Paleozoic terrains are in marked contrast.

THE GRENVILLE SERIES.

The Grenville Series consists of coarsely crystalline white and blue limestones,skarn rocks,and biotite gneiss in long parrallel

bands which are followed by the river valleys.

The crystalline limestones are a highly folded sedimentary series with very few sandstone or shale partings,in fact only one shale bed half an inch thick was found in the whole area.This shale was practically unchanged althoughthe limestones on either side were profoundly silicated and recrystallized.The limestones consist largely of interlocking crystals of calcite with negligable percentages of magnesium carbonate,silicates such as wollastonite and more rarely diopside,phlogopite,scapolite,chondrodite and small hexagonal flakes of graphite.The bedding is shown by a local abundance of graphite and silicate minerals or in the one instance by the thin bed of unaltered shale.In some localities the limestones are so pure, massive and uniform that all traces of stratification are lost.

The skarn rocks are of three general types which are more or less distinct since the minerals of one type seem to be more or less unwilling to form in the other.However there is always a gradation both latterally and along the strike from one type to the other.Some of the types which have been studied are:-

1. Diopside,talc,albite,carbonates,phlogopite,and a few grains of almandite and grossularite.
2. Diopside,quartz,albite,and a small quantity of sillimanite.
3. Almandite,quartz,andesine,orthoclase and magnetite.

Skarn rocks of the first type are massive,and coloured green by the diopside present;it has a glittering appearance due to the numerous small flakes of talc and the cleavage planes of the carbonate.It weathers readily and does not form prominent ridges like the other skarn rocks.

Skarn rocks of the second type are likewise massive and white or mottled in appearance due to the green pyroxene;they have a foliated structure and stand out as ridges or mounds along the margins of the crystalline limestone.

The third type has a mottled appearance due to the dark pink or red almandite garnets,one quarter to one third of an inch in diameter,standing out in relief against the white or colourless feldspar and quartz.The garnets are most abundant in parralel[1] bands which appear to represent bedding planes.This rock forms prominent knobs and ridges along the edge of the bands of Grenville rocks.

The skarn rocks lie between the Grenville limestone and biotite gneisses which have a distinctly foliated appearance due to the parallel arrange ment of the mica which is so prominent in the rock;in other cases the gneiss has a mottled appearance due in some cases to the developement of pegmatic knots of feldspar and in others to almandite garnet.Pegmatite dykes break through these gneisses and also intrude them in lit-par-lit fashion to such a degree as to form a large part of the paragneisses.Along the valleys rocks of this type exfoliate under the action of frost and give steep cliffs of variable height.

A few dykes,which are now completely altered to serpentine having a lattice structure,intrude the Grenville series in the vicinity of the magnesite deposits.These dykes seem to have been chiefly peridotites and olivine bearing peroxenites and have been called the Buckingham Series.[1] In this work they are referred to as early differentiates of the Laurentian Batholith and in other areas similar rocks have been shown to be such.[2]

Aegerite granite and syenite dykes from the Laurentian batholith intrude the Grenville Limestones at the Limestone Chute. These are of the nature of pegmatites having a consertal fabric; their shape is extraordinary in that the coarsely pegmatitic phases have a tendency to pinch and swell in some cases completely

1. Memoir 98,C.G.S.
2. Communication from Mr.Colony.

separated.This state is not due to subsequent deformation since the minerals show no deformation whatever and the primary pegmatic structures are still retained.

THE LAURENTIAN GRANITE.

The biotite gneisses which have been described occur next to and are intruded by Laurentian granite batholiths.These intrusive masses form ridges or divides between the limestone areas;near the contact they are highly foliated and contain numerous inclusions of the gneiss which are to be regarded as roof curtains rather than xenoliths since their axes are arranged parallel the the general structure of the region.The inclusions have very nearly the same composition as the magma and as will be shown later this seems to be due to reactions with vapours rather than with the liquid solution of the magma itself.When free from inclusionsor roof remnants,which is the case about two miles away from the contact,the intrusions are pink and contain practically no ferromagnesian minerals but consist of orthoclase and albite feldspar,as separate crystals and as injection perthites in the orthoclase,quartz with exceedingly numerous gas inclusions and many microscopic needles of rutile,a few grains of an aegerite augite,and many magnetite grains.

About three miles from the contact ferromagnesian minerals become more prominent locally and the rock takes on a dark gray to almost black appearance of a diorite,representing a basic differentiate of the magma.

ALGOMAN INTRUSIVES.

Diabase dykes intrude the Laurentian granite but have not been found intruding the Grenville Stock or Batholith.Very femic dykes of the composition of a granodiorite were found associated with this batholith and were intermediate in composition between the deep-seated rock and the diabase;since their composition was

far more femic than the granite of the Grenville stock it seems quite possible that a process of differentiation was going on and that the diabase represents a very early stage of intrusion of the Algoman granite which is here called the Grenville Granite.

The stock itself is about twenty miles in diameter and is composed of a variable granite and syenite rock which in some places is a distinctly red rock and in others is a grayish quartz syenite.The rock is composed of orthoclase,which is usually twinned according to the Carlsbad Law,variable amounts of albite,a colourless quartz,and a green ferrous hornblende.Contrary to the general expectability the granite sometimes contain acid or silic/secretions some of which were found in Brunett's Quarry.

Orthophyres and quartz porphyries intrude the Grenville stock and Laurentian granite about quarter of a mile north of the Limestone Chute.The contact phase is a true graphophyre and consists of quartz and orthoclase as a graphic intergrowth of exceeding fineness;the ferric mineral is specular haematite which is also found along the joint planes of the granite.Microscopic needles of apatite occur as small clusters which are only visible under the very high powered lens of a microscope.The stocks themselves are strongly porphyritic and contain phenocrysts of orthoclase and quartz but littleor no ferromagnesian minerals.The fine grained trap dykes come from these later intrusives.The traps are as a rule felsitic and in rareinstancescarry a sodic hornblende which is bluish green in colour.The porphyritic rocks and the trap dykes represent the extreme products of the differentiation of this magma for this locality and in every case the order of intrusion is in the direction of increasing salic content.

THE PALEOZOIC SEDIMENTS.

The Paleozoic sediments lie unconformably above the older

crystallines.They are but slightly folded and dip at an angle of about five degrees away from the Pre-Cambrian complex.Outcrops are very numerous along the North River in the Town of Lachute especially below the dam at Wilson's paper mills.Since they bear no relation to the magnesite deposits a detailed description will not be included.

QUATERNARY DEPOSITS.

Glacial morrainal detreitus mantles the bed rock in large parts of the area but beyond concealing the outcrops it has no bearing on the magnesite deposits.Nowhere is the deposit very thick in the Pre-Cambrian region but on the plains of the Ottawa Valley if forms thick deposits.

The Champlainian sea stretched far up the Ottawa Valley and formed thick deposits of clay and sand which are extensively cultivated.

North of Lachute extensive areas of drifting sand cover the country.These are probably old loess deposits.They occur in a narrow belt just below the edge of the Pre-Cambrian shield.

THE CRYSTALLINE LIMESTONES AND DOLOMITES.

The deposits of dolomite and magnesite occur in the Grenville Limestone and are intimately associated with the skarn rocks, biotite gneiss and dykes of Laurentian age. Therefore a more detailed account of these rocks in their normal state should be made next.

The crystalline limestones, when free from magnesium carbonate, are blue in colour and coarse in grain. The crystals of calcite range in size from an eighth of an inch to three inches across a face, the grains sometimes have rounded corners and are exceedingly closely interlocking. Usually they are twinned and have a hydrous magnesian silicate developed along the twin planes; this mineral is analogous to spadaite which occurs in the calcite from Burgess.[1] Graphite flakes with parallel arrangement and hexagonal outline occur throughout the mass of the rock; these flakes not only do not occur in the silicates but appear to be pierced by them. Wollastonite (occurs in large nodules or sheaves which weather out and form rough knobs on the calcite mass.

The limestones are intruded by dykes of Laurentian age and by intrusives of the Algoman granite. Near the Laurentian dykes the carbonates have a finer grain and silicates such as phlogopite, chondrodite, scapolite, diopside, pyrope and almandite, forsterite and tremolite are developed in the limestone. Furthermore these minerals and the fine grained carbonates occur only in the crystalline limestone lying below the dykes, the hanging wall remaining practically free and unchanged except for an increse in the size of the grain, the quantity of silicates and the freedom from graphite for a distance of six inches from the dyke.

The carbonate rock below the dykes is more resistant to weathering and corrasion, it is finer in grain, tougher and harder, than the average crystalline limestone; in addition it has a dense

appearance and in the hand specimens does not show twinning of the carbonates .Chondrodite occurs in bands as small yellow grains. Phlogopite is found as pale yellow to bronze coloured flakes which sometimes have a good crystal outline but more often occur in between irregular carbonate grains.Scapolite forms irregular crystals both within and in between the carbonate grains.Diopside and forsterite occur as irregular grains while tremolite is found as long fibres.These minerals are usually altered to serpentine.Pyrope occurs as grains surrounded by a kelyphite rim.Sulphides such as pyrrhotite and chalcopyrite are very common along with these silicates and dense carbonates.Graphite is almost entirely lacking in this type of rock.

A detailed study and examination of the limestones along the West River on Range IX of Chatham Township was undertaken.Representative samples of fresh rock were chipped from areas about a foot square,both above and below,at a distance from and also near to,the dykes of different ages.Analyses of these samples showed that the blue limestone above the dykes contained less than one percent of magnesium carbonate,an average amount of silicates and calcium carbonate.Atypical analysis gave:-

Insoluble	5.7%
$Fe_2O_3 + Al_2O_3$	0.1
$CaCO_3$	91.7
$MgCO_3$	0.8

The material obtained twenty feet to forty feet from the footwall of the dyke showed a similar composition except for a remarkable increase in insolu ble.Some of the analyses are given below.(The insoluble represents the silicate minerals.The silicates and carbonates were separated with one fifteenth hydrochloric acid since it was found by previous experiment that this strength of acid did not affect the silicates but completely dissolved the carbonates

when heated at a boiling temperature for ten minutes).

Insoluble	29.3	37.3	26.1
$Fe_2O_3 + Al_2O_3$	0.2	0.1	1.2
$CaCO_3$	69.1	62.6	72.0
$MgCO_3$	0.0	0.0	0.0

The samples obtained from immediately below the dykes of Laurentian age contained appreciable percentages of magnesium carbonate as is shown by the following analyses:-

	(1)	(2)	(3)	(4)
Insoluble	18.5	17.34	8.2	14.6
$CaCO_3$	70.6	60.2	87.9	59.2
$Fe_2O_3 + Al_2O_3$	0.70	1.3	0.2	2.05
$MgCO_3$	10.15	21.15	3.5	22.15

Samples (1) and (3) are taken about a foot from the dykes while samples (2) and (4) are taken about three feet away.These analyses seemed to show an intimate relation between the dykes and the magnesium carbonates in the limestone.The dykes and the beds of crystalline limestone were then mapped with chain and offset and plotted on a scale of five feet to the inch.The maps show two dykes from three to five feet thick and smaller pegmatites running off from them;these larger dykes and their associated pegmatites are of the same age as the closing stages of the activity of the Laurentian batholith as will be shown from a consideration of their mineralogy and structure.These are in turn cut by a dyke of Algoman age, which is about two feet thick.A sample taken from below this younger dyke gave the following composition:

Insoluble	23.2
$Fe_2O_3 + Al_2O_3$	0.5
$CaCO_3$	76.0
$MgCO_3$	0.0

A sample from above the same dyke gave the following results:-

Insoluble	29.3
$Fe_2O_3 + Al_2O_3$	0.2
$CaCO_3$	69.1
$MgCO_3$	0.0

These analyses seem to show that $MgCO_3$ was not associated with this intrusive

genetically or structurally since the results do not vary appreciably from those for any other part of the Grenville limestone below the Laurentian dykes.

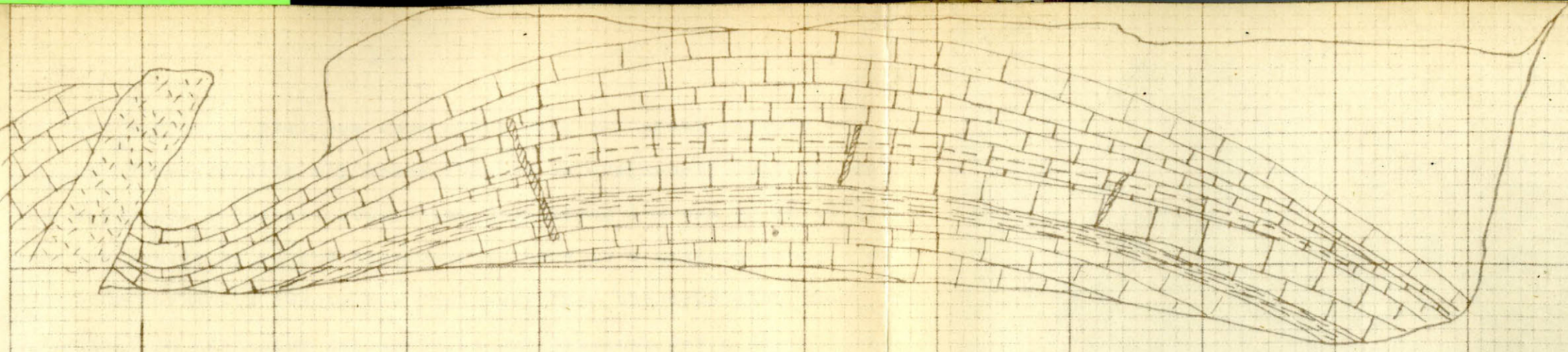
An inclusion of crystalline limestone about eight feet long by five feet wide was found while mapping the larger dykes. This inclusion was sampled after the manner already described,and the sample analysed.It was found to contain:-

Insoluble	16.4
$Fe_2O_3 + Al_2O_3$	2.2
$CaCO_3$	81.6
$MgCO_3$	0.5

Two others were tested for magnesium carbonate,one of which showed a trace and the third none at all.This seemed to show rather conclusively that this series of dykes did not bring in any magnesia bearing waters.

The next step was to find out how the magnesium carbonate was distributed where it did occur.With this point in viewtwo beds which were widely separated and yet seemed representative of the limestones as a whole,were selected and channel sampled.Care was taken to include only fresh rock and to cut the sample as evenly as possible.The chips were gathered for each two feet and placed in individual canvas sacks to prevent any loss of powder which might produce selective salting.The first of these samples began below the large dyke and followed the bed across a pegmatite dyke to another large dyke.The other channel sample began at the second dyke and followed the bed to near the edge of the stream.The samples were analysed in duplicate and the results are given below.For clearness and usefullnessthe analyses are plotted on curves and are also shown on the map on the location from which they were taken.

Nº 2



70

60

50

40

30

20

10

0

COMPOSITION IN PERCENTAGE

$CaCO_3$

INSOLUBLE

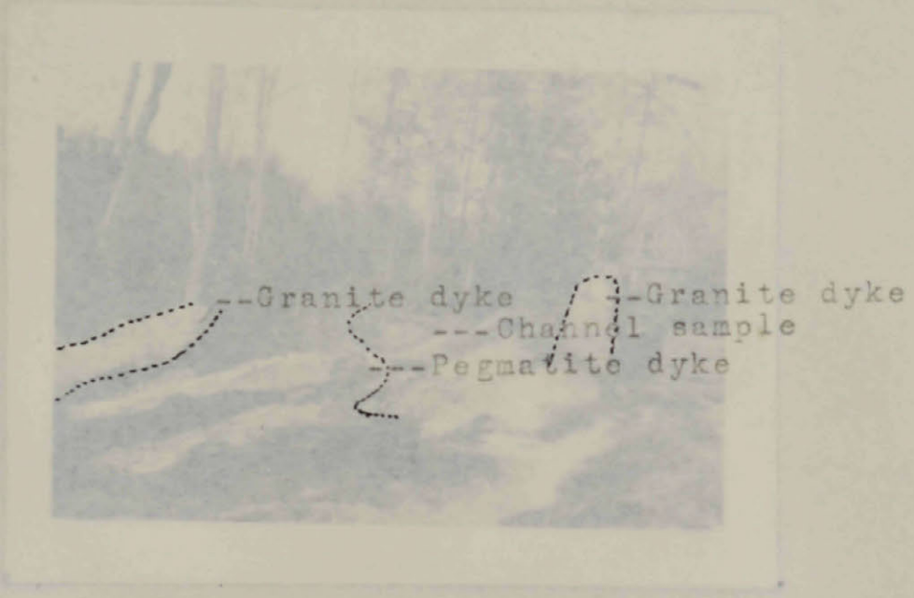
$MgCO_3$

$Fe_2O_3 + Al_2O_3$

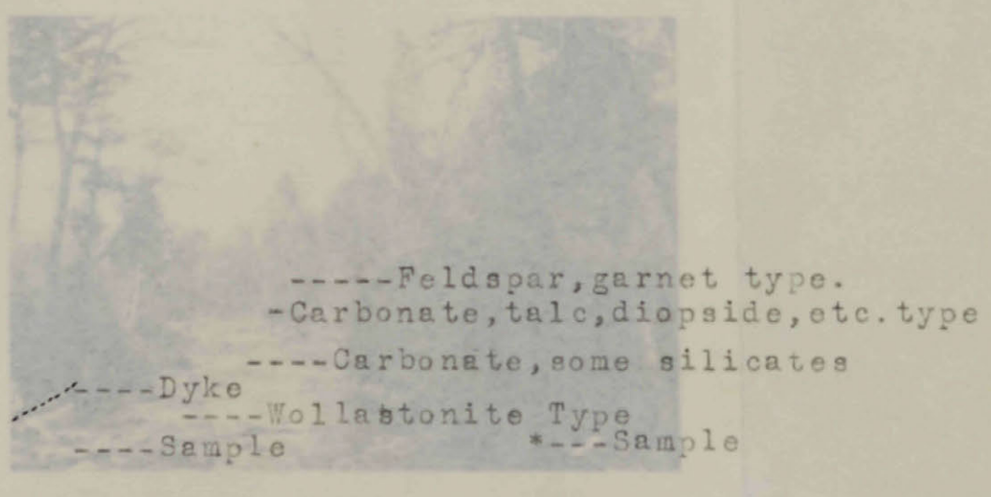
0 4 8 12 16 20 24 28 32 36

DISTANCE IN FEET

Plate IV.



The southern end of the Limestone Chute.The photograph shows the two aegerite granite dykes and a smaller pegmatite.The white lines show the channel sample of Series I.The footbridge crossing the river is seen in the extreme right hand corner.



The Limestone Chute in low water.The white line in the lower left hand corner marks the channel sample of Series II.The water is very shallow and the transition from dolomite to the skarn types may be followed quite readily.





Distance in feet	0--2	2--4	4--6	6--8	8--10	10-12
Insoluble	30.50	26.19	18.50	18.59	19.60	17.54
$Fe_2O_3 + Al_2O_3$	0.50	1.04	0.70	1.04	0.10	1.30
$CaCO_3$	60.85	66.10	70.60	65.75	59.30	60.20
$MgCO_3$	4.32	6.70	10.15	14.65	21.50	21.15

Distance in feet	12-14	14-16	16-18	18-20	20-22	22-24
Insoluble	14.50	29.69	19.00	17.34	12.35	16.74
$Fe_2O_3 + Al_2O_3$	1.00	2.19	1.50	1.04	0.90	1.14
$CaCO_3$	59.40	70.00	70.00	66.25	78.70	74.35
$MgCO_3$	12.40	8.79	9.20	14.70	8.65	7.05

Distance in feet	24-26	26-28	28-30	30-32	32-34	34-36	36-38
Insoluble	12.35	21.80	18.80	31.20	15.10	15.16	15.00
$Fe_2O_3 + Al_2O_3$	0.90	1.81	1.20	2.10	1.15	0.96	1.00
$CaCO_3$	79.00	70.20	71.50	57.40	78.00	77.50	79.00
$MgCO_3$	8.20	6.52	8.70	10.10	6.35	5.64	4.80

In studying both these analyses and those to follow it would be well to bear in ones mind the following facts:-

(1) The beds unless otherwise stated are of uniform thickness over the portion sampled.

(2) The beds dip at about 10°W as shown on the map and meet the dykes at an acute angle.

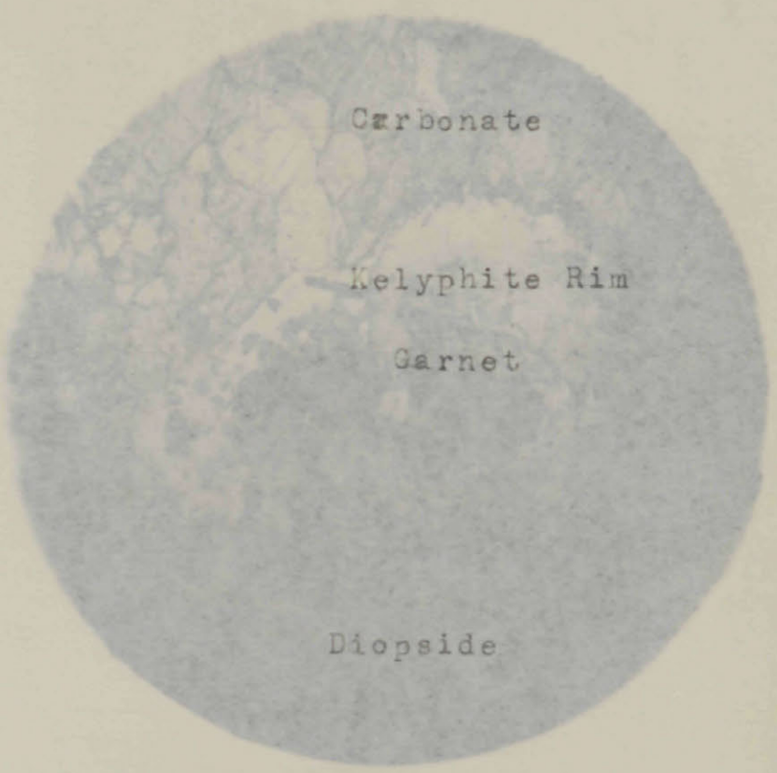
(3) The beds are cut by numerous granite and pegmatite dykes which have a selvage of silicate minerals and coarsely crystalline calcite.

