

THE
NORTH GAP DYKE
OF THE
TRANSKEI

BY

ALAN C. MOORE, B.Sc.(Hons.)

Thesis presented for the Degree of Master of
Science, to Rhodes University, Grahamstown.

January 1964.

CONTENTS.

	Page
ABSTRACT	1
INTRODUCTION	2
ACKNOWLEDGEMENTS	3
PREVIOUS WORK	4
 <u>CHAPTER ONE: FIELD RELATIONSHIPS.</u>	
Abstract of Chapter One	5
General Setting	6
Weathering and Topographical Features	7
Attitude and Jointing	8
Appearance of the Gap Dyke	9
Metamorphism	11
Age of the Dyke	12
 <u>CHAPTER TWO: PETROGRAPHY.</u>	
Abstract of Chapter Two	13
PETROGRAPHY.	14
The Core	14
The Dolerite Flanking the Core	16
The Thomas River Area	17
The "Transkei Type" Dolerite	22
The Petrography of the Sediments	26
 <u>CHAPTER THREE: MINERALOGY.</u>	
Abstract of Chapter Three	28
MINERALOGY OF THE DOLERITE.	29
Plagioclase Feldspar	29
Pyroxene	38
Amphibole	42
Micropegmatite	46
Other Minerals	49
MINERALOGY OF THE CORE MATERIAL.	60
Quartz	60
Feldspar	60
Chlorite and Serpentine	61
Other Minerals	61

	Page
<u>CHAPTER FOUR: PETROLOGY.</u>	
Abstract of Chapter Four	63
MICROMETRIC DATA	64
CHEMICAL DATA	67
The f(norm)	74
ORIGIN OF THE CORE	76
EFFECT OF THE CORE ON THE DOLERITE	80
CLASSIFICATION OF THE "TRANSKEI TYPE" DOLERITE	83
ORIGIN OF THE MAGMA	84
SUMMARY	89
 <u>CHAPTER FIVE: SUMMARY AND CONCLUSIONS.</u>	
SUMMARY	90
Chapter One: Field Relationships	90
Chapter Two: Petrography	90
Chapter Three: Mineralogy	92
Chapter Four: Petrology	93
CONCLUSIONS.	94
 <u>REFERENCES.</u>	 95

ABSTRACT.

Field work and mapping with the aid of aerial photographs have shown the north Gap Dyke to be a vertical intrusion $93\frac{1}{2}$ miles long. It extends from a point about $4\frac{1}{2}$ miles south of Cathcart to the coast where it enters the sea about 100 yards north of the Ngadla River mouth.

It is composed of several rock types including dolerite pegmatite, granophyric dolerite, subophitic dolerite, and it has a more or less central core of mobilized sediment at the western end. The essential minerals of the dolerite types include zoned plagioclase, which is described in some detail, and augite. Less important are hornblende and micropegmatite. Accessories include apatite, ilmenite, magnetite, quartz, actinolite, prehnite, calcite and epidote. Iddingsite (?), saussurite and chlorite occur as alteration products.

The mode of origin of the Gap Dyke magma remains an open question: it may have arisen as a result of normal crystal fractionation or as the result of hybridization in depth followed by differentiation.

INTRODUCTION.

Of the two Gap Dykes of the Transkei described by Mountain (1943) the northern one was chosen for study because it contains an unusual feldspathic sandstone core and also shows a greater degree of variation than the southern. The aim of the present investigation is to give a fuller account of the petrography and petrology of this dyke and to examine in detail the occurrence of the mobilized sediment core found at the western end.

A total of only three weeks was spent in the field, during which time the dyke was carefully remapped with the aid of aerial photographs. The section west of the Kei River was accurately mapped by walking along the course of the dyke and linking the various outcrops. East of the Kei mapping was carried out by tracing the course of the dyke along the prominent "gaps" and by noting where it was intersected by roads and rivers. Near the coast the strike varies and several "gaps" occur and it was once again necessary to follow the dyke in detail on foot.

All the laboratory work was carried out in the Department of Geology, Rhodes University. I prepared over 120 microscope slides from specimens of the dyke rock and surrounding Beaufort sandstone. One complete analysis and two partial analyses were carried out by me, and I completed another done partially by Mr. M. Johnson, a geology Honours student.

Even with the additional information gained from this study there still remain unanswered fundamental problems, such as the origin of the core, and of the various types of dolerite found making up the dyke. However, it is hoped that this study will give a better idea as to the types of problem encountered and possibly stimulate further research.

ACKNOWLEDGEMENTS.

Professor E.D. Mountain, Head of the Geology Department, Rhodes University, undertook the task of acting as supervisor of research during this investigation. For his active interest and enthusiasm I am extremely grateful. Without his assistance, which ranged from advice and suggestions to the loan of microscope slides and specimens used for the preparation of his own paper, "The Dikes of the Transkei Gaps" in 1943, it is doubtful whether this study could have been completed.

To Dr. H.V. Eales, also of the Geology Department, I am indebted for his critical examination of the final script. His willing assistance and advice on many aspects of the practical work have been invaluable.

I wish to express my thanks to the C.S.I.R. for the award of a post-B.Sc.(Hons.) bursary. Without this financial assistance I could not have completed this investigation in the time available.

Mr. G. Walters, the Rhodes University photographer, and Rev. W. Meyer assisted me in producing the photographic illustrations and I wish to express my gratitude to both.

I thank my parents and brother not only for their encouragement and material assistance during the year, but also for providing the transport for two of the field trips.

Thanks are due to some of my fellow students: Messrs. Meyer, Ward, Wulff and Johnson, for their encouragement and, in many cases, severely destructive, though sincere, criticism of the work. For help with the chemical analyses I am indebted to Mr. M. Johnson.

Finally, I thank the numerous farmers with whom I stayed and whose hospitality to a complete stranger was quite overwhelming.

PREVIOUS WORK.

Rogers and Schwarz (1904) were the first to describe the two Gap Dykes of the Transkei and they considered their account should be regarded as only a preliminary report. They classed the rocks as quartz diorite. Walker (1942) published a paper in which he concluded the dykes were produced by crystal differentiation of a normal Karroo dolerite magma in some deep seated chamber. He concentrated on the southern dyke, considering the two to show identical petrographic characteristics and to be connected underground. His work on this dyke is, moreover, confined to the Kentani district of the Transkei.

The most recent paper on these dykes was by Mountain (1943) in which he gave a general description of both dykes and presented the first complete map of them. He mapped them without the aid of aerial photographs. He concluded that the dolerite pegmatite magma of the dykes arose by contamination of normal Karroo dolerite magma, either in some intercrustal reservoir, or in the dyke positions in which they are now found, as the result of neighbouring sediments. The feldspathic sandstone core found in the western end of the northern dyke he considers to be a gigantic example of mobilized sediment.

Walker and Foldervaart (1949) revised the facts and hypotheses concerning the two Gap Dykes. They considered the Gap Dykes to be represented by their "Kentani type" dolerite, "most probably representing an advanced stage of differentiation of the Karroo magma."

CHAPTER ONE

FIELD RELATIONSHIPS

ABSTRACT OF CHAPTER ONE.

The north Gap Dyke is a vertical intrusion which strikes more or less east-west and extends from a point about $4\frac{1}{2}$ miles south of Cathcart to the coast, where it enters the sea about 100 yards north of the Ngadla River mouth.

The width narrows gradually from about 250 yards at the coast until the dyke dies out altogether near Cathcart. Particularly in the Transkei, the dyke weathers more readily than the surrounding Beaufort sandstone and so forms longitudinal valleys termed "gaps". Such valleys are absent further west and outcrops take the form of boulder-like joint-blocks.

Metamorphism produced by the dyke is slight. Absolute age determinations, by McDougall, indicate the dyke to be about 171 million years old; it cuts all other intrusions of dolerite in the area.

GENERAL SETTING.

The northern dyke was remapped with the aid of aerial photographs from a point about 100 yards east of the Cathcart-Alice main road, some $4\frac{1}{2}$ miles south of Cathcart, where the first outcrops of the feldspathic sandstone core were found, to the coast, where it enters the sea about 100 yards north of the Ngadla River mouth. The course of the dyke was then replotted from the aerial photographs on to a base map with a scale of 1:250,000. This base map was prepared from the Queenstown sheet, SE 33/26, with a scale of 1:500,000, published by the Department of Irrigation in 1960. The final map (See Map 1) of the dyke agrees closely with that prepared by Mountain (1943).

The length of the dyke is $93\frac{1}{2}$ miles. It strikes east-west for the greater part of its length, but towards Cathcart it changes to west-north-west ($N68^{\circ}W$) and near the coast the strike varies from $N110^{\circ}E$ to $N80^{\circ}E$. The general trend of dykes in this area is more or less east, or north-north-west (Border Regional Survey, 1957), and so the north Gap Dyke follows the normal trend.

Accurate width determinations could be made only at Lujilo and Surbiton, but fairly accurate estimations were made at other points because of the typical gap in the topography and because the vegetation often varies slightly where the dyke is present. (See figure 1.) The approximate width of the dyke at various points along the length is tabulated in Table I.

TABLE I.

Dyke-width at various points along the length.

Place	Total Width	Width of Core	Width of Dolorite	Distance in miles west of eastern limit
Coast	250 yds.	-	250 yds.	93½
Qoboqobo	200 yds.	--	200 yds.	67
Toleni Bridge	150 yds.	-	150 yds.	52
Lujilo	120 yds.	-	120 yds.	41
Undula	80 yds.	-	30 yds.	15
Thomas river	42 yds.	-	42 yds.	10
Surbiton	34 yds.	9 yds.	25 yds.	6½
Stoneridge	22 yds.	4 yds.	18 yds.	½

WEATHERING AND TOPOGRAPHICAL FEATURES.

The name "Gap Dyke" is apt because of the effect this dyke has on the topography, particularly in the more dissected areas. In the Transkei, particularly, the dyke weathers more easily than the surrounding Beaufort sandstone and forms conspicuous trench-like features which are often followed by river valleys. These features, clearly seen on the aerial photographs, are termed "gaps". (See figure 3.) In the "gaps" there is a tendency for the northern slopes to be steeper than the southern. (See figure 2.) This is the result of normal insolation effects of the sun. West of the Kei River the dyke has less influence on the topography, although locally it still occupies valleys, e.g. at Kei Gates. Where it traverses narrow watersheds it forms necks, e.g. near Lujilo. Further west the dyke gives rise to no conspicuous features at all and outcrops are poor, though in some places the course of the dyke can be followed by a line of rounded, boulder-like joint-blocks. (See figure 4.) Near Cathcart, where the core appears, outcrops of the dolerite are rare and were it not for the feldspathic sandstone core the course of the dyke could not be followed at all. Right at the coast there are no outcrops of the north Gap Dyke, but about 800 yards inland, on the banks of the Ngadla River, rounded outcrops of the dyke occur. (See figure 5.)

The dolerite may weather to considerable depth and it is often found that the margins, where in contact with the invaded sediments, are weathered to a greater extent. There is an apparent tendency for the dolerite to weather to greater depths where the core material is present. Where exposed the dolerite shows typical spheroidal weathering, the native name for the weathered material being "sabunga". Microscope sections of this "sabunga", made from specimens taken from the Surbiton railway cutting, show the pyroxene and feldspar

EXPLANATION OF FIGURES 1 AND 2.

Figure 1: The course of the north Gap Dyke in the Thomas River area clearly seen by differences in vegetation.

Figure 2: Typical "gap" valley, showing the asymmetrical valley produced. Near Toleni Bridge, facing east.

