A STUDY OF THE DIABASE DYKES OF THE CANADIAN SHIELD

by

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(A thesis submitted in partial

fulfilment of the requirements

for the degree of Master of Science)

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May 1948

ACKNOWLEDGEMENTS

The author wishes to express his appreciation for the guidance and helpful criticism received from Professor J. E. Gill of the Department of Geological Sciences, McGill University.

Thanks are due to faculty members Drs. C. H. Stockwell, and A. W. Jolliffe for their kind suggestions and assistance in connection with the obtention of certain required data.

CONTENTS

ABSTRACT

This paper deals with the results of a study and review of the petrographical, stratigraphical, and structural characteristics of certain basic intrusives, generally distributed throughout the Canadian Shield, which are described as "diabase" dykes and sills.

It is found that the cutting relationships reported afford positive evidence of at least four sequences of "diabase" intrusion.

Except for degree of alteration, the sequences resemble each other so closely that positive age correlation on a petrographical basis is precluded.

The dykes have predominant north west, north-south, and north east trends.

The writer concludes that structural evidence suggests the hypothesis that the dykes are emplaced in fissures which began opening in the crust above a basaltic substratum, along lines of weakness striking approximately north west, north-south, and north east, during stretching of the crust; and that surface trends have been modified somewhat by diversion of the magma into some pre-existing local fissures.

INTRODUCTION

Throughout most of the explored parts of the Canadian Shield there are certain intrusions, usually described as "diabase" dykes and sills, all of which have some general characteristics in common. The widths of the dykes are remarkably consistent over traceable lengths. The dykes are generally continuous and show persistent trends in those parts of the Shield which have been mapped in detail. In most areas the dykes are found to be the youngest consolidated rocks. They generally have a basic composition and are apparently unrelated genetically to other igneous intrusives.

DISTRIBUTION OF THE "DIABASE" DYKES

The dykes are distributed generally throughout the Shield but they are more abundant in Northern Ontario, the southern part of the Shield in Quebec, and the explored parts of the North-West Territories than in Manitoba or Saskatchewan. Their relative abundance in the Ungava-Labrador Peninsula cannot be established from data available at present, but they have been described in great numbers along the Labrador Coast from Belle Isle to Navchak Fiord. Large diabase sills outcrop along the East coast of Hudson Bay and in the Belcher Islands.

PETROGRAPHY OF THE "DIABASE"

Composition

While it can be said that the "diabase" dykes generally have a gabbroic or basaltic composition, a review of compositions of "diabase" described in all parts of the Shield indicates a considerable variation in the calcicity.of the plagioclase that precludes rigorous application of the term diabase to all the dykes. The plagioclase in some dykes is reported to be andesine or even oligoclase, and many descriptions report both the presence of labradorite and andesine. Variation in the kind and amount of pyroxene present has been noted in many areas. The combinations of the different variations in the essential minerals plagioclase and pyroxene permit application of the rock names, diorite, norite, gabbro, and even anorthosite, in some instances. Those dykes which contain these varieties of rock are found to have no other distinguishing characteristic which might justifiably exclude them from being considered part of systems of "diabase" dykes that intrude the rocks of the Shield. They preserve the general and continuous trends of the true "diabase" dykes in the areas in which they occur, are consistent in width, and so far as can be determined are of the same age as the true "diabase" lying adjacent and parallel to them in many areas. They have the same general appearance and texture as the true "diabase", and are generally distributed from Labrador, through Quebec and Ontario to the North West Territories. While a separation of these rocks from the rest of the "diabase" of which they constitute roughly one-third can be made on a petrographically basis, no evidence has been found to support the assumption of genetic relationship to any igneous bodies other than the true diabase dykes.

The essential minerals of the bulk of the "diabase" are labradorite and augite. Biotite, apatite and "iron ores" (iron oxides and sulphides) are common accessory minerals. The diabase may be divided into those types which contain free quartz, those with olivine and those with neither. The free quartz bearing types frequently contain quartz and potassic feldspar in micrographic intergrowth.

From a summary of about one hundred petrographic descriptions of "diabase" which is appended to this paper, it is found that there is more variation in the compositions of sills than dykes, and in the compositions of the quartz diabases than in either the olivine or the "normal" type.

In dykes the plagioclase feldspar ranges from labradorite to oligoclase, and porphyritic varieties have been reported to contain bytownite or anorthite phenocrysts. The plagioclase in sills ranges from labradorite to albite. Individual sills may have a range in the composition of the plagioclase. In such cases more sodic plagioclase occurs in the upper parts, and the more calcic near the bottom, where the composition of the sill may be identical with the true "diabase" dykes.

The varieties of pyroxene reported to occur are augite, titaniferous augite, diopside, pigeonite, enstatite, hypersthene and bronzite. The "iron ores" described are magnetite, titaniferous magnetite, pyrite, and ilmenite. Other accessory minerals are apatite, sphene and zircon.

Minor differences exist between the composition of the quartz and olivine diabases. None of the olivine "diabase" has been reported to contain sphene, and none of the quartz "diabase" has been reported to contain zircon.

From a review of the petrographic descriptions of "diabase", from all parts of the Shield, of known and unknown ages, summarized in Appendix A, it has been found that there is no composition which is characteristic or peculiar to "diabase" of a particular age, or a particular geological province. The minor differences that occur in the content and variety of accessory minerals are found in "diabases" of the three types, quartz diabase, olivine diabase and diabase, throughout the entire Shield area.

Frequently the essential minerals, and to a lesser degree the accessory minerals of the "diabase" are altered to secondary minerals such as saussurite, kaolin, sericite, chlorite, epidote, limonite, hornblende and uralite. In general the younger "diabase" is altered to a lesser degree than the older, but descriptions of the degree of preservation of the rocks indicates that freshness is neither universally characteristic of the younger rocks, nor a reliable criterion for distinguishing older from younger "diabase". Alteration induced by diastrophism occurs of course more frequently among the older than the younger rocks.

Fabric

Grain size in the dykes ranges from fine to coarse. Some of the narrow dykes are aphanitic, and glassy margins have been reported. About two-thirds of the "diabase" is reported to possess the "characteristic" ophitic texture. Porphyritic textures have been described in all ages of the "diabase". They are particularly well developed in some of the earliest and latest dykes. Some dykes have phenocrysts of olivine up to one inch in diameter, but most of the phenocrysts mentioned are fresh or altered plagioclase feldspar from one to six inches in diameter.