The analyses of samples 2-0,2-4,14-16,16-18,30-32 show a high insoluble content which is due to the selvage of silicate minerals along the dykes.From 0-10 feet the magnesium carbonate increases to a maximum and the change is repeated between 16-20 feet.In both cases it will be noticed that the maximum magnesium carbonate occurs at a distance away from the dyke proportioal to the thicknes of the dyke or to the selvage of silicate minerals and recrystallized zone.

Specimens corresponding to 8-10,24-26,and 34-36 were collected and thin sectioned for examination under the microscope.

The section corresponding to 8-10 showed the rock to be inequigranular and to consist of interlocking grains of calcite and dolomite with a few more or less rounded grains of chondrodite, scapolite,pyrope,pyrrhotite and elongated flakes of phlogopite and graphite.The carbonate grains range in size from 0.2 to 2.0 mms.

Plate V.



Incipient Developement of Garnet.

Ordinary light. Magnification about 30 diameters. The garnet is surrounded by a broad kelyphite rim. Other silicates such as diopside and wollastonite occur along with it.

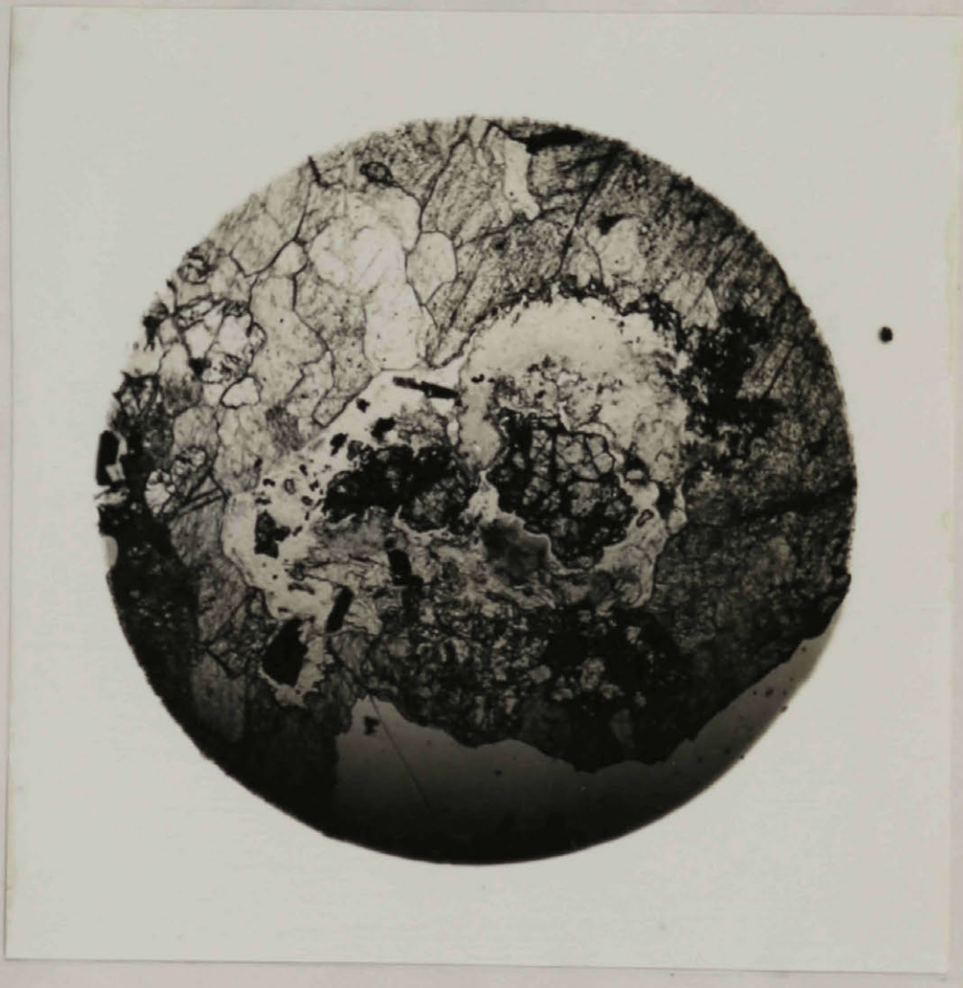
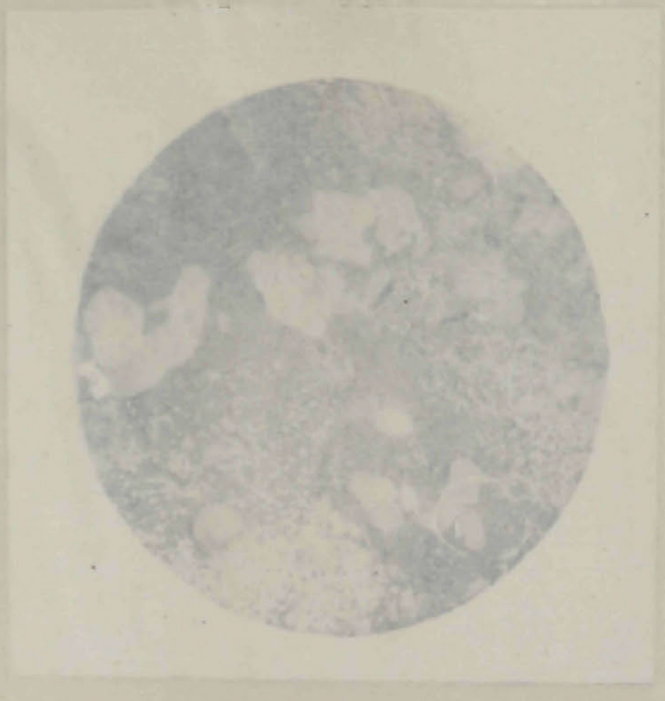


Plate VI.



Microphotograph of polished section treated with Lemberg's solution. Dolomite (white) Calcite (black).

Analysis V, Series (1) was made with this specimen.



Microphotograph of polished section treated with Lemberg's solution. Dolomite (white). Calcite (black).

Analysis III, Series (1) was made from this specimen.

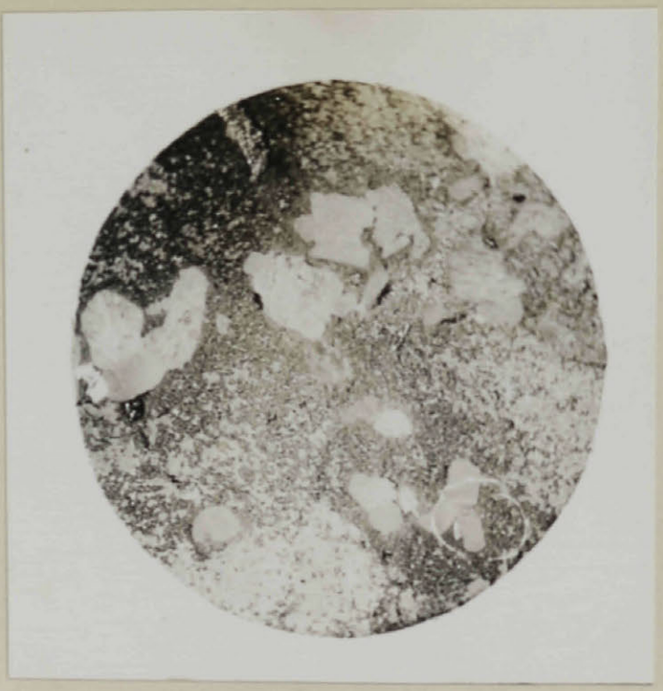
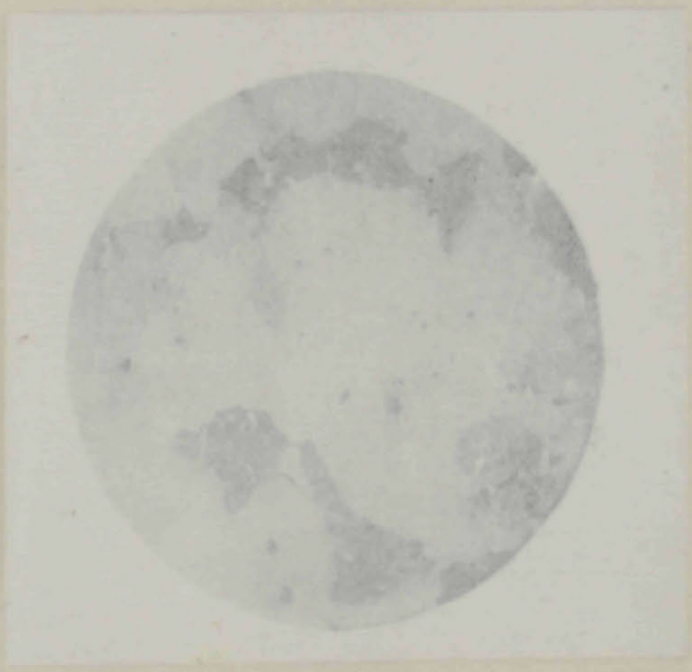


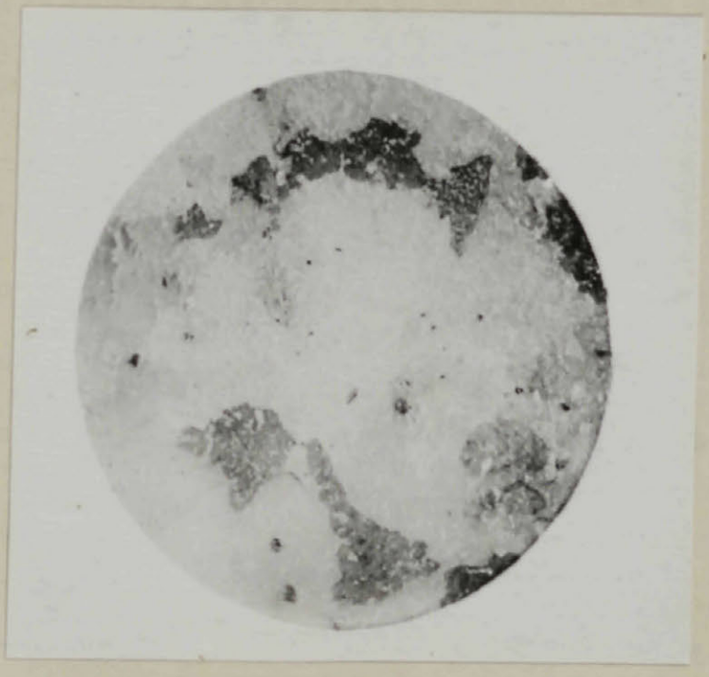


Plate VII.



Microphotograph of polished section treated with Lemberg's solution. Dolomite (white). Calcite (black).

Analysis II, Series (1) was made from this specimen.



in diameter.When the fine grained areas are examined under crossed nicols they are seen to consist of a number of connected grains having simultaneous extinction and twin lamellae broken by a number of smaller grains which extinguish at various angles to one another. Since the enclosing crystals extinguish simultaneously and since the twinning lamellae although broken,are in line they seem to belong to a single grain which has been twinned and in which smaller grains of a different carbonate have developed at a later stage.A polished surface of the rock was treated with Lemberg's Solution and showed that the enclosing crystals were calcite and that the smaller untwinned grains were dolomite.(This was studied on several slabs with the same result so that the characteristics of the small grains just given may be taken to indicate dolomite where it is not advantageous to make a special section or destroy the one in use.A caution may be added that although this holds in this one deposit it may vary for others since the character is due to the method of formation).

Elongated black opaque flakes of graphite and similar flakes of phlogopite occur between the grains and more often in the carbonate grain itself.Neither of these grains occur within or penetrating the silicates.Chondrodite occurs in rounded grains,half a mm. or less in diameter,showing polysynthetic twinning and occuring between the carbonates.These grains are traversed by cracks filled with pale yellow serpentine with a parting of magnetite down the centre of some of the cracks.Scapolite occurs as irregular or rounded grains between the carbonates.Pyrope forms irregular to rounded grains,about half a mm.in diameter and surrounded by a kelyphite rim equal in width to the diameter of the grains.The garnet is slightly fractured and altered to a chloritic material along these cracks.

The rock corresponding to sample 24-26 is equigranular and consists of closely interlocking grains of calcite about five mms. in diameter.Enclosed within the calcite are small irregular grains of dolomite and pyrrhotite.The dolomite has the same relation as before but since the number of dolomite grains is not so numerous the structure is more evident.Graphite and phlogopite occur as flakes within or between the calcite crystals.In some cases the phlogopite is altered to a chloritic material.Chondrodite occurs interstitially or as irregular grains showing polysynthetic twinning.The crystals are fractured and altered to a serpentine as before. Scapolite has the same relationships as chondrodite but shows no twinning ;it is somewhat fractured and altered to a pale green clinochlore.

Section 34-36 shows essentially the same features as the previous setions except that the calcite grains are slightly larger in size and there is a decrease in the amount of dolomite,chondrodite,and scapolite and a slight local increase in phlogopite.

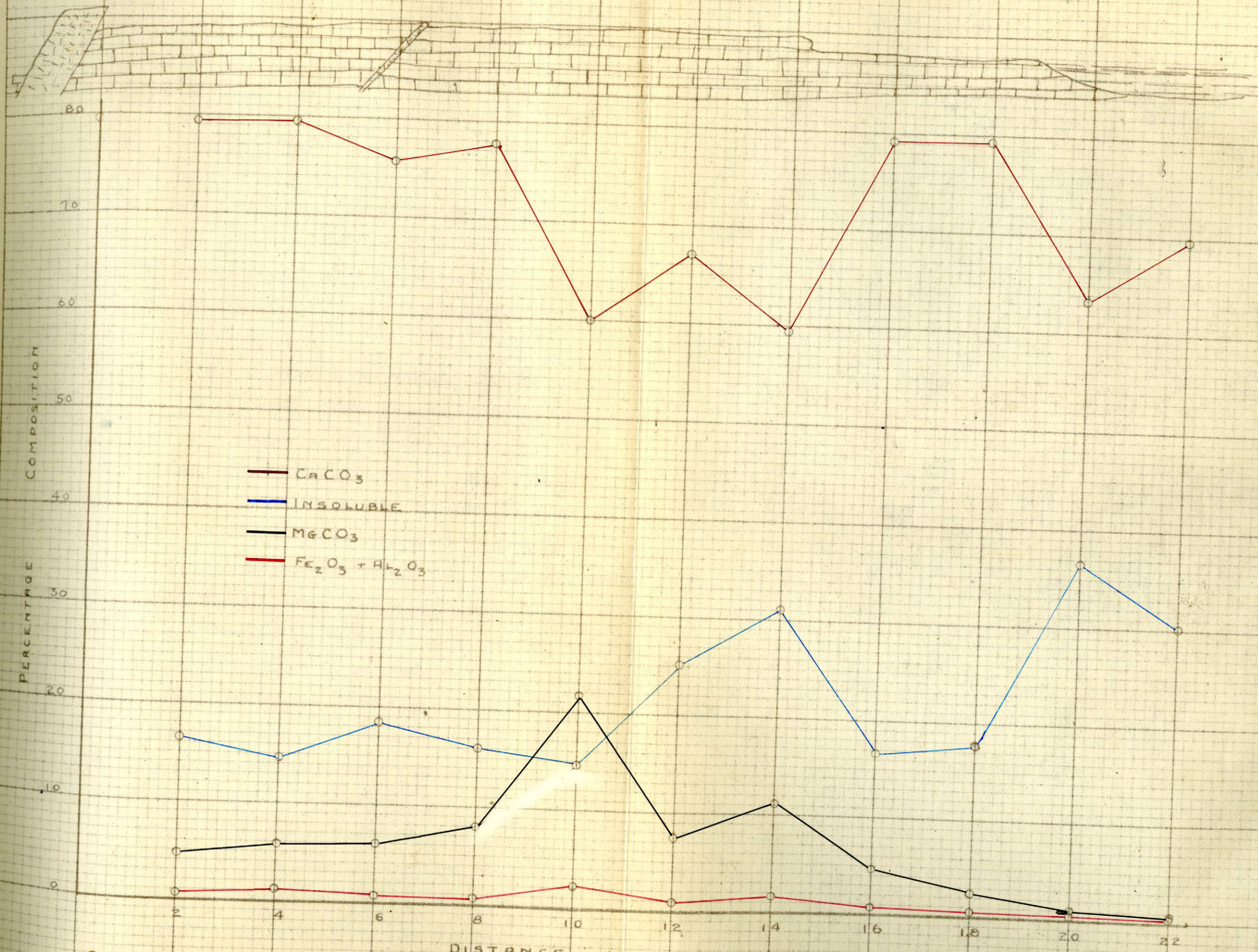
The second series of analyses is somewhat shorter than the first but the results of the two series are in general agreement. The analyses are given below:-

Distance in feet	0--2	2--4	4--6	6--8	8--10	10--12
Insoluble	16.25	14.50	18.25	15.80	14.60	24.75
$Fe_2O_3 + Al_2O_3$	0.50	0.65	0.65	0.90	2.05	0.95
$CaCO_3$	78.80	79.20	75.00	76.70	59.20	66.10
$MgCO_3$	4.81	5.68	5.99	7.77	22.15	7.95

Distance in feet	12--14	14--16	16--18	18--20	20--22
Insoluble	30.05	16.25	17.40	36.60	30.00
$Fe_2O_3 + Al_2O_3$	1.30	0.60	1.15	1.40	0.25
$CaCO_3$	58.85	78.50	78.45	61.85	69.70
$MgCO_3$	10.75	4.47	2.80	0.10	0.07

The high insoluble from 18-20 is due to the large quantity of lime and magnesian silicates present in the limestone along a zone in the limestone at this distance and which seems to occur no matter what bed is in the zone at that paticular distance from the dyke.

Nº 3

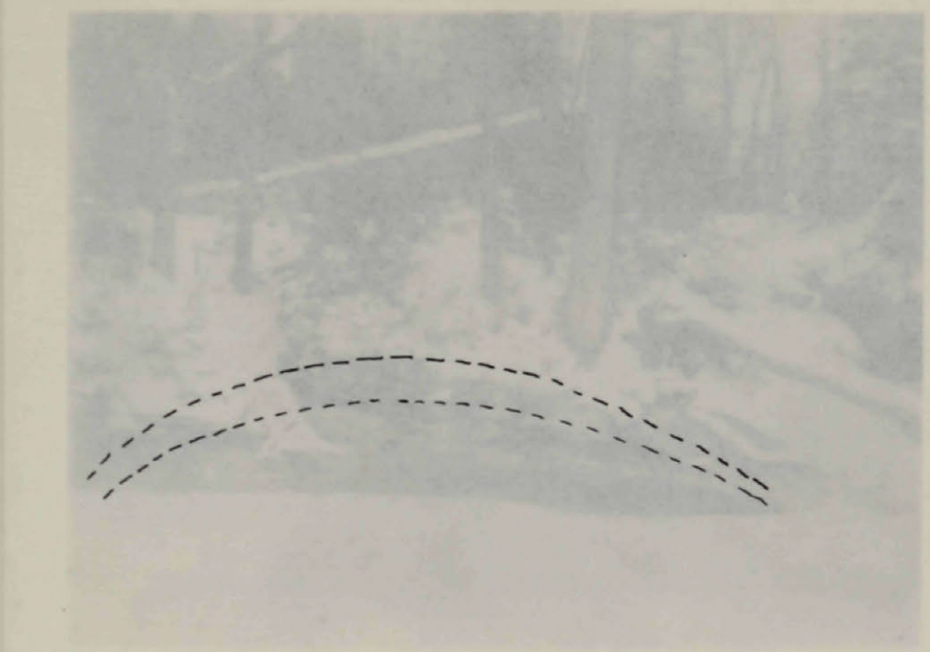

80
70
60
50
40
30
20
10
0
COMPOSITION
PERCENTAGE
$CaCO_3$
INSOLUBLE
$MgCO_3$
$Fe_2O_3 + Al_2O_3$
2
4
6
8
10
12
14
16
18
20
22
DISTANCE IN FEET

The same silicated zone continues to the far side of the stream. This occurence will be explained in the section devoted to the interpretation of the analyses and petrographical descriptions.

The field work was now carried to the far side of the stream to ascertain whether the same relations held when the dyke was followed beyond its intersection with the Algoman dyke.

Analyses showed that both above and below the Algoman dyke and above the Laurentian dyke there was no magnesium carbonate. Below the Laurentian dyke magnesium carbonate occured as had alredy been shown for the other beds. However a number of interesting structures were observed and studied.

The limestones are folded into an anticline which plunges at asteep angle upstream or to the north. The beds of this anticline are quite distinct and are thicker on the crest than on the flanks in about the proportions shown on the diagramatic cross-section above the curve representing the analyses. The arch of the beds has been undermined by the river giving an excellent longitudinal as well as horizontal and vertical cross-sections on a single bed which was somewhat more resistant and resembled the magnesium carbonate facies already described. This bed was traversed by fissures at right angles to the bedding. These fissures extend down to a layer of biotite gneiss or schist about six inches thick where they stop; when followed upward they rapidly die out in the upper limestone. The first of these fissures is about three quarters of an inch wide and is filled by plates or scales of talc crystallized perpendicular to the walls. This fissure is about twelve feet from the dyke. The other two fissures are at 22 and 30 feet from the dyke and are merely gliding planes of small displacement but for an eighth of an inch on either side they are coloured green by an abundance of serpentine. In one case the serpentinization extended for half an inch away on the



Cave at the bend in the River - Limestone Chute. In the centre of the picture the strata are horizontal, while on the right they dip 30° in the that direction. Farther to the left the beds dip in the reverse direction.



Serpentine vein (dark) cutting dolomite beds in the cave.