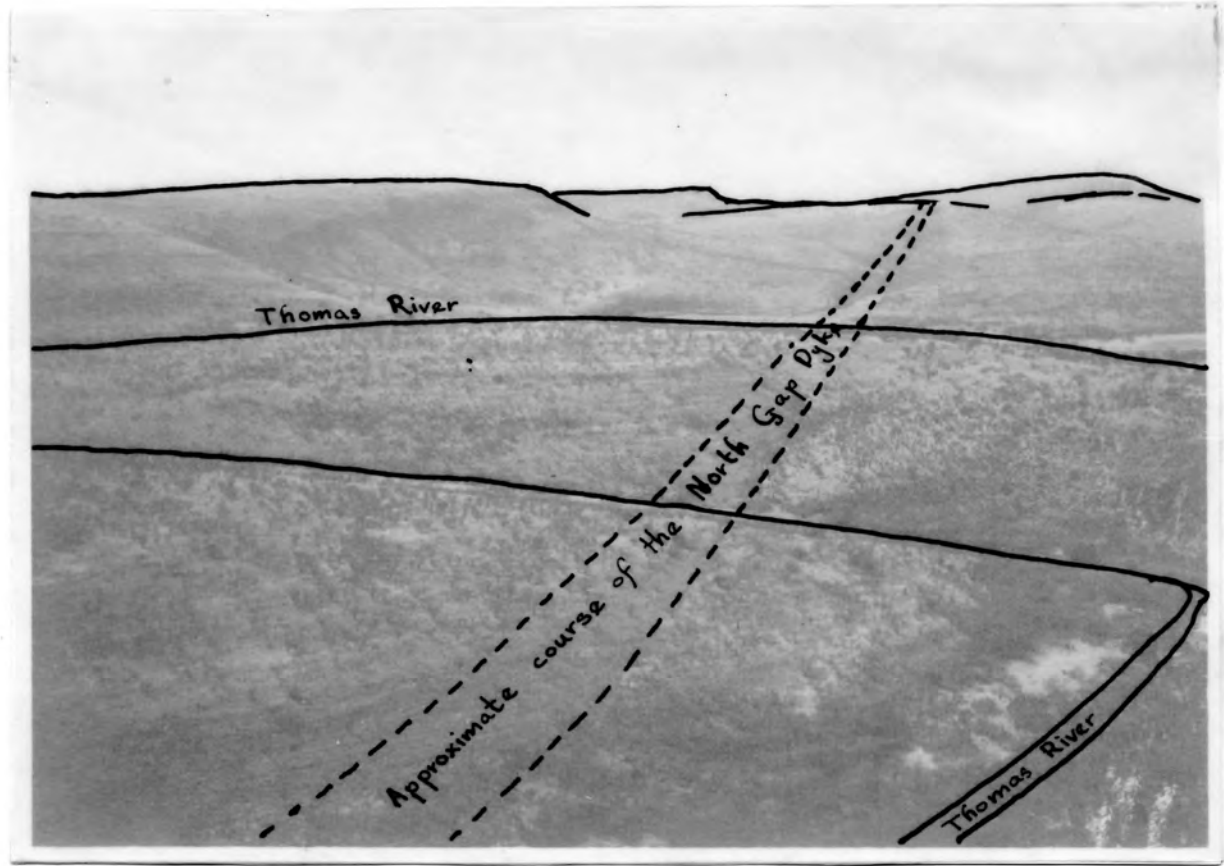


Figure 1

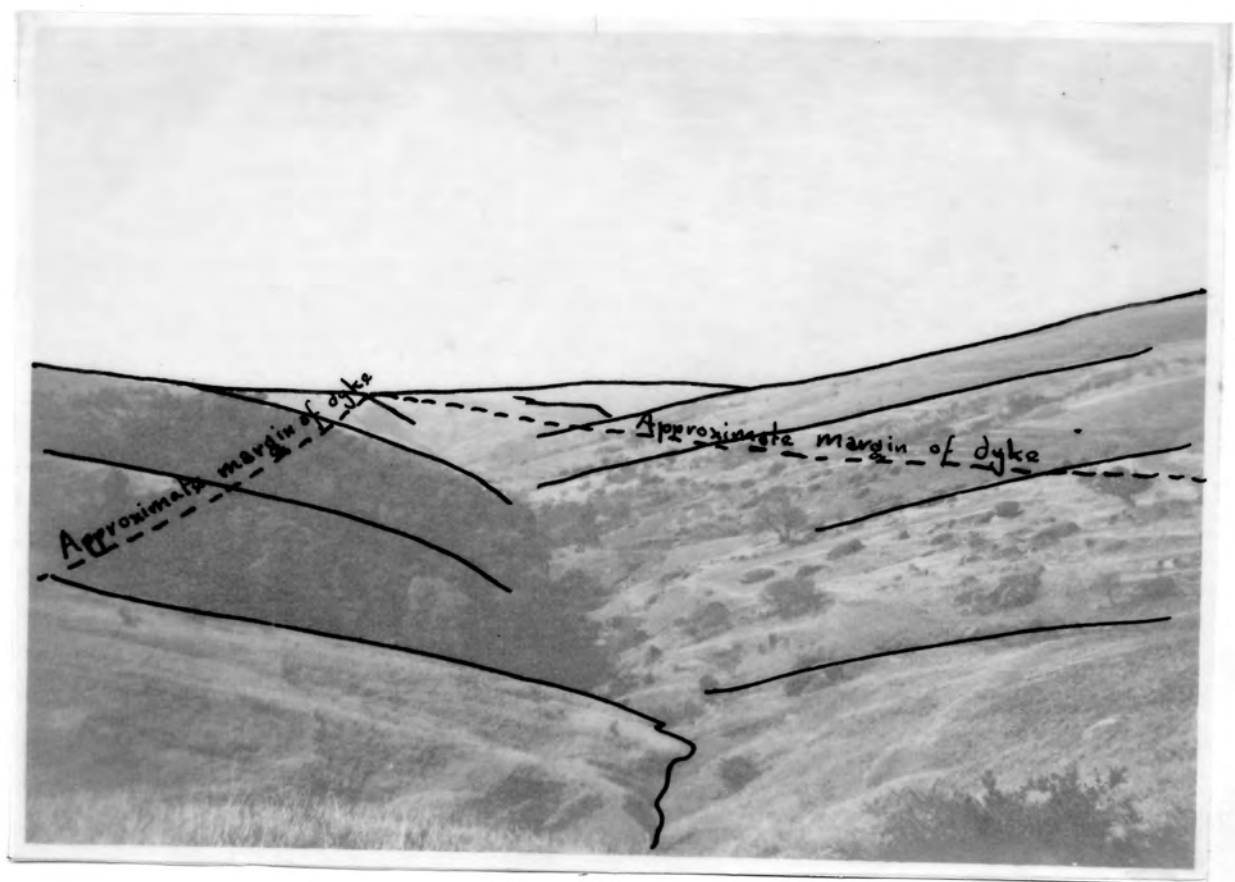


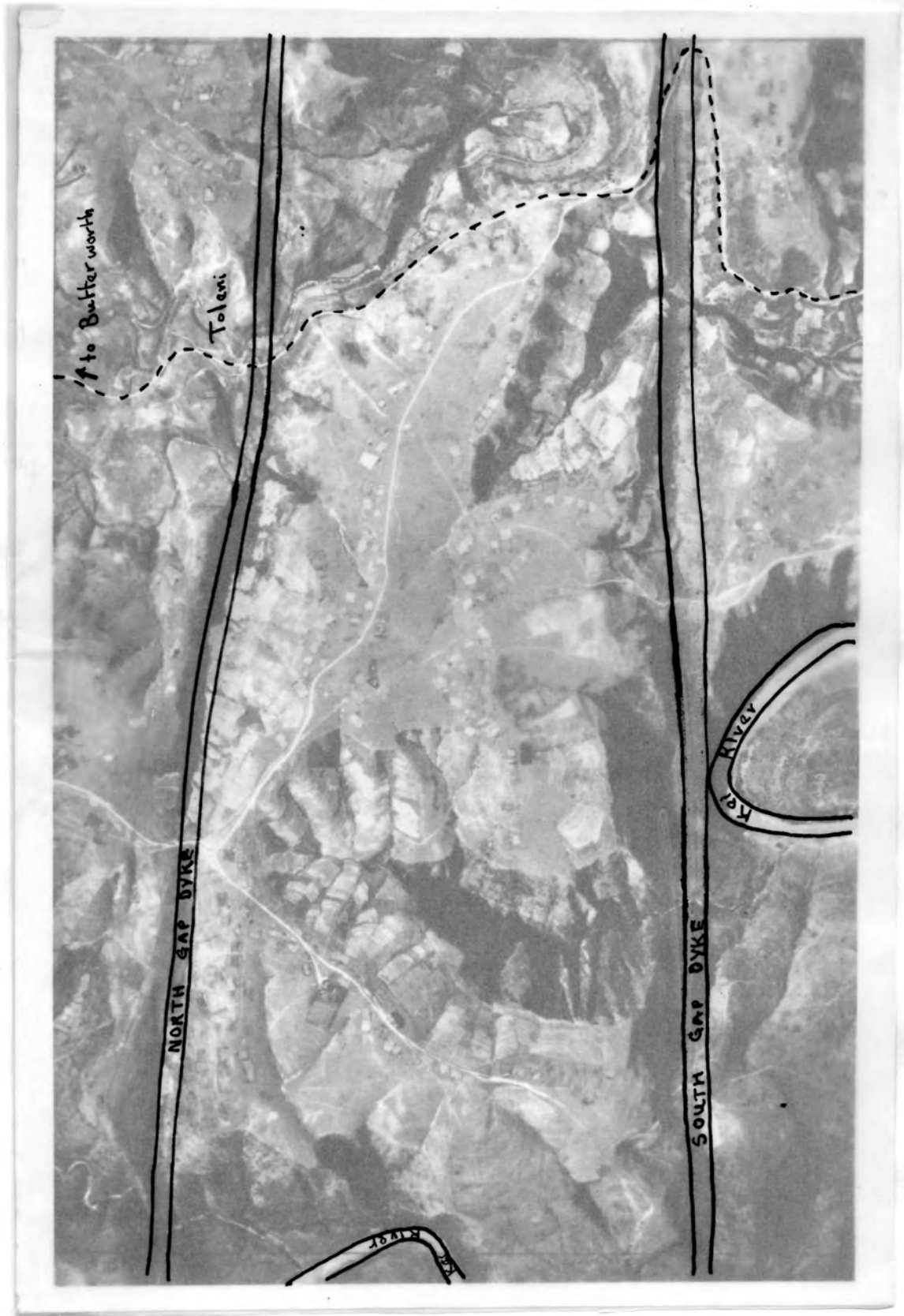
Figure 2

EXPLANATION OF FIGURE 3.

Aerial photograph showing the course of both Gap Dykes, near Toleni. The typical "gap" valleys can clearly be seen.

SCALE: Approximately 2" = 1 Mile.

(Reproduced from aerial photographs belonging to the Geological Survey. Job No. 468; Strip 14; Number of photograph -- 8323.)



EXPLANATION OF FIGURES 4 AND 5.

Figure 4: Typical rounded, boulder-like outcrops
of the north Gap Dyke, near Lyall.
Facing east.

Figure 5: Outcrops of the north Gap Dyke near
the coast, on the banks of the Ngadla
River about 800 yards from the sea.
Facing west.



Figure 4

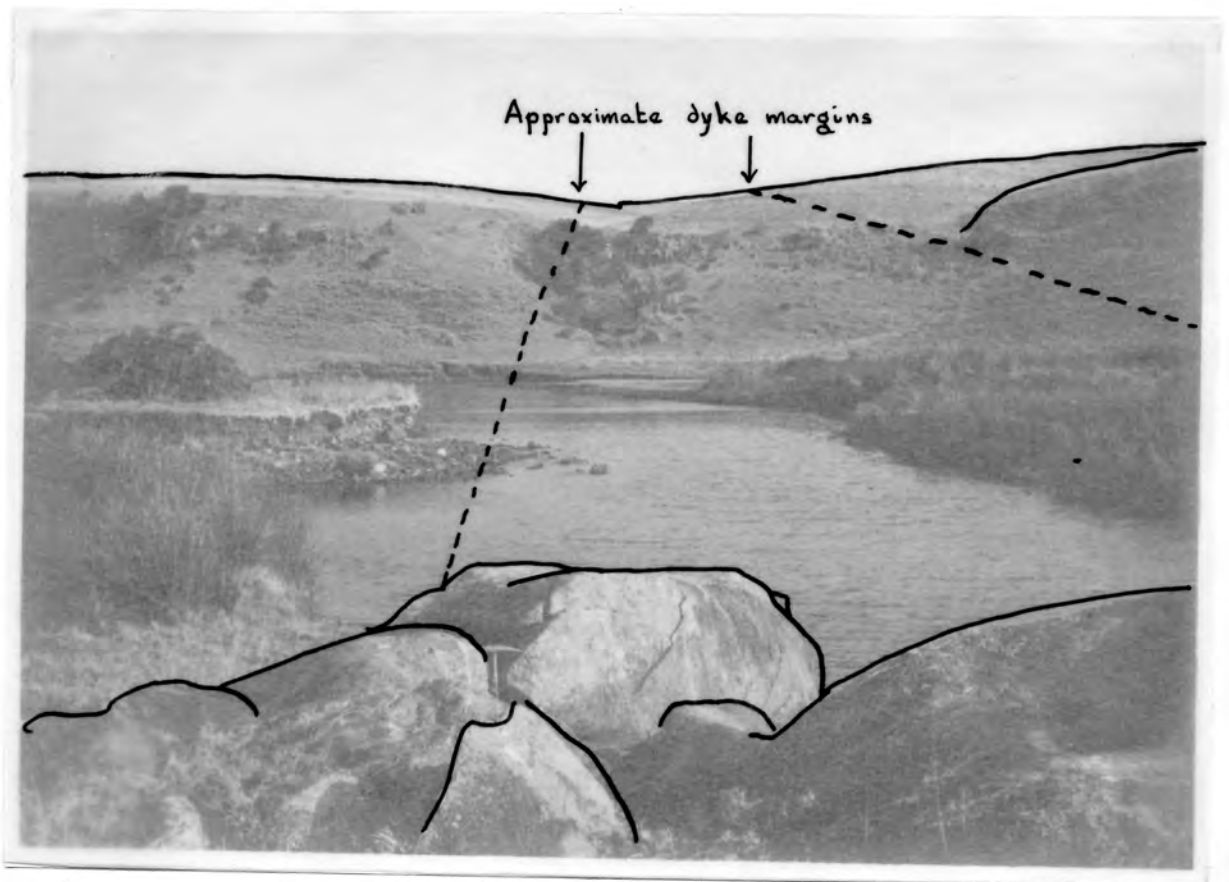


Figure 5

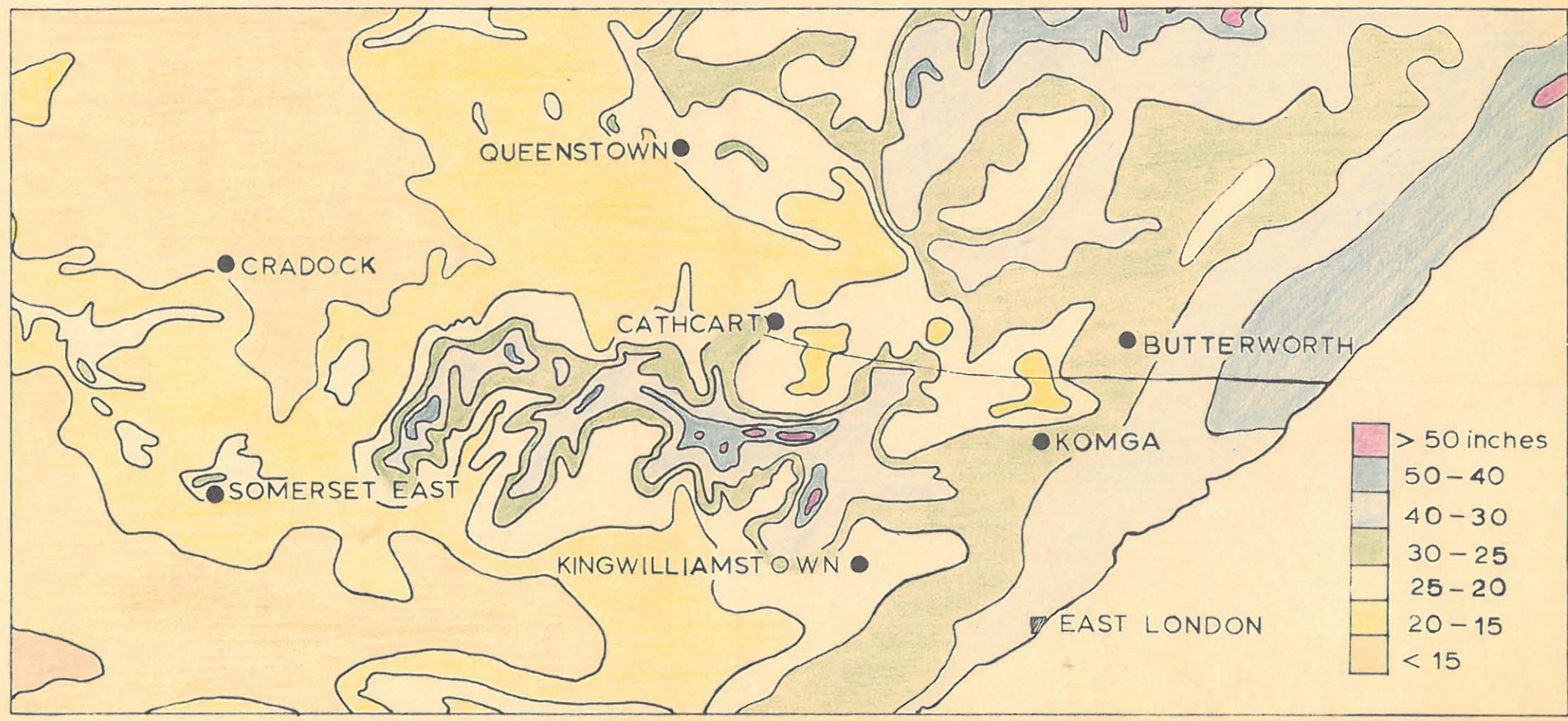
DESCRIPTION OF MAP 2.

Rainfall Map of an area around the north Gap Dyke, showing that the greater length of the dyke falls within an area receiving more than 20" per annum and the area where the most conspicuous "gaps" occur falls within an area receiving from 25" to 50" of rainfall per annum.

Isohyetal tints represent annual rainfall in inches.

(Adapted from the rainfall map of the Union of South Africa (1948) published by the Irrigation Department. Code No. $\frac{AB}{11}$)

SCALE 1:1,500,000



41

to be relatively fresh so that the brown colouration is thought to be entirely due to oxidation of the ore minerals. The final product of weathering is a coarse, yellowish-brown friable material. This is characteristic of both Gap Dykes in the Transkei and thus, even when weathered, they are distinguishable from other dolerite intrusions which weather to a red or dark brown, clay-rich soil. Several other dykes in the Transkei, especially near the coast, produce similar, though smaller, gaps in the topography. Such dykes are known to have a different mineral composition from the north Gap Dyke, and so it is obvious that the weathering into trenchlike gaps is not the result of mineralogical differences. It may be because the dykes which are so affected all have a coarse grain size, and because the region in which they occur is one of high rainfall, as is seen on Map 2.

ATTITUDE AND JOINTING.

The dyke is vertical. This attitude is best observed in the railway cutting at Surbiton and in the Transkei "gaps" where the dolerite of the dyke has been eroded away where the dyke cuts across steep sided valleys. The resistant Beaufort sandstone reveals the form of the intrusion, e.g. at Kei Gates.

Generally, there is no indication that the dyke has folded or disturbed the wall rock. However, at Lujilo the bedding of the Beaufort sandstone at the northern contact has been slightly disturbed and the rock also shows steep southward dipping joints. Similar jointing has developed in the sandstone at Surbiton. In the railway cutting the joints are seen to dip at $15^{\circ} \pm 5^{\circ}$ away from the intrusion at both contacts and gradually flatten so that, five yards from the walls of the dyke, the jointing is horizontal. Because of the massive nature of the sandstone in this area it is difficult to trace the bedding, which

EXPLANATION OF FIGURES 6 AND 7.

North Gap Dyke exposures in the Surbiton railway cutting.

Figure 6: The west wall of the cutting showing the core
and jointing in the wall rock. Facing south.

Figure 7: Facing north.