None of the varieties of fabric described is exclusively characteristic of the "diabase" of either a particular area or a particular age.

AGE OF THE "DIABASE"

Certain areas north of Lake Huron, in which the Precambrian geological column is more complete than elsewhere, afford positive evidence of the existence of at least four different ages of "diabase" in the Shield. On the basis of cutting relationships the ages, from oldest to youngest, are

Pre-Cobalt, Post-Cobalt, and Pre-Killarney No. 1; Post-Cobalt and Pre-Killarney No. 2; and Post-Killarney.

Pre-Cobalt

In the vicinity of Matachewan, Ontario, Cooke[1] has described a series of "diabase" dykes that intrude the Keewatin and Kiask Series and the Post-Keewatin granitic intrusives, but were not found to cut the Cobalt Series.

In the area around Gowganda, Ontario, Burrows[2] has described a series of "diabase" dykes that cut the Algoman granite and are overlain unconformably by the Cobalt Series. The conglomerate at the base of the Cobalt contains fragments of the dykes.

Todd[3] has also described "diabase" dykes which cut Algoman granite but underlie the Cobalt in the Matabitchuan area.

The age of the Pre-Cobalt "diabase" is thus defined relatively closely between the Algoman as a lower, and Cobalt as an upper limit in the geological column.

Post-Cobalt and Pre-Killarney, Nos. 1 and 2.

In the Sudbury region Cooke[4] has described two series of Post-Cobalt and Pre-Killarney "diabase" intrusions. The older series consists principally of large sills and a few dykes of quartz gabbro, thought to represent the Nipissing "diabase" . These intrusives cut the Cobalt, Bruce and older

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formations, but are themselves cut by a younger series of porphyritic olivine "diabase" dykes that are not seen to intrude the Killarney granite.

Two series of "diabase" intrusives in nearly similar relationship are described from the East Bull Lake area, twenty miles northwest of Espanola, Ontario, by Moore and Armstrong[1]. The older series consists principally of quartz diabase sills and a few dykes which intrude formations up to and including the Bruce Series. There are no Cobalt rocks in the map-area. The younger series, consisting of "normal diabase" dykes intrudes the older series, but none of the dykes is seen to intrude the Killarney granite.

The age of these two sequences of intrusion, which appear to be closely related in time, is fixed between the Huronian rocks intruded and the Killarney granite, and may range from Middle Huronian to Middle Keweenawan.

Post-Killarney

Collins[2] has described porphyritic olivine "diabase" dykes in areas containing Killarney granite north of Lake Huron. Some of the dykes are seen to cut the granite.

In the East Bull Lake area, Moore and Armstrong[1] report olivine "diabase" dykes which cut all other consolidated rocks including the Killarney granite.

In the Sudbury area Cooke[3] reports that some olivine "diabase" dykes cut the Whitewater series and granite known to be of Killarney age.

The age of these dykes is therefore at least late Keweenawan.

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Relative Age of Quartz and Olivine "Diabase" Intrusives.

In many areas Post-Cobalt sequences of "diabase" intrusion are the youngest rocks, and the sequences are unseparated by intervening formations. Where the relative age can be established by cutting relationships, olivine "diabase" is invariably younger than the quartz "diabase".*

Only olivine "diabase" is known to be definitely younger than the Killarney granite, but individual sequences of unknown age, containing both quartz and olivine "diabases" have been reported from many areas.

Correlation

Until certain correlation is achieved between the Precambrian of Ontario and the rest of the Canadian Shield, the ages of the "diabase" intrusions in the major part of the Shield must remain doubtful.

In those areas where correlation of major geological formations is reasonably certain, it has been found that none of the "diabase" intrusions is definitely older than the Late Archaean granite and gneiss. Many of the intrusions cut rocks which are tentatively correlated with the Late Proterozoic of Ontario. A revew of cutting relationships summarized in Appendix B shows that there is no evidence to preclude tentative correlation of the "diabase" intrusions in other parts of the Shield with the four ages established in Ontario, north of Lake Huron. It is possible, therefore, that the sequence of "diabase" intrusions occurring in Northern Ontario is represented more or less completely in other parts of the Shield.

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* cf. Moore, E.S.; "[redacted] Olivine Diabases of the Canadian Shield", Trans. Roy. Soc. Can. Series 3, Vol. 23, Sec. 4, pp. 44-45.

TRENDS AND STRUCTURAL RELATIONS OF THE "DIABASE" DYKES

Strikes and Dips

The average trends of the dykes in various areas of the Shield, described by workers of the Provincial and Federal Geological Surveys are plotted on the map at the end of this paper. In general it is found that there is a striking parallelism among the individual dykes of a particular map-area. The dykes in only three of about one hundred map-areas appear to have no outstanding trend or trends. In some areas there are two or more trends defined by prominent sets of parallel dykes. The degree of "parallelism" varies, but in the majority of map-areas, the dykes follow a common direction very closely. In most areas where only one trend of dykes is detectable, the dykes strike within 20° of the statistical average, which frequently coincides with the strike of the largest and most continuous dykes. In some map-areas containing numerous dykes, a minor number of nearly parallel dykes often constitute a subordinate set striking at angles of 45° to 90° to the dominant trends. Most of the minor trends are east-west.

The map shows that three dominant trends striking roughly northwest, north, and northeast are present in the explored areas of the Shield. The only exception occurs in the Grenville sub-province north of the Ottawa to Montréal section of the Ottawa river, where the dominant trend is more nearly east-west.

The prominent north trend is best represented north of Lake Huron and in the western part of Quebec. In this region, dykes known to be of Matachewan (Pre-Cobalt) age strike within a few degrees of north, but there is also a large number of similarly striking dykes whose age cannot be established. Northwest and northeast trends represent the strike of one or more sequences of diabase intrusions in all parts of the Shield. The northwest trend is poorly represented in Quebec, except near the western provincial boundary.

The dykes are reported almost always to dip vertically. In a few cases the reported dip is "steep", from 75° to 90°.