Uppermost side.Since so many interesting structures were shown and since the rock appeared to be highly magnesian,samples were taken in the same manner as in the other localities,both from a bed across the anticline and from the same bed down the plunge of the structure A large specimen containing the gliding plane of one of the fissures and about eight inches of adhering rock was also obtained by blasting.The samples were analysed in duplicate.Those across the fold yielded:-

Distance in feet	12-14	14-16	16-18	18-20	20-22	22-24:	24-26
Insoluble	5.40	12.69	18.90	7.70	10.60	4.14	7.85
$Fe_2O_3 + Al_2O_3$	0.75	1.10	1.70	0.50	0.75	0.24	0.65
$CaCO_3$	57.00	56.10	55.50	55.00	54.62	55.50	54.60
$MgCO_3$	37.20	29.10	24.50	37.60	34.50	40.95	37.10

Distance in feet	26-28	28-30	30-32	32-34	34-36	36-38
Insoluble	7.25	14.30	6.46	10.40	16.50	20.50
$Fe_2O_3 + Al_2O_3$	0.39	0.75	0.36	1.03	0.65	1.60
$CaCO_3$	55.70	52.70	55.80	51.10	51.90	52.00
$MgCO_3$	37.00	31.25	37.90	36.00	31.90	25.60

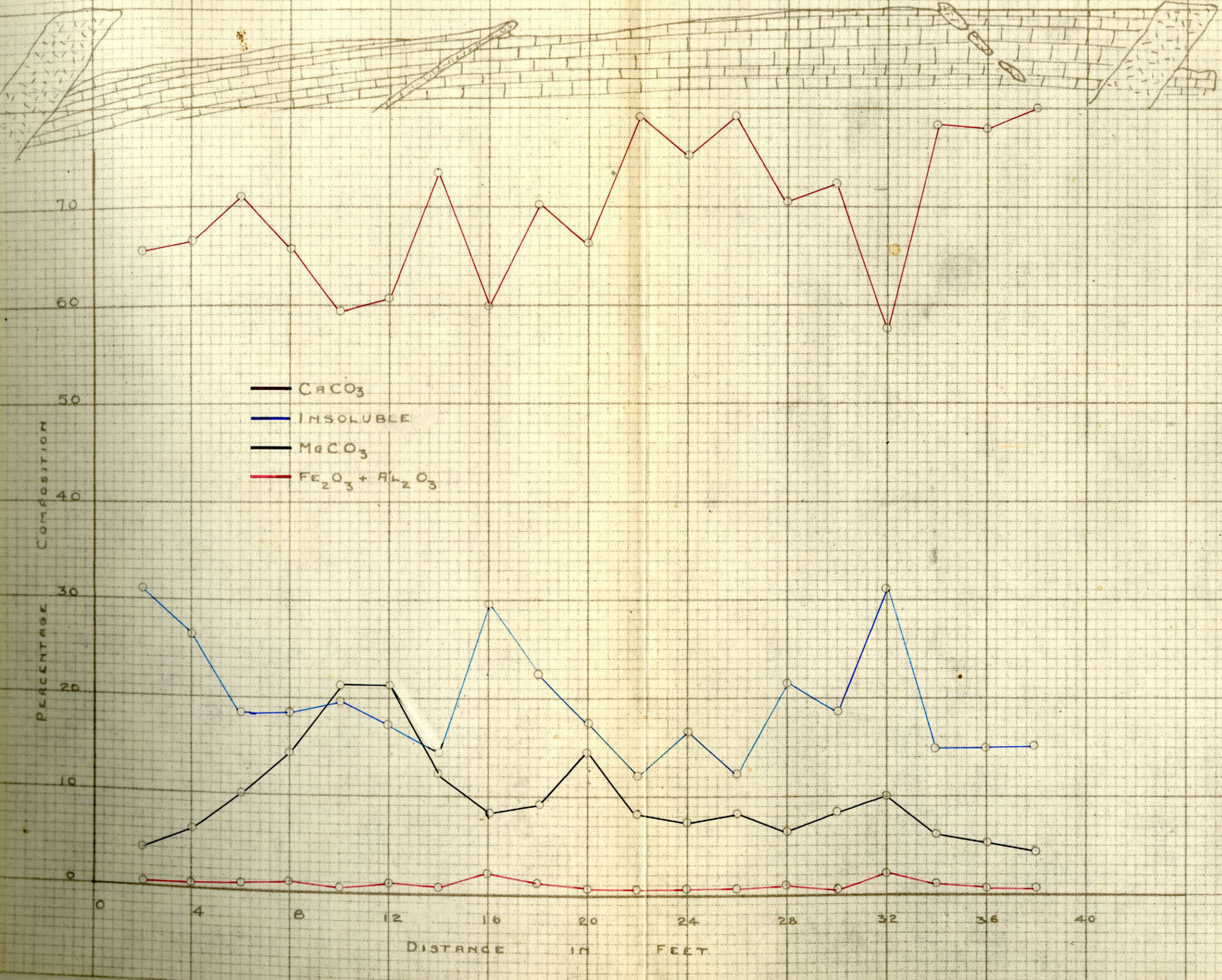
From the analyses it will be seen that the greatest magnesium carbonate is about twenty to twenty four feet from the dyke and that this distance also marks the crest of the fold.It will also be noted that the values are higher near the magnesium silicate veinlets.

The next point ot be considered is the variation of the magnesium carbonate down the plunge of the fold.The sampling and analyses were carried out as usual,the channel sample running,from the channel across the fold,to the waters edge.The analyses of the samples are given below:-

Distance in feet	0--2	2--4	4--6
Insoluble	6.46	8.66	12.91
$Fe_2O_3 + Al_2O_3$	0.36	0.66	1.26
$CaCO_3$	55.80	54.00	54.10
$MgCO_3$	37.90	36.80	31.30

The analyses show a continuous decrease in magnesium carbonate and increase in insoluble as the bed is followed down the plunge of the anticline.

Nº 1


70
60
50
40
30
20
10
0
PERCENTAGE COMPOSITION
$CaCO_3$
INSOLUBLE
$MgCO_3$
$Fe_2O_3 + Al_2O_3$
0
4
8
12
16
20
24
28
32
36
40
DISTANCE IN FEET

The last two series of analyses apparently show different results or are out of accord with all those obtained before (namely that the maximum magnesium carbonate occurs ten feet along the bed or about two feet vertically below the dyke) because here is a maximum content of magnesium carbonate twenty two feet away from the dyke; also the percentage of magnesium carbonate is not constant for a given distance from the dyke because the samples taken down the plunge are at equal distances from the dyke and their composition shows a regular variation as has been pointed out. It will be remembered that the magnesium carbonate occured only on the footwall side of the dykes so that perhaps the dykes formed a favourable structure. These questions of structure will be taken up later.

In the analyses it was noticed that the magnesium carbonate values rose near the serpentine and talc veins. When this was found out the large specimen, containing the vein and the adjacent serpentenized zone as well as the adhering carbonates was analysed and gave the following results:-

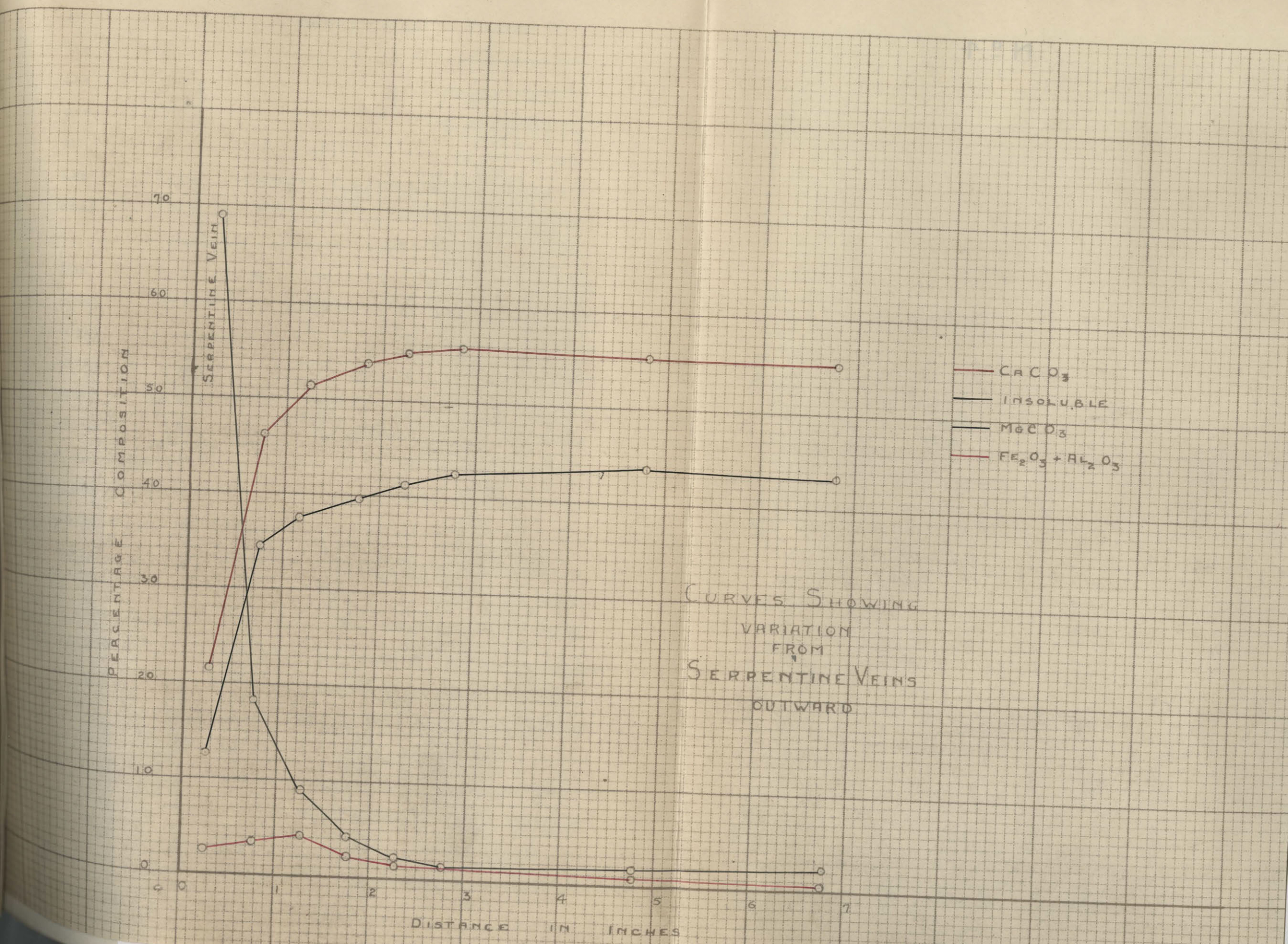
Distance in inches	0	0--0.5	0.5--1	1--1.5	1.5--2	2--2.5
Insoluble	68.45	18.40	8.50	4.35	2.00	1.30
$Fe_2O_3 + Al_2O_3$	1.20	1.50	1.75	0.65	0.60	0.50
$CaCO_3$	17.85	46.50	51.50	54.70	55.00	56.00
$MgCO_3$	12.70	34.20	37.80	39.75	41.20	42.80

Distance in inches	2.5-4.5	4.5-6.5	6.5- 8.5	8.5-24.0
Insoluble	1.70	2.10	4.14	7.85
$Fe_2O_3 + Al_2O_3$	0.40	0.25	0.24	0.65
$CaCO_3$	55.70	55.50	55.50	54.60
$MgCO_3$	44.00	43.50	40.95	37.10

The analyses show that the vein and the adjacent wall rock contain a high percentage of silicates, but that farther out the magnesium carbonate reaches a maximum and then begins to decrease. From this it would appear that fissures mineralized by magnesium silicates are related to an increase in the magnesium carbonate.

The serpentine veins were examined both in the hand spec-

Nº 4



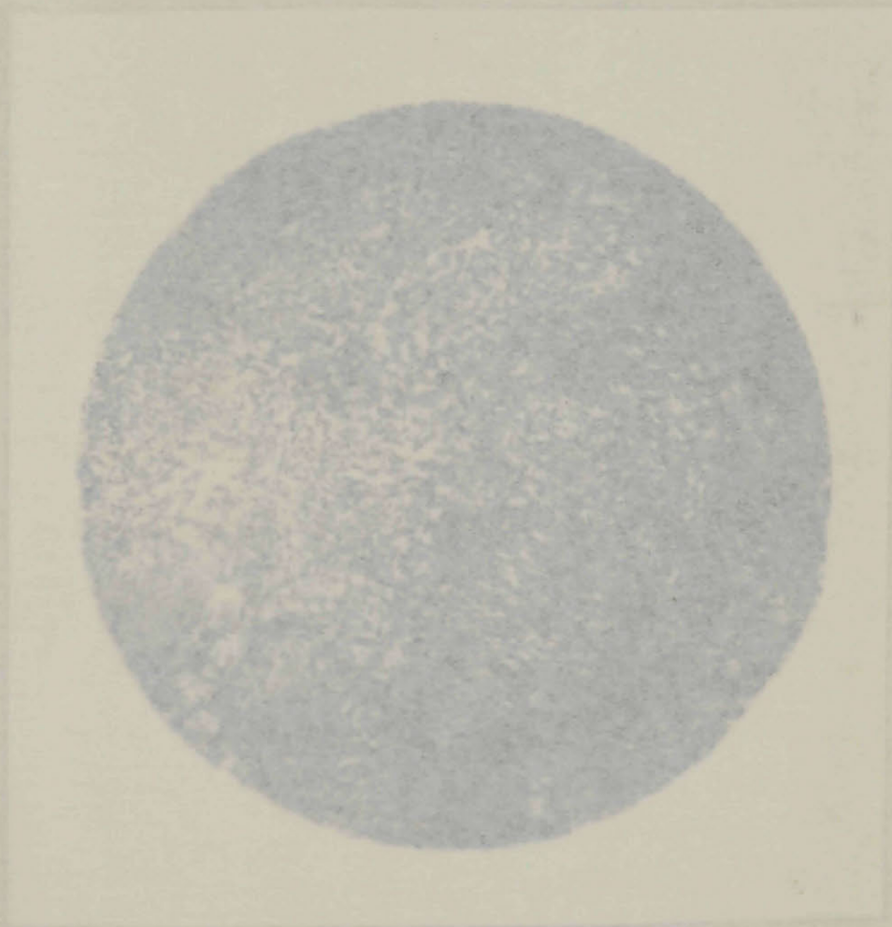
CURVES SHOWING
VARIATION
FROM
SERPENTINE VEINS
OUTWARD

imen and in thin sections.One of the veins was serpentinous only locally and the thin sections examined were taken from a portion low in serpentine.The second vein was largely serpentinous along the fracture.Sections of both the vein and the adjacent rock were prepared for study.The type of vein first mentioned will be described first and the other later.Three sections were prepared in each instance,first a section of the vein,second a section half an inch away from the vein,and third a section an inch away from the vein.

A section of the rock an inch from the vein showed that the specimen consisted of small irregular interlocking grains of dolomite and some large twinned crystals of calcite surrounding them.It has already been mentioned that the twin lamellae may come up against a dolomite crystal and become obscure only to come into evidence again beyond the grain.Occasionally however the twinning plane can be recognised in the dolomite crystal by the presence of a foreign silicate but cannot be due to the twinning of the dolomite since the axes of the dolomite are almost invariably inclined to those of the calcite.Apparently the twinning of the calcite antedates the formation of the dolomite grains.Scapolite occurs as fresh rounded or irregular grains,from 0.05 to 0.5 mms. in diameter,intersticial to or surrounded by the carbonates.Small grains of twinned chondrodite,flakes of graphite,rounded grains of pyrrhotite and crystals of phlogopite occur in the carbonates.

A section of the vein as well as the adjacent rock for half an inch away showed a decreasing amount of carbonate,in which the dolomite and calcite were intergrown.The vein showed a small amount of serpentine which gave the rock a green colour but the main portion was a mosaic of scapolite and chondrodite in a matrix of dolomite.A single band of fibroud serpentine stretches across the section.

Plate IX.



Intergrowth of Calcite, Dolomite and Diopside.

Crossed nicols. Magnification about 30 diameters. The section is taken from within half an inch of one of the silicate veins and contains about 18.25% of insoluble or silicates. The silicates and dolomite have a higher relief (in this photograph) than calcite. Much of the replacing material of the intergrowth is dolomite; even some of the silicates are carbonated.



The vein of the second series is of a more highly serpentinized nature and different minerals and arrangements of minerals are found in the sections.A specimen taken half an inch from the vein consisted of an interlocking mass of calcite grains about two mms. in diameter,filled with small dolomite grains from 0.1 to 0.5 mms.in diameter.Intergrowths of twinned calcite and untwinned dolomite are common.The silicates present were forsterite,scapolite, chondrodite and serpentine.Forsterite,which occurs in grains about one mm. in diameter is somewhat fractured and altered to a colourless serpentine;sometimes the fibres form a matted aggregate while at others they have a radial arrangement.The serpentine is associated more with the fractured rounded grains of chondrodite than with the forsterite.

A section taken half an inch from the fissure showed an increased developement of the silicates and a pronounced intergrowth appearance in the carbonates.

A section containing the vein and a portion of the adhering limestone showed an almost complete absence of calcite.However the developement of another carbonate probably magnesite has begun in the dolomite.Chondrodite and scapolite occur as minute grains 0.05 mms. in diameter scattered through the rock.On the margin of the vein itself,serpentine is developed in the carbonate and usually shows aggregate polarization but more raely occurs as veins of chrysotile about 0.05 mms.wide.

An analysis of the vein which was described first gave:-

SiO_2	40.37
Fe_2O_3 (FeO	0.31
Al_2O_3	3.24
CaO	28.52
MgO	17.10
Loss on ignition	10.83

All the analyses were plotted on curves and then it became apparent that high magnesium carbonate and low insoluble or low magnesium carbonate and high insoluble always corresponded.The problem then arose might not the process known as dedolomitization have caused the magnesia to enter into the silicates where the insoluble content was high and the magnesium carbonate low,that is,was there any change in the magnesia content of the rock?Such a process had been believed to account for the variation in the Grenville and other recrystallized limestones.Complete analyses were made from samples corresponding to a large number of the proximate analyses already given,with a view to proving or disproving any question which might be raised in connection with this problem.The results obtained were as follows:-

Series I,(extending from dyke to dyke).

Distance in feet	4--6	8--10	14-16	20-22	36-38
SiO_2	6.45	7.00	0.67	4.97	5.93
Fe_2O_3) FeO)	0.62	1.11	0.62	0.31	0.51
Al_2O_3	2.60	1.95	8.44	3.49	1.96
CaO	39.60	33.10	34.35	44.40	46.40
MgO	13.55	20.84	13.61	7.51	7.32
CO_2) H_2O)	36.15	35.50	31.39	38.44	38.44
K_2O) Na_2O)	1.58	0.55	1.53	0.66	0.00
	100.55	100.05	99.61	99.78	100.56

From a comparison of these analyses with those alredy given it will be seen that the magnesia and the magnesium carbonate vary in the same way and that there is no evidence either from the chemical analyses nor from the thin sections that the silicates are formed by the recrystallization of the limestone with or without the addition of nothing but silica from the neighbouring dykes;on the contrary they seem to show a regular variation in silica,alumina, iron oxides,lime and magnesia which could not have been possible in the original sediments.

Another series of analyses corresponding to Series II,or from the dyke to the river,was also made.It seems to confirm thec results of Series I.

Distance in feet	8--10	10--16	20--22
SiO_2	6.00	6.65	16.05
Fe_2O_3)	0.42	0.42	1.54
FeO)			
Al_2O_3	3.33	2.63	0.14
CaO	35.83	44.91	46.65
MgO	14.00	5.00	5.25
H_2O)			
CO_2)	39.35	37.45	30.80
K_2O)	Not determined		0.00
Na_2O)			
	99.93	97.06	100.43

THE SKARN ROCKS.

The general occurance and geological relationships of the skarn rocks has been given,in as detailed form as is necessary,in the section devoted to the general geology of the region as a whole. However a more detailed account with special reference to chemical and mineral composition is necessary in order to fully appreciate the extreme metamorphic processes that have been acting on the limestone in the region of the contact zones.The first series of changes which involves the silication of the limestones and developement of skarn rocks,was studied by following a single bed outcropping in the bottom of the West River at the Limestone Chute,and also in the vicinity of Campbell's dam on the Middle Branch of the West River near Dalesville.Excellent specimens had just been blasted out while excavating a bed for a waterwheel.

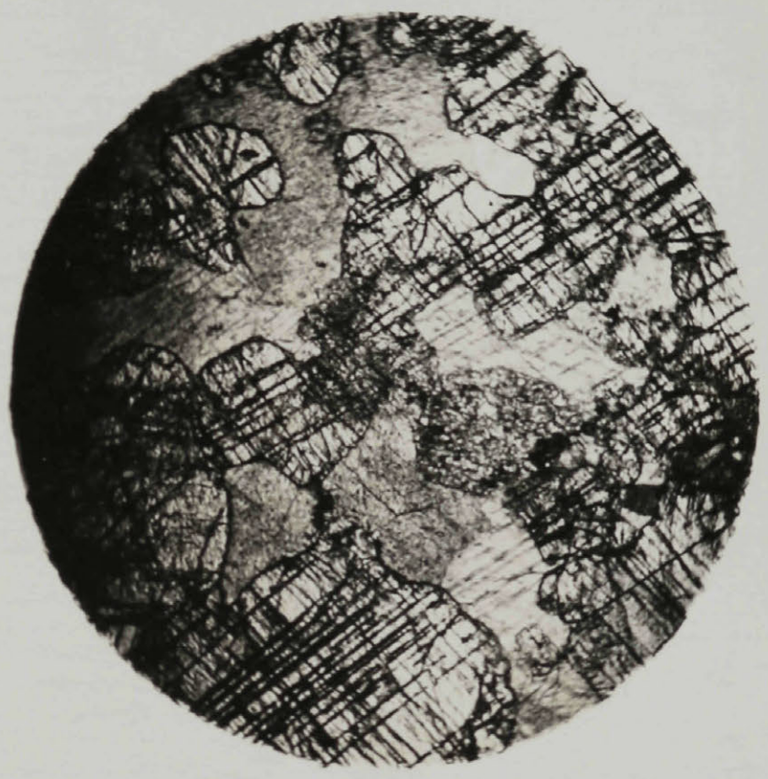
When the bed is followed from the dolomitized zone below the dyke it becomes at first highly silicated due to the presence of many knots of wollastonite.This zone is succeeded by another much richer in calcite;this last zone becomes richer in silicates until at the head of the Limestone Chute only a small amount of calcite and dolomite remains as interstitial grains rather than the matrix of the former rock.It might be argued that in the Grenville limestone a bed might be too severely crumpled to be followed with great exactness but such is not the case;even if the crumpling was exceptionally severe and a bed a few feet away was mistaken for the one being followed,it would make no difference since the bed chosen lay in the centre of a broad,uniform limestone series exposed in the bottom of the stream and the entire series changed to skarn rock of the type about to be described in a distance of from six to eight hundred feet,the distance being measured along the strike from the carbonate series described above as crystalline limestone.It is equal

Plate X.