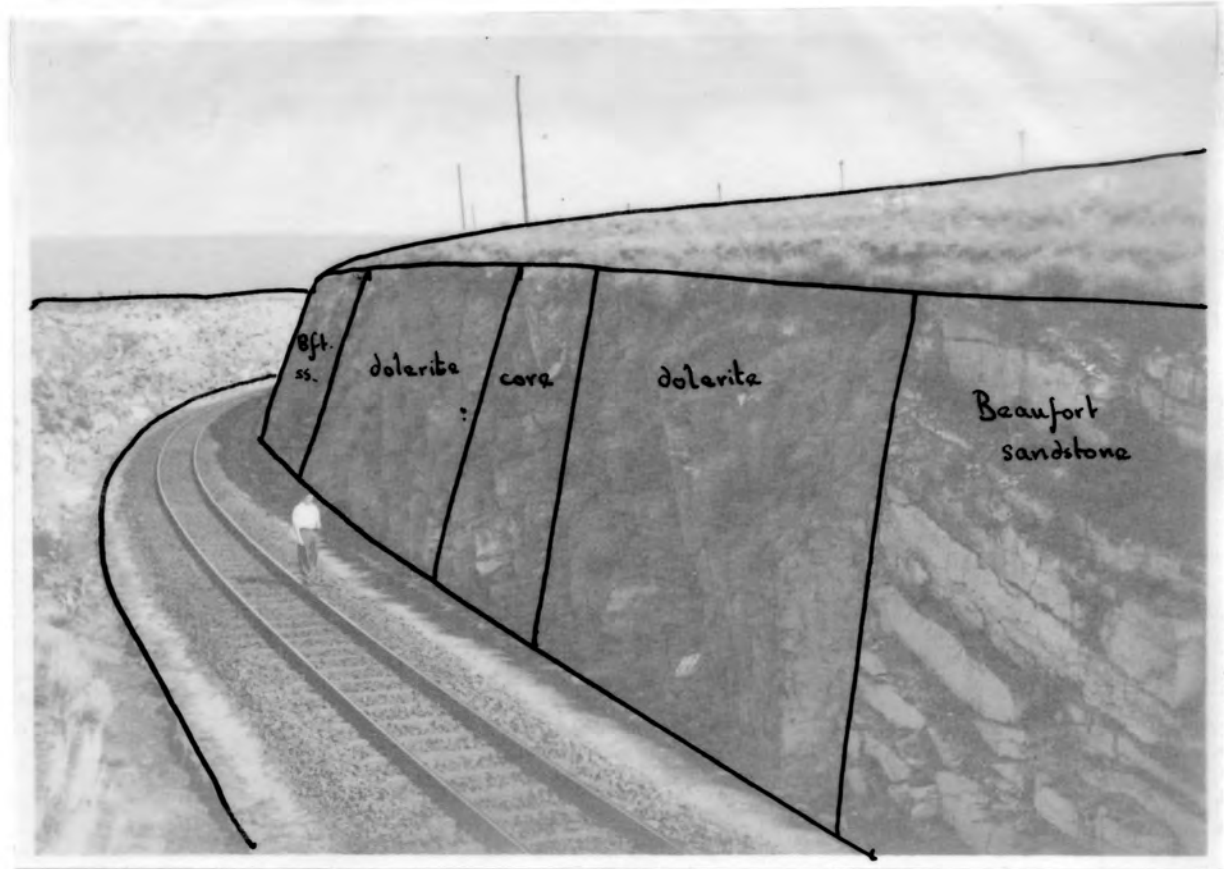


Figure 6

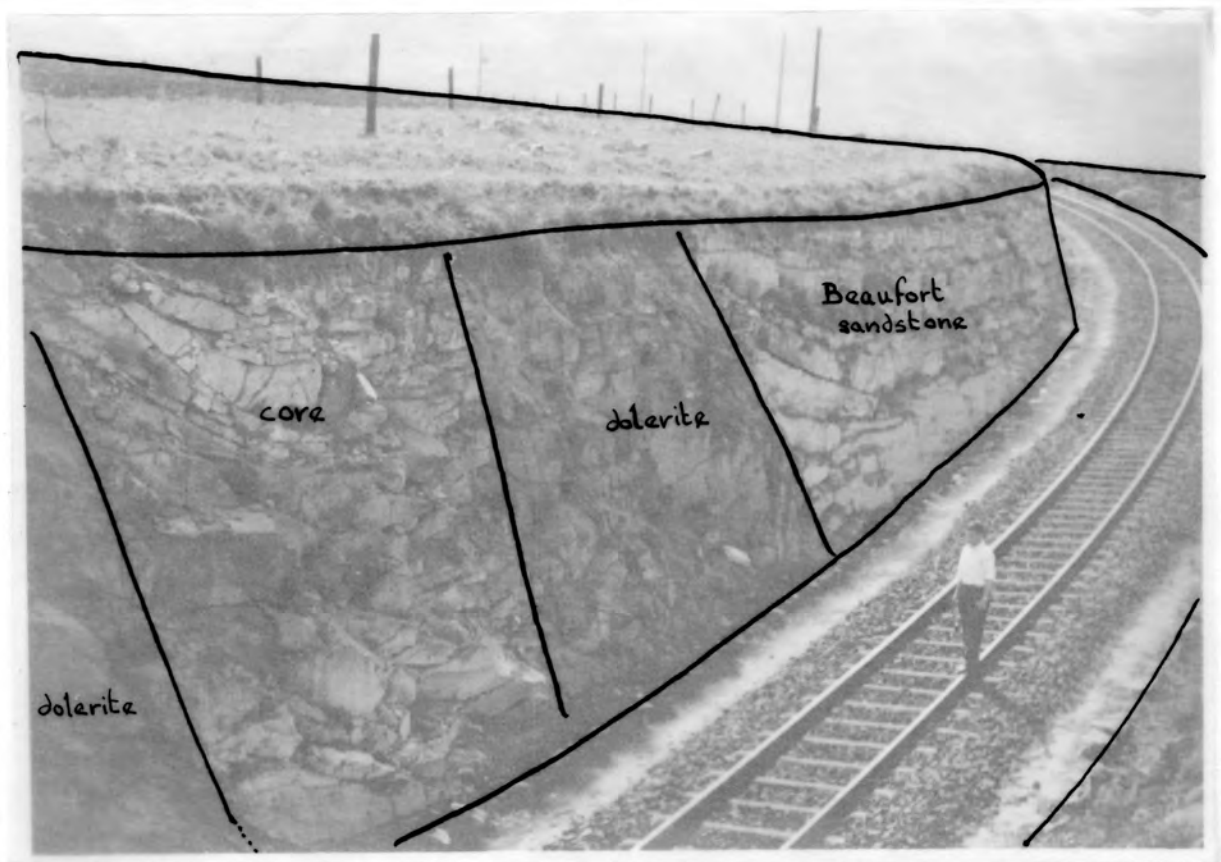
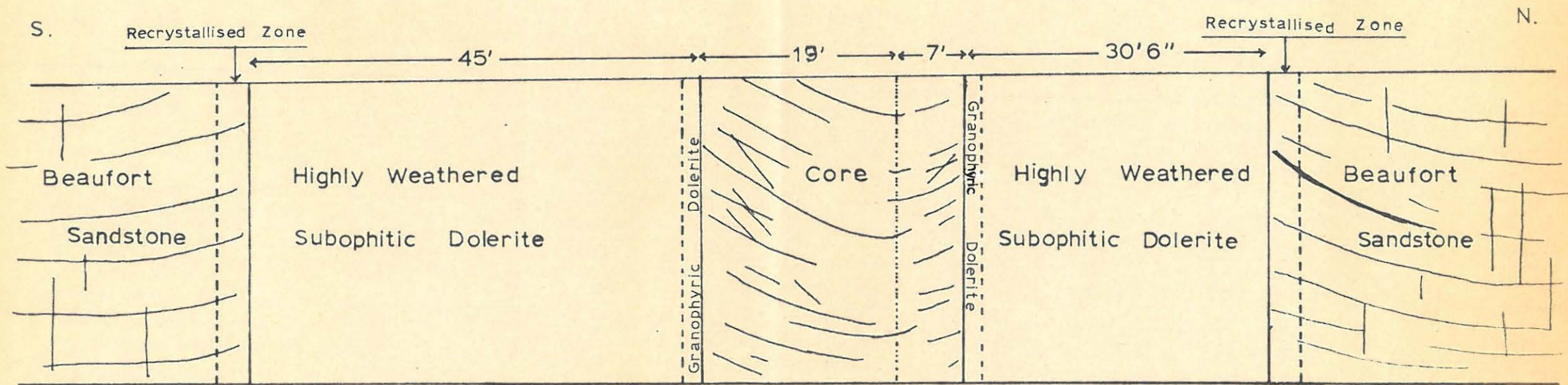


Figure 7

FIGURE 8.

SCALE: 1cm. = 2 ft.

STRIKE: E. N. E.



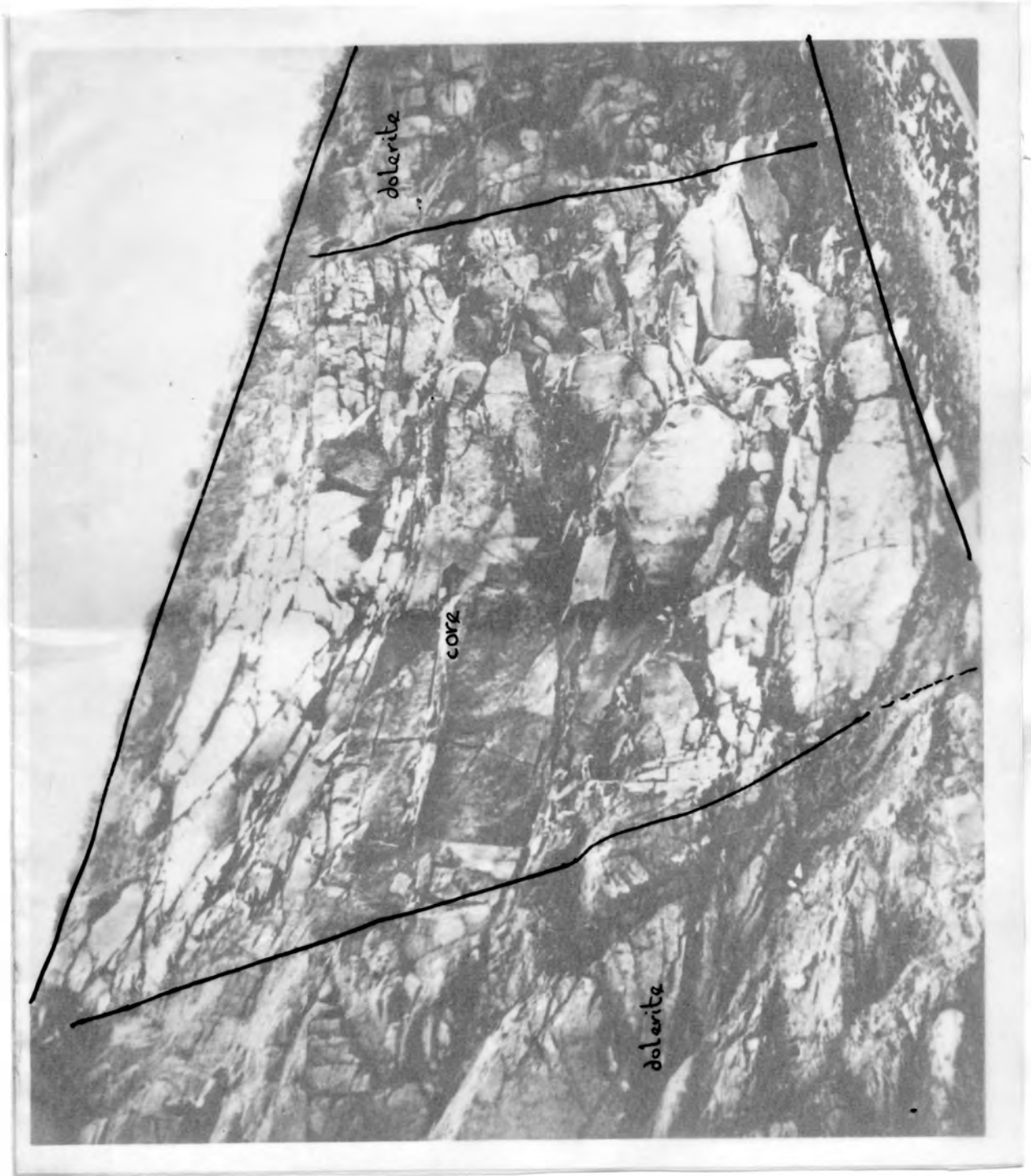
EXPLANATION OF FIGURE 8.

Diagrammatic section of the north Gap Dyke
as it is exposed in the Surbiton railway cutting.

Notice the asymmetric jointing in the
granophyric quartzite core, and the position of the
core in the dyke.

EXPLANATION OF FIGURE 9.

Photograph of the core material as exposed
in the western wall of the Surbiton railway cutting.
Note the sharp contact with the surrounding dolerite
and the jointing in the core.



may have been similarly disturbed. However, there are some indications that the bedding remains horizontal and has not been affected. In general, the sandstone shows vertical jointing developed parallel to the walls of the dyke as well as some horizontal jointing parallel to the bedding. Other than the boulder-like joint-blocks, jointing is not seen in the outcrops of the dolerite and it appears to be either absent or inconspicuous.

In the west the core material has developed both vertical and nearly horizontal joints along which weathering takes place forming large slab-like masses. The core in the Surbiton cutting shows jointing dipping at $28^{\circ} \pm 3^{\circ}$ north near the southern contact (well developed) and gradually turning over until the joints dip at $12^{\circ} \pm 3^{\circ}$ south near the northern contact (poorly developed.). See figures 6, 7, 8 and 9.

APPEARANCE OF THE GAF ROCK.

From Stoneridge to the Thomas River the dyke consists essentially of two different rock types. There is a central core material which, in hand specimens, bears a close resemblance to the surrounding Beaufort sandstone but which shows no sign of bedding. This is flanked by dolerite. The core contains irregular dark patches of shale-like material which vary in size from tiny fragments to pieces up to 6 inches by 1 inch. The core shows no sign of flow structure and the dark inclusions show no preferred orientation. This is the feldspathic sandstone or granophyric quartzite core which has been traced from Stoneridge, where it forms the predominant outcrops, to the west bank of the Thomas River. It vanishes suddenly about $\frac{1}{2}$ mile west of the river but reappears just as suddenly on the crest of the hill on the east bank, about 500 yards east of the river. Here the outcrops

seem to occupy the entire dyke width, some 200 feet, but east of this only scattered outcrops are found, the last being on Rexfield.

Flanking the core is a highly weathered yellowish-brown dolerite which, in the immediate vicinity of the core, grades into a slightly less weathered granophyric dolerite. This granophyric dolerite varies considerably in width, from 1 foot on either side of the core in the Surbiton railway cutting to 14 feet on Stoneridge. Beyond the eastward limit of the first part of the core the dyke is composed of a pale, fairly fine-grained granophyric dolerite. This granophyric dolerite continues eastward until the east bank of the river where the dyke is cut for the first time by the meanders. The character of the rock changes only slightly eastward, becoming coarser and somewhat darker.

Outcrops of the dyke in the cultivated land west of the river show the granophyric dolerite to contain coarse patches which are paler in colour and which contain rod-like dark minerals arranged in an irregular criss-cross pattern. Individual rods measure about 2 to 5 mm. by 0.5 mm. and less. The patches, the largest of which measure 2 feet by 6 inches, grade uniformly but fairly sharply into the surrounding granophyric dolerite.

On the west bank and in the bed of the river there are, in the dolerite, veins of coarse material which bear a close resemblance to schlieren. They are not lens shaped but occur as narrow veins up to 2 inches wide and irregularly scattered through the dolerite, extending for lengths of up to 5 feet. They are acid in character and contain laths of amphibole measuring 20 mm. by 2 mm. and less. The dolerite on the immediate east bank of the river is essentially a coarse grained pale dolerite with a very blotchy appearance caused by the aggregation of mafic minerals into clusters each measuring up to 2 cms. across. It is termed a "mottled rock". It contains no veins but has occasional

EXPLANATION OF FIGURES 10, 11 AND 12.

Figure 10: Hand specimen of the core material from Stoneridge. (Magnification x 1.5).

Figure 11: Hand specimen of the granophyric dolerite found at the eastern end of the western section of the core material in the Thomas River area. (Magnification x 1.5).

Figure 12: Hand specimen of the metasomatized sediment xenoliths ("coarse patches") found in the granophyric dolerite in the Thomas River area. (Magnification x 1.5).