Forms of Intrusion

Nearly all the "diabase" is intruded as dykes. Sills are few, though of large area, and irregular intrusions in the form of stocks, bosses and "fingers" occurring north of Sault Ste. Marie, Ontario are exceedingly rare.

It has been found that almost all of the dyke intrusions have regular form. They have remarkably consistent widths, and where it has been possible to trace them along the length, some are known to extend over distances up to 25 miles. The outcrops of dykes in areas covered with scattered debris are very frequently aligned. In several instances where no differential movement of the dyke walls is apparent, contacts of formations striking the dykes obliquely have been observed to be displaced at right angles to the walls. The phenomenon suggests that these dykes were emplaced in fissures opened by pressure transmitted through the magma or by tensional forces operating perpendicular to the walls, rather than by stoping action.

The dykes have sharp contacts and chilled margins.

In a few areas, the dyke intrusions are less regular in form. Some dykes are sinuous, widening in sediments. Others follow schistosity, and at other places cross it. In a few areas they follow the curved strike of schistose rocks, and fill in around the borders of gneisses. In two areas dykes have been reported to die out in siliceous sedimentary rocks. A step-like form has been assumed by some vertical dykes traversing dipping bedded rocks.

Relation to Folds

The dominant trends of the dykes are perpendicular, oblique or parallel to fold axes in their respective map-areas. Most often the trends are perpendicular or oblique at angles from 25° to 65°, and only seldom are they parallel to the axes. The attitude assumed in relation to the fold axes in a particular area appears to be the one which is more nearly parallel to one of the three dominant trend directions in the Shield. This is well shown in Ontario and parts of Québec. In some of the northern parts the axes of old mountain ranges strike generally east-west. Here the dominant trends are perpendicular or oblique to the axes of the folds, whereas in the Frontenac Axis north of the St. Lawrence River, the dominant north-east trend of the dykes is parallel to fold axes.

Under opposed horizontal compressive stresses, a fold system may develop tension cracks perpendicular and parallel to the axial plane as well as a set of vertical shear planes oblique to the axial plane. Though it cannot be conclusively proved, it seems probable that some dykes, perhaps many, were emplaced in such fracture planes developed by folding.

Relation to Faults

There is frequent parallelism between pre-dyke faults and dykes in all parts of the Shield, and many dykes are known to be emplaced in faults. In a few map-areas, the dominant trend of the dykes is perpendicular or oblique to the strike of the pre-dyke faults. Where there are two or more faults systems the dominant trending dykes often lie in or parallel to those fault systems that more nearly coincide with the three major Shield trends.

SUMMARY

At least four sequences of "diabase" intrusions, mostly dykes striking in the three common directions northwest, north, and northeast are known in some parts of the Shield, and may be represented all over. Except for degree of alteration, the sequences resemble one another so closely that positive age correlation on a petrographical basis is impossible. The dykes are generally vertical, and show striking parallelism and continuity. Individual dykes are remarkably consistent in width and strike over traceable lengths. Frequently dykes have been observed to be emplaced along predetermined planes of weakness such as faults and joints, or they can be related to hypothetical joint planes developed by folding.

CONCLUSION

It is apparent that to some degree regional or local structure has exercised control over the emplacement of dykes by providing some of the fissures that are filled with "diabase". There are factors that suggest that the "diabase" intrusions are not solely governed by the regional and local structures. One of these is the fact that while available channels strike in many different directions, only those which more nearly coincide with the main "diabase" trends in the Shield are filled with dykes. If hydrostatic pressure behind advancing diabasic magma was responsible for opening the fissures, the channels most easy of access would be expected to be filled, at least initially, by the "principle of least work". The evidence available does not support the assumption. The majority of the dykes have created or filled long straight fissures, which, without deviation, have traversed contacts between sediments, extrusive, and intrusive rocks at many different angles. In addition, it has already been stated that in areas containing various sets of faults, the "diabase" has frequently been emplaced in or parallel to one set of faults in preference to another. In those areas where lines or planes of weakness have not been detected, the "diabase" dykes maintain a parallelism and regularity which would not be expected were the force behind the magma solely responsible for opening channels.

The hypothesis which appears to explain best the observed facts is one which assumes a stretching of the earth's crust at different periods of time so as to open tension cracks of variable size, which tapped basaltic magma at depth. Stretching of the crust could be brought about by abnormal thermal expansion of the interior during these periods. After pressure was relieved by rupture along the original lines of weakness, northwest, north and northeast, the basalt started to flow upward with little disturbance, through tensional fissures which must have commenced opening at the bottom. The pressure behind the basalt was a subordinate factor contributing to the creation of openings. Where the original channels were connected to channels descending from the surface, opened during the stretching, the magma was diverted to a degree which accounts for the variation in the observed strike of the dykes. Elsewhere, tensional fissures originating below may have extended all the way to the surface.

A calculation based on data summarized in Appendix C indicates that a volume increase in the Shield crust of about 5% would be provided by the "diabase" filled fissures.

The phenomenon suggested does not correspond to the sequence of granitic intrusion that occurs during mountain building periods, and there is little evidence to suggest association in age. The irregular intrusions seeking all lines of weakness through rocks under compressive stresses during mountain building is unlike the regular intrusions of "diabase" easily explained if the crust were under great tensional stress. If the widespread parallel dykes intrusions occurred during orogeny and attendant granitic intrusion, it is difficult to account for the relatively discontinuous and irregularly striking satellitic acid dykes of those periods.

The wide chilled margins and denseness of many of the "diabase" dykes suggest that they cooled shortly below the surface. The fact that the characteristic occurs over wide areas suggests that the periods of dyke intrusion are more nearly related to periods of peneplanation than orogenic times.

Investigations of repeating patterns in relief and structure of the landsurface of North America by Hobbs[1] have suggested that there are two sets of controlled fracture patterns. One pattern set comprises structures striking approximately northwest and northeast. The other set strikes roughly along north-south and east-west lines.

If the directions of the dominant trends of the "diabase" dykes in the Shield are not fortuitous coincidence, a connection in origin and development between Hobbs' patterns and the "diabase" trends is suggested by their striking congruity.