Diopside Type of Skarn Rock.

Ordinary light. Magnification about 30 diameters. The diopside (high relief) is growing all through the carbonates. The area outlined is an intergrowth of two carbonates, dolomite and calcite, in such a way as to give a micrographic structure the pseudoeutectic structure of some writers.



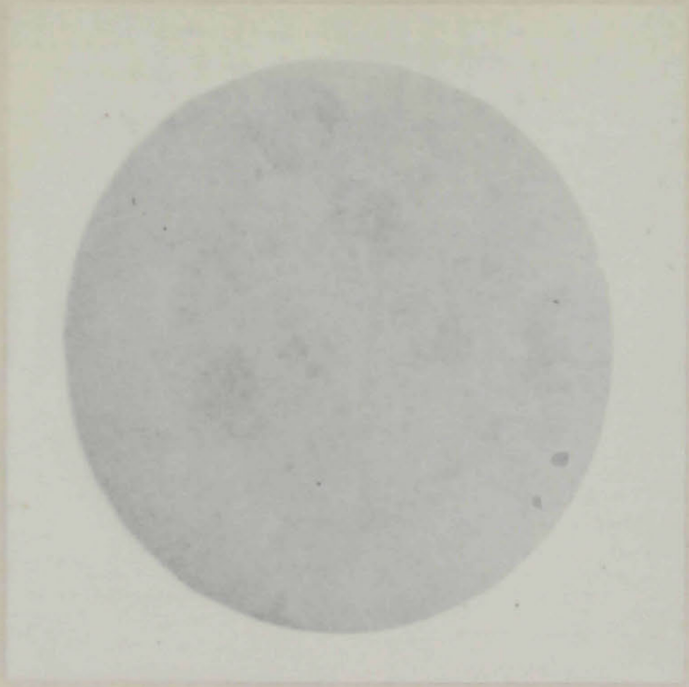
ly impossible to expect an almost pure limestone to change in character and composition to such an extent as would give a difference in composition equal to that found in these rock types.(In field work in less metamorphosed sediments occuring lateral to shales the author has found it unusual to find an equal variation in a distance of one mile much less in a distance of eight humdred feet).

The first skarn type to be encountered had a coarsely granitoid texture and massive structure."hen examined more carefully under the microscope the carbonates present were found to be calcite and dolomite intergrown so as to give a pseudoeutectic structure. Their behavior,such as twinning and orientation,were the same as before and need not be described here.Secondary strain effects were shown by bent micas and a slight granulation of the other minerals. The twinning of the calcite is also indicative of excessive strain. The mineralogy of the type is comparitively simple and the following minerals are present in approximately the percentages indicated.

Diopside\	47%
Wollastonite\	
Phlogopite	5%
Calcite \	45%
Dolomit e\	
Pyrrhotite	2%
Magnetite	1%

The carbonates and pyroxene make up the major portion of rock and the other minerals may be regarded as minor accessories. The relation of the pyroxenes to the carbonates is such that the carbonates surround or nearly surround the pyroxenes and occur as small patches having the same orientation within them.This relationship strongly suggests a replacement of the carbonates oy the pyroxene The phlogopite is usually flaky but sometimes occurs as spherulites and bundles about a mm.in diameter.Numerous grains of magnetite and pyrrhotite occur scattered through the calcite.

Plate Xa.

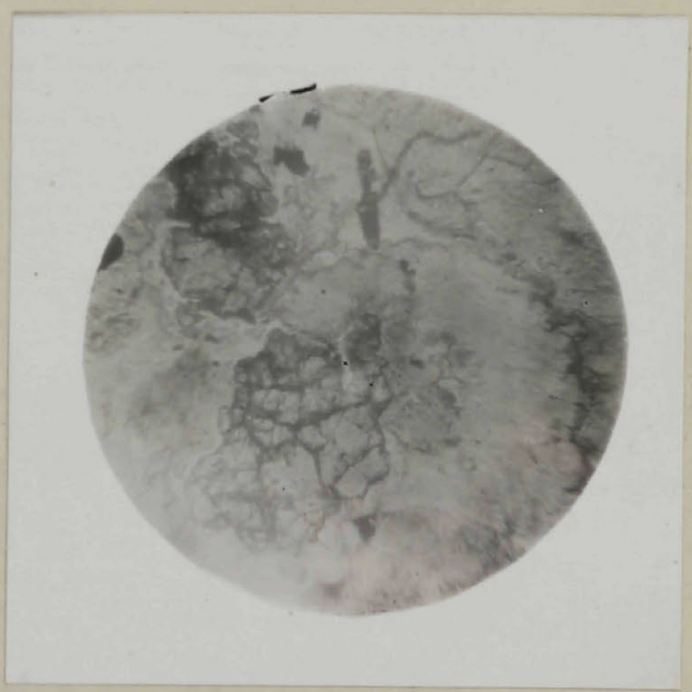


Microphotograph of almandite growing in diopside, feldspar, talc rock.



Garnet, with kelyphite rim, growing in dolomitic limestone.





After a few feet this skarn rock gives place to a type almost entirely free from carbonate and containing feldspars some of which show polysynthetic twinning.As before the texture is granitoid and a poor pseudoeutectic structure occurs in an otherwise simple,massive rock.The minerals present show the result of intense contact action and possibly slight granitization although the effect of the latter process is reflected more in the composition than in the structure.The minerals present include:-

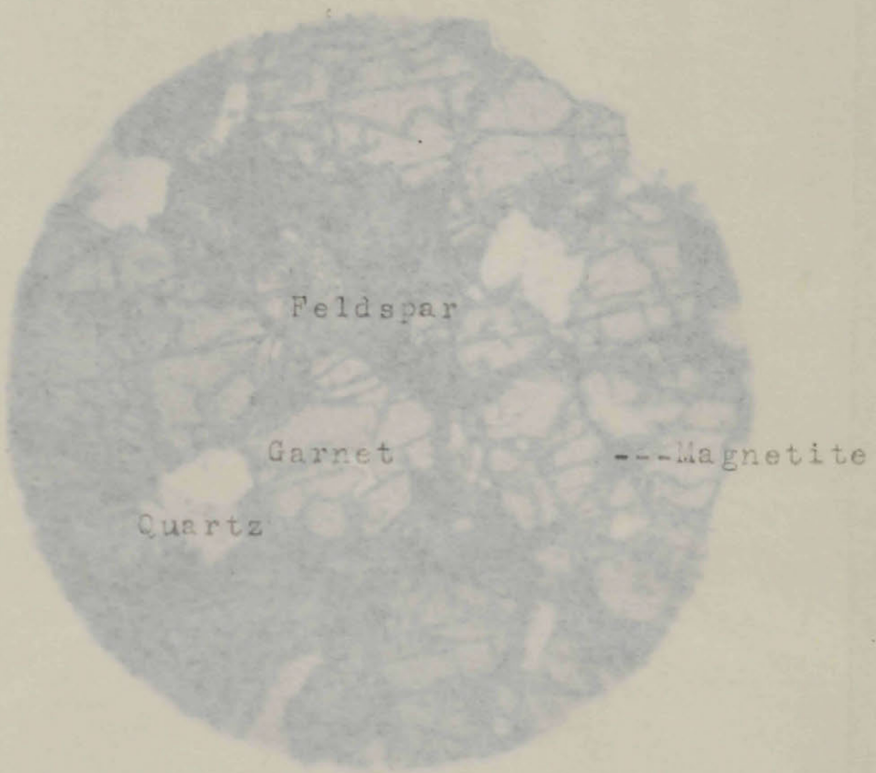
Orthoclase)	75%
Andesine)	
Almandite	10%
Pyroxene	4%
Carbonate	8%
Phlogopite	1%
Magnetite)	2%
Pyrrhotite)	

The calcite occurs interstitially and is much cut up by the feldspar growing through it.As a rule the feldspars are small and very irregularly shaped in such a way that they could not have possibly originated in crystal outgrowths from sand grains.

Several cloudy dark areas occur in the slide.These are due to badly fractured diopside,with many small isotropic crystals which appear to be almandite,traversed in all directions by innumerable microscopic cracks in part filled by dusty opaque magnetite.The contact of the minerals having different indices of refraction and the presence of dusty magnetite both tend to prevent the passage of light and give a cloudy appearance which can only be resolved under the high power of the microscope.

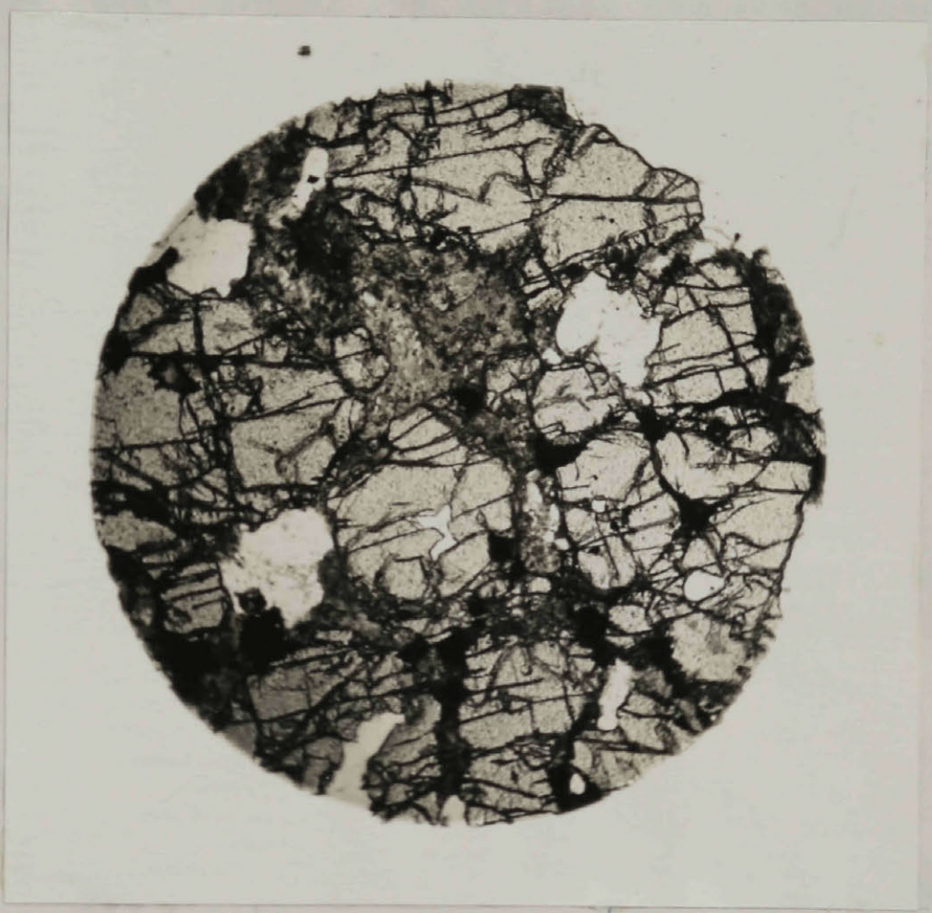
The feldspars seem to be incipient growths of innumerable small crystals oriented in nearly the same direction so as to give the appearance of a single crystal.When sections perpendicular to an optic axis are examined in convergent light under the high power of a microscope they give a curved brush which is extraordinarly wideand points to the above method of formation.

Plate XI



Feldspar, Garnet skarn Rock
or
Garnet Gneiss.

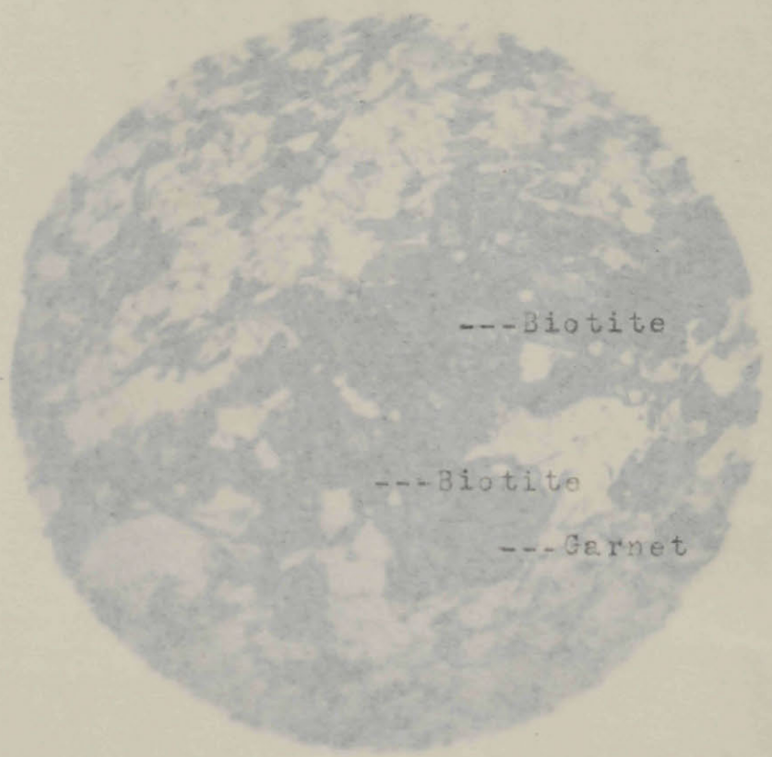
Ordinary light. Magnification about 30 diameters. The microphotograph represents a garnet rich portion of the skarn rock from near Campbell's dam. The garnet is badly fractured but not altered to any degree. Scattered areas of magnetite (black) occur at the intersection of the various fissures. The clear white areas are quartz and the cloudy areas feldspar. In the average rock the feldspar is much more abundant.



The rock found at Campbell's dam is of essentially the same composition except that it contained about eight percent of quartz and more almandite.The change was offset by the exclusion of phlogopite,pyrrhotite,a large part of the pyroxene and some of the feldspar.In making the excavation for the waterwheel some dolomite containing mica,graphite,and garnet was blasted out but since the machinery has been put in place the outcrops furnished were not accessible for a study of the structural relations;the occurrence is merely mentioned for the sake of the record which might otherwise be lost.The information and samples were given by Mr.Arthur Campbell who made the excavation.The garnet rocks outcrop behind the sawmill and both these and the garnets in them were analysed.The composition was as follows:-

	Garnet rock	Garnet	Garnet
SiO_2	53.10	41.15	41.33
Al_2O_3	24.38	20.60	20.77
Fe_2O_3	2.86	Tr.	Tr.
FeO	11.21	30.09	30.05
MnO	Tr.	Tr.	Tr.
CaO	1.16	2.41	2.37
MgO	2.40	5.73	5.67
K_2O	1.40	----	----
Na_2O	2.94	-----	----
H_2O	0.60	----	----
	100.14		

Plate XII.

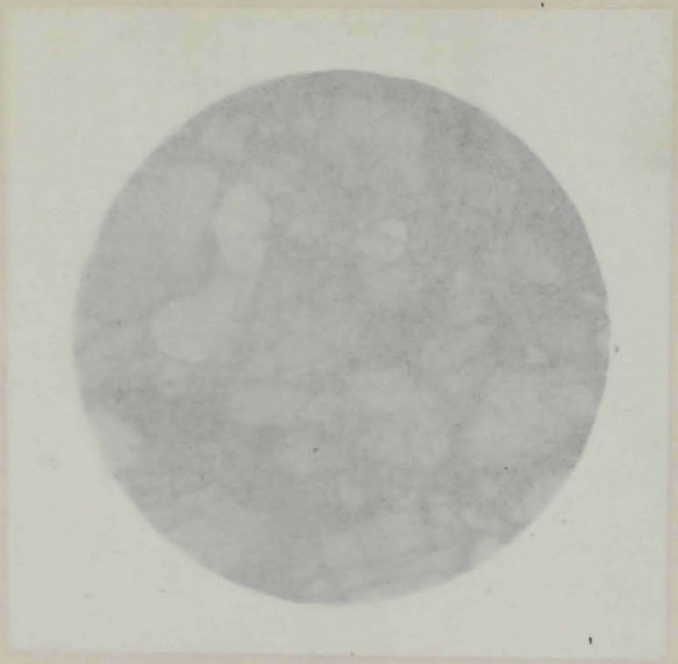


Biotite Garnet Gneiss.

Ordinary light. Magnification about 30 diameters. The garnet is badly fractured and altered to chlorite (dark) along the fractures. Some of the larger dark areas represent brown biotite, some of which was analysed. The dark areas in the remainder of the rock represent biotite. The light coloured minerals are quartz and feldspar.



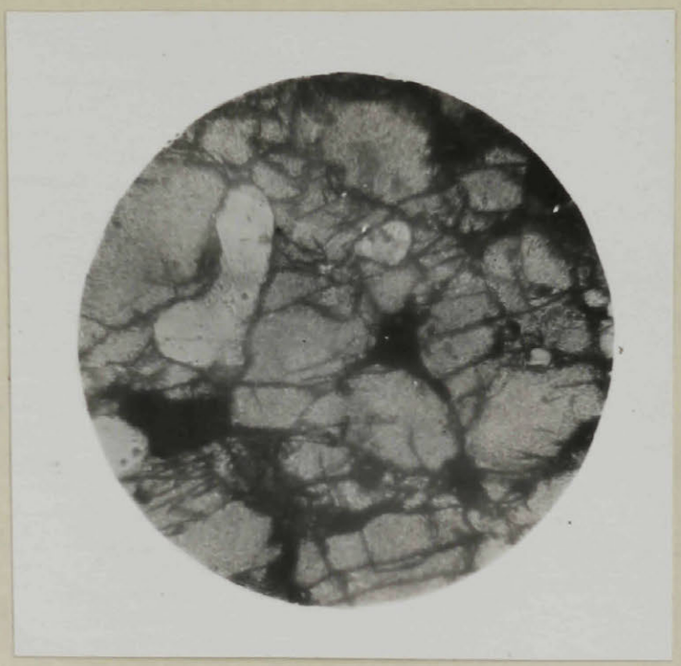
Plate XIa.



Microphotograph showing limestone entirely replaced by garnet, magnetite, quartz and feldspar.



Crushed garnet altered to chlorite along the fractures. The chlorite is being replaced by biotite.





THE BIOTITE GNEISS.

In a preceeding part of this work it was observed both from the chemical analyses and the examination of the thin sections under the microscope that the highest magnesium carbonate occurs on the crest of the plunging anticline and especially near the serpentine veins which pass down into a thin layer of biotite garnet gneiss or schist but do not pass through it.When followed up wards the veins pinch out,after a few feet,in the crystalline limestone.

A number of specimens of biotite gneiss were collected and examined both in the hand specimen and in the thin sections.The rock has a foliated structure and if it were not for the large amount of quartz,orthoclase,and plagioclase present the rock might be classed as a schist rather than a gneiss.Anotherstriking feature about this gneiss is the mottled surface due to what appears to be almandite garnets about five mms.in diameter.The gneisses are intruded by pegmatite dykes from the Laurentian granite.

When the biotite gneiss is examined under the microscope it is seen to have the same marked foliated appearance .The texture is inequigranular and lacks uniformity;the mineral composition is likewise very irregular.An average of several sections showed that the rock contained about:-

Biotite	15%	Almandite	5%
Quartz	25%	Sillimanite	5%
Chlorite	15%	Carbonates	3%
Orthoclase	12%	Diopside)	2%
Andesine	15%	Sericite)	

The oldest mineral and what was once the main constituent of the rock is almandite.It is badly fractured and altered to chlorite along the cracks.Magnetite accompanies the chlorite.In places garnet and chlorite derived from it fill the field of the microscope while in others the chlorite has been largely replaced by biotite having a brown to dark brown colour.Sillimanite occurs

Plate XIII.

Biotite Garnet Gneiss.



Biotite Garnet Gneiss.

Ordinary light. Magnification about 30 diameters. The photograph shows a large garnet almost completely altered to chlorite and magnetite (fine black spots). The chlorite is changing to a light coloured biotite which in many cases becomes a dark brown by reaction with magnetite. The white areas are quartz and the clouded areas feldspar.



as well developed prisms 0.05 to 0.5 mms.in diameter,along with the biotite developed from the chlorite.The sillimanite itself is changed to chlorite in many instances to such an extent that only the prismatic outline remains.The flakes of chlorite are usually arranged parallel to the cleavage.The orthoclase is highly sericitized but may be recognised by its cleavage and low polarization between crossed nicols.Biotite and quartz are the only un attacked minerals in the rock and even the biotite was bleached in one or two instances.