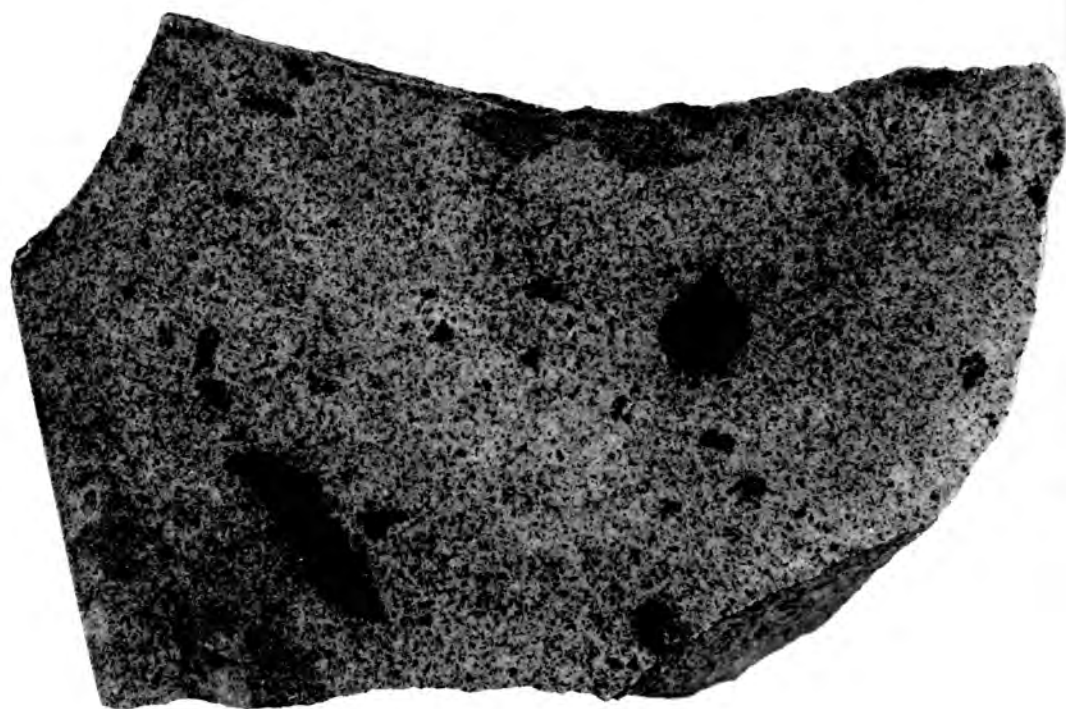


Figure 10

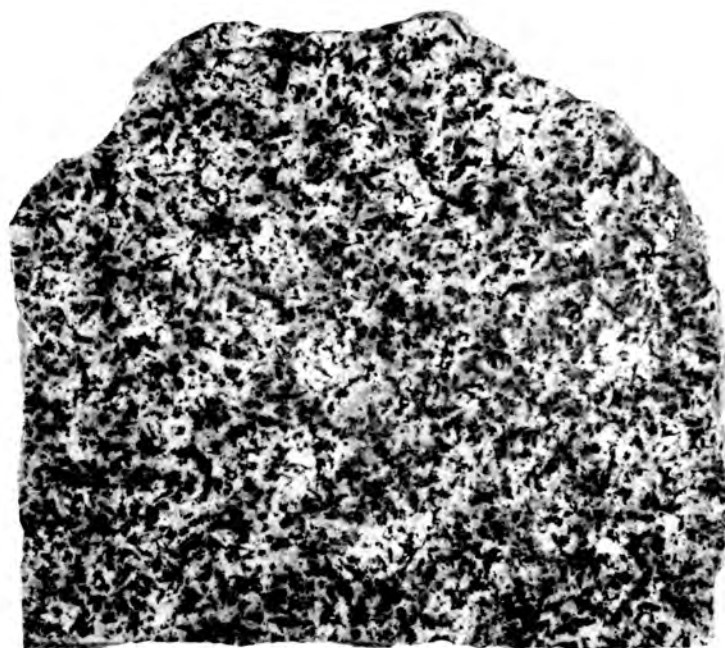


Figure 11

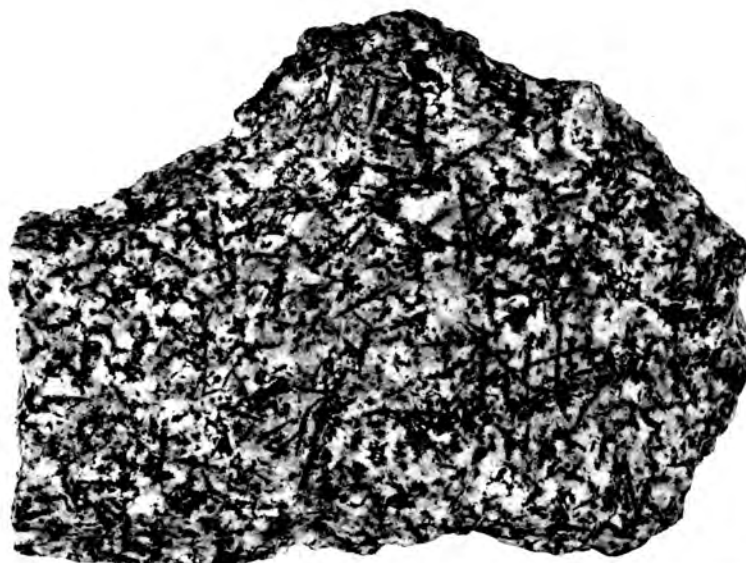


Figure 12

EXPLANATION OF FIGURES 11a, 12a AND 15a.

Figure 11a: Photomicrograph of the granophyric dolerite shown in Figure 11. Between crossed nicols. (Magnification: x 33.)

Figure 12a: Photomicrograph of the metasomatized xenolith shown in Figure 12. Between crossed nicols. (Magnification: x 12.)

Figure 15a: Photomicrograph of the coastal variety of the "Transkei type" dolerite pegmatite, showing the typical texture of this rock. Specimen is from the Ngadla River, near the coast. Note the complete absence of quartz and micropegmatite. Between crossed nicols. (Magnification: x 12.)

pl (rim) = plagioclase crystal with rim of clay (?) minerals.

py = pyroxene.

act = actinolite.

bi = biotite.

il = ilmenite.



Figure 11a

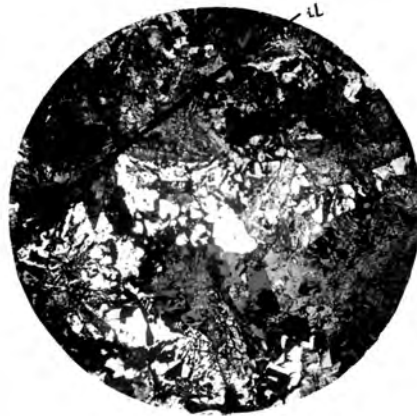


Figure 12a

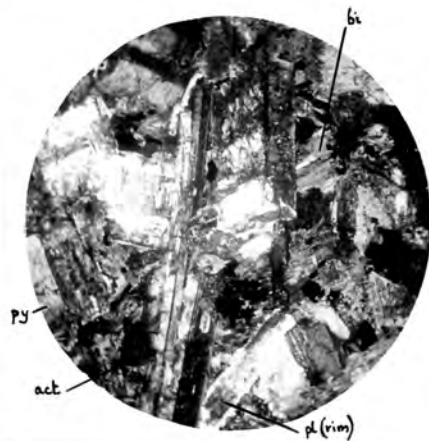


Figure 15a

EXPLANATION OF FIGURES 13, 14 AND 15.

Figure 13: Hand specimen of part of one of the acid veins found in the granopyric dolerite on the west bank and in the bed of the Thomas River where it cuts the dyke for the third time. (Natural size).

Figure 14: Hand specimen of the "mottled rock" found on the east bank of the Thomas River. (Magnification x 1.5).

Figure 15: Hand specimen of the dolerite pegmatite ("Transkei type") which makes up the greater length of the north Gap Dyke. Specimen is from Toleni Bridge. (Magnification x 1.5).

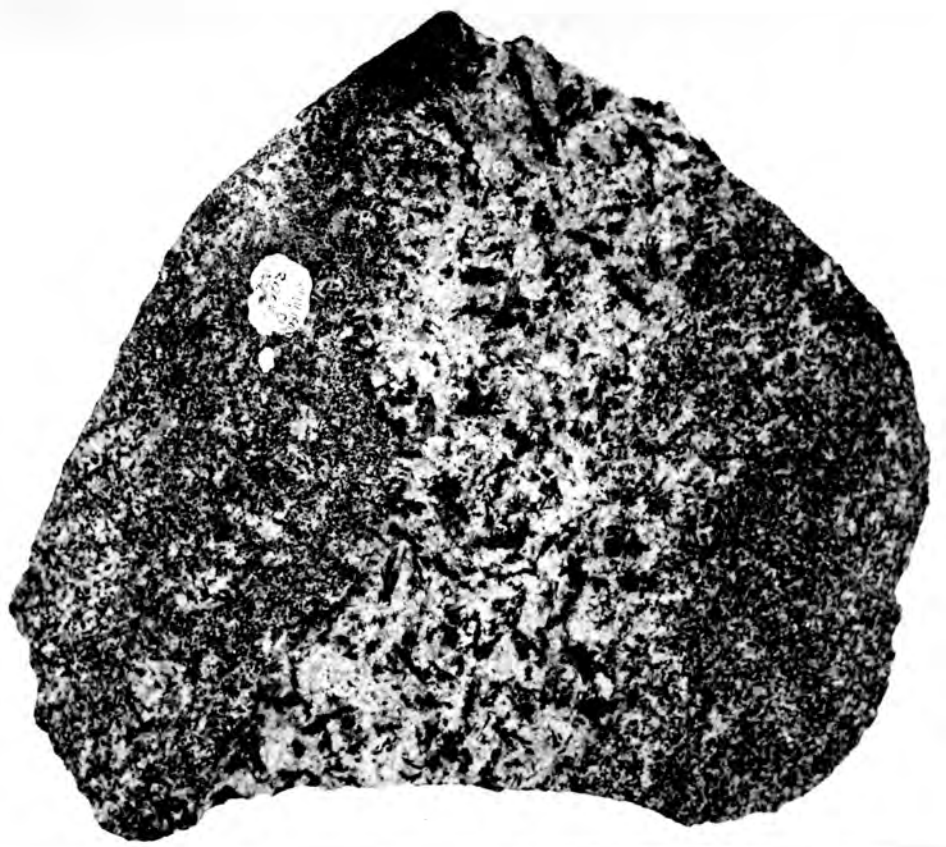


Figure 13

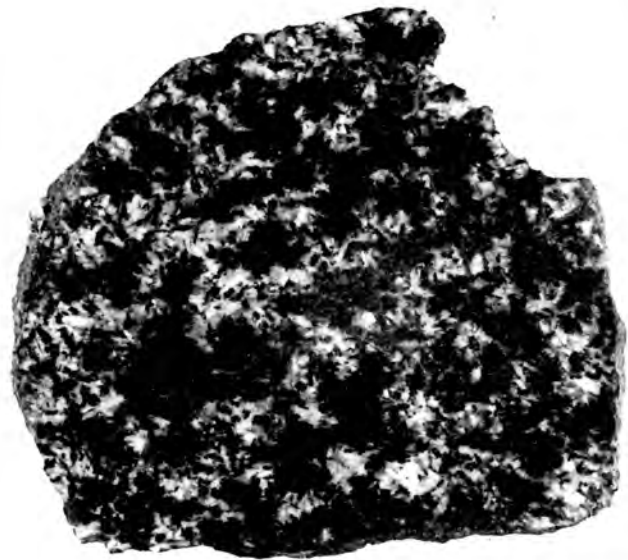


Figure 14

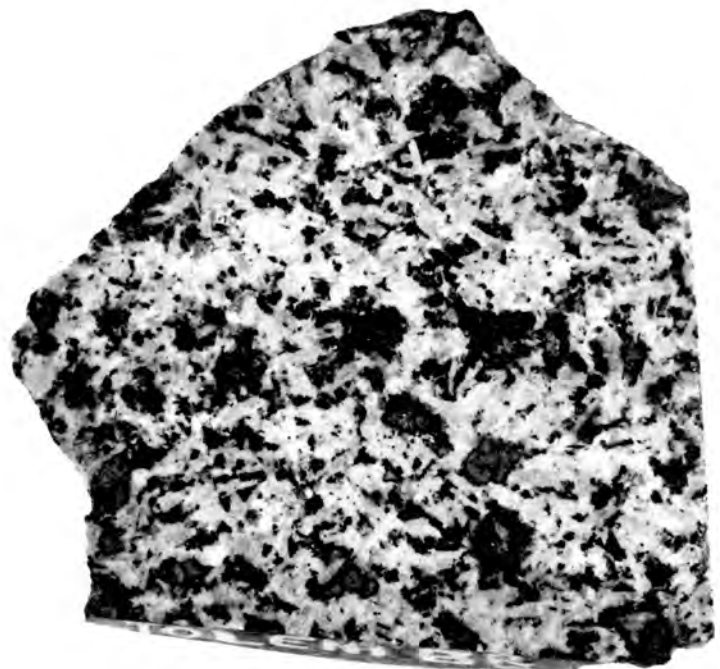


Figure 15

pale patches scattered through it.

East of this, the dyke becomes more uniform in character apart from the large outcrop of core material found at the crest of the hill on the east bank of the river. The core outcrops occur over an area about 60 yards wide here, and no dolerite is seen in the vicinity. The last outcrop of the core is found on Rexfield, some 2 miles east of the Thomas River. The dolerite itself gradually becomes coarser eastwards until, about 22 miles east of Stoneridge, it is almost dioritic in appearance with large white feldspar laths, coarse pyroxene crystals and occasional flakes of brown mica. The outcrops are seen as large rounded boulder-like masses but further east the rock is more weathered and forms the "gaps". Figures 10 to 15 show the appearance of some of the rock types in hand specimens.

The appearance of the dyke rock remains remarkably consistent from Undula right through the Transkei until about two miles from the coast. Here it shows an increase in the amount of dark minerals present. At the Ngadla River the last outcrops occur on the north bank of the river about 800 yards from the sea. (See figure 5.). In contrast to the south Gap Dyke there are no outcrops of the north dyke right at the coast, and a wide beach completely free of rocks seems to indicate the course of the dyke out to sea. The dyke, because it is more easily eroded than the sediments which, with other dolerite intrusions, form the remainder of the rocky coastline in this area, forms a sandy beach to the north of the Ngadla River mouth.

METAMORPHISM.

In spite of the great length and width of the north Gap Dyke, the metamorphic effects produced are very slight. In all cases the host rock is Beaufort sandstone, which changes character only very slightly:

it is more feldspathic and slightly finer grained inland. The dyke has produced recrystallisation of the sandstone to a distance of not more than 3 feet from the contacts. A series of microscope slides made from specimens of Beaufort sandstone in the Surbiton railway cutting show it to be unaffected five feet from the contacts.

AGE OF THE DYKE.

The north Gap Dyke cuts all previous dolerite intrusions in the area and nowhere was it found to be cut by another dolerite. From this evidence it is considered to be a late stage of the intrusions of Karroo dolerite IN THIS AREA. McDougall (1953) gives an average age of 171 million years for the South Gap Dyke: (an average of seven measurements; two with biotite, three with plagioclase and two with pyroxene.). Assuming that the two dykes have a similar, if not identical, age then the north Gap Dyke is about 171 million years old. This age is very similar to that of other dolerite intrusions in the area, but slightly younger than the pegmatitic dolerite from a sheet at Rooikrans Dam, Kingwilliamstown which is dated as 179 million years old. Because of the nature of the methods of absolute age determinations the difference between 171 million and 179 million years is not a very significant one, and is within the limits of experimental error. The Gap Dykes are, however, certainly older than the dolerite forming the Schwarzwald sheet at Hogsback which is dated as being 153 million years old.

CHAPTER TWO

PETROGRAPHY

ABSTRACT OF CHAPTER TWO.

Because of the diverse types of rock making up the north Gap Dyke the petrography is most conveniently dealt with by describing each type separately. In the western end a mobilized sediment core occurs flanked on either side by subophitic dolerite and granophyric dolerite. The granophyric dolerite occurs right against the core, and like the core itself, varies in width. In the Thomas River area the core is absent and the dolerite found there is essentially a granophyric variety, but several other interesting features are found. These include a mottled dolerite, acid veins, metasomatized xenoliths and a dolerite xenolith. The greater length of the dyke is made up of dolerite pegmatite which is fairly uniform in character. However, at the eastern end of the dyke, where it enters the sea, there is ^a more basic variety without quartz or micropegmatite.

PETROGRAPHY.

Because of the great variation in character along the length of the dyke, the petrography is most conveniently dealt with by describing separately the core material, the dolerite flanking the core, the complex Thomas River area and the dolerite pegmatite found throughout the greater length of the dyke, mainly in the Transkei.

(i) The Core.

Hand specimens are very similar in appearance to the Beaufort sandstone, being light gray or brown in colour. The core differs from the sandstone in that it shows no bedding and contained within the rock are irregular dark patches of varying size. These patches are indistinguishable from shale or mudstone. They tend to be angular and are often elongated but show no preferred orientation within the rock. In spite of a careful examination of the core outcrops no sign of flow structure was observed. These angular fragments vary tremendously in size, from tiny fragments only a few millimeters in diameter to chunks measuring six inches by one inch. (See figure 10.).

Under the microscope the first impression is that the rock is a highly metamorphosed, fine-grained sandstone. It has a fairly uniform texture and consists essentially of quartz and feldspar. The margins of individual grains of the equigranular quartz and feldspar are intergrown in such a way that they tend towards a graphic intergrowth. Towards Surbiton the core shows a greater degree of recrystallisation than at Stoneridge and becomes even more like a

granophyre. Here it consists almost entirely of quartz areas, about 0.1 mm. in diameter, which have uniform extinction and which are intimately intergrown with turbid feldspar. Free quartz, as rounded grains and not intergrown with feldspar, is occasionally seen but is far less common than at Stoneridge.