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60°
110°
100°
50°
90°
80°
70°
TRENDS OF THE DIABASE DYKES
in
THE CANADIAN SHIELD
Legend
Dominant trends
Subordinate trends
No trends
Sill
33
Reference number
60
0
60
120 MILES

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AR for annual report
Mem. for Memoir
Q for Quebec
O for Ontario
Can. for Canada
DM for Department of Mines
BM for Bureau of Mines
P for paper
GS for Geological Survey
GR for geological report

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APPENDIX A

SUMMARY OF PETROGRAPHIC DESCRIPTIONS

The following tables compare descriptions of the quartz, olivine and "normal" types of "diabase" from the various parts of the Shield. Because the age of most of the "diabase" is not positively established, a comparison is necessarily made between some "diabase" thought to be of a certain age, and some known to be of the same age. The limited data available from many parts of the Shield permit comparison only in a general way between those "diabases" known and presumed to be Post-Cobalt (or Post-Huronian) in Ontario with "diabase" thought to be a similar age in other parts of the Shield.

In the same way, a comparison is made between the Pre-Cobalt "diabase" of Ontario, and "diabase" in the rest of the Shield thought to be Pre-Huronian.

Explanation of Tables

O - Texture described as ophitic.

SO -- Texture described as sub-ophitic.

P - Texture described as porphyritic.

MI - Micrographic intergrowth.

D - Texture described as "diabasic".

A - Texture described as amygdaloidal.

alb	- albite	lab	- labradorite
oligo	- oligoclase	anor	- anorthite
and	- andesine	plag	- feldspar described as "plagioclase".

Ti-aug	-	titaniferous augite	feld	-	feldspar
Ti-mag	-	titaniferous magnetite	byt	-	bytownite

TABLE I

Post-Cobalt Quartz "Diabases"

Location	dyke or sill	Feldspar Range	Free Quartz	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	ilmenite	sphene	hypersthene	enstatite	pyroxene	diopside	Ti-aug	Ti-mag	MI	Texture
Quebec	dyke	lab	x	x	x	x	x							x			x	O & P
"	"	"	x				x							x				O
"	"	"	x										x					
"	"	"	x	x		x	x											P
"	"	"	x														x	O
"	"	"	x	x	x	x	x										x	
"	"	"	x										x					
"	"	"	x	x														D
"	"	"	x	x			x											
"	?	"	x		x		x	x					x					O
Ontario	dyke	lab	x	x	x				x								x	
"	"	"	x	x						x							x	
"	"	"	x	x					x			x						
"	"	"	x										x					SO
"	"	"	x	x						x								O
"	"	"	x				x						x					O
"	"	"	x	x			x										x	O
"	both	"	x	x					x								x	O
"	sill	"	x	x	x	x	x	x									x	O
"	"	"	x				x						x				x	O
N.W.T.	sill	lab	x			x		x					x				x	
Ontario	sill	plag	x	x														
"	both	"	x	x														
"	dyke	"	x			x	x	x					x					O
"	"	"	x	x	x	x	x											O
"	"	"	x	x				x										
"	"	"	x	x	x				x									

TABLE I (Cont.)

Location	Dyke or Sill	Feldspar Range	Free Quartz	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	ilmenite	sphene	hypersthene	enstatite	pyroxene	diopside	Ti-aug	Ti-mag	MI	Texture
Ontario	dyke	lab - and	x			x	x						x				x	
"	"	" "	x	x										x			x	
"	"	" "	x	x				x									x	P
"	"	" "	x	x			x											O
Quebec	dyke	lab-and	x	x	x	x	x											O
"	"	"	x		x		x	x					x					O
Quebec	dyke	and	x	x	x	x	x										x	O
"	"	"	x	x			x											O
Quebec	dyke	lab		x	x	x	x										x	O
"	"	"		x		x	x										x	
"	"	"		x		x											x	O
"	"	"					x							x			x	O
"	sill	"		x		x											x	O
Grenville	dyke	"		x			x										x	O
Manitoba	dyke	lab		x		x	x										x	P
"	"	plag		x		x			x								x	
N.W.T.	dyke	lab		x		x		x									x	P
"	"	lab-byt		x	x	x	x										x	
"	"	and		x		x		x									x	
Ontario	dyke	lab		x				x									x	O
"	"	"		x	x	x	x										x	
"	"	"		x			x										x	P
"	"	"		x				x	x								x	O
"	"	and-lab		x	x				x								x	O
"	"	"		x		x	x						*				x	O
"	"	"		x	x	x											x	
"	"	"		x				x									x	P
"	"	plag		x	x		x	x									x	

TABLE I (Cont.)

Location	Dyke or Sill	Feldspar Range	Free Quartz	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Ilmenite	Sphene	Hypersthene	Enstatite	Pyroxene	Diopside	Ti-aug	Ti-mag	MI	Texture
Ontario	Dyke	plag		x				x									x	
"	"	"		x				x									x	
"	Both	lab		x					x								x	O
"	Sill	lab		x		x										x	x	O
"	"	and-lab		x				x									x	O
"	"	plag			x		x		x		x						x	
"	"	"		x				x			x						x	O
"	"	alb-lab		x					x								x	P
"	"	oligo		x	x	x	x		x								x	A

* pigeonite   ‡ pyrite

TABLE II

Post-Cobalt Olivine "Diabases "

Location	Dyke or Sill	Feldspar Range	Olivine	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Ilmenite	Pyrite	Zircon	Hypersthene	Diopside	Pyroxene	Ti-aug	Texture
Ontario	dyke	lab	x	x	x	x	x									
"	"	"	x	x	x	x	x									
"	"	"	x	x	x	x										
"	"	"	x	x												O
"	"	"	x	x	x			x								O
"	"	"	x	x			x				x					
"	"	"	x	x		x		x								P
"	"	"	x	x	x	x										P
"	"	"	x	x			x									
"	both	"	x	x			x									P
Quebec	dyke	lab	x	x	x		x									O
"	"	"	x	x		x		x		x						SO
"	"	"	x	x	x	x		x							x	
"	"	"	x	x		x									x	O
"	"	"	x	x		x		x								
"	both	"	x	x		x										P
"	sill	"	x	x		x										O
Manitoba	dyke	lab	x	x												O
"	"	"	x	x			x									
"	"	"	x	x												
"	"	"	x	x			x									
Ontario	dyke	plag	x											x		O
"	"	"	x	x				x								O
"	"	"	x	x		x	x									
"	"	"	x	x												O & P
"	"	"	x	x		x		x								O
"	"	"	x	x			x									O
"	"	"	x			x								x		P
"	"	"	x	x		x	x									O
"	"	and-lab	x	x	x				x		x					O
"	"	" "	x	x	x	x										
"	"	and	x	x					x							P
"	"	"	x	x			x		x							O
"	"	Feldspar	x	x					x							
"	sill	"	x	x		x	x			x						O & P
"	sill	Plag	x	x	x		x		x			x				O & P

TABLE II (Cont.)