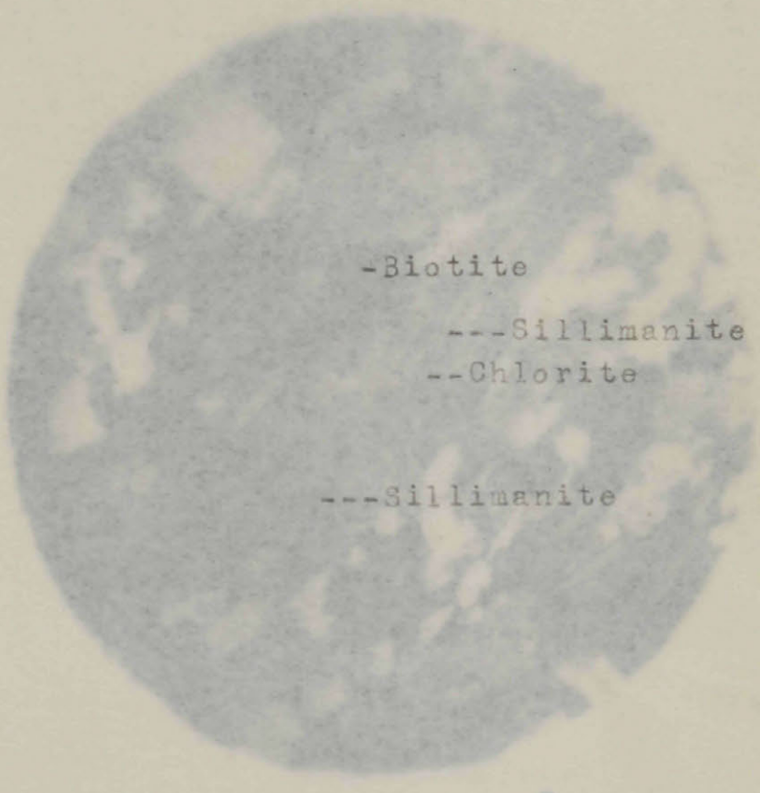
The biotite gneiss and the biotite were analysed and the results are given below.The analysis of the Laurentian granite/gneiss is also included;this analysis was made by Dittrich[1] and the specimen came from just north of Lachute.

	Biotite	Biotite gneiss	Granite
SiO_2	36.93	55.91	59.89
Al_2O_3	22.32	18.44	22.32
Fe_2O_3	15.53	2.37	1.95
FeO	1.41	7.42	2.71
CaO	2.73	3.50	2.53
MgO	9.22	3.61	1.56
MnO	Tr.	Tr.	----
K_2O	3.07	1.13	5.83
Na_2O	3.12	2.08	5.74
TiO_2	---	---	0.96
P_2O_5	---	---	0.17
CO_2	---	)	0.39
H_2O	)	)4.74	0.29
F	)4.6°	)	----
	99.01	99.20	104.34

A comparison of the analyses of the garnet gneiss,biotite gneiss,and granite/gneiss will serve to show that there has been a shift in composition in the direction of that of the granite.This feature is even more pronounced in the field since in the vicinity of Mud Lake east of the Limestone Chute the biotite almost entirely disappears and the feldspar and quartz increases.This variation in chemical and mineralogical composition is so gradual that it is impossible to tell where the paragneiss ends and the granite begins. The change in composition has not been due to extensive intrusion of

1. Annual Report of C.G.S.-Vol.XII-1899.

Plate XIV.



Biotite Garnet Gneiss.

Ordinary light. Magnification about 30 diameters. The photograph shows a part of the rock in which the garnet has almost entirely dissappeared. Biotite is abundant and a few sillimanite needles are present. The sillimanite(white of the crystal) is seen to be altering to chlorite along the cleavage planes. Biotite is replacing the chlorite.



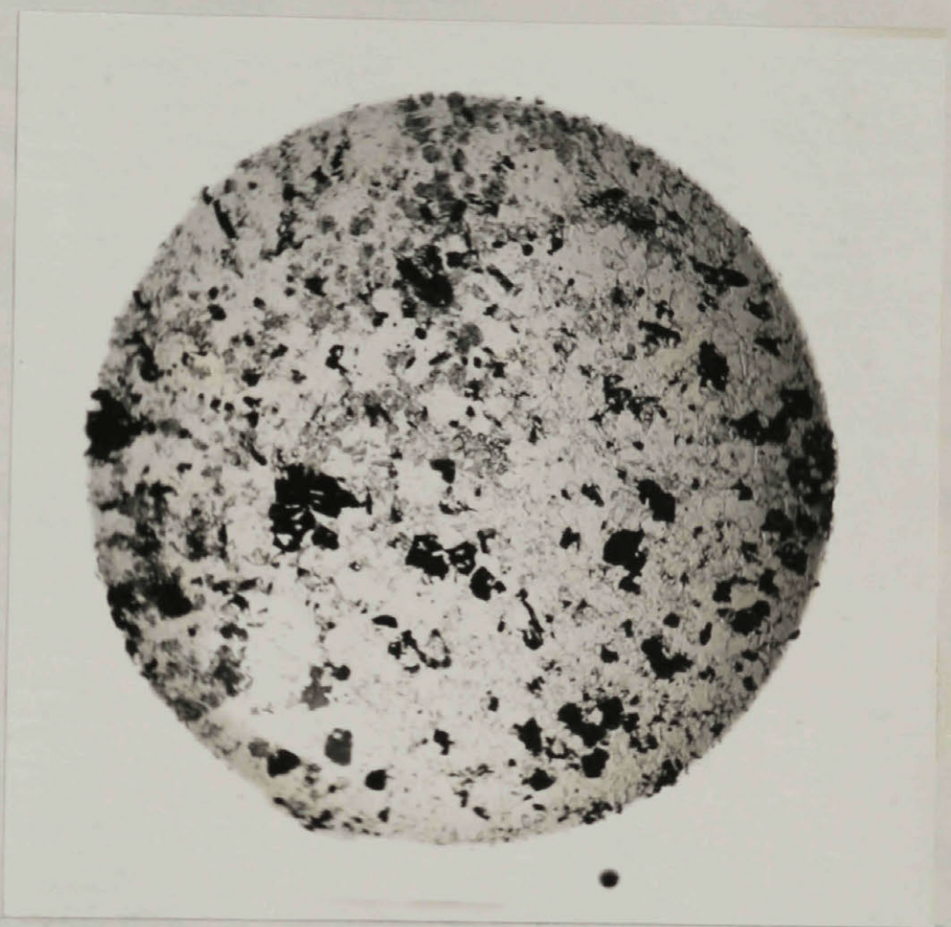
magma at a high temperature but was caused by the soaking of the Grenville Gneiss with magmatic vapours and to a lesser extent their more concentrated forms the pegmatites.The occurance of pegmatite knots separate from any apparent source shows that the vapours had a viscosity approaching zero and were able to penetrate the capillary openings without causing rupture of the rock.As the gneiss at the immediate granite contact,which in this case is a more or less imaginary boundary,assumed the same composition as the granite it took on the other physical and chemical properties of the magma resulting in the contact zone being pushed farther out into the limestone. Thus for example the granite at the contact represents the old age of the biotite gneiss,the biotite gneiss the old age of the garnet gneiss,the garnet gneiss the old age of the skarn rocks and the skarn rocks the old age of the limestone.Since the contact gneiss contains very little ferromagnesian minerals these minerals are being gradually increased both by addition from the magma and by concentration of the original content.The essential difference between the process as outlined and the actual occurence is that the first is represented as a series of hiatuses whereas it probably was much more continuous.

Plate XV.



The Aegerite Granite Dykes.

Ordinary light. Magnification about 30 diameters. The photograph shows intersticial fluorite in the centre of the field; it may be distinguished by its high relief due to its low index of refraction. The fluorite occurs intersticial to all the other minerals. The black areas represent dark green aegerite.



the area under consideration its petrographical desription is not included,its only significance being that similar dykes might be found by a more careful study of the magnesite area.

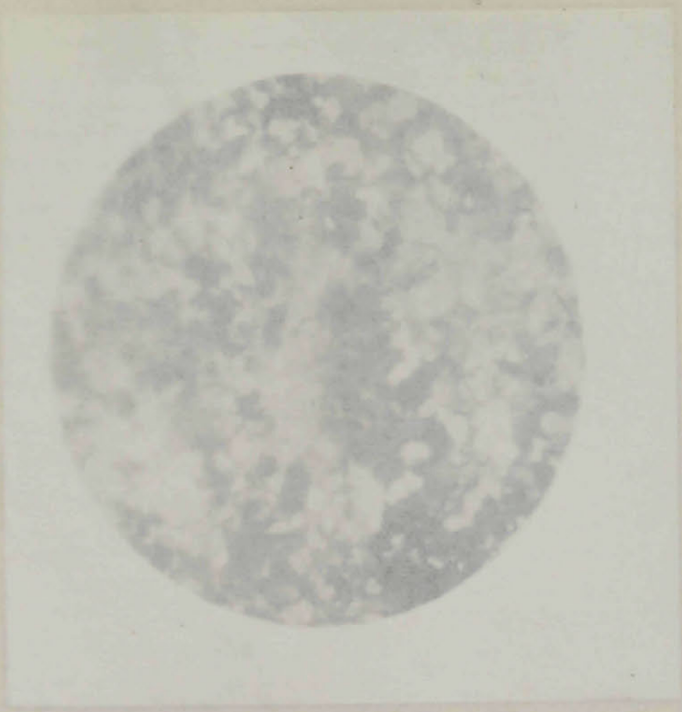
AEGERITE GRANITE DYKES.

Two of these dykes cut the limestones at the Limestone Chute but have not been found anywhere else in the region although it is quite possible that when the country between Dalesville and Lake Louisa is as carefully explored as that between Brownsburg and Dalesville many more may be discovered.The dykes are about three feet thick and have a umiform dark green colour on a fresh surface.When weathered a number of dark areas due to elongated prisms of aegerite about 7 mms.long stand out as discolourations;these however are very rare.Except for these small phenocrysts the rock has a felsitic equigranular texture and is composed chiefly of well formed oligoclase laths about 0.3 mms.long and 0.1 mms. in diameter.The structure is strictly massive except at the border where the weathered surface shows a crude banding due to granulation of the chilled marginal facies which flowed slightly during crystallization giving the rock a saccharoidal texture at the immediate margin.The minerals of the rock include:-

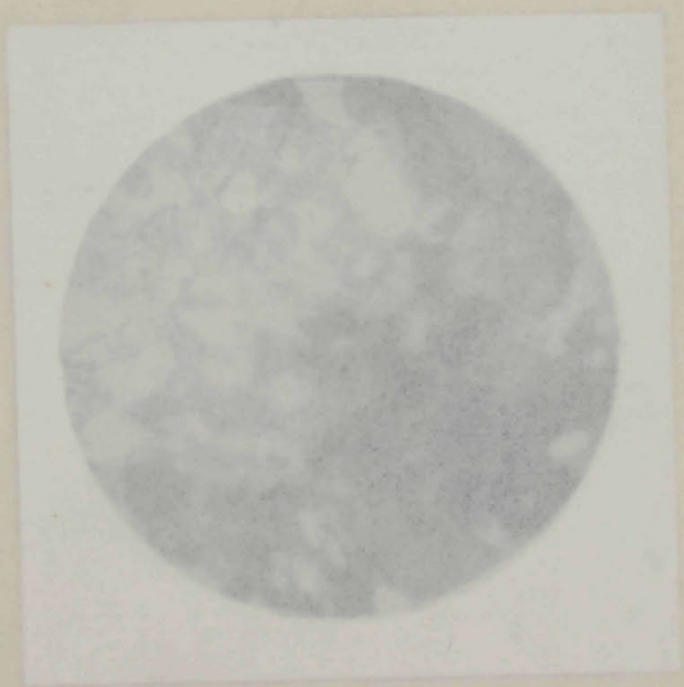
Oligoclase	60%
Orthoclase) Microcline)	15%
Quartz	15%
Aegerite	9%
Fluorite	1%

Microcline is subordinate to the orthoclase and is prominent in the border facies.The orthoclase and quartz occur as rounded or irregular interstitial grains between the oligoclase;they never show crystal outline although in one slide a Carlsbad twin of orthoclase was present and its margin was indented by numerous smaller crystals of quartz and oligoclase.Some of the oligoclase

Plate XVIa.



Microphotograph showing a phenocryst of orthoclase, twinned according to the Carlsbad law, and later strained. The fine grained texture of the rock is due to simultaneous crystallization.and marginal granulation.



Microphotograph showing graphic intergrowth of quartz, plagioclase and microcline of pegmatite dykes.



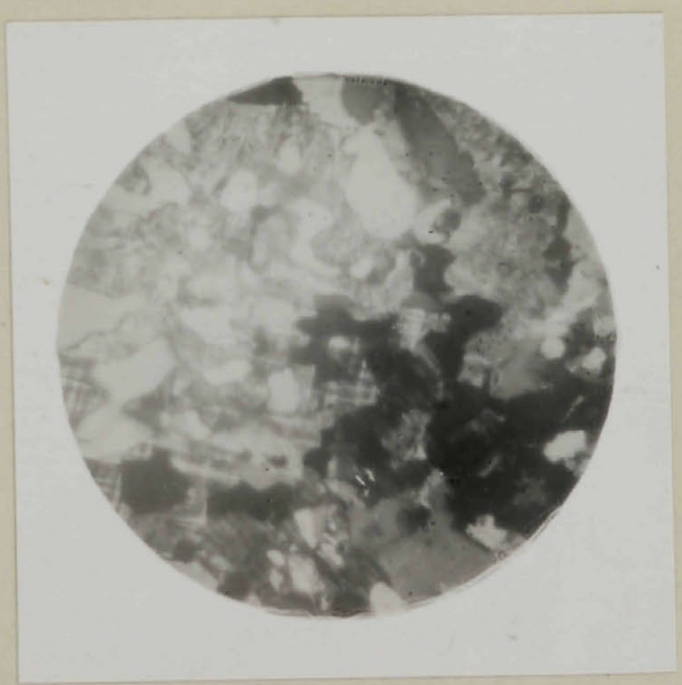
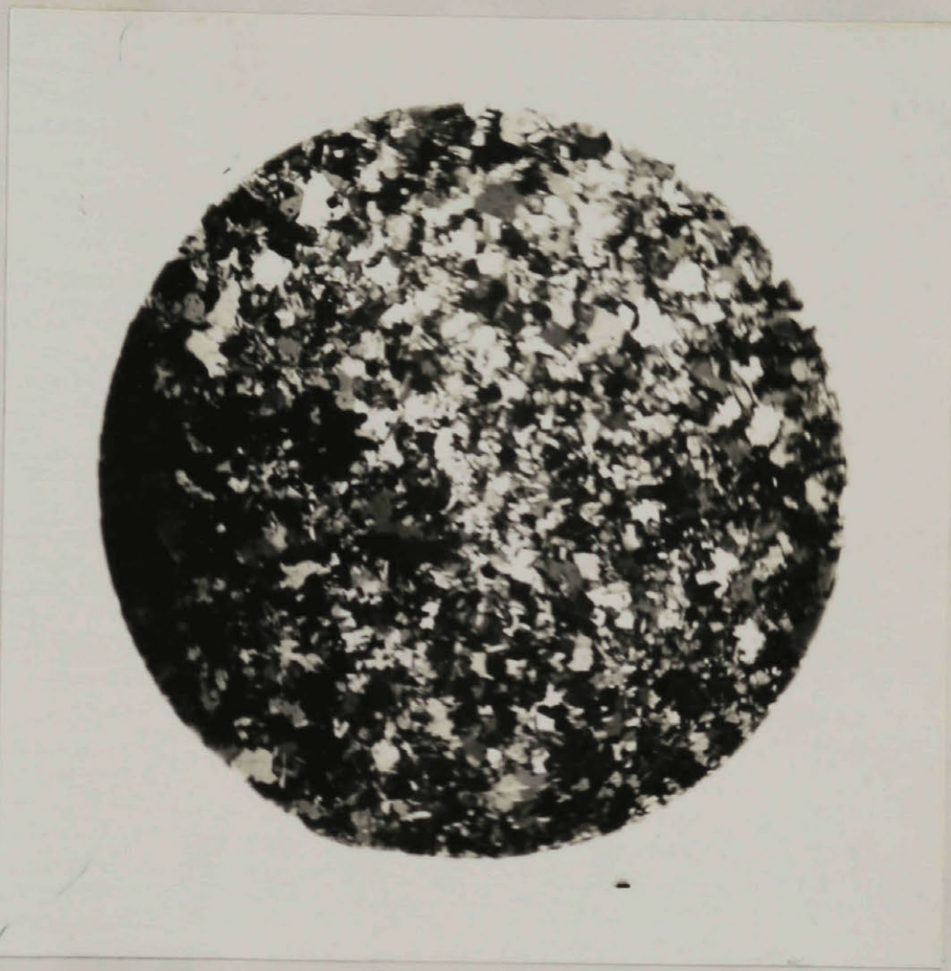


Plate XVI.



The Aegerite Granite Dykes.

Crossed nicols. Magnification about 30 diameters. The microphotograph shows the exceedingly fine equigranular texture of the rock and the tendency towards the lathlike developement of the plagioclase feldspars. Many of the large white grains are quartz.



shows polysynthetic twinning but simple albite twims are more common. The quartz grains are also twinned but the twinning plane is of the nature of a broad undulating zone while in other cases it is even more irregular;this character would seem to point to the quartz having crystallized in the β form.The aegerite usually has a euhedral outline and occurs as crystls about 0.4 mms.long and 0.2 mms.wide although in rare cases larger ones occur.The fluorite is almost colourless and occurs interstically;it has a very uniform distribution several grains being found in all five slides which were examined.

THE AEGERITE PEGMATITES.

The aegerite pegmatites are derived from the dykes already described and not from the parent magma.The place where the granite dyke ends and the pegmatite begins is almost imperceptible;the pegmatites do not seem to cut the granite dykes but simply run out from them into the limestone.Several of these occur at the Limestone Chute and are remarkable for two features:first pegmatites cutting limestone are exceedingly rare;in fact a pegmatite will cut through a great thicknes of schist yet when it reaches the limestone it stops almost immediately;secondly pegmatites are regarded as producing heavy impregnation or granitization at the contact but the effect of these pegmatites is no greater and possibly even less than for a simple intrusive of the same size.

Two types of pegmatites are to be found and perhaps even the large granite dykes just described may be pegmatites of a transition type.The first type of pegmatite and that which is the most common is a quartz-aegerite-microcline rock although in some cases the aegerite completely dissappears leaving only quartz and microcline The second type of pegmatite is a simple quartz aegerite which seems to be a transition to the mineral veins and it has produced a greater

contact action than the first series.

QUARTZ-AEGERITE-MICROCLINE PEGMATITES.

Four of these pegmatites were found in the small area studied and their field occurence is extraordinary.Two of the dykes are less than an inch across and yet they do not vary a sixteenth of an inch in thickness for twenty feet when they pass under drift in one case and into the river in theother.The larger pegmatites do not show this regularity in shape but tend to pinch and swell on both sides at the same time as is shown on the geological map.In the case of one dyke it is pinched out completely in several places.

The aegerite shows a tendency to form euhedral crystals along the margins and this is more pronounced in the small dykes than in the large ones.In the larger dykes the marginal phase is usually fine grained while the centre is exceedingly coarse grained. The aegerite which did not crystallize along the margin usually shows poor crystal form or occurs as anhedral grains like the rest of the rock.The pegmatite is coarsely granitoid,the grains ranging in size from 3 to 5 mms. in diameter.A micrographic structure due to the intergrowth of quartz and microcline is very prominent.

The mineralogy is very simple;quartz and microcline in equal amounts constitute about 90 percent of the rock.About 8 percent of aegerite and 2 percent of inclusions make up the remainder.The aegerite shows a zoned structure due to the variation in composition of the solution from which it crystallized.The inclusions are all limestone but have developed in them rosettes of a mineral resembling scapolite but owing to the minuteness of the grains its exact nature was not determinable.

QUARTZ AEGERITE PEGMATITES

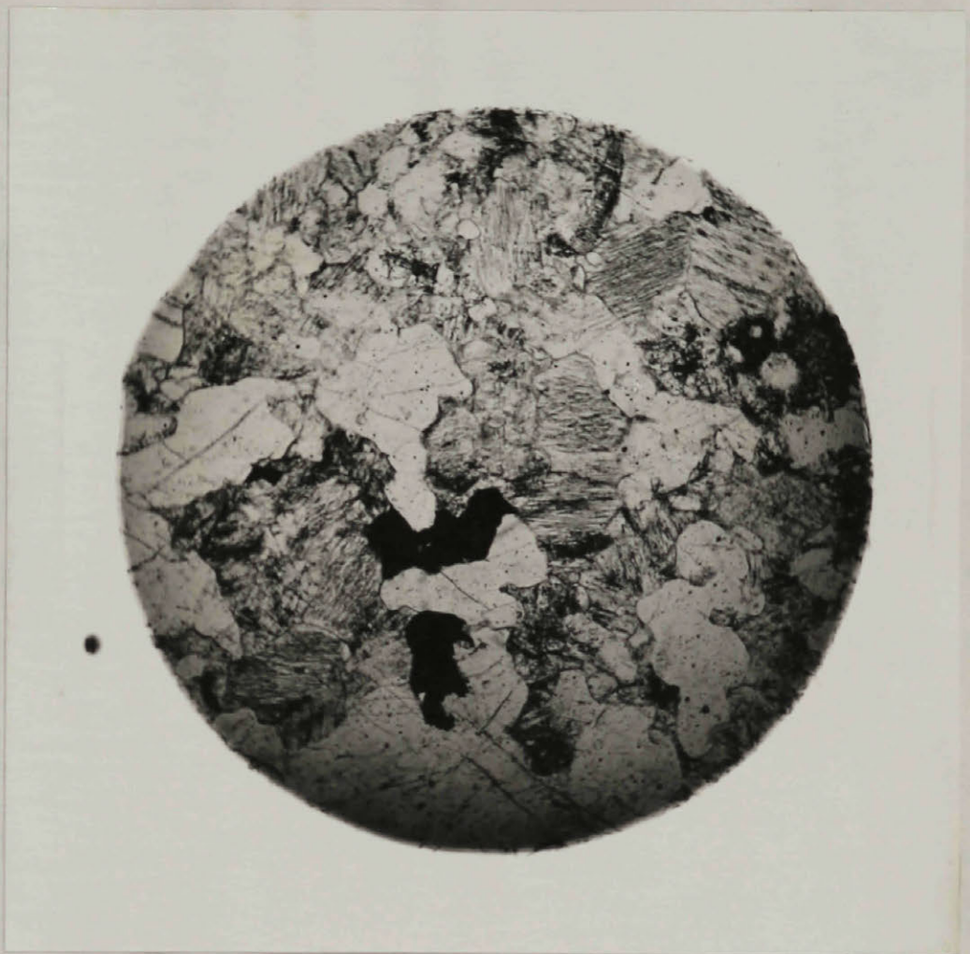
Only one dyke of this type was observed;it was about an inch

Plate XVII.