Grain size measurements are difficult because of the recrystallised nature of the specimens. Rough measurements show the average grain size to be 0.2 mm., the maximum about 1 mm. and the minimum less than 0.05 mm. This is very similar to that of the surrounding Beaufort sandstone which has an average grain size of 0.2 mm., the maximum being about 0.75 mm. and the minimum less than 0.05 mm. The close resemblance between the core and the Beaufort sandstone is further shown by Table II which shows the micrometric analyses of two specimens of core (done under a high power objective to distinguish between the intimately intergrown quartz and feldspar) and one of Beaufort sandstone. The core material found at Surbiton is a more highly recrystallised example of the core found at Stoneridge where the rock showed only the beginnings of the recrystallisation responsible for the production of the granophyric quartzite as found at Surbiton. (See figures 16, 17 and 18).

The dark, angular patches are indistinguishable from shale under the microscope and consist of a fine-grained mass of chlorite, sericite, quartz, and feldspar. The average specific gravity of these dark inclusions, separated from the quartzitic material, is 2.723. Their contacts with the enclosing granophyric quartzite are sharp and even under the microscope no gradation from one to the other is seen. These angular fragments are not found in the Beaufort sandstone and are thought to be fragmented shale bands, which were broken up when the core material was mobilized.

TABLE II.

Micrometric analyses of core material and Beaufort sandstone: (Volume %.).

	(1)	(2)	(3)
Quartz	63.1	57.8	60.6
Feldspar	24.7	28.0	10.7
Chlorite and Serpentine	11.9	13.0	9.8
Ore Minerals	0.3	1.2	0.9
Matrix (3 only)	---	---	18.0
Colour index	12.2	14.2	10.7
Specific Gravity	2.62	2.63	2.62

All analyses exclude garnet, zircon, apatite, sphene and calcite which were ignored. The "matrix" of (3) includes all the material which could not be identified with certainty, even under the high power objective.

- (1) Core material from Stoneridge.
- (2) Core material from Surbiton railway cutting.
- (3) Beaufort sandstone from Stoneridge.

EXPLANATION OF FIGURES 16, 17 AND 18.

Figure 16: Photomicrograph of Beaufort sandstone, at Stoneridge. Between crossed nicols.
(Magnification: x 38.)

Figure 17: Photomicrograph of the core at Stoneridge showing the recrystallised nature of the material. Between crossed nicols.
(Magnification: x 38.)

Figure 18: Photomicrograph of the core at Surbiton. Notice the very highly recrystallised nature of the material, and compare it with figure 17. Between crossed nicols.
(Magnification: x 38.)

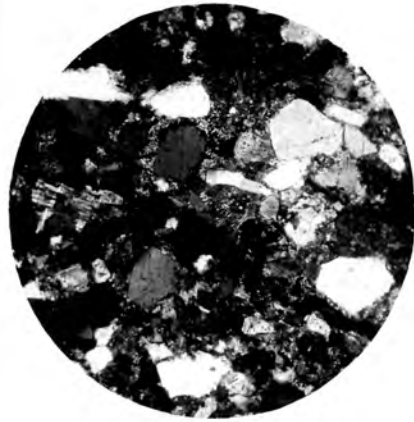


Figure 16

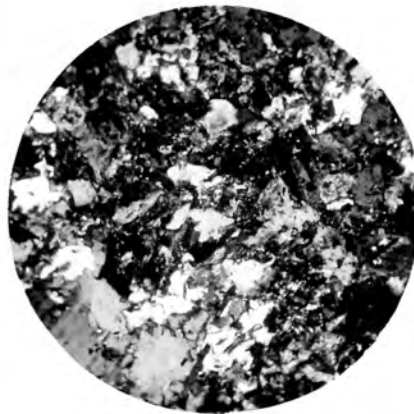


Figure 17



Figure 18

At the crest of the hill immediately to the east of the Thomas River, on the farm Stonehenge, the core material crops out over a width of nearly 200 feet and no dolerite outcrops are seen. This shows that the width of the core material varies tremendously. From here the core can be traced by intermittent outcrops to the farm Rexfield. It seems to thin gradually and beyond the little stream flowing north through the farm no further outcrops of the core are found. It is thought that the core dies out somewhere near the eastern boundary of Rexfield, about 14 miles from the westward limit of the dyke. (See figure 19.).

(ii) The Dolerite Flanking The Core.

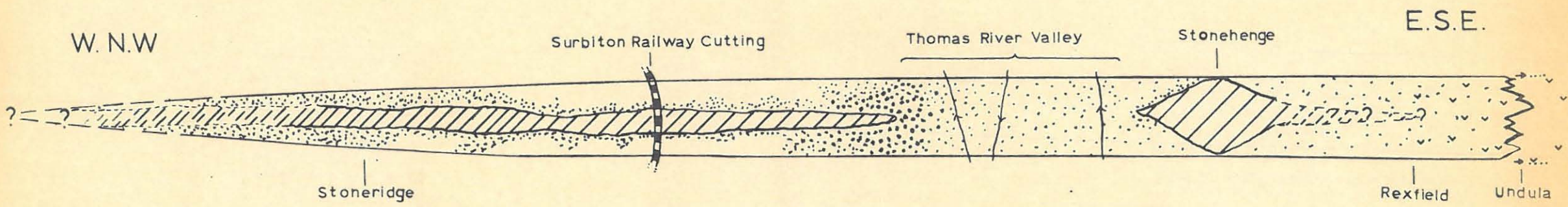
The dolerite is identical on either side of the core and is generally highly weathered. It is a subophitic dolerite with augite and plagioclase as the predominant minerals and has a small amount of quartz and the usual accessory minerals, such as skeletal ilmenite and apatite. Near the core it becomes granophyric in texture with a corresponding increase in the amount of quartz present. Here it is best described as a granophyric dolerite, but it does not grade into the granophyric quartzite of the core. Rather, the contact between the two is sharp and distinct. The granophyric dolerite consists essentially of turbid plagioclase laths (up to 1 mm. in length) with a subophitic relationship towards the pyroxene, micropegmatite and quartz. In places the micropegmatite is seen to replace plagioclase laths but more often it forms around, and radiates from, them. It usually has sharp margins with the laths and becomes coarser outwards from them. Augite, often largely replaced by chlorite, is an essential mineral of the granophyric dolerite while ore minerals and apatite are common accessories.





EXPLANATION OF FIGURE 19.

Figure 19 shows the supposed shape and extent of the mobilized sediment core at the western end of the north Gap Dyke. It is only a diagrammatic representation, and not drawn to scale.

FIGURE 19

-NOT TO SCALE-



-  Core (mobilized sediment)
-  Granophyric Dolerite (types)
-  Subophitic Dolerite
-  Dolerite Pegmatite

146

The subophitic dolerite and the granophyric dolerite do not have a sharp contact between them but grade into one another, and the width of each is very variable. In the Surbiton railway cutting the granophyric dolerite occurs only as zones three feet wide on either side of the core, while the rest of the dyke is subophitic dolerite. (See figure 8.). On Stoneridge it appears as if all the dolerite is of a granophyric variety, though this may not be said with certainty because exposures are poor. It certainly extends for more than 6 feet on either side of the core and, in quarries near the old national road to Cathcart, it is seen to extend for 18 feet on either side of the core, leaving only 9 feet of subophitic dolerite on one side and 6 feet on the other. The core material dies out suddenly about half a mile west of the Thomas River and east of this the width of the whole dyke consists of granophyric dolerite, while no subophitic dolerite is seen. A detailed examination of the subophitic dolerite could not be satisfactorily ~~be~~ undertaken because of the lack of exposures and because of the high degree of weathering. For this reason the micrometric analysis of the subophitic dolerite is not to be regarded as very accurate. Table III shows the micrometric analyses of the dolerite types flanking the core.

(iii) The Thomas River Area.

In the Thomas River area, where the core is absent, granophyric dolerite occupies the full width of the dyke. This granophyric dolerite differs from the granophyric dolerite which flanks the core further west in that, in hand specimens, it appears to be paler in colour and coarser in grain. (See figure 11.). This is due to the congregation of felsic minerals into larger groups, but

TABLE III.

Micrometric analyses of the dolerite flanking the core.

	(1)	(2)
Plagioclase	43.1	51.6
Pyroxene + Chlorite	23.4	43.8
Quartz, Orthoclase and Micropegmatite	31.3	1.3
Ore minerals	2.2	3.3
Colour Index	25.6	47.1
Specific Gravity	2.764	--

- (1) Granophyric dolerite flanking the core; Stoneridge.
- (2) Subophitic dolerite (highly weathered); Surbiton railway cutting.

under the microscope the plagioclase laths are in fact smaller than before and the predominant mineral is micropegmatite which has a relatively large area surrounding the laths. This micropagmatite not only surrounds the plagioclase laths but often replaces them along their margins and composition planes. It becomes coarser outwards, sometimes grading into free quartz or orthoclase. Orthoclase may make up as much as 15.5% (volume) of the rock. There is a slight tendency for the mafic minerals to form subradiating clusters. Augite makes up 12.4% (volume) of the rock and generally shows some alteration to chlorite. Chlorite is not only associated with the pyroxene but may also occur separately as distinct plates or wisps. Accessory minerals include skeletal crystals of **ilmenite**, needles of apatite and a few crystals of epidote.

Eastwards the rock changes in character, becoming coarser in grain and showing the presence of amphibole and a corresponding decrease in the amount of micropegmatite. This strongly pleochroic brown or green amphibole occurs both as subhedral crystals and as mantles around pyroxene crystals. The character of the plagioclase also changes: the anorthite content increases sharply by about 10% of anorthite in the dolerite near the west bank of the river, where the dyke is cut for the **third** time, and decreases by a similar amount in the dolerite on the east bank where the granophyric sandstone core crops out once more.

The grain size increases fairly sharply from west to east, reaching a maximum on the east bank of the river, where the dyke is cut for the **first** time, in the mottled-looking dolerite. East of this there is a decrease and a minimum is again reached in specimens taken from dolerite outcrops near the crest of the hill, where the wide outcrop of core material is present. All changes in the character

of the rock appear to be gradational.

The dyke shows a number of interesting features in the vicinity of the Thomas River where the river cuts the dyke for the first time, in the eastern part of the valley.

(a) Metasomatized Xenoliths. Some distance from the river, on the west bank, small outcrops of the dyke occur in the cultivated lands and these show coarse patches, up to 2 feet by 6 inches, in the granophyric dolerite. These patches grade fairly sharply into the surrounding rock but are quite distinctive because of their coarser grain (1.5 mm. \pm 0.5 mm.) and because they contain rods of dark minerals in a pale uniform matrix. (See figure 12). These rods, which vary from 2 mm. to 5 mm. in length, are seen, under the microscope, to consist largely of greenish-yellow serpentine with a high birefringence (0.028 max.) and some ilmenite plates. The serpentine is fibrous and contains chlorite intergrown with the fibres. The chlorite is weakly pleochroic, from pale green to greenish-yellow, and it may contain pleochroic haloes. In places dark brown, strongly pleochroic biotite occurs associated with serpentine. The pale, uniform matrix consists essentially of coarse micropegmatite with intergrowth areas of up to 2 mm. in diameter and showing uniform extinction. There is very little plagioclase, the composition of which cannot be accurately determined because of the high degree of alteration to saussurite. Accessories include apatite, ore minerals, sphene, epidote, some prehnite and some calcite. There is no pyroxene or hornblende, but the serpentine-chlorite rods are thought to be pseudomorphous after pyroxene, by comparison with similar serpentine rods described by Walker and Poldervaart (1942, pp. 292 and 295).

(b) Acid Veins. In the granophyric dolerite on the immediate west bank and in the bed of the river there are a number of coarse-grained veins traversing the outcrop. These are termed 'acid veins' and not schlieren because they differ from true schlieren in that they are not lenticular in shape but irregular in their trend. They extend for 4 or 5 feet with constant thickness of $1\frac{1}{2}$ to 2 inches before merging with the surrounding rock. These irregular acid veins consist of coarse-grained dolerite pegmatite containing laths of green hornblende in a pale matrix of quartz and feldspar. The amphibole laths may be as long as 20 mm. Under the microscope the rock is seen to consist essentially of acid plagioclase, with little or no zoning, micropegmatite and quartz. The amphibole laths are identical to those found in the surrounding granophyric dolerite, except for their large size. They contain occasional relict grains of pyroxene. Accessory minerals include apatite needles, skeletal ilmenite, pleochroic green to yellow chlorite, some prehnite, serpentine and leucoxene. (See figures 13 and 20.).

(c) Dolerite Xenolith. Also contained in the granophyric dolerite which crops out in the river bed is a xenolith of dolerite measuring 26 inches by 12 inches. It consists essentially of subophitic labradorite, which is strongly zoned, and zoned augite. The accessories include some quartz, very little micropegmatite, skeletal and anhedral crystals of ore minerals, some apatite crystals, brown serpentine and green, weakly pleochroic chlorite. The grain size is small, the average diameter being about 0.25 mm. Surrounding this xenolith is a zone, 2 to 4 inches wide, of coarse dolerite pegmatite identical in appearance and mineral composition to the acid veins. This grades into the surrounding granophyric dolerite fairly sharply in parts and gradationally in others. (See figure 21.).

EXPLANATION OF FIGURES 20 AND 21.

Figure 20: Acid veins in the granophyric dolerite
on the west bank of the Thomas River.

Figure 21: Dolerite xenolith in the granophyric
dolerite, Thomas River.