Location	Dyke or Sill	Feldspar Range	Olivine	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Ilmenite	Pyrite	Zircon	Hypersthene	Diopside	Pyroxene	Ti-aug	Texture
Manitoba	dyke	plag	x			x		x						x		
Quebec	dyke	and	x	x				x								
Grenville	"	plag	x	x		x		x				x				O

TABLE III

Post-Cobalt "Normal" Diabases

Location	Dyke or Sill	Feldspar Range	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Ilmenite	Pyrite	Sphene	Bronzite	Diopside	Pyroxene	Ti-Aug	Ti-Mag	Texture
Ontario	dyke	lab	x					x								O
"	"	"	x			x										
"	"	"	x											x	x	O
"	"	Plag			x								x			P
"	"	"	x					x					x			O
"	both	Feldspar						x					x			
Grenville	dyke	lab	x	x		x				x						
Quebec	dyke	lab	x	x	x	x		x								P
"	"	"	x													O
"	"	"	x													O
"	"	plag				x		x				x				
Grenville	dyke	lab	x	x												O
"	"	and	x	x	x	x										
"	sill	plag	x						x		x					O
N.W.T.	dyke	plag	x					x								O
"	"	lab				x							x			
"	"	"	x		x		x									
Manitoba	dyke	lab	x				x									P

TABLE IV

Pre-Cobalt Quartz Diabases

Location	Dyke or Sill	Feldspar Range	Free Quartz	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Pyrite	Sphene	Pigeonite	Ti-Mag	MI	Texture
Ontario	dyke	lab	x	x			x							O
"	"	"	x	x			x							
"	"	"	x	x						x			x	
"	"	"	x	x			x							O & P
"	"	lab-and	x	x		x	x				x		x	O
"	"	and	x	x		x	x		x					O
"	"	Plag	x	x	x		x							O & P
"	"	"	x	x			x	x						
Quebec	dyke	and-anor	x					x			x		x	P
"	"	lab	x	x	x	x	x						x	O
"	"	"	x	x		x	x						x	P
"	"	"	x	x	x	x						x	x	O

TABLE V

Pre-Cobalt Olivine Diabases

Location	Dyke or Sill	Feldspar Range	Augite	Apatite	Biotite	Magnetite	"Iron Ores"	Ti-aug	Olivine	Texture
Quebec	dyke	lab-and	x	x	x		x		x	
"	"	lab		x	x		x	x	x	
Ontario	dyke	lab	x			x			x	O
"	"	and	x			x	x		x	O
"	"	plag	x						x	
"	"	"	x						x	

DIABASE IN THE UNGAVA-LABRADOR PENINSULA

A few descriptions of "diabase" dykes of unknown age have been given by Low (156, 158-161). None of the specimens described is fresh, and the plagioclase is considerably altered. Most of the dykes contain "iron ores", ilmenite, and pyrite. Olivine accompanied by augite is noted in one specimen from Dyke Lake, Labrador.

Tanner (162) states that olivine, olivine-free, and porphyritic varieties occur intruding the rocks around Hamilton Inlet, Labrador.

Wheeler* has described quartz bearing, olivine bearing and "normal" types of diabase along the Labrador Coast from Hopedale to Okak. He has classified four types after Törnebohm. The descriptions do not vary significantly from descriptions of "diabase" in other parts of the Shield.

*Wheeler, E. P. II : "A Study of some Diabase Dykes on the Labrador Coast", J.G. Vol. 41, No. 4, May-June 1933, pp. 421-428.

APPENDIX B

CUTTING RELATIONSHIPS OF THE "DIABASE" DYKES

Ontario

In many areas in Ontario "diabase" dykes and sills are the youngest consolidated rocks in the geological column, and they have been reported to intrude the following formations :-

1. Temiskaming.
2. Post-Temiskaming batholithic intrusions, and Algoman intrusions with which they may be correlated.
3. Post-Grenville batholithic intrusions.
4. Huronian.
5. Post-Huronian "diabase" dykes and sills.
6. Kaministikwan.
7. Middle Keweenawan.
8. Keweenawan.
9. Whitewater.
10. Killarney.

Elsewhere "diabase" dykes and sills are not the youngest rocks and have been reported to be older than the following formations :-

11. Silurian.
12. Pre-Keweenawan batholithic intrusions.

1. Temiskaming

Quartz "diabase" dykes that intrude the Temiskaming series, and series correlated with the Temiskaming have been described from many areas.

Most workers have considered them to be of Post-Cobalt age, on the basis of petrological and structural characteristics. Other workers have considered them to be Pre-Cobalt on the same basis.

Berry (59) reports that north-south striking dykes in the Bigwater Lake Area, Cochrane District, cut Keewating type volcanoes, and Temiskaming formations. They are not seen to cut the granite thought to be Algoman, but are placed with the Matachewan (Pre-Cobalt) dykes by Berry. Dykes known to be Pre-Cobalt age in this region strike north-south, and many of them are coarsely porphyritic.

Further west, in the Little Long Lac Area, Thunder Bay District, north-south striking, non-porphyritic dykes are placed provisionally with the Keweenawan by Bruce (106).

Further west, in the Eagle Lake Area, Kenora District, Moorhouse (132) has referred some altered "diabase" dykes to the Keweenawan apparently on the basis of their trend.