The Laurentian Granite. Magnification, 30 diameters.

Photograph taken with ordinary light to show the strong perthitic structure and the numerous liquid inclusions in the quartz. These inclusions are represented by the numerous small dark spots in the clear colourless mineral. The large black areas represent a dark green horneblende or aegerite. Magnetite is usually more abundant than is represented by this section.



thickand three feet long.As before the aegerite was crystallized along the border of the dyke in euhedral crystals about 5 mms. long and 3 mms. across the face of the side pinacoid.The centre of the dyke was composed of pure white quartz.In contrast to the other pegmatites a contact zone equal in thickness to about half the thickness of the dyke was formed.The calcite was recrystallized and a purple and also yellow fluorite was developed in the carbonate

THE LAURENTIAN GRANITE.

The next intrusion to penetrate the Grenville Series was the great Laurentian Batholith of the so called granite gneiss.The effects of the batholith on the Grenville Limestone has already been described but the effect of the limestone on the batholith has been left until this part of the discussion.

Since the marginal phases of the granite have been effected both structurally and texturally by the presence of roof pendants a specimen from the interior of the batholith will be described because it probably represents the true granite more nearly than anything else.The specimen chosenfor study came from a locality half a mile south and a mile east of Dalesville where the granite showed no gneissic structure.

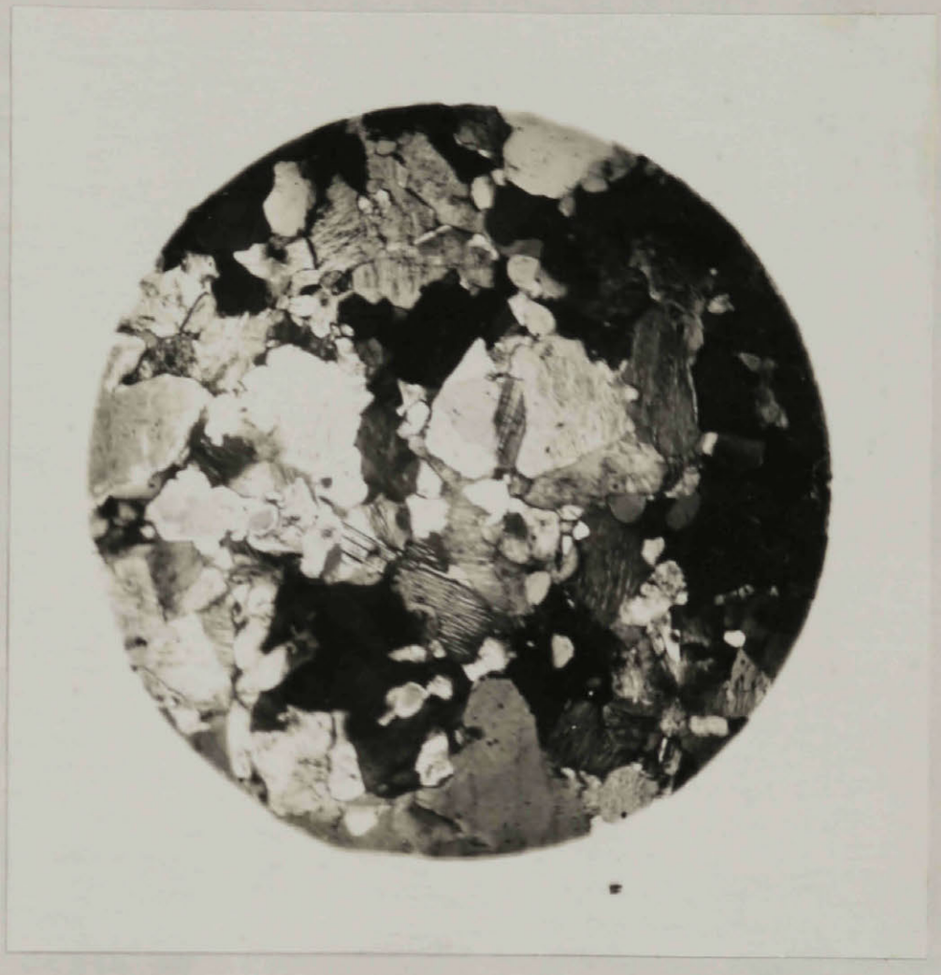
The granite is very even grained and consists of closely interlocking perthite and quartz with accessory magnetite,albite, mica and hornblende.Except in the case of the albite and magnetite the grains have an anhedral outline.The hornblende and mica together constitute less than 5 percent of the rock,the iron bearing minerals being represented by about 3 percent of magnetite.The perthitic feld spar is of the injection type in which the albite occurs as eye-shaped grains 0.4 mms.long and 0.1 mms.across.Most of the quartz and albite ranges around 0.5 mms.in diameter and occurs interstitial to the feldspars.

Plate XVIII.



The Laurentian Granite.

Crossed nicols. Magnification about 30 diameters. The microphotograph shows a complete absence of cataclastic effects; the plagioclase crystals show polysynthetic twinning without the least tendency to wedge out; undulose extinction is absent or very indistinct.



Since the interior of batholith contains practically no ferromagnesian minerals it is necessary to account for the parallel bands rich in biotite and hornblende which are so prominent around the borders.The contact of the intrusive is not vertical, in fact it dips at an appreciably flat angle- 20° to 50° -as is shown by the many sections afforded between Brownsburg and Lake Louisa.The ferromagnesian stringers represent roof pendants soaking in the magma.If they were fragments or more correctly speaking xenoliths they ought to show a heterogeneous arrangement rather than a parallelism to the strike of the Grenville Limestone and to the general structure of the region.Two hypotheses have been advanced concerning these so called xenoliths:-

1.They are basic secretions of the magma.

2.They are stoped off blocks or xenoliths.

The first hypothesis assumes a magma so viscous as to allow the basic differentiates to be held and drawn out by movement.The second assumes a magma so viscous that the blocks spalled off from the contact cannot get out of their former orientation.Was the magma as viscous as postulated by either of these hypotheses?

Experimental work has shown that the viscous solutions of salic minerals will not crystallize to any marked degree such as is found in the Laurentian Granite.Also the batholith would have had nearly the same composition as the aegerite granite dykes if it could have formed these "basic secretions".It has been shown that except at the immediate margin these dykes were exceedingly fluid and allowed the oligoclase to separate out in good crystal form. The granulated margin serves to compare the viscosities of the magma with that of a chilled solution.Further evidence of the fluidity is found in the pegmatitic nature of the contact facies and the presence

of large quantities of mineralizers in the granite itself as is evidenced by the abundant gas bubbles in the quartz and the in jection perthites of the granites.

In addition to the above objections the first theory presupposes movement of a profound nature while the magma was consolidating and in a viscous state if such could exist.The granites of the interior of the batholith where it would be free from inclusions or roof pendants shows no cataclastic effect whatever and contains no "basic secretions".

Since assimilation of the contact rock is taking place it might be expected that differentiation would take place by the gravitative sinking of crystals precipitated by equilibrium changes brought about by changes in composition.Equilibrium changes do occur but they cannot be due in any marked degree to changes in composition since,as has been shown in the discussion of the biotite gneiss,the contact rock has practically the same composition as the intrusive granite.However the potential energy of the magma was continually decreasing owing to the change of the contact rock from the solid to the liquid phase at a temperature far below the critical temperature of the gas having the same composition as the granite.* Since the balance between the material assimilated and the material precipitated is a very delicate one,depending upon pressure and temperature and concentration of mineralizers,reaction could be expected to continue until complete solidification of the magma had taken place.The length of the reaction would be greatly prolonged by the liberation of mineralizers during the crystallization and removal of crystals by gravitative processes followed by introduction of fresh magma fully charged with mineralizers.Thus although differentiation is taking place it is not affecting the composition at all.

*The change from the liquid to the solid or solid to the liquid above the critical temperature does not involve a change in energy.

THE ALGOMAN INTRUSIVES.

The Algoman intrusives are of late Pre-Cambrian age and are practically unmetamorphosed by any external agencies.The diabase dykes which have been described by Logan,[1] Adams,[2] and Wilson,[3] were not found in the region under study but others intermediate in composition between these and the granite of the Grenville Stock were observed.Acid orthophyres and quartz porphyries were found intrusive into the Grenville stock and probably represent the youngest intrusives of the region lying outside the Monteregian Petrographical Province.

THE GRANODIORITE DYKES.

Only one of these dykes occurs in this particular area.It is a fine even grained dark rock occuring in a dyke about two feet thick which cuts the older series of intrusives or aegerite granite dykes at N 45°E.This dyke has a doleritic texture and consists of grains about one mm.in diameter;the primary structure is quite massive and secondary structures are lacking.The rock consists of the following minerals:-

Hornblende	30%
Biotite	10%
Orthoclase	30%
Andesine	25%
Apatite	5%
Quartz	Few grains.

The hornblende shows slight reaction effects and has gone over in part to magnetite.Pyrite and chlorite have also formed along the cleavage planes.The high percentage of apatite is an unusual feature in the rock.

The alteration of hornblende to chlorite,magnetite,and pyrite are secondary effects closely related to the consolidation of the dyke and not long subsequent processes,since although the hornblende

1.Geology of Canada 1863.
2.Annual Report C.G.S. Vol.XII,1899.
3.Memoir 98 C.G.S.

is altered the other minerals are comparitively fresh.Such a selective alteration could only be possible owing to changes in equilibrium at the time of consolidation which rendered the hornblende unstable.

THE GRENVILLE GRANITE STOCK.

The Grenville granite and syenite stock has been studied with great care by the early workers on the Pre-Cambrian of Canada. Sir Wm.Logan[1] has made an excellent field study of the stock and the author knows of only three important dykes or intrusions which he has not recorded in his first publication.[1] His order of succession of intrusion is also better than the more recent work and shows a more observent type of field study than has been carried on since. Le Roy[2] has made a valuable contribution to our knowledge of this granite following more particularly a study of the petrography and and chemical composition.

The rock is coarsely granitoid and has three sets of joint-planes of which one set is vertical or nearly so,another is at right angles to the first and inclined at 75° to the horizontal,and the third which is the poorest is horizontal.The joints are about fifteen feet apart although a few minor ones occur in between.These joints are heavily mineralized with haemetite and along some the red granite has been heavily chloritized and altered to a greenish white rock; this alteration probably accompanied the mineralization by haemetite.

A soda orthoclase makes up about 70% of the rock while quartz occurs in amounts up to 10 percent.Dark green hornblende and augite make up about 10 percent,and apatite,plagioclase,magnetite, and brown biotite make up the remainder of the rock.Orthoclase forms euhedral crystals about 8 mms. long and 3 mms.across the cleavage face;Carlsbad twinning is a common feature.Hornblende is intersticial to or graphically intergrown with,the feldspar.Quartz occurs in round

1. Geology of Canada 1863. 2.Bull.G.S.A. Vol.XII pg.377-394

or angular grains,up to 5 mms. in diameter,occuring interstically to the feldspar;fluid inclusions in the quartz are very common.

According to LeRoy the rock corresponds very closely with the Rigaud quartz syenite an analysis of which is given below.

SiO_2	62.62
Al_2O_3	15.69
Fe_2O_3	2.07
FeO	4.73
MnO	0.10
CaO	2.60
MgO	1.61
K_2O	5.95
Na_2O	3.87
H_2O	0.61

(Analyst O.E.LeRoy).

THE ORTHOPHYRES AND QUARTZ PORPHYRIES.

These occur both as stocks and dykes in the Grenville and Laurentian granites,they are characterized by phenocrysts of orthoclase twinned according to the Carlsbad law and occuring in a red or gray groundmass.Rounded quartzes are frequently found.The rock occurs in two localities,the better known being that in Grenville Township on the narrow gauge railway running into the magnesite quarries;the other occurs about a quarter of a mile notth of the Limestone Chute and continues eastward to near the village of Dalesville.

The rock is holocrystalline and the ratio of the phenocrysts to grounmass is about six to one so that the degree of porphyricity would be dosemic and since the dominant phenocrysts of the rock are orthoclase,it forms the major portion of the rock.This orthoclase is rich in soda as a hidden molecule.The ferromagnesians which are confined to the grounmass are highly chloritized and show resorption effects;in some cases resorption has gone so far that only magnetite and haemetite outlines of the original minerals remain.

An analysis of the Rigaud quartz syenite porphyry is given by LeRoy who shows that the two rocks are almost identical.

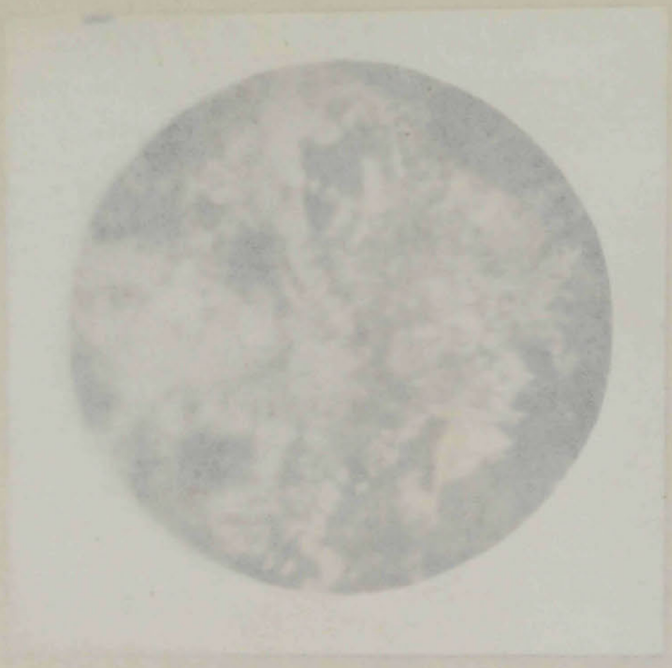
Plate XIX.



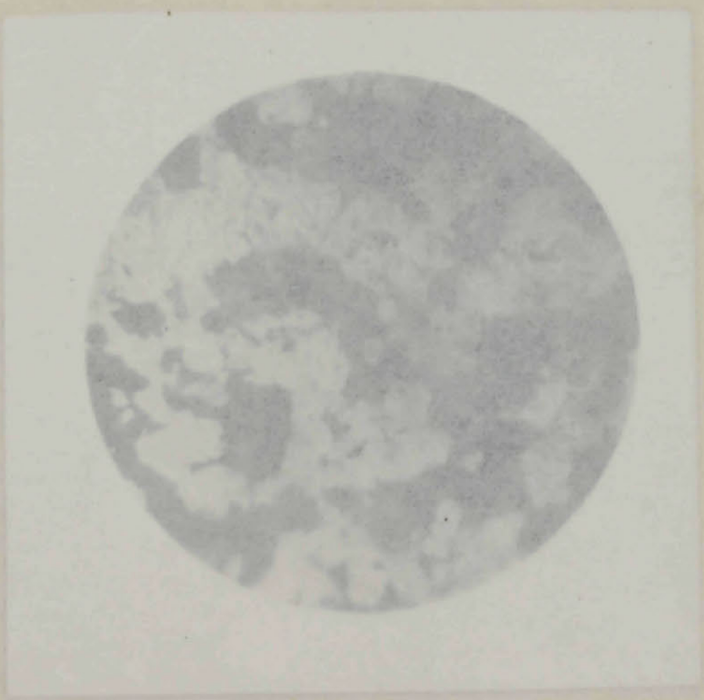
The West River in Winter.

Many places which could not be visited in the summer and autumn were readily accessible when the rapids had frozen over. The ice in this photograph is twelve feet above the level of the river in summertime.



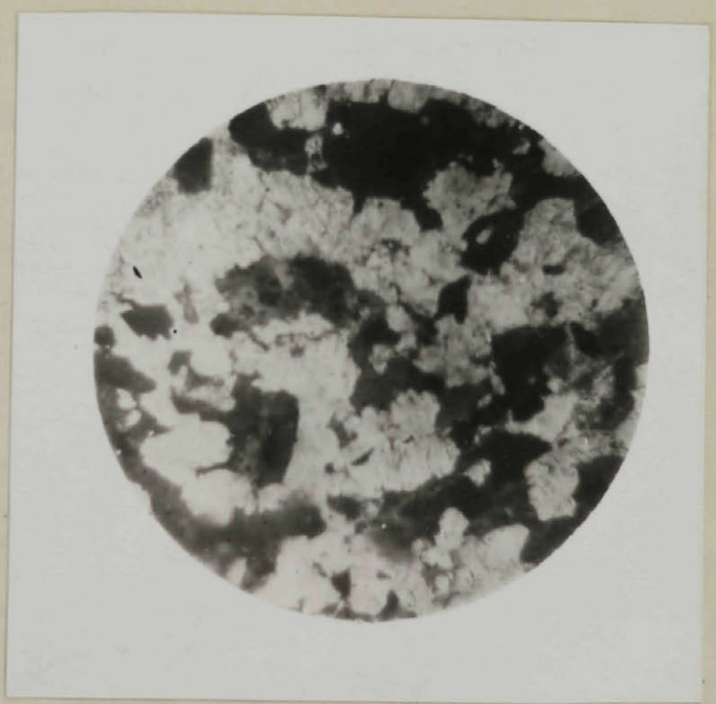


Microphotograph of granite porphyry from contact with the Grenville stock. The rock shows a strong graphic intergrowth of quartz and orthoclase.



Microphotograph of younger series of dyke associated with the Grenville stock. (Ordinary light).





This analysis is reproduced below:-

SiO_2	69.48
Al_2O_3	14.69
Fe_2O_3	3.89
FeO	1.47
MnO	0.12
CaO	0.90
MgO	0.68
K_2O	4.34
Na_2O	5.32
H_2O	0.72

(Analysist O.E.LeRoy).

MICROGRANITE OR MICROPEGMATITE.

Red igneous rocks of granitoid texture form the walls of the rapids above the Limestone Chute;these walls rise perpendicular for thirty feet above the rapids of the river.However the rocks are not all granitoid as was formerly thought and the error was probably due to the difficulty of getting near the west cliff during the summer.A red aphanitic rock intrudes the Grenville stock at this point the contact between the two being practically perpendicular.The actual contact on the southern side shows an earthy iron oxide zone about three feet wide,while on the north side the intrusive relationship is evidenced by apophyses and trap dykes,from the microgranite, which intersect the Grenville stock.

The rock has a felsitic texture and is quite massive.When examined under the microscope it is seen to consist of quartz and orthoclase in equal amounts and micrographically intergrown,sometimes with angular outlines as in graphic granite.In no case do the grains exceed 2 mms. in diameter and usually are somewhat smaller.The original magma contained hornblende and biotite but these have been completely resorbed leaving behind skeletons of haemetite and magnetite grains which are more abundant along old cleavage planes.A few euhedral crystals of apatite about 0.5 mms.long and 0.1 mms.in diameter are prominent.In addition the rock contains two other minerals

STRUCTURE.

The Grenville series of sedimentary rocks is thrown into steep overturned folds which have superimposed upon them minor flexures.In some places they depart from their true northerly strike and swing to the northeast for short distances.This deflection may be due to to the presence of the intrusives of Algoman age which seem to be intimately associated with the change in direction.

These folds have a more or less undulating crest;for example the fold along which the West River flows at the Limestone Chute, plunges northward at the southern end and southward at the northern end of the Chute.

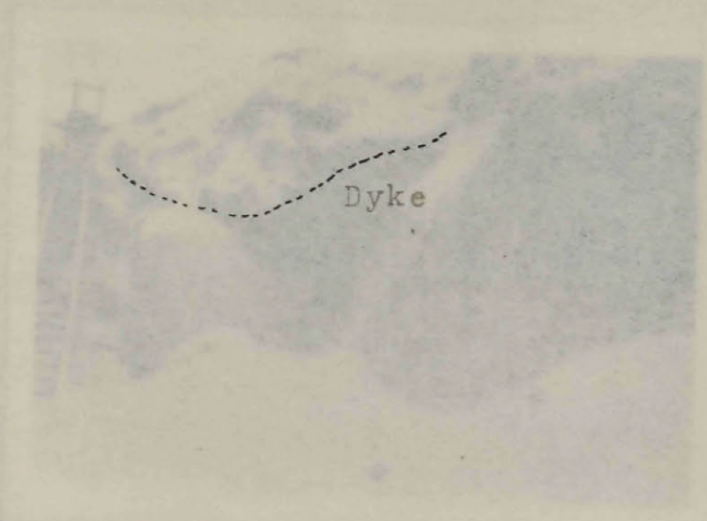
Even with these variations the structure is not as complicated as that northeast of Lachute where the limestones are crumpled in an accordeon fashion and it is almost impossible to follow a bed. However the one inch layer of shale back of the Wason house serves as an excellent guide.

The structure in the vicinity of the magnesite deposits follows the general north south direction,but the folding is much more intense than in the area between Brownsburg and Lake Louisa. Parallelcrumplings are superimposed on gentle anticlines and syncline of 30°or more.The American Magnesite Quarry owes its existance to the occurence of an almost symmetrical north south fan fold.