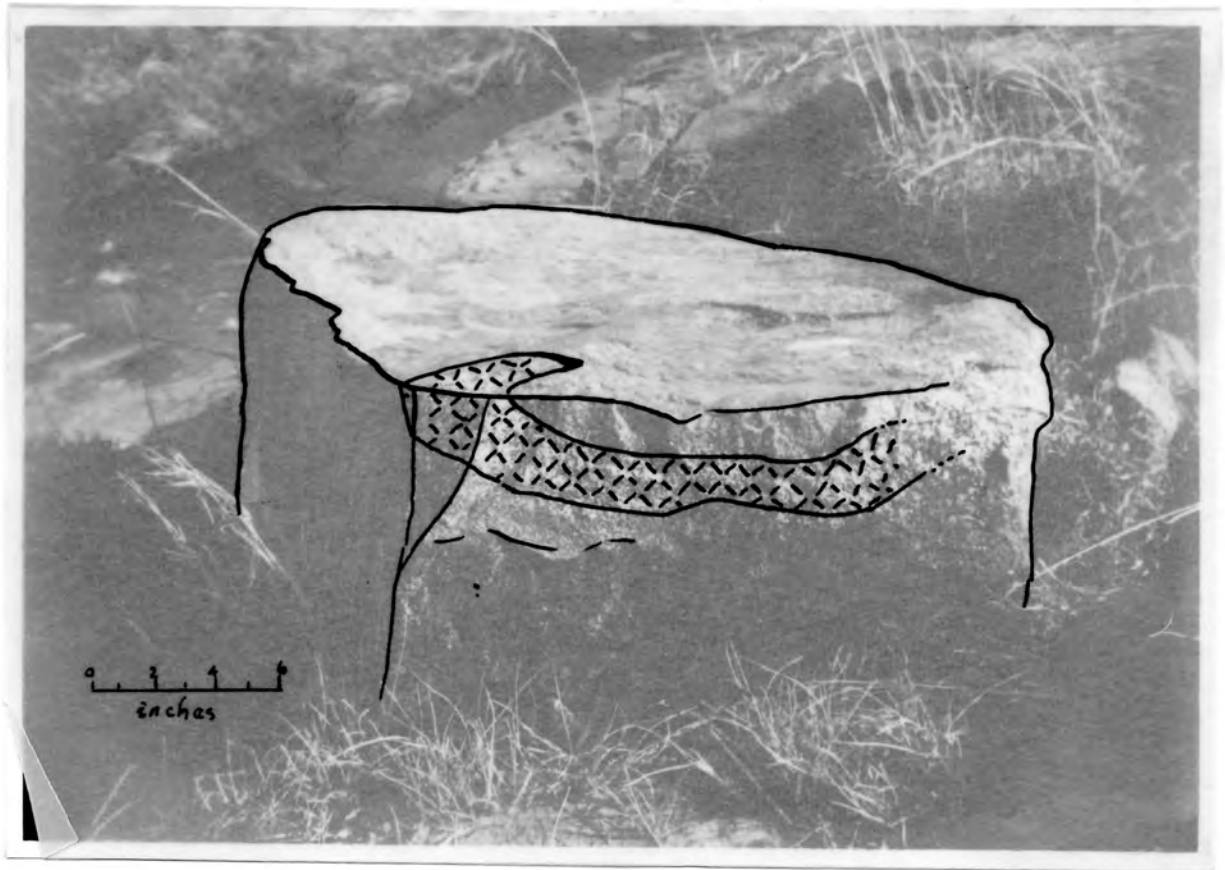


Figure 20

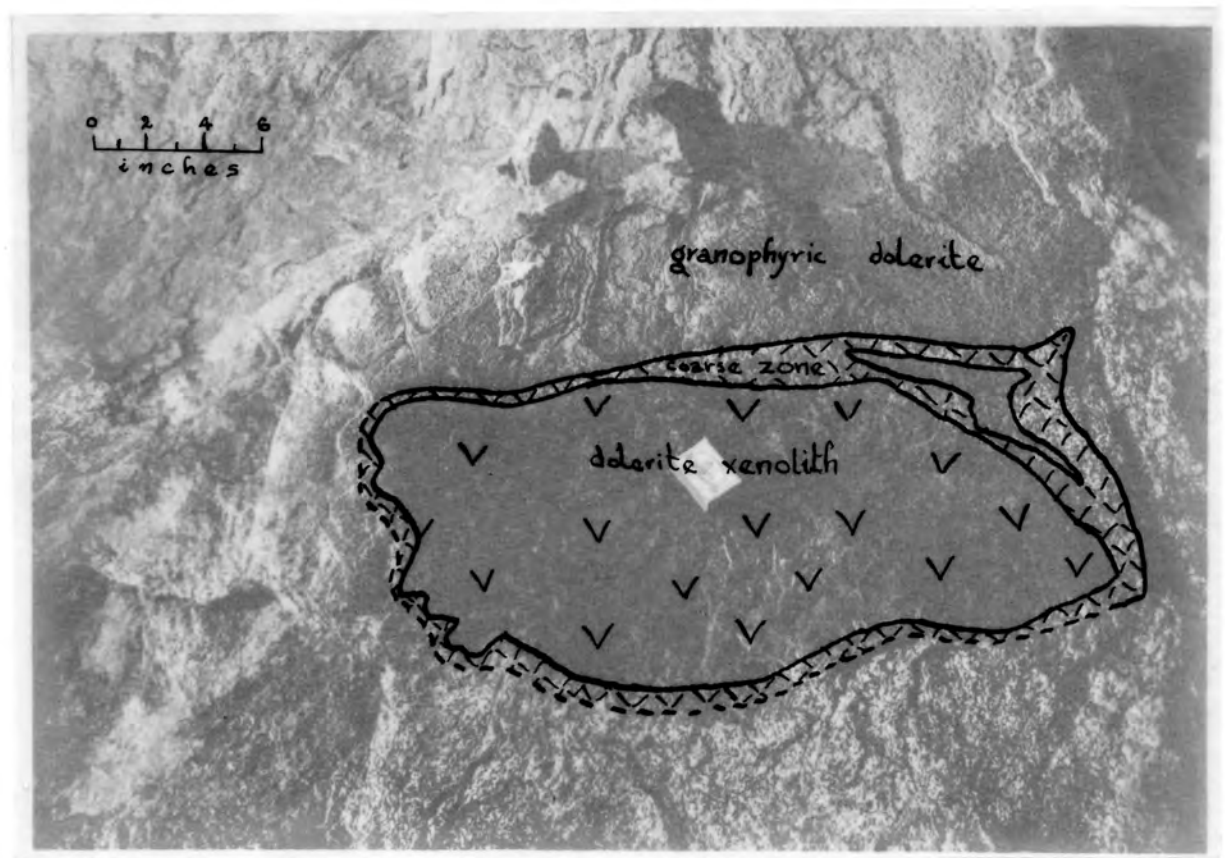


Figure 21

(d) "Mottled Rock". On the east bank of the river the granophyric dolerite passes into a peculiar-looking mottled rock, which appears to make up the whole width of the outcrop. The dark minerals in this rock show a marked tendency to gather into clusters, subradiating or otherwise, each patch reaching up to 5 or 6 mm. in diameter. In thin section the rock is seen to be fairly coarse grained (1 to 2 mm. diameter) and the dark patches of the hand specimen lose their identity and are seen to consist mostly of chlorite and amphibole which have replaced pyroxene. There are a few crystals of augite, mostly with their centres replaced by chlorite, which show subhedral basal sections. The most abundant mafic mineral is green or brown hornblende often with subhedral basal sections and occasionally showing tiny relict pyroxene cores. The plagioclase laths may reach a length of 4 mm. and are very turbid because of much alteration to saussurite. They are strongly zoned. The "mottled rock" is very rich in quartz and also contains a small amount of micropegmatite.

Contained in the "mottled rock" are pale patches with a similar texture and grain size. These are roughly circular or elongated in shape and have sharp margins against the surrounding mottled dolerite. They are very rich in quartz and plagioclase and in some cases contain large amounts of calcite and epidote. Measurements show the composition of the plagioclase to vary considerably, even in a single microscope slide, but it is a soda-rich variety. Accessories include much sphene, sometimes as subhedral crystals, and some apatite crystals.

Table IV shows a series of micrometric analyses of the rocks in the Thomas River area.

TABLE IV.

Micrometric analyses of the rocks in the Thomas River area.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Plagioclase	14.5	37.9	24.4	35.1	43.0	49.5	22
Pyroxene + Chlorite	21.8	19.4	16.7	15.9	4.2	11.4	20
Micropegmatite, quartz and orthoclase	59.1	35.9	56.5	32.0	43.1	20.7	50
Ore minerals	4.1	3.5	2.4	2.9	1.8	3.8	5
Amphibole	-----	3.3	-----	14.1	7.9	14.5	3
Colour Index	25.9	26.2	19.1	32.9	13.9	29.7	28
Specific Gravity	2.76	2.76	2.65	2.79	2.69	2.79	---

- (1) Granophyric dolerite forming the whole width of the dyke at the eastern end of the western section of the core. About half a mile west of the Thomas River.
- (2) Granophyric dolerite found making up the north Gap Dyke in most of the Thomas River area.
- (3) Coarse patches in the granophyric dolerite. (Metasomatized xenoliths).
- (4) Granophyric dolerite found in the bed of the Thomas River where the dyke is cut for the first time by the river.
- (5) Acid veins contained in (4).
- (6) "Mottled rock" on the east bank of the river.
- (7) Metasomatic granophyre. Walker and Poldervaart (1949. p. 619).

(iv) The "Transkei Type" Dolerite.

The type of dolerite forming the dyke in the eastern part of the Thomas River area grades gradually and continuously into the type called the "Transkei type". The division between the two is purely arbitrary and is made where the differences in mineral compositions become most noticeable. The name "Transkei type" is given only to distinguish the dolerite, forming the greater part of the dyke, from the types already described. There is a continuous increase in grain size eastward until a maximum (0.7 ± 0.01 mm.) is reached some 22 miles east of the western limit of the dyke. (See Graph 2). The changes in mineral composition are best seen by the micrometric analyses made from specimens taken at various distances along the length of the dyke. (See Table V.).

The arbitrary point of division between the rocks considered to be "Thomas River type" and the "Transkei type" dolerite is chosen between (4) and (5) of Table V where there is a significant change in the proportions of plagioclase, pyroxene and quartz + orthoclase + micropegmatite. These micrometric analyses (volume percentage) show only a general trend and not too much importance should be attached to individual analyses. This is because specimens could be collected only where outcrops occur and are, therefore, necessarily random. There is some variation across the width and, depending on the sample chosen different results could be recorded. This is shown in Table VI which shows a series of micrometric analyses of specimens from outcrops across portion of the dyke width on Undula. In spite of the fact that only random specimens could be collected the width of the dyke in most cases, can be estimated and the tendency for the centre rather than the margins to crop out has been noted. Therefore, specimens are generally taken from points close to the centre of the dyke.

Specific gravity measurements of the "Transkei type" dolerite

TABLE V.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Plagioclase	37.9	34.1	39.8	39.9	61.4	60.2	62.4	60.6	60.8	58.3	57.7	55.3	54.4	54.6	58.7	59.2
Pyroxene + Chlorite	19.4	25.6	20.8	24.7	12.3	14.2	12.5	9.8	3.9	7.6	7.3	4.5	6.7	22.4	18.6	8.4
Micropegmatite, Quartz, Orthoclase	35.9	36.0	30.2	24.8	7.9	8.4	14.8	11.8	12.5	14.7	11.9	13.9	15.8	--	5.9	12.1
Ore minerals	3.5	2.9	3.1	4.1	3.8	3.5	3.2	2.9	2.6	1.8	3.3	3.2	3.9	3.3	3.6	3.2
Amphibole + Biotite	3.3	1.4	6.1	6.5	14.6	13.7	11.4	14.9	20.1	17.6	19.3	23.1	19.2	19.7	13.6	17.1
Colour Index	26.2	29.9	30.0	35.3	30.7	31.4	37.1	37.6	35.6	27.6	30.4	30.8	29.8	45.4	35.4	32.3
Specific Gravity	2.76	2.79	2.81	2.82	2.81	2.80	2.79	2.80	2.80	2.82	2.82	2.81	2.81	2.89	--	2.81
Grain Size (mm.)	--	0.23	0.26	0.35	0.56	0.63	0.70	0.68	0.69	0.70	0.69	0.69	0.71	0.69	--	0.69
An % (centres)	64	52.5	66	66	67	64	64	63	66	66	64	65	63	64	--	--

(1) Granophyric dolerite in the Thomas River area. (See Table IV, No. 2).

(2) West boundary of Rexfield.

(8) Lyall

(14) Ngadla River mouth.

(3) East of the river on Rexfield.

(9) Ringstone.

(15) "Kentani type" --- Walker and Poldervaart, (1949).

(4) South of Undula homestead

(10) Lujilo.

(5) East boundary of Undula

(11) Toleni Bridge.

(16) Average of (5) to (13).

(6) Quacu Heights.

(12) Qoboqobo.

(7) Quacu Forest.

(13) Cats Pass.

TABLE VI.

Distance from southern contact in feet	7	23	41	59	76	94	112	130	160	Average
Plagioclase	52.0	55.9	61.4	50.6	54.3	51.4	52.9	61.8	54.5	55.4
Pyroxene + Chlorite	19.7	20.5	12.3	19.4	12.1	15.3	12.1	6.1	11.1	14.2
Micropegmatite, quartz, Orthoclase	5.9	9.3	7.9	6.6	10.3	8.2	10.3	7.4	8.2	8.7
Ore minerals	6.1	3.1	3.8	4.3	4.8	4.9	4.2	3.9	3.7	4.2
Amphibole + Biotite	16.3	11.2	14.6	19.1	18.5	20.2	20.5	20.8	22.5	17.5
Colour Index	42.1	34.8	30.7	43.8	35.4	40.4	36.8	30.8	37.3	35.9
Specific Gravity	2.81	2.79	2.81	2.84	2.81	2.83	2.84	2.82	2.83	2.82

Average grain size: 0.56 mm.

Total width estimated as being 240 feet at this point.

show a variation from 2.786 to 2.887 along the length, the average specific gravity being 2.806. All measurements were made by accurate hydrostatic weighing using blocks cut to remove weathered portions and ground to remove any irregularities which may have trapped air bubbles. There is a rough correspondence between specific gravity and colour index, as would be expected, but in cases where much of the pyroxene has been altered to chlorite, and where the plagioclase is highly altered to saussurite, the specific gravity is low. The greatest actual increase and rate of increase in the specific gravity are between Cats Pass and the coast.

Micropegmatite is abundant in the western part, particularly in the rocks forming the transition between the Thomas River dolerites and the "Transkei type" dolerites, but eastward the amount of micropegmatite decreases rapidly and only free quartz is found. Where the micropegmatite is present in large amounts it is frequently found replacing plagioclase laths, often to such an extent that only "ghost structures" are left. Where smaller amounts occur, as in the rocks at Undula (Table VI), it is nearly always interstitial and forms straight margins against the feldspar. Quartz is found throughout, but at the coast neither quartz nor micropegmatite is present. The dolerite here consists essentially of plagioclase and mafic minerals.

The plagioclase in the "Transkei type" dolerite consists of large, well zoned and usually highly altered laths. Apart from the high degree of alteration to saussurite and sometimes to calcite the laths are often replaced by irregular quartz and orthoclase veins, and also by brown serpentine veins. Such veining is absent in the plagioclase of the coastal dolerite types.

Throughout the dyke, in all varieties of dolerite, the pyroxene is augite and neither orthopyroxene nor pigeonite was

encountered. The pyroxene shows a subophitic relationship to the plagioclase laths, and occasionally a poikilophitic texture is seen where very small laths of plagioclase are entirely enclosed by the pyroxene. This texture possibly indicates a slightly earlier initiation of the crystallisation of plagioclase than pyroxene.

The amphibole, which increases in amount eastward, is thought to be late magmatic and is found both as subhedral crystals and as mantles around augite crystals. These mantles may be so well developed as to leave only tiny cores of augite. The mantle is obviously formed as the result of reaction but is not uralite. Uralite is fibrous and pseudomorphous after pyroxene: the mantle amphibole is crystalline. The most common amphibole is identified as hornblende and it is usually strongly pleochroic from dark brown to pale greenish-yellow, or from pale green to dark green. A single crystal may vary in colour from the centre outwards: brown in the centre and blue-green at the extremities. Less abundant, except in the coastal variety of the dolerite, is actinolite which usually occurs in small amounts as acicular crystals or "brushes" of crystal aggregates. It is more common nearer the coast where, in some cases, acicular crystals of actinolite are seen penetrating quartz. The outcrops near the Ngadla River mouth show no hornblende and the only amphibole is actinolite, which makes up 12.65% (volume) of the rock.

Accessories include the ore minerals, mostly ilmenite which frequently shows alteration to leucosene. The ore minerals occur in varying proportions, from 1.8% to 4.1% (volume.). The granular crystals are often surrounded by biotite and an indeterminable orange mineral, which is possibly stained serpentine, both of which appear to be replacing the ore. Biotite is a common accessory and becomes more abundant eastward so that at the coast it makes up 7% of the rock.

increase in the percentage of dark minerals, and no quartz is found. Actinolite "brushes" and "needles" are common and, together with chlorite, replace much of the pyroxene. There is no hornblende while brown, and some green, biotite is much more common than in the more westerly specimens. The biotite frequently grades into chlorite, and biotite wisps in a chlorite crystal are common.

(v) The Petrography of the Sediments.

The dyke invades Beaufort sandstone throughout at the surface. There is little variation in the character of the sediment over the length of the dyke, except that, in the west near Cathcart, it is slightly coarser in grain and could be termed a feldspathic sandstone rather than a sandstone. These massive feldspathic sandstones in the west are classed, by Mountain (1945, Plate III and page xxiv.), as belonging to the Middle Beaufort horizon while the sandstones in the east belong to the Lower Beaufort horizon.

Outcrops of the sandstone, which are not usually very weathered, have a pale yellowish-brown appearance because of slight weathering which usually only extends a few inches deep. Fresh specimens are grey-green or pale greenish-brown. The sandstone is massive or only slightly bedded: well defined bedding is not common. Occasional interbedded dark green shale bands occur, as in the Thomas River area, but such bands are very thin and do not exceed 5 inches in thickness.

Although for great distances the Beaufort sandstone is normally very uniform and of constant grain size, occasionally it is seen to contain calcareous nodules. Very common inclusions, but usually confined to distinct areas where a great number occur together, are small lens-shaped patches of green shale. These patches are not more than 1 inch in diameter and 1 mm. thick, and lie in the ill defined bedding planes. Such areas appear to be similar to the

TABLE VII.

Micrometric analysis of the coastal variety of the "Transkei type" dolerite which crops out about 800 yards west of the Ngadla River mouth.

Plagioclase	54.62
Pyroxene	11.42
Ore minerals	3.33
Biotite	7.02
Actinolite	12.65
Chlorite + Serpentine	10.96
Colour Index	45.38
Specific Gravity	2.887

"wash outs" containing "clay-pellet conglomerate" described by du Toit (1956, page 293.) except that they are also found near the western termination of the dyke, on Stoneridge, an area which is considered to be Middle Beaufort.

Under the microscope the rock is seen to consist of sub-angular or rounded quartz grains, often recrystallized together, and varying amounts of similarly rounded orthoclase and plagioclase. The plagioclase varies in composition, but is always a soda-rich variety. The fine-grained matrix consists of quartz and feldspar. Other minerals include chlorite, magnetite, limonite, rounded zircon, garnet, a few grains of rounded apatite and occasional grains of microcline. The grain size varies, but an average diameter for the larger grains is about 0.2 mm., while the matrix is composed of very much finer grains. Only a slight degree of recrystallisation is shown, except near the dyke walls.