2. Post-Temiskaming and Algoman.

Post-Temiskaming batholithic intrusions, which cannot be conclusively correlated with the Algoman, are found mainly in Western Ontario, and "diabase" dykes cutting such formations have been assigned a Keweenawan age on the basis of lithological resemblance. In the Keezhik-Miminiska Area, Patricia Portion of Kenora District, Prest (122) describes olivine, quartz and "normal" diabases, which he places provisionally with the Keweenawan. Satterly (125) considers that the olivine diabase in the North Caribou Lake Area of the same district can be correlated with the Keweenawan. North of the Lake of the Woods, Thomson (137) has referred to Keweenawan age a quartz "diabase" cutting granite thought to be Algoman.

"Diabase" dykes which cut Algoman batholiths north of Lake Huron have a wide variation in texture and composition. In the Groundhog River Area, Cochrane District, Todd (69) describes "Matachewan" dykes that strike north-south, most of them containing phenocrysts of altered feldspar ("huronite").

In the Goudreau Area, Algoma District, Moore (96) reports ophitic quartz and olivine "diabases" cutting the Algoman intrusives.

Bruce (60) describes ophitic olivine "diabase" dykes cutting the Algoman in the Redstone River Area, Temiskaming District, which he has referred to the Keweenawan period with the reservation that some of the dykes may be "Matachewan" (Pre-Cobalt).

In the Robb-Jamieson Area, Cochrane District, Berry (66) divides the "diabase" dykes cutting the Algoman into a "Matachewan" age and a "Keweenawan"age. The later set cuts the earlier, is fresher than the earlier, and is thought to resemble other olivine diabase in the Porcupine Belt.

Similar cutting relationships with Post-Temiskaming, and Algoman intrusives are described in the areas (see Map) : 53,55,67, 68, 93, 94, 100, 107, 109, 117, 118, 127, 128, 131, and 133.

3. Post-Grenville Batholithic Intrusions.

Wright (47) describes a fresh ophitic diabase from the Brockville Mallory Town Area which cuts Post-Grenville Granite, but has not been seen to cut the Paleozoic rocks.

In the Grimsthorpe, Kaladar, Kennebec Area, Meen and Harding (48) report a number of "diabase" dykes cutting a Post-Grenville granite.

In the Mattawan-Olrig Area, Nipissing District, Harding (49) describes a dioritic diabase which can be separated only with difficulty from local dioritic intrusions. The "diabase" cuts the Grenville series, later amphibolites and a pink gneiss.

If correlation of the Post-Grenville intrusives with the Algoman sequence in southern Ontario is accepted, the "diabase" dykes cutting these rocks may correspond to any of the four definitely established sequences of diabase intrusion.

4. Huronian.

"Diabase" sills and dykes, intrusive into the Cobalt series and other Huronian rocks, occur in many places north of Lake Huron. The age of this diabase, called the Nipissing diabase in some localities, may range from Huronian to Keweenawan. Where it is the youngest rock, workers have considered it Keweenawan.

Dyer (56), in the Powell and Cairo Twnsps, Temiskaming District, and Emmons (89), in the Wakomata Lake Area, Algoma District, report "Keweenawan" quartz "diabase" dykes and sills which intrude the Huronian rocks.

Osborne (85), describes both quartz and olivine "diabase" dykes and sills, cutting the Huronian in the Cartier-Stralak Area, Sudbury District.

5. Post-Huronian "Diabase" Sills and Dykes.

In certain map-areas of the Temiskaming District where the Post-Huronian "diabase" sills and dykes are not the youngest rocks, they are cut by other quartz and olivine bearing "diabase" dykes.

In the Matabitchuan Area (50) and the Anima-Nipissing Area (51) Todd describes fresh, porphyritic, occasionally ophitic olivine "diabase" cutting sill and dyke intrusions in the Cobalt Series which are thought to be "Nipissing" diabase.

In the Tyrrel-Knight Area, Graham (62) describes porphyritic quartz and olivine "diabase" dykes cutting sills "of great areal extent" along bedding planes in the Cobalt Series.

Collins describes fresh olivine "diabase" dykes cutting "Keweenawan" quartz "diabase" and quartz-norite sills and dykes which have intruded Huronian rocks in the Onaping Map-Area.

Olivine and quartz "diabases" have been reported by Burrows (79) to intrude "Nipissing" sill diabase in the Gowganda Silver Area. The sills intrude the Cobalt Series.

From the cutting relationships reported, the quartz and olivine "diabase" which is younger than sills known to be Post-Huronian, may correspond to either the Post-Cobalt and Pre-Killarney No. 2 age, or the Post-Killarney age.

6. Kaministikwan.

In the Fort William, Port Arthur and Thunder Cape Areas, Tanton (113) describes noritic "diabase" sills and dykes which cut the formations grouped under the name Kaministikwan. According to Tanton the Kaministikwan consists of the Animikie and succeeding strata generally known as Keweenawan. In this area the Keweenawan is represented by the Sibley and Osler lavas and sediments.

The age of these "diabase" intrusions is definitely Post-Cobalt, and is probably to be be correlated with either the Post-Cobalt and Pre-Killarney No. 2 age, or the Post-Killarney age.

7. Middle Keweenawan.

Moore (91) describes olivine "diabase" dykes which cut Middle Keweenawan lavas and sediments in the Batchawana Area, Algoma District.

It is not known whether the dykes cut the Upper Keweenawan.

The age of these "diabase" intrusives is probably to be correlated with one or the other of the two youngest sequences of "diabase" intrusion definitely established north of Lake Huron.

8. Keweenawan.

"Diabase" dykes are described from the Thunder Bay Region which cut the undivided Keweenawan formations in the area. In the Block Creek map-area of this region Jolliffe (115) reports porphyritic and ophitic quartz "diabase" dykes and sills cutting a formation thought to be the Sibley Series.

In the townships of Dorion and McTavish Hawley (112) has noted gabbroic and noritic "diabase" dykes cutting Keweenawan sediments referred to the Sibley Series.

The age of these "diabase" intrusives may correspond to any one of the Post-Cobalt sequences described in this paper.

9. Whitewater.

Burrows (83) and others have described fresh porphyritic olivine "diabase" dykes which cut the Whitewater series in the Sudbury Basin. The age of the Whitewater Series has been considered equivalent to Upper Huronian, and more recently Early Keweenawan by Cooke[1]. In either case the olivine "diabase" may be correlated with one of the definitely established Post-Cobalt ages of intrusion.