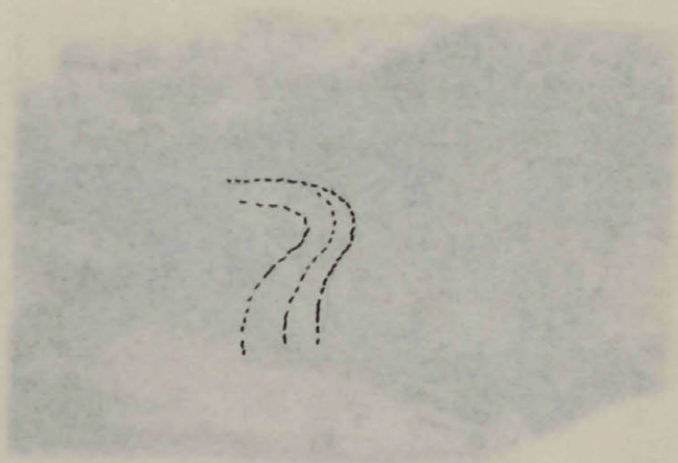
At the Scottish Canadian Magnesite Quarry the dip is almost vertical and is greatly complicated by faulting,but there is a suggestion of a tight anticlinal fold or fan fold similar to the better exposed structure in the large quarry of the North American Magnesite Co.

Flexure and folding seem to have been more prominent than faulting although strong slickensiding in a northeasterly direction was noticed in the Scottish Canadian Magnesite quarry.Also in the

Plate XX.



Serpentine dyke which forms one side of the North American Magnesite Quarry at White Rock Lake.



Fan fold in the North American Magnesite Quarry. The fan fold is intersected by the serpentinized dyke just beyond the left side of the photograph. All the magnesite in the deposit occurs along the axis of this fold.





Plate XXII.



East side of North American Magnesite Quarry -
White Rock Lake.
A dyke (dark) cutting the Grenville series is seen about half way down the ladder and a few feet to the right.



This photograph shows an inclusion of Grenville limestone (white) in the serpentized dyke (dark).





limestone quarry north of Lachute a small east-west fault plane forms the hanging wall of the pit.

The strike of the schists parallels the the strike of the limestones and the foliation is to be regarded as due to the same set of forces as threw the Grenville Limestones into the north south folds.Intricate folding becomes prominent in some of the gneisses which are heavily intruded and impregnated by pegmatites;this folding is probably due to the irregular distribution and discontinuous nature of the pegmatite dykes and knots as well as the ordinary stresses produced in the processes of mountainbuilding,rather than to such special agencies as near fusion and kneading of the pasty mass. If one imagines a pegmatite knot over a foot in diameter or a dyke foot thick which suddenly ends it ought to be nothing extraordinary if folding did occur.Such an occurence is not purely hypothetical in fact innumerable cases such as that just outlined occur in the hill just east of the Limestone Chute.When these rocks are examined in thin section they show no trace of semifusion as would be the case if the crumpling was due to ptygmatic folding.Therefore a better name to use would be pseudoptygmatic folding to describe sunh crumpled structures.

The Laurentian granite contact roughly parallels the strike of the schists although in some cases it may cut across them to a slight degree.This would be true only if the structure was considered in a horizontal plane.If looked at in vertical section the contact would show the granite intrusive into the Grenville Series for a great distance and pendants of biotite gneiss hanging down into it.

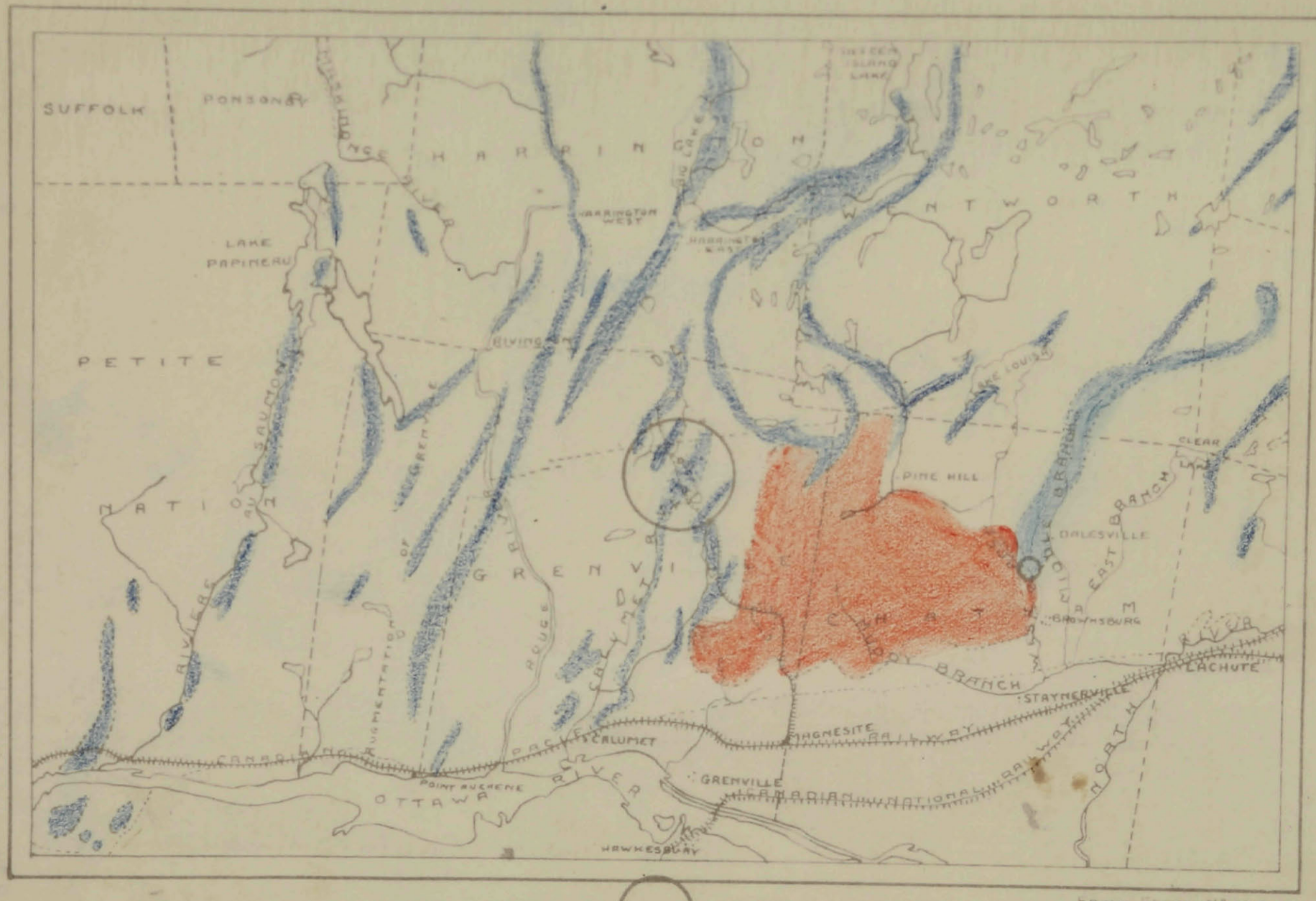
Since only two dykes of Laurentian granite are known it is difficult to form any conclusion in regard to their general direction These dykes however have a north south direction for the greater part of their length.

The diabase dykes which are to be regarded as coming from the parent magma of the Grenville Stock invariably have an east-west trend and this has been noticed by the early observers.[1] The succeeding granodiorite dykes simply radiate from the Grenville Stock for short distances.

Unlike the Laurentian granite the Grenville granite and syenite porphyry have almost vertical walls as is shown by the many places where the contact is exposed between Dalesville and the West River. These rocks have withstood erosion better than the Laurentian granite and the Grenville gneiss so that in many places one may look straight down for fifty feet and see the contact immediately below.

The microgranite, which represents the last stage of igneous activity is exposed at only one locality which has been described. Since the trap dykes came from this magma it must underlie a much greater area because these dense dark gray dykes have been observed to cut the granite and syenite wherever it is exposed over large areas.

1. Geology of Canada 1863.
   Annual Report C.G.S. Vol.XII, 1899
   Memoir 9[illegible] C.G.S.



FROM SHEET No 121
G.S.C.

THE MAGNESITE DISTRICT

LIMESTONE CHUTE

LOTS XI & XII
RANGE VIII, CHATHAM TOWNSHIP
ARGENTEUIL COUNTY, P.Q.

SCALE:- 1 INCH = 5 FEET

FOOT BRIDGE

- CRYSTALLINE LIMESTONE
- DOLOMITE
- AEGERITE PEGMATITE DYKE
- AEGERITE SYENITE DYKES
- HORNEBLENDE SYENITE DYKES

THE PATH OF THE SOLUTIONS.

Although the proofs that the deposits are due to uprising solutions is left until a later section it seems quite permissable to deal with their paths of travel.In the summary of the various processes of formation of magnesite outlined in the introductory section every method required the presence of solutions to effect the concentration so that it seems quite reasonable to imagine the former presence of circulating solutions.Later,definite proof of their presence will be submitted.Although the reasoning seems to be ahead of its proper place the subject of the paths of the solutions is introduced at this point because of their intimate connection with the structure and the concentration of magnesium carbonate.

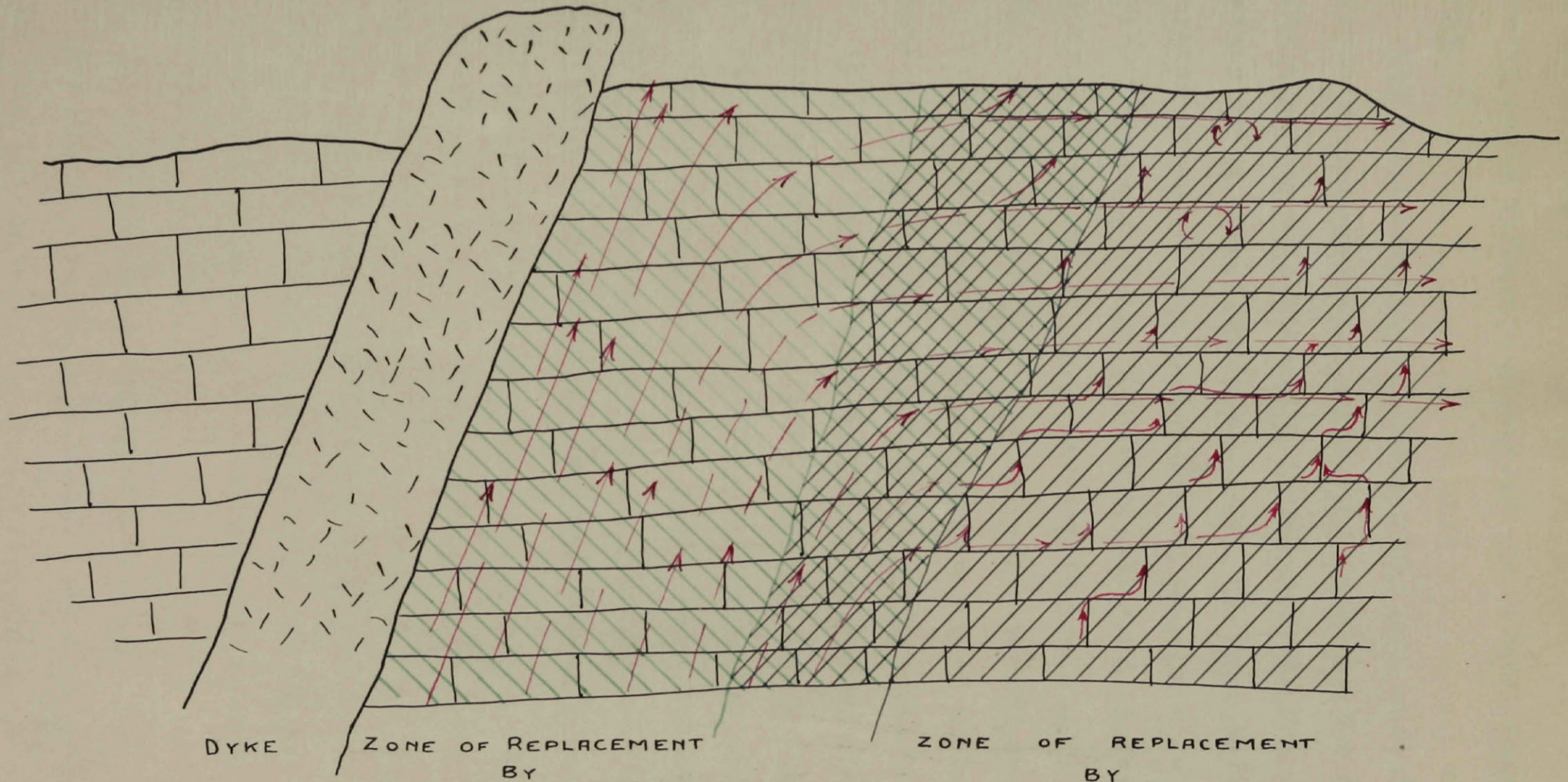
The greatest concentration of magnesium carbonate occurs below dykes or on the crests of folds lying below the dykes. Now the solutions could move in three directions:-

1. They could descend from above.
2. They could rise from below.
3. They could migrate laterally.

Descending waters would have been shed from the magnesian zones by the overlying intrusive dykes.Therefore the solutions must have come up from below under pressure or they must have migrated laterally.Along the line of analyses of Series I they could not have migrated laterally for any great distance because of the interference of the easternmost of the two aegerite granite dykes.Therefore the solutions must have come up from below and where dykes did not interfere subsidiary lateral movement may have taken place.

If the complete and proximate analyses of Series II were critically examined it would have been noticed that after the point of maximum magnesium carbonate was passed the insoluble showed a more or less steady rise until the silicates formed over 36% of the limestone.The dyke under which this concentration had taken place

Plate XXI.


DYKE
ZONE OF REPLACEMENT BY DOLOMITE & MAGNESITE
ZONE OF REPLACEMENT BY LIME SILICATES.
PATH OF SOLUTIONS.

was the easternmost of the aegerite granite series so that beyond it no restraining influence prevented the lateral migration of the solutions.

The zonal arrangement between the dyke and the river is illustrated on a diagramatic cross-section.Since the dyke is inclined it exerts a strong effect tending to concentrate the solutions immediately below itself.These solutions are presumably under considerable pressure from behind-for if they were not they would not rise-so that succeeding solutions will tend to force the spent liquids or vapours out of their way laterally.In this direction there has been a heavy concentration of wollastonite and accessory diopside

Except to point out the significance of these facts,the importance of this section is practically exhausted.Later it will be shown that the solutions were rich in magnesium silicate which reacted with the limestone to give magnesite and wollastonite as wellas a smallamount of diopside.The reactions are analogous to the formation of magnesite from the peridotites.The presence of wollastonite as a"discharge"product in these contact zones is very significant in checking up the exact chemical reactions which took place.

THE ORIGIN OF THE MAGNESITE.

In the introductory section, the origin of magnesite was discussed at length so that as the reader was taken through the maze of geological structures and relationships as well as the changes in composition, texture and structure and the physical condition of the Pre-Laurentian rocks he might be able to form an opinion or better still a picture of the genesis of the deposits of dolomite and magnesite. If he has done this, the first three of the possible origins can be disposed of with a brief comment. The fourth will require a little more attention and perhaps the reader may have developed an entirely new conception of how the changes have come about.

MAGNESITE AS AN ALTERATION OF SERPENTINE.

Magnesite derived by the double decomposition of serpentine in and olive bearing rocks such as peridotites and pyroxenites requires first, a huge body of these rocks and secondly that the magnesite be deposited in practically the same place as the decomposition took place. Some migration might occur but changes in temperature and more especially pressure, would cause a rapid precipitation due to the escape of CO_2. Two vital objections are presented against this mode of origin; first large bodies of basic rocks are not found anywhere in the region and dolomite and magnesite are found where no basic rocks whatever are present. Some magnesite of no commercial importance occurs in the peridotite dyke in the North American Magnesite Quarry but it is infinitesinally small compared with the large body being quarried.

MAGNESITE AS A SEDIMENTARY DEPOSIT.

The deposits occur in a bedded series of marine sediments and might possibly be due to original deposition. The difficulties encountered in supporting this mode of origin is even greater than

in the former case.First the chemical composition of the deposit is strongly against that mode of origin because between the pure dolomite of marine deposits and the almost pure magnesite of lake deposits there is no sediment of intermediate composition which would fit that of the dolomitic magnesite removed from the quarries.Even if such a deposit could be formed after some geological process which acted in the past and ceased to be effective before experimental geology began,it is impossible to explain the variation in composition of such an extent in a single bed as has been shown to take place unless variation in volume due to removal of calcium carbonate. should also occur.In the field work attention was devoted almost entirely to beds of uniform thickness.The greatest difficulty of allcomes in explaining the structural relations.The"magnesian" limestones or more properly speaking the dolomitic magnesites occur only on the crests of folds and especially where these folds are intersected by dykes of Laurentian age.If the deposits were of sedimentary origin it is hardly conceivable that they could become richer in magnesium carbonate practically up to the dyke and that their continuation on the other side be almost pure calcium carbonate.

MAGNESITE AS FISSURE VEINS.

The quarrymen at White Rock Lake speak of two veins of magnesite which dip at one another at very steep angles.When the "veins"are examined they are found to be the same bed which is bent around in a close fan fold and brought almost together so that both beds can be worked from the same pit.A vein presupposes an opening but in this case no opening equal to the width of the bed could have existed at the time of formation of the magnesite deposit owing to the intense pressure upon the limestones as is indicated by the twinning of the calcite and other stress features which seem to be contemporaneous with the deposition of the dolomite and magnesite.

It has also been shown that where openings exist silicates and not carbonates are precipitated.From these considerations the deposits cannot be regarded as deposits formed in open fissures that is vein deposits.

MAGNESITE AS A REPLACEMENT OF LIMESTONE AND DOLOMITE.

The pseudoeutectic structure of the dolomite and magnesite strongly suggests a replacement deposit and is considered by many petrologists as sufficient indication of the method of formation.The regular decrease of the magnesium carbonate after the maximum is attained strongly favours precipitation from magnesia bearing solutions.These solutions were moving in only one direction since the magnesium carbonate invariably occurs in greatest concentration if not entirely below dykes and on the crests of folds while the hanging walls are free from all but amounts less than one percent of magnesium carbonate.Thus the direction of movement of the solutions must have been upwards.If the direction had been downwards the concentration would have been in the hanging walls of the dykes and in the troughs of the synclines as in the deposits of iron ore in the Lake Superior Region.

All the evidence points to an origin by replacement of the limestone by magnesia bearing solutions and all the evidence points against any other mode of formation.

ORIGIN OF THE SOLUTIONS.

Since the geological evidence points to rising magnesia bearing solutions as the source of the magnesite it is essential to know the source of these solutions in order to determine the possible geographical distribution of the magnesite deposits.

The presence of such minerals as forsterite,wollastonite, diopside,and garnet point to high temperature conditions.Kemp[1] has

conclusively shown by a series of mathematical calculations based upom geological observations,that it is a physical impossibility for meteoric water to sink down into the earth and to be heated even to temperatures hundreds of degrees below that at which these minerals were formed.(Lindgren[1] and Whitehead have shown that the temperature of most of these deposits are formed between 350°C and 575°C). The presence of fluorine bearing minerals such as phlogopite,and chondrodite indicate emanations from a magma.The intimate association of these minerals with the occurence of magnesite and dolomite strongly suggest contemporaneous origin.

POSSIBLE SOURCES OF MAGMATIC VAPOURS.

Magmatic origin of vapours in a region where there are two series of intrusives and three periods of intrusion in each series leaves almost the same number of considerations to be taken up as before it was decided that the solutions were of magmatic origin.

THE BASIC DYKES OF THE LAURENTIAN SERIES.

The deposits of magnesite occur beneath the peridotite dykes of the Buckingham Series of early Laurentian age.If the deposits were formed before the intrusion of these dykes they ought to occur irrespective of the location of the intrusives.Also since the deposits occur only below the dykes it is hardly conceivable that the dykes acted as the source of the solutions because in that case the magnesite ought to occur on the hanging wall as well as on the footwall side of the dyke.

THE AEGERITE GRANITE DYKES OF THE LAURENTIAN SERIES.

The same argument might be used in proving that the source was not in the fluorite bearing aegerite granite dykes of later Laurentian age but in this case more conclusive evidence was available.An inclusion of limestone about eight feet long by five feet wide was found in one of the dykes and the maximum magnesium

carbonate cantained in it was under one percent or about the average content of the Grenville Limestone.A few crystals of wollastonite and diopside were present but none of the minerals characteristic of the highly magnesian limestones were found.

THE LAURENTIAN BATHOLITH.

Direct evidence of the source of magnesia bearing waters in the Laurentian Batholith is not evident at this stage of the "trail"so that it will be better to go ahead to the late Pre-Cambrian or Algoman series of intrusives.

THE ALGOMAN DIABASE DYKES.

The diabase dykes are not associated in any way with the magnesium carbonate content of the rock and this feature in itself ought to be enough to tell us that the deposits were formed in Pre-Algoman times.But suppose objections were raised to such a slight piece of evidence,as lack of important deposits of magnesian limeston in connection with these dykes,and attention is centred on the granodiorite dykes at the Limestone Chute.

THE ALGOMAN GRANODIORITE DYKES.

Not only does no magnesite occur above this dyke,which it should if the dyke was a source of magnesia bearing solutions,but there is no magnesium carbonate below it unless the structure of the older dykes interfere with the simple relationship.Thus the geological relationships force one to returnto the Laurentian Batholith and make a more careful study of the changes which have taken place.

THE "TRAIL" OF THE SOLUTIONS.

The logical place to begin would be where the magnesium carbonate content was the highest,namely near the serpentinized zone along the fissures which run downwards into the biotite garnet gneiss The biotite garnet gneiss apparently has a very intimate relationship with the source of the magnesia bearing solutions.

CHEMICAL COMPOSITION OF THE ROCKS OF THE CONTACT ZONES.