CHAPTER THREE

MINERALOGY

ABSTRACT OF CHAPTER THREE.

The mineralogy of the dolerite types of the north Gap Dyke is fairly simple. Plagioclase feldspar, which shows considerable variation in both grain size and composition, is the most abundant mineral. Only one pyroxene, augite, is recognised and this has similar properties in all the dolerite types. Less important is the amphibole which is either hornblende or, less commonly, actinolite. Accessories include micropegmatite, quartz, orthoclase, biotite, the ore minerals, apatite, iddingsite (?), prehnite, epidote and calcite.

The core of mobilized sediment is fairly consistent in mineral composition and is composed essentially of quartz and feldspar with apatite, ore minerals and chlorite as accessories.

MINERALOGY OF THE DOLERITE.

(1) PLAGIOCLASE FELDSPAR.

(a) Grain Size Measurements.

Grain size measurements were carried out on a number of specimens taken from points both across the width and along the length of the dyke. The areas of about 40 to 50 plagioclase laths were measured in each slide and these areas recalculated to give the diameters of circles with areas equal to those of the grains measured. An average diameter was then used to represent the average grain size of that specimen. Only the largest grains were chosen for measurement because the largest grains in a thin section are the most significant in grain size studies because:

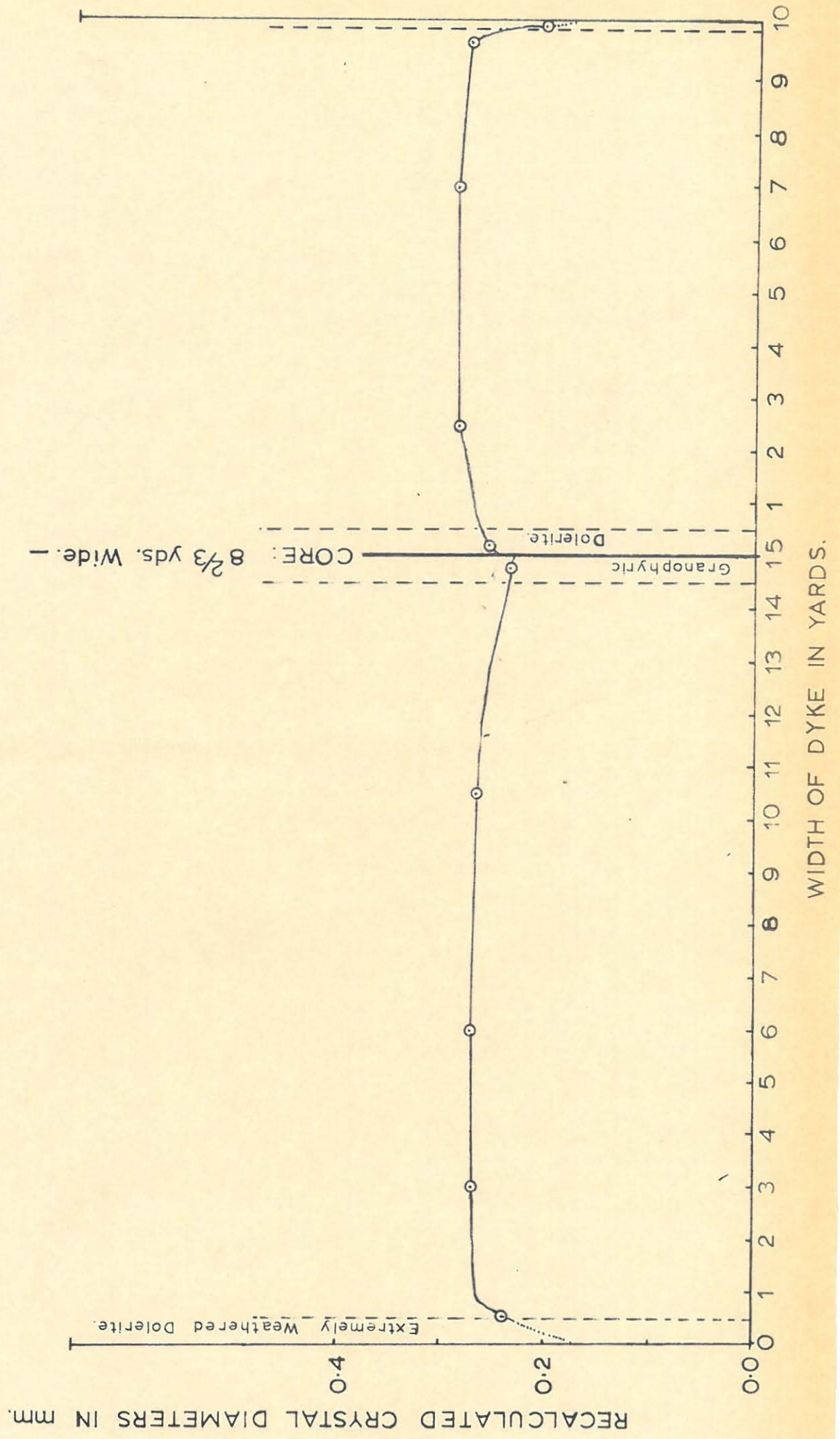
"Lane, recognising that thin sections present chance sections, prefers to chose for measurement the largest grain in each microscopic field instead of all grains." Quoted by Alling (1936, page 323.).

Before measurement each grain was examined carefully between crossed nicols to ensure that it was free of possible intergrowths.

The only outcrop across the complete width of the dyke occurs in the Surbiton railway cutting. Here the rock is, unfortunately, very highly weathered. Nevertheless, specimens were collected across the width at regular intervals and microscope slides prepared by soaking the specimens in liquid Canada balsam before mounting. The poor quality of the slides possibly means that the results are slightly inaccurate, but the results do show a definite pattern, as shown by Graph 1. This graph shows the average grain size, represented by the diameter (in millimeters) of a circle with an area equal to the average

EXPLANATION OF GRAPH 1.

This graph shows the variation in grain size of plagioclase crystals across the width of the dyke where it is exposed in the Surbiton railway cutting.



GRAPH 1.

area of the plagioclase laths measured, plotted vertically, against the width of the dyke (in yards), plotted along the abscissae. The ratio R/R_0 (where R_0 = distance from the centre to the margin of the dyke, and R = distance from the centre of the dyke to the specimen) as suggested by Winkler (1949, page 557) could not be used because the dyke is complicated by the presence of the granophyric quartzite core. Thus, grain size measurements in this case can only show a possible variation across the dyke and can not be used to determine the temperature ranges within which the feldspar had crystallised.

The graph shows that the grain size, as represented by the size of the plagioclase laths, varies only very slightly across the entire width of the dyke: from 0.202 mm. at the margin to 0.281 mm. in the centre of the dolerite between the core and wall and 0.252 mm. at the core. This shows that there is no significant chilled margin, a fact borne out by the field evidence which shows that no fine grained varieties of the dolerite exist near the dyke margins. Right at the contacts the dolerite is extremely weathered and so a chilled margin may be present, but if it is then its extent must be very limited. Although the Surbiton cutting affords the only complete section across the dyke width there are a number of outcrops exposing wide areas of the dyke, such as at Stonehenge, Undula, Toleni and Lujilo. Similar grain size measurements were made on specimens collected from such partial width exposures, and these gave results which showed little or no variation across the width. In no case, however, were the margins exposed where fresh specimens could be collected.

This lack of variation in grain size across the width of the dyke is important in that it not only means there is no significant chilled margin, but that if specimens are collected at random points from outcrops along the length of the dyke then the distance from the

margin will not affect the grain size. Thus, random specimens will be representative of the dyke at that point along the length, especially considering that there is only slight variation in mineral composition across the width, as shown by Table VI.

Graph 2. shows the grain size, represented by the size of the plagioclase laths, recalculated to diameters in millimeters, plotted against the length of the dyke in miles. It shows that there exists a definite relationship between the grain size of the dolerite and the core of granophyric quartzite. Where the core is present the grain size of the dolerite is small (only about 0.25 mm.) and in the Thomas River area, where there is a break in the core material, there is a sharp increase in grain size of the dolerite, (to 0.57 mm.). Beyond this where the core again appears the grain size of the dolerite decreases rapidly. Eastward it increases gradually to an almost constant size of about 0.7 mm.

Because grain size of igneous intrusions is, in the early stages, influenced by the rate of cooling, and because the grain size of the dolerite forming the north Gap Dyke is influenced by the presence of the core of mobilized sediment it seems reasonable to suppose that the core has had a direct influence on the rate of cooling of the dyke. Apart from the Surbiton railway cutting the width of the core cannot be measured anywhere with accuracy and varying thickness may also influence the grain size of the flanking dolerite. Since the eastward limit of the core is not precisely known a gradual thinning might account for the gradual increase in the grain size of the dolerite east of Stonehenge.

(b) Composition and Zoning. The plagioclase feldspar shows considerable variation in composition, but in general is more basic where there is no granophyric quartzite core material and more acid where there is.

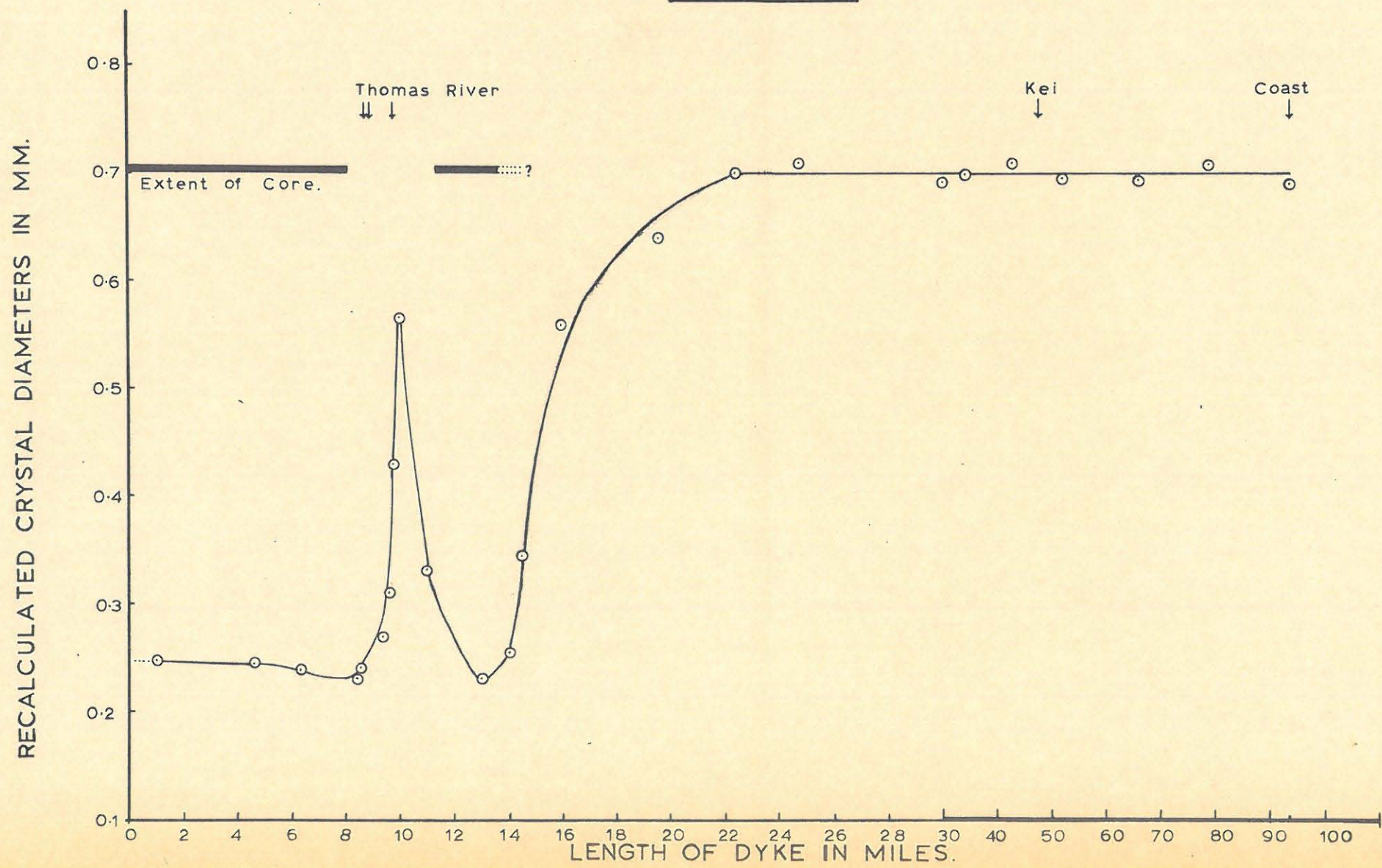
EXPLANATION OF GRAPH 2.

This shows the variation in the size of plagioclase crystals along the length of the dyke. Note the sudden increase in the Thomas River area where the core is absent, and the gradual increase east of the eastern section of the core.

GRAPH 2.

WEST

EAST



912

This generalisation has local exceptions particularly in the Thomas River area. Throughout the length of the dyke the plagioclase feldspar shows normal zoning to be well developed, and nowhere was oscillatory or ~~rythmic~~^h rhythmic zoning found.

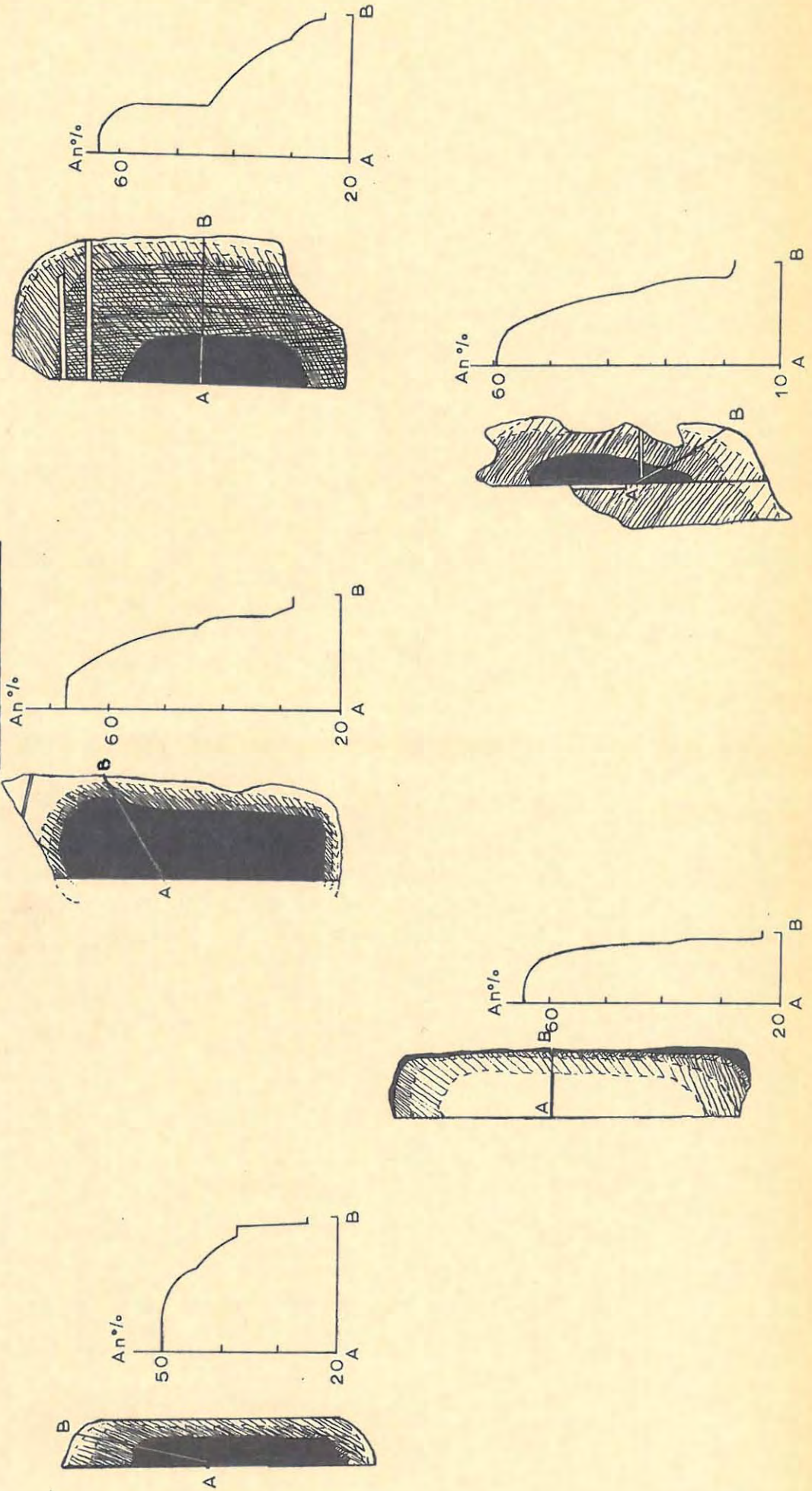
The most suitable method for studying zoned crystals of this type was found to be the zonal method of Rittman (Chudoba and Kennedy, 1933). The successive shells are not sharply demarcated but the extinction shadow moves gradually from the basic centre to the acid margin of the crystal. This is the normal progressive zoning produced when continuous readjustment between the solid and liquid phases of the cooling magma is not permitted through lack of time and because of high viscosity (the rate of heat loss is too great) thus allowing for the production of a residuum rich in alkalis. Where in contact with other crystals the most sodic part of the zoned lath occurs in embayments of the other crystal, so that crystal interference has in fact limited the degree of zoning along the surface of contact.