10. Killarney.

"Diabase" intrusives which cut the Killarney granite have been discussed in an earlier part of this paper.

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1. Cooke, H.C. : Canada Dept. of Mines and Resources, Geol. Survey Bull. 3
Problems of Sudbury Geology, Ontario.

11. Silurian.

A large, altered quartz "diabase" sill is reported by Hawley (155) and Dowling[1] to underlie the Silurian formations at Sutton Lake, in the Patricia Portion of Kenora District west of James Bay. On the basis of similar sequence and lithological similarity, Hawley has correlated the "diabase" tentatively with the Animikie age. As no "diabase" sills have been reported to intrude Pre-Algoman bedded rocks, it is possible that this sill may be correlated with any one of the four definitely established sequences of intrusions.

12. Pre-Keweenawan Batholithic Intrusions.

Moore (91) describes a "normal" altered "diabase" in the Batchawana Area, Algoma District, outcropping as hills, which he has called the Maimanse diabase. The relations of the Maimanse diabase and the Batchawana Series are not entirely clear. Moore states that both the Batchawana Series and the diabase are cut by a granite which is older than the oldest identified Keweenawan in the area. The "diabase" is placed in the Middle Huronian because Moore considers that the Batchawana Series on which the diabase lies resembles the Hemlock Formation in the Crystal Falls iron district, Michigan, thought by Van Hise and Leith[2] to be middle Huronian. The uncertainty of relationship and age of formations precludes definite assignment of an age to this "diabase". It might be referred to any one of the four definitely established sequences of intrusion.

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1. Dowling, D. B. : Part of the West Coast of James Bay, Geol. Survey Can. Ann. Rept. Vol. XIV, Part F.

2. Van Hise, C. R. & Leith, C. K. : Geology of the Lake Superior Region, U.S.G.S. Monograph 52, p. 294.

Quebec

In most areas in Quebec "diabase" dykes and sills are the youngest rocks in the geological column. They have been reported to intrude the following formations in different areas :

1. Keewatin
2. Temiskaming
3. Post-Temiskaming and Post-Keewatin batholithic intrusions.
4. Cobalt Series.
5. Chatham-Grenville Stock.
6. Pentcôte Granite.
7. Chibougamau Series.

1. Keewatin.

In the Opaoka River Area, Freeman and Black (27) describe quartz and olivine "diabase" dykes which cut Keewatin type volcanics and a basal complex. The olivine bearing type cuts a diorite which the quartz type does not cut.

These "diabase" intrusives may be correlated with any of the four definitely established ages of diabase intrusion.

2. Temiskaming.

In the Villebon-Denain Area, Lowther (21) describes quartz gabbro dykes cutting Temiskaming sediments.

In the Kinojévis and Cléricy Areas, James and Mawdsley (38) describe olivine and quartz bearing "diabase" dykes cutting Temiskaming sediments.

The age of the dykes in both areas has been referred to the Pre-Cobalt on the basis of petrographical similarity to the "later gabbro" described from the Opasatika Area by Cooke (43), and from the Rouyn-Harricanaw Area by Cooke, James and Mawdsley (36). These "diabase" intrusives may be correlated with any of the four definitely established ages of diabase intrusion.

3. Post-Temiskaming and Post-Keewatin.

Bell and Bell (24) report quartz "diabase" dykes, intruding Post-Keewatin granite in the Senneterre Area. They consider the dykes to be Pre-Cobalt age on the basis of their petrographical resemblance to the "quartz gabbro" of the Rouyn-Harricanaw Region, described by Cooke, James and Mawdsley (36).

In the Lamaque Sigma Mines Area, Bell (34) describes an olivine "diabase" which cuts the Post-Keewatin granodiorite.

In the Lamotte-Fournière map-areas, James and Mawdsley (35) note a "remarkable similarity" between the olivine and quartz gabbros cutting the Post-Temiskaming granite of that area, and the "Keweenawan" "diabase" of the Lake Superior Region.

Quartz and olivine "diabase" dykes are also described cutting the Post-Temiskaming and Post-Keewatin batholithic intrusions in the areas (see map) : 12, 13 14, 16, 17, 18, 19, 25, 26, 28, 31, 37.

As there is no conclusive evidence to show that "diabase" dykes cutting such batholithic intrusions are Pre-Cobalt, they may be correlated with any of the four definitely established ages of "diabase" intrusion.

4. Cobalt.

In the Kewagama Lake Map-Area (36) and the Lake Temiskaming Mining Region (42) Wilson has described quartz and olivine "diabase" dykes and sills intruding the Cobalt series which are thought to be the "Nipissing" diabase.

These intrusives are probably to be correlated with the Post-Cobalt and Pre-Killarney (No. 1) age of "diabase" dykes established in Ontario. (p. 7)

5. Morin Series.

In the Lachute Area, Argenteuil and Papineau Counties, Osborne (5) reports "diabase" dykes which cut the Morin Series. If the Morin Series is considered to be approximately equivalent in age to the Late Archaean batholithic intrusions of the Abitibi region, the age of the dykes may be correlated with any of the four definitely established ages of "diabase" intrusion.

6. Pentcôte Granite.

Fassler (4) reports ophitic olivine and "normal" diabase dykes cutting the Morin Series and Pentcôte Granite in the Sept Îles region, Saguenay County. As the Pentcôte Granite is tentatively correlated with Killarnean granitic intrusives, this "diabase" may be equivalent to the Post-Killarney age established in Ontario.

7. Chibougamau Series.

Mawdsley and Norman (10) describe olivine "diabase" and gabbro from the Chibougamau Area which they inferred was younger than the Chibougamau Sediments by its freshness, absence of shearing, and parallelism with post-sediment faults. If the Chibougamau Series is considered to be equivalent to the Huronian of Southern Ontario, this "diabase" may be any one of the definite Post-Cobalt ages established north of Lake Huron.

Manitoba.

The reported "diabase" dykes and sills are the youngest rocks in the Precambrian geological column. They intrude the following formations in different areas :-

1. Oxford and Hayes River Groups.
2. Post-Missi Granite.

1. Oxford and Hayes River Groups.

In the Stull Lake Area Downie (138) reports a few olivine "diabase" dykes cutting the Oxford and Hayes River Groups which are considered to be Archaean. The dykes are not known to cut late Archaean batholithic intrusions, but Downie considers them the youngest rocks in the area. These intrusions of "diabase" may correspond to any of the four definitely established ages.