The change in the composition of the contact zones and the source of the magnesia bearing solutions thus becomes intimately associated. Later it will be shown that not only the change in composition of the rocks of the contact zones but that the assimilation of the granite gneiss is intimately locked in the processes which effected a concentration of magnesium carbonate in sufficient quantity to yield magnesite. For a comparison of the compositions four analyses previously used will be placed together for convenience

Rock.	1. Silicated Limestone	2. Garnet Gneiss	3. Biotite Gneiss	4. Granite Gneiss
SiO_3	16.05	53.10	55.91	59.89
Al_2O_3	0.14	24.38	18.44	17.70
Fe_2O_3	-----	2.86	2.37	1.95
FeO	1.54	11.21	7.42	2.71
MnO	----	tr.	tr.	----
CaO	46.65	1.16	3.50	2.53
MgO	5.25	2.40	3.61	1.56
K_2O	----	1.49	1.13	5.83
Na_2O	2.94	2.08	2.08	5.74
TiO_2	----	-----	----	0.96
P_2O_5	----	----	----	0.17
CO_2	)30.80	----	----	0.39
H_2O	)	0.60	)4.74	0.29
F	----	----	)	----

(Column 4 analyst Dittrich).

NOTE:- The Laurentian granite gneiss of Dittrich was collected from north of Lachute where the granite contains many pendants hanging from the roof. The analysis shows that the sample contained much more MgO than the true granite of the Laurentian batholith which has been described in an earlier part. For the above reasons it cannot be considered as a gneissoid granite or granite and therefore should be classified as a granite gneiss because it has very nearly the composition of the granite. Also in the following calculations the silicated limestone will not be considered for the reasons outlined in the section devoted to the movement of solutions in the limeston

From the analyses it will be seen that the change in the principal comstituents of the rock is in the direction of equilibrium with the granite gneiss and the granite.Two possibilities present themselves as explanations of how this equilibrium is attained:-

1. The biotite gneiss is diluted by pegmatitic action until it assumes the same composition as the granite gneiss.

2. The granite gneiss rejects additions of iron and magnesia and returns them in the solutions which permeate the biotite gneiss.

The first possibility undoubtedly does occur because the biotite gneiss is penetrated in all directions by pegmatie dykes and is filled with pegmatitic knots.The best criteria for the second possibility is to be found not in the change that is taking place but in the following one,which if it shows any differences,should show a variation due to the rejected material of the preceeding change.For this purpose the compodition of the garnet gneiss,biotite gneiss and granite gneiss have been calculated to molecular proportions.

	Garnet gneiss	Biotite gneiss
SiO_2	880	929
Al_2O_3	239	180
Fe_2O_3	18	15
FeO	156	103
CaO	21	62
MgO	60	90
K_2O	16	12
Na_2O	47	34

In interpreting these analyses innumerable methods are possible but of these,three stand out as being far more probable:-

1. The alumina has decreased by its removal.
2. The alumina of the original rock has remained constant and been diluted by the addition of other materials.
3. The alumina has increased but at a slower rate than the dilution.

To the first possibility a great objection stands in the way and that is if the alumina of half a mile of former biotite gneiss was removed to the extent indicated where did it go?It certainly is

not all concentrated in the garnet gneiss zone which is about one hundred yards wide as a maximum and as a rule it is much less. Aluminous minerals have no prominent place in the limestone although small amounts of phlogopite are present.In contact zones which have not been so deeply eroded aluminous minerals have no prominent place, also ldw temperature zones and spring deposits do not contain any appreciable amount of alumina as introduced matter.Therefore it would seem that all the alumina discarded would have to be used up in the narrow garnet zone which is often almost missing.It has been poimted out previously that almost all the alumina of this zone is due to mild granitization effects.Thus it would seem that once the alumina was precipitated it would be hard to cause it to migrate far untilit had been assimilated by the magma,reworked and discharged again in pegmatites.

The other two alternatives would seem to be the only two logical ones to consider.Supposing that the second possibility was the correct one consider the changes that would take place.

	Garnet gneiss	Biotite gneiss $\times \frac{239}{180}$		Differ.
		$\frac{239}{180}$		
SiO_2	880	929 X	=1235	355
Al_2O_3	239	180	239	0
Fe_2O_3	18	15	20	2
FeO	156	103	137	-19
CaO	21	62	82	61
MgO	60	90	120	60
K_2O	16	12	16	0
Na_2O	47	34	45	2

The change involves a gain of SiO_2,CaO,and MgO while there is a slight decrease in iron.If our hypothesis is correct,that each succeding zone will be richer in the constituents rejected by the preceeding zone,the zone preceeding the biotite gneiss ought to be poorer in magnesia and lime and the succeeding one ought to be richer in iron.That the succeeding one is richer in iron than formerly is shown by the abundance of introdused almandite garnet.

Suppose the zone of granite gneiss is considered in the same way:-

	Biotite gneiss	=Granite gneiss X $\frac{180}{173}$		Difference
SiO_2	929	993 X $\frac{180}{173}$	=1033	104
Al_2O_3	180	173	180	0
Fe_2O_3	15	12	12.5	-2.5
FeO	103	38	40	-63
CaO	62	45	47	-15
MgO	90	39	41	-49
K_2O	12	92	96	84
Na_2O	34	62	65	31

This change involves an increase in SiO_2, K_2O, and Na_2O with a decrease in Fe_2O_3, FeO, CaO, and MgO. The decrease in the oxides is what was predicted from the preceeding analysis. When the granite itself is analysed it will be found to be slightly poorer in alkalies and the potash will be lowered more than the soda but for the small difference between the granite and the granite gneiss it would be difficult to predict the changes acurately because an error in sampling would be sufficient to throw the results the other way.
(In all the changes SiO_2 is left out of the consideration because it occurs as the uncombined oxide quartz)

To consider the third possibility suppose the alumina increased 10 percent, a value which will give the trend of the change of value as well as any other.

	Garnet gneiss	=Biotite gneiss X $\frac{239}{180}$ X110=		Differ.
SiO_2	880	929	1358	478
Al_2O_3	239	180	263	24
Fe_2O_3	18	15	22	4
FeO	156	103	151	-5
CaO	21	62	90	79
MgO	60	90	132	72
K_2O	16	12	18	2
Na_2O	47	34	49	2

Thus if there has been an addition of alumina to dilute the rock there has been an increase in the soda, potash, magnesia, and lime and a tendency of the iron to increase with increased additions thus reaching an equilibrium which would prevent an increase of iron

in the succeeding zone and the formation of bodies of magnetite which might have formed if an excess of alumina had not been added. Alumina was probably added in a ratio which would just bring the iron content above the negative quantity and allow some to pass since it is highly improbable that any iron was fed in from an outer contact zone,Also all the oxides represented in the difference column must have been added along with the alumina.The preceeding zone ought to become poorer in magnesia at a greater rate than for lime,that is the lime ought to be decreasing in the additions.

Consider the effect of a corresponding increase of alumina in the granite gneiss:-

	Biotite gneiss	=Granite gneiss	X $\frac{180}{173}$ X110=	Differ
SiO_2	929	993	X $\frac{180}{173}$ X110=1092	163
Al_2O_3	180	173	190	10
Fe_2O_3	15	12	13	-2
FeO	103	38	42	-61
CaO	62	45	50	-12
MgO	90	39	43	-47
K_2O	12	92	101	89
Na_2O	34	62	68	34

By increasing the alumina added to the granite gneiss a very slight change is produced and this change will decrease with increased additions of alumina .Such a condition is to be expected as the contact facies approaches nearer and nearer the composition of the magmatic body.Even the small change that does take place is very significant from the point of view of field evidence for it shows an increase in feldspar content by pegmatitization which is the chief agent in bringing the contact rock to the same composition as the magma. The results may also be taken to indicate that the magma is not giving off magnesia at the end but is furnishing a means of concentration of what it gave out at a slightly earlier stage.

Of the many hypotheses the evidence seems to favour addition of alumina and this is strengthened by the field evidence and struct-

ural relations.Extensive pegmatitization has occured throughout the biotite gneiss and granite gneiss.These pegmatites are composed of quartz and feldspar the latter predominating,nor does the chemical evidence fail here for the feldspar although orthoclase is a macroperthite and contains considerable soda as was indicated by the additions along with the alumina.

Although the ten percent ratio appeared to be chosen haphazard it is nearer the correct figure than would be suspected because the increase in rock volume due to pegmatitization is somewhere between 10 and 20 percent.This ratio appears to have established an equilibrium which halted greater pegmatitization because of the decrease in assimilation of the granite gneiss due to the absence of mineralizers in sufficient quantity which as was pointed out is one of the essential features of the process.Since the pegmatites did not possess an indefinite amount of energy they could not wander an unlimited distance from the parent magma,but were held in check until equilibrium was established.

From the calculations and chemical analyses it has been shown that there is a source of magnesia in the granite and the biotite gneisses and that the pegmatitic juices serve as excellent transporting agents.

THE FORM OF THE MAGNESIA IN THE SOLUTIONS.

When the magnesia was precipitated in fissures or near them before the solutions had time to react with the limestones,silicates such as diopside and forsterite were precipitated.Chondrodite is also prominent but it appears to have been a more stable compound which did not react reddily to yield carbonates.However reaction did start and went as far as the serpentine stage in a large percentage of the grains.Fluorides,aluminates and hydroxides apparently were in the solution along with the silicates,because aluminous,hydrous

silicates containing fluorine accompany the magnesite.

THE ALTERATION OF THE SOLUTIONS.

Some of the forsterite and diopside were precipitated in crystal form and subsequently altered to serpentine and magnesite but the major reaction took place before precipitation.The solutions reacted with the limestone to set free CO_2 which immediately attacked the unstable forsterite the same as they would a crystallized peridotite the only difference being that in this case reaction could take place more readily.This reaction may be represented as taking place as follows:-

$$Mg_2SiO_4 + 2CaCO_3 + SiO_2 = 2MgCO_3 + 2CaSiO_3$$

The wollastonite is carried away in solution to be precipitated in the silicated zone lying just beyond the dolomitized zone beneath the dykes.In the above reaction the end product has been given for simplicity but in the actual reaction the reacting solution was probably much more complex and catalytic agents in the limestone probably had as great an effect as porosity in causing certain beds to be more completely replaced than others.The full reactions neglecting the presence of catalysts,which do not enter into the end reaction,are given below:-

$$9Mg_2SiO_4 + 12H_2O = 6H_4Mg_3Si_2O_9 + 3SiO_2$$

forsterite — serpentine

$$3SiO_2 + 3CaCO_3 = 3CaSiO_3 + 3CO_2$$

limestone — wollastonite — Removed in solution.

$$6H_4Mg_3Si_2O_9 + 3CO_2 = 3MgCO_3 + 5H_4Mg_3Si_2O_9 + 2SiO_2 + H_2O$$

$$3MgCO_3 + 3CaCO_3 = 3(CaCO_3.MgCO_3)$$

solution — dolomite

$$15CaCO_3 + 15SiO_2 = 15CaSiO_3 + 15CO_2$$

limestone — Magmatic silica — wollaston. — removed in solution

$$15H_4Mg_3Si_2O_9 + 15CO_2 = 15MgCO_3 + 30SiO_2 + 30H_2O$$

$$30SiO_2 + 30CaCO_3 = 30CaSiO_3 + 30CO_2$$

wollastonite ---------- removed in solution

$$15MgCO_3 + 15CaCO_3 = 15(CaCO_3 \cdot MgCO_3)$$

dolomite

In this way the entire rock is converted to dolomite and the wollastonite removed in much the same way as the silica is in deposits formed by the decomposition of peridotite in the presence of CO_2. The change to magnesite takes place by the reaction between the dolomite and the $MgCO_3$ molecule of the solution and results in the replacement of the $CaCO_3$ portion of the molecule by $MgCO_3$ forming pure magnesite in a matrix of dolomite.

$$3CaCO_3 \cdot MgCO_3 + 3SiO_2 = 3CaSiO_3 + 3CO_2 + 3MgCO_3$$

dolomite — wollastonite, magnesite : ---------- removed in solution

$$H_4Mg_3Si_2O_9 + 3CO_2 = 3MgCO_3 + 2SiO_2 + 2H_2O$$

solution — magnesite

The process may be halted in any one of these stages and the earlier it is stopped the easier it is to study and the less value it is as a deposit of magnesite. The deposit at the Limestone Chute had just started to pass the dolomite stage when the activity of the Laurentian Batholith came to a close. In the vicinity of the magnesite quarries the activity had continued for a much greater period of time or had continued more actively and in fact the limestone zone was narrowed down until the width of the quarry represents the entire width of carbonate rocks.

ECONOMIC GEOLOGY.

The economic possibilities of the magnesite deposits have been studied by Wilson and a very excellent report[1] upon the quantity and quality of material available prepared. The analyses published in this report will be used freely by the writer in discussing the quality of the magnesite; in regard to the quantity available in the fourteen deposits described by Wilson no further contributions can be made without additional data.

GEOLOGY IN THE VICINITY OF THE MAGNESITE DEPOSITS.

A close study of the structural features illustrated by the maps accompanying the report[1] will show that the same zonal arrangement occurs as in the other areas of the Grenville Series in the region. The structure likewise is very similar since the deposits occur on minor anticlinal folds superimposed upon the larger structures which form the valleys. In the North American Magnesite Quarry an excellent grade of magnesite is obtained from just a few feet below the dyke which forms the hangingwall of the deposits.

COMPOSITION OF THE MAGNESITE ROCK.

Several analyses of magnesite from the north half of Lot 18, Range XI of Grenville Township are given and will serve to illustrate the grade of material being mined.

Insoluble	0.50	2.90	0.88	2.16	0.10	2.00
$CaCO_3$	15.60	12.20	14.21	26.60	21.35	28.32
$MgCO_3$	84.18	84.60	84.98	71.86	79.26	69.14
CaO	8.77	6.83	7.96	14.90	11.96	15.86
Insoluble	1.50	6.10	2.32	0.50	2.20	2.24
$CaCO_3$	20.40	21.78	14.87	25.55	19.94	21.00
$MgCO_3$	78.96	74.61	82.34	74.70	78.08	75.44
CaO	11.25	12.18	8.33	14.31	11.17	11.76

Analyst H.A.Leverin[1]

All of the analyses show a high percentage of $CaCO_3$ or an amount of CaO ranging from 6.83% to 15.86%. This $CaCO_3$ is present in the dolomite molecule $CaCO_3.MgCO_3$ rather than as a homogeneous lime-

1. Memoir 98 C.G.S.

bearing magnesite.This relation is shown clearly in the photographs illustrating polished surfaces of the calcined material.

EFFECT OF DOLOMITE ON THE PROPERTIES OF MAGNESITE.

The polished surfaces of magnesite show varying percentages of dolomite.As long as the dolomite grains occur only in isolated areas and the magnesite is of sufficient thickness in between to support any strain to which the rock may be subjected no injurious effects of a serious nature can be expected by using this grade of material.If the distribution of the magnesite is uniform,dolomite present in amounts up to 25% of the rock will not affect the quality of the material for the ordinary purposes for which it may be used. On the other hand if the distribution of the magnesite and dolomite is irregular magnesite rock containing over 15% of dolomite should not be used for work requiring a high temperature under exacting conditions.

RELATION OF DISTRIBUTION TO THE QUALITY OF THE MAGNESITE

The reasons for these specifications are that lime,or even calcined dolomite,has astrong affinity for silica;if now a melt carrying silica is contained in a crucible lined with magnesia containing calcined dolomite,the silica will react with the lime of the dolomite to give calcium silicate which is fusible far below the melting point of magnesia.The molten silicate will be at liberty to flow out of the cracks and leave behind a cellular mass which will not have enought strength to withstand any marked strain.As long as the dolomite grains are not connected up,the reaction between the lime and the silica would stop as soon as the surface reaction had gone to completion and injurious effects would not be produced.

AMOUNT OF DOLOMITE REQUIRED TO PRODUCE INJURIOUS EFFECTS

When the amount of dolomite present does not exceed 15 to 20 percent the rock appears to be fairly satisfactory.Such a grade

of material from domestic quarries is to be desired much more than sources of supply situated in Europe or elsewhere.The average office man at the quarries does not understand how to estimate the amount of dolomite in the rock but he can readily determine the amount of lime in it.Since dolomite contains;-

MgO	21.7%
CaO	30.4%
CO_2	47.9%

the amount of permissable lime can be determined by multiplying the amount of allowable dolomite by 0.304.The lower figure should be specified for all high grade material and in that case magnesite rock containing less than 5% CaO and negligible amounts of insoluble would fulfil the requirements quite satisfactorily.In the case of the rock containing 20% of dolomite,shipments containing about 6.5% of CaO could be accepted.

GRADING OF MATERIAL.

The magnesite should be graded as it comes from the quarry because mixing pure magnesite with the lower grade material to bring up"quality"of rock high in dolomite will not effect the lower grade magnesite in the least and will serve to lower the quality of the pure magnesite.The poor grade magnesite will remain poor no matter how the composition of the car lot is affected by dilution.

EFFECTS OF TREATMENT.

It is claimed that by calcining at a much higher temperature than is ordinarly used the lime is rendered"inert".This can hardly be true because in no case does magnesite high in lime give as good results and durability as the purer grades.What happens at the higher temperature has not been studied but from the behavior it would seem that a rearrangement of the lime and magnesia took place.The lime appears to be distributed more evenly and is protected from reaction with SiO_2 by a veneer of magnesia.When the veneer is corrod-

ed off the reaction between the lime and silica takes place rapidly to completion after which it stops until another pathh of lime is exposed.Thus although corrosion of the magnesia lining of the crucible is slower when the magnesite is treated in this way,the life of the lining is much shorter than when the pure material is used.

Nevertheless by this treatment material containing 9% of CaO might be used where magnesia containing only 5% of CaO was required before.Similarly where 6.5% was allowable,magnesite containing 11.5% of CaO could be used.

To guard against dangers of unequal distribution of lime buyers should sample the shipment and also take selected specimens in order to get an approximation towards the lime content.

In the analyses previously given only four fulfil the requirements of high grade magnesite while only two more are good enough to be used for less exacting work.The high lime and great variability of these deposits require a very careful sampling of all the shipments to keep the maximum lime in any one piece below the allowable limit.

CONCLUSIONS.

Since the work which has been carried out was limited to a small area of highly metamorphosed rocks,wide,sweeping,conclusions cannot be drawn from any of the conclusions obtained.Nevertheless if the reader believes that the conclusions drawn are correct for the evidence presented it may be of help to him in some future work. Although the conclusions are stated in general terms,the author intends that the generalities should be applied omly to the area under discussion,until such time as they have been shown to be of wider application.

CONCLUSIONS AS TO THE ORIGIN OF THE DEPOSITS.

1. Deposits of dolomite and magnesite of this type can be expected only in the crystalline limestones or in their metamorphic equivalents,where a remnant has not been silicated.
2. The deposits are closely associated with paragneisses, rich in ferromagnesian minerals,which have been contact metamorphosed and hydrothermally altered by Laurentian granite and syenite magmas.The metamorphism was largely through pegmatitic action although simple vapours played a very prominent part.
3. The deposits occur below dykes of Buckingham or early Laurentian age,and on the crests of anticlines superimposed upon the major structure of the valleys.Magnesite deposits are to be expected wherever dykes cut across these folds and in some instances where only folds exist.
4. The silicates increase with depth so that the deposits cannot be expected to continue downwards to the granite contact.In some cases the increase in silicates is very rapid while in others it is comparitively slow.

5. The dolomites are harder and more resistant than the limestone.They are finer textured and furnish good outcrops which have weathered little since the glacial period Magnesite bears the same relation to dolomite as dolomite bears to calcite.Some beds contain more magnesitein proportion to dolomite than others.

6. The rocks consist of definite carbonates calcite,dolomite and magnesite.When the rocks are considered as small units calcite and dolomite or dolomite and magnesite occur together.Calcite and magnesite never occur together.Associated with the carbonates are fluorine and hydroxyl bearing minerals such as phlogopite,chondrodite,scapolite, biotite,talc,etc.High magnesia bearing minerals like forsterite are found along fissures.

7. Dolomite and calcite are intergrown and have a pseudo-eutectic structure characteristic of replacement deposits. The amount of dolomite in any bed of limestone varies in a regular manner as shown on the variation curves.Magnesite shows the same relations to dolomite as dolomite shows to calcite.

8. The magnesium carbonate is highest near the small fissure mineralized by forsterite and lesser chondrodite both of which have been altered in part to serpentine.The alteration was practically contemporaneous with their formation. Chondrodite has changed in practically the same way.The fissures pass down into garnet biotite gneisses.

9. The biotite and garnet gneisses have been subjected to pegmatitic action which has liberated the magnesia which they contained.Part of this magnesia appears to have been original and part introduced from the magma in its earlier

stages.Some magnesia was given off by the Laurentian granite magma up to the time of consolidation.Assimilation was a prominent process in helping to liberate magnesia from the contact gneisses.

10. The solutions which reached the limestone contained mainly magnesium silicate but in addition they held fluorides,hydroxides,sulphides and silicates in lesser amounts.Also the solutions found it easier to permeate and replace some beds than others.

11. Reaction between the calcium carbonate of the limestone and the magnesium silicate of the solutions produced magnesium carbonate and calcium silicate.The complicated series of reactions is given on another page.Precipitation of magnesite took place in the space vacated by the calcite.The decrease in volume gave some of the silicates a chance to precipitate but as a rule they were carried away in solution.Too great a concentration of solution resulted in the precipitation of forsterite as is indicated by its occurence in fissures.In some cases the forsterite was decomposed,practically contemporaneously with depositionto give a beautiful ophicalcite

12. The deposits are distinct replacement deposits formed at great depth and high temperature.Replacement occurs without any appreciable change in volume.

ECONOMIC FEATURES.

1. If contact zones similar to those described were found in other Grenville areas intruded by Laurentian Granite and dykes of very early Laurentian age were found truncating the structure, prospecting beneath these dykes might be carried on with some hope of returns.
2. Since the rock is composed of definite carbonates a lower percentage of lime is specified by consumers. The defect may be partly overcome by heating the magnesia unusually high when a redistribution tending to uniformity takes place. This overcomes the major drawback but leaves the minor defects unchanged.
3. Magnesite containing up to 11.5 CaO may be used for some purposes when it is treated in the above way.
4. Low grade dolomites free from iron would make an excellent artificial building stone.