In general, the larger the crystal the more sodic the outer margin and, although there does not appear to be any consistent relationship between composition and distance from the centre of the crystal, there does exist some definite relationship such that the most sodic zones are furthest from the centre. The diagrams showing the zoning and variations in composition (Figure 22) reveal that in a direction parallel to (010) there is a gradual and fairly uniform decrease in anorthite content until zones of composition less than An_{45} are reached when the change is far more rapid. In orientated crystals the decrease in anorthite content along the Z axis direction, parallel to (010) twin planes, as in Carlsbad or Carlsbad-Albite twins, is very gradual until a point near the margin where, if the acid zones are present at all, the greatest rate of change is found. Where present,

EXPLANATION OF FIGURE 22.

Graphs showing the nature of the zoning in plagioclase crystals. The drawings are camera lucida drawings of different crystals between crossed nicols, and the zoning is indicated by the varying densities of shading. Because the zoning is progressive, and the extinction shadow moves gradually across the crystal during rotation of the stage the limits of each zone are only approximate, and the graphs are, for the same reason, not extremely accurate. The graphs show the composition changes across each crystal.

FIGURE 22



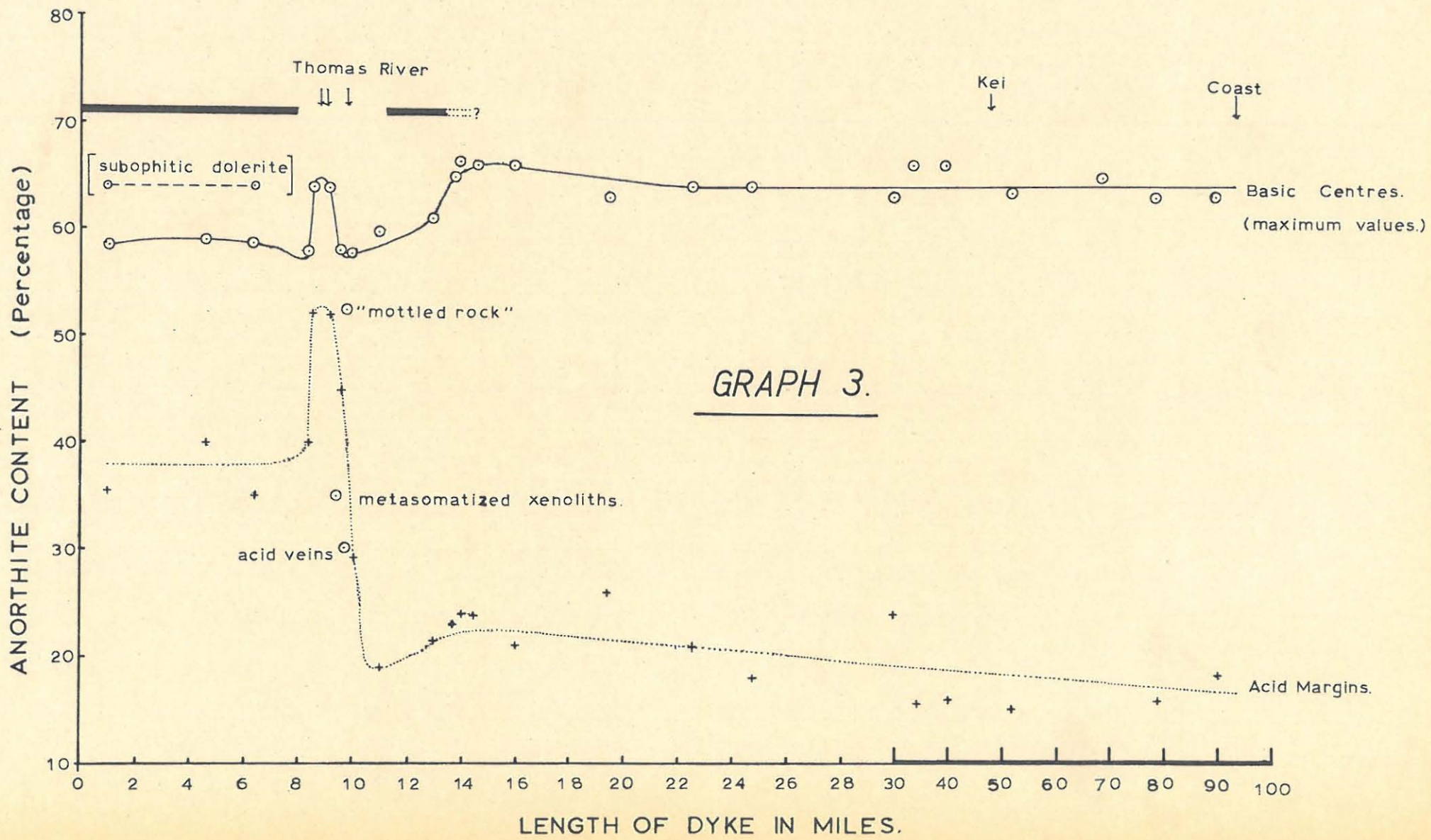
and wide enough for the extinction to be seen, these zones can be shown to have the same composition as zones perpendicular to (010). The sodic outer mantles often pass into micropegmatite and optical continuity between the plagioclase and the feldspar of the micropegmatite is preserved, although the plagioclase itself need not necessarily enter into the formation of the micropegmatite.

The plagioclase of the subophitic dolerite flanking the core has centres of $An_{60} - 64$ and the most acid margin measured was An_{50} . The zoned plagioclase laths of the granophyric dolerite vary greatly but most have centres of $An_{55} - 58$ and margins as low as An_{28} . The granophyric dolerite found making up the dyke in most of the Thomas River area has plagioclase with the composition of An_{64} for the centres and An_{52} for the margins. Near the east bank there is a sudden increase in the anorthite content of the plagioclase and the peculiar "mottled rock" contains plagioclase having centres with the composition of An_{52} and margins of An_{30} . The acid veins in the granophyric dolerite on the west bank, in the same area, have acid plagioclase laths which show little or no zoning and which have the composition $An_{28} \pm 2$. The pale patches found in the "mottled rock" have very acid plagioclase crystals, with compositions ranging from An_4 to An_{28} , and with little or no zoning. East of the Thomas River the dolerite has plagioclase crystals of more or less uniform composition. These are well zoned, with their centres and margins differing by as much as 30% of anorthite. The centres have compositions varying between An_{63} and An_{66} and the margins vary from An_{16} to An_{25} .

Because of the nature of the zoning the curve showing the variations in the composition of the sodic outer mantles of the plagioclase laths should be interpreted only allowing for a large margin of error, while the curve showing the variations in composition

EXPLANATION OF GRAPH 3.

The graph shows the variation in the anorthite content of the plagioclase crystals in different specimens at various points along the length of the dyke.



33b

for the more basic centres is more likely to be accurate. (See Graph 3.) There is no variation in the composition of the plagioclase laths in specimens taken across the width of the dyke, except in the case of the plagioclase in the subophitic dolerite and the granophyric dolerite flanking the core.

(c) Twinning.

In all specimens the commonest types of twinning in plagioclase were found to be the Carlsbad and complex Carlsbad-albite twins. Pericline twins were fairly common and several examples could usually be seen in every slide. Where present and where possible such twins were used for accurate composition determinations of the zones. In all the sections examined under the microscope, which numbered over 100, only two contained plagioclase crystals showing Baveno twinning.

(d) Alteration and Replacements.

The plagioclase in specimens along the dyke length is commonly altered, but the degree of alteration may be greater in some parts than in others. The alteration is to saussurite and, in some cases, to calcite only. This gives the feldspar a turbid appearance in thin section. The basic centres seem to be more susceptible to alteration than the more acid margins and it is not uncommon to find the centre of a lath highly altered to saussurite and the margin untouched while the contact between altered and unaltered portions of the crystal may be quite sharp.

The plagioclase is frequently found to be replaced by micropegmatite, particularly in the western part of the dyke where micropegmatite becomes a dominant constituent of the rock. This replacement is seen to take place along the composition planes or along the margins of laths. Where present in large amounts the micropegmatite may replace the plagioclase to such an extent that

it appears only as scattered residual patches, their former continuity being shown only by the fact that the twin planes of crystals may be interpolated. (See figures 23, 24 and 25.). This replacement by micropegmatite is most noticeable in the western part of the dyke, and eastwards where the amount of micropegmatite decreases considerably, eventually to vanish altogether, no further replacement is noticed.

In many of the microscope slides veins of both quartz and orthoclase are seen replacing plagioclase, though this is not strikingly developed in the western part of the dyke. These veins do not appear to follow any crystallographic directions but anastomose irregularly through the laths. The intensity of this veining varies considerably and is not confined to any particular part of the dyke. Specimens taken only a few feet apart may show considerable differences in the intensity of veining. There does not seem to be any relationship between the intensity of veining and the amount of micropegmatite, or free quartz, present. In some sections with large quantities of micropegmatite the plagioclase may be unveined, although it may be replaced by the micropegmatite itself. Most of the veins are of quartz, but staining techniques and optical examination of crushed fragments reveal that a number are in fact orthoclase, with the following properties:

Biaxial negative, with approximate refractive index of 1.526.

Both quartz and orthoclase, crystallizing under late magmatic conditions are thought to replace the early formed plagioclase either together, as micropegmatite, or separately, as monomineralic veins. (See figure 26.).

EXPLANATION OF FIGURES 23, 24 AND 25.

Figure 23: Photomicrograph showing a typically gradationally zoned plagioclase crystal with sharp margins against the surrounding micropegmatite. Between crossed nicols. (Magnification: x 38.)

Figure 24: Photomicrographs showing partial replacement of plagioclase laths by micropegmatite. Between crossed nicols. (Magnification: x 38.)

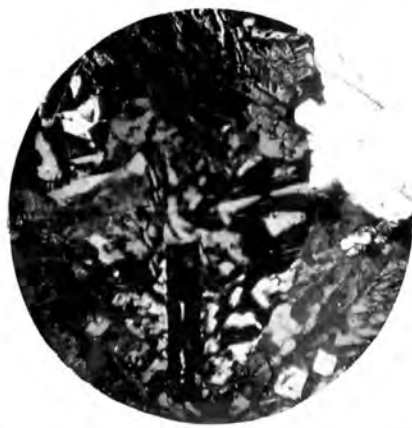
(a): Lath has sharp margins with the surrounding micropegmatite, but replacement has started along the composition plane.

(b): Replacement is quite far advanced along the composition planes, and the crystal has some irregular margins with the micropegmatite.

Figure 25: Almost complete replacement of a plagioclase lath by micropegmatite. The lath shows "ghost" structure. Between crossed nicols. (Magnification: x 38.).



Figure 23



(a)

(b)

Figure 24



Figure 25

EXPLANATION OF FIGURE 26.

Photomicrograph of quartz and orthoclase veins in
a plagioclase crystal. Between crossed nicols.
(Magnification: x 38.)

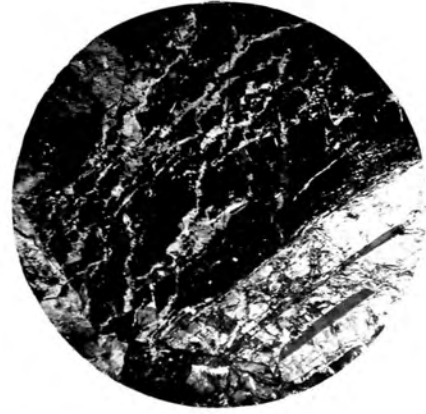


Figure 26

Around the margins of the zoned plagioclase laths is frequently found a rim of a very turbid material, grey to pale yellow in colour but appearing mottled and streaky. It has sharp margins against the laths, usually coinciding with a twin plane, but the outer margin is irregular. Where the plagioclase is in contact with a quartz crystal these turbid rims may be more conspicuous. They have a low interference colour. These rims are most likely to be alteration products of the plagioclase and are thought to be due to sericitization, forming clay minerals, and are not the result of hydrothermal alteration. It is not likely that these rims are due to clouding because they do not occur in the calcic centres of laths but around the sodic margins, contrary to normal clouding. Clouding in feldspars, as described in other rocks, is usually brown while these rims are a turbid, streaky grey or yellow colour.

(e) Summary.

The plagioclase laths are zoned throughout the entire length of the north Gap Dyke, the only type observed being normal progressive zoning. Crystals which grew unhindered by crystal interference developed the most sodic margins, while those impeded by crystal interference have less sodic margins. The composition of the centres shows considerable variation within the first 20 miles of the dyke, from west to east, and thereafter remains fairly constant with a composition of An_{63-66} . Grain size measurements show little variation across the dyke width at various points and no significant chilled margin was observed. Along the length of the dyke the grain is coarsest where there is no core material, and finest where the central core material is present. The grain size remains fairly constant throughout the greater length of the dyke in the eastern part.

On the basis of grain size measurements and variations in the anorthite content of the plagioclase it is obvious that the greatest amount of variation occurs within the first 20 miles along the length of the dyke, from Stoneridge to Undula. This is, in some way, related to the presence of the granophyric quartzite core.

(2) PYROXENE.

(a) Occurrence.

Throughout the entire length of the dyke, including all the varieties of dolerite found, only one type of pyroxene has been recognised. It is seldom found in a state ideal for a satisfactory examination of its properties because it is usually altered to amphibole or pseudomorphed by chlorite and serpentine. However, in most slides some fairly suitable sections were found and the optical properties determined, and in crushed fragments separation of some unaltered pyroxene was possible under the microscope. The properties show that the pyroxene is unzoned augite which shows no variation in properties along the entire length of the dyke. Nowhere is a core of pigeonite found, and nowhere is orthopyroxene found.

(b) Properties.

The properties were determined by using immersion methods for the refractive indices and a Universal Stage for other optical properties. After crushing whole rock samples fairly finely a reasonably clean separation of the pyroxene could be effected under the microscope. Once separated unaltered fragments of the pyroxene were further crushed and the refractive indices determined using sodium light and checking the refractive indices of the oils after each determination on a Leitz-Jelley refractometer. The pyroxene, when crushed, shows a tendency for a small number of fragments to lie on the (100) and (001) parting planes, and these were used to determine the β index accurately. In the case of the north Gap Dyke, pyroxene fragments lying on the (001) parting plane are more common than those lying on (100) because this parting direction is well developed, as seen in thin sections. These grains show fairly low interference

colours because the optic axis emerges at an angle of approximately 20° from the vertical. Where cleavage is visible in grains lying on the (100) parting plane these grains show parallel extinction as $\beta = Y$, the optic axial plane being (010). The optic picture obtained from such fragments, and from fragments lying on the (001) parting plane, which have symmetrical extinction when cleavage is visible, is off-centre. When the isogyre is east-west then β is north-south, and can be accurately determined.

Although (110) cleavage fragments are very common these were not suitable for the determination of α and γ , and (010) parting tablets had to be used. Fragments which showed a maximum extinction angle were chosen for these index determinations.

Optic axial angle and Z/γ measurements were carried out on the Universal stage following the methods described by Hess (1949) using twinned crystals which have their optic axial planes not more than 20° from the vertical. By rotation about Y the angles between the two optic axes of the one twin and the one optic axis of the other twin were measured. By rotation about Y to the point where the interference colours of the twins are identical the direction ^{of} the Z axis, or the pole of (100), was found. From these results both Z/γ and $2V_\gamma$ were determined simultaneously.

Several pyroxenes from points along the length of the dyke were examined optically and the results found to be remarkably consistent. The optical properties may be summarised as follows:

Biaxial positive with $2V_\gamma = 52^\circ$. $Z/\gamma = 44^\circ$.
 $\alpha = 1.692$ to 1.698
 $\beta = 1.701$ $\gamma - \alpha = 0.028$ to 0.031 .
 $\gamma = 1.723$ to 1.725

In plane polarised light the pyroxene is