2. Post-Missi Granite.

Wright (143) describes a fresh labradorite diabase with abundant olivine from the vicinity of Wintering Lake in northwest Manitoba. The dykes cut the Post-Missi Granite, thought to be Late Archaean Age, and may therefore correspond to any of the four established ages.

North West Territories.

In most areas of the North West Territories "diabase" dykes are the youngest rocks. In a few places they are cut by giant quartz veins and stockworks. Where they are the youngest rocks they have been reported to cut the following formations in different areas :-

1. Yellowknife Series.
2. Et-Then Series.
3. Hornby Bay Series.

1. Yellowknife Series.

Campbell (153) has discussed "diabase" dykes in connection with the great faults on Yellowknife Bay, Great Slave Lake. The dykes cut the Yellowknife series and the diorite and granite which are considered to be late Archaean. The "diabase" dykes may therefore correspond to any one of the four established ages.

2. Et-Then.

Sills and dykes of quartz "diabase" cutting the Et-Then series of late Proterozoic age, are described by Stockwell (147) from the Great Slave Lake-Coppermine River Area. These "diabase" intrusions are probably to be correlated with the Post-Cobalt ages of intrusion established north of Lake Huron.

3. Hornby Bay.

In the Great Bear Lake Area, Kidd (151) describes flat lying quartz "diabase" dykes and sills, intruding the bedded formations of the Hornby Bay Series which is thought to be equivalent to the Keweenawan Period. The diabase may be correlated with any of the Post-Cobalt diabasic sequences established north of Lake Huron.

In the area from Rae to Great Bear Lake, Kidd (152) describes two ages of diabase. The earlier is a sill of quartz diabase which is not seen to cut an Archaean granite. Because the diabase is not apparently altered by the granite, Kidd concludes that it is probably younger. The younger age of diabase cuts the Hornby Bay series.

It is possible that both these ages of "diabase" are Post-Cobalt.

Labrador-Ungava Peninsula.

The limited information about this region precludes even tentative correlation of "diabase" on the basis of cutting relationships with the better known parts of the Shield, except in a few areas.

From traverses throughout the peninsula, Low (156, 158-161) has noted great "diabase" dykes which cut rocks up to, and including the "Cambrian". The "Cambrian" of Low is perhaps to be correlated with either Keweenawan, or the Animikie of the Lake Superior District. Along the East Coast of Hudson Bay, Low (158) recognizes two ages of "diabase" in various places. He implies that the earlier is separated from the later by granite. It is possible therefore, that any or all of the definitely established ages of "diabase" intrusion may be represented throughout the peninsula.

In the Belcher Islands Young (157) describes a fine grained "normal" diabase containing curious pegmatoid patches of feldspar, which intrudes the iron bearing formations thought to be either Keweenawan or Animikie age.

Wheeler[1] describes similar "diabase" with inexplicable pegmatoid patches of feldspar intruding rocks of undetermined age along the Labrador Coast.

On the north-east Labrador Coast Coleman[2] reports a "badly weathered" diabase that is not seen to cut the Ramah and Mugford Series which are thought to be equivalent to the Keweenawan or Animikie in part. Some "diabase" sills are reported to intrude the Mugford Series[3] and more than one age of "diabase" intrusion may be present.

Tanner (162) has summarized the conditions of "diabase" intrusion along the Labrador Coast. He states there are definitely different sequences and that the older predominate around Hamilton Inlet and Domino Run. He concludes that the connection between the "diabase" intrusion and the Keweenawan Sandstone of Labrador is not yet clear.

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1. Wheeler, E. P. II : op. cit. p. 418.
2. Coleman, A. P. : The Northeastern Part of Labrador and Northern Québec, Geol. Survey. Can. Memoir, 124, p. 21.
3. Coleman, E. P. : Op. cit. p. 25.

APPENDIX C

NUMBER AND AVERAGE WIDTH OF THE "DIABASE" DYKES IN THE SHIELD

Average Number of Dykes per Map-Area

The number of "diabase" dykes in the various parts of the Shield has frequently been described by the terms "rare", "scarce", "abundant" or"innumerable". Representative quantitative data are difficult to obtain because for the many dykes plotted on geological maps there be as many more unplotted or unnoticed.

The significance of the data collected is limited because the unit of area used - a "map-area" - varies from province to province, and according to the nature of the report. Because many of the sheets are more nearly a square of 15 minutes latitude by 30 minutes longitude, roughly a 15 miles square, this area is taken as a suitable unit. It is found that the average number of dykes reported in the various regions of the Shield per 15 mile square is approximately :-

Ontario - - - - - - - - - - - 20
Québec - - - - - - - - - - - - 4
North West Territories - - -25
Manitoba & Saskatchewan - - rare
Ungava-Labrador Peninsula - no data

Because most of the dykes strike more nearly north-south than east-west, and are generally parallel and continuous, it is possible to calculate the number of dykes per east-west mile :-

$$\frac{(20+4+25) \text{ per 15 mile square}}{3 \times 15 \text{ miles}} = \text{approximately one per east-west mile.}$$

Average Width of the Dykes

The width of "diabase" dykes reported ranges from a few inches up to a maximum of 800 feet. In two map-areas in Québec both the average and the maximum widths of the dykes are given, the average being about one-sixth of the maximum of 600 feet. The average widths of the dykes in the different parts of the Shield are :-

Ontario (average of 56 map-areas)	---	109 feet
Québec (average of 34 map-areas)	---	118 feet
Manitoba and Saskatchewan (average of 5 map-areas)	---	149 feet
North West Territories (average of 5 map-areas)	---	120 feet

The average of these figures is 125 feet, or roughly one-sixth of the maximum reported width, which is in good agreement with the average and maximum relations obtained in the two Québec map-areas.

If one fracture 125 feet wide per east-west mile is filled with diabasic material, the linear and corresponding volume increase in the crust is :-

$$\frac{125}{5280} \times 100 = \text{about } 2.5\ \%$$

If it is presumed that the reported dykes represent only half the true number, the volume increase provided by the filling of fissures would be about 5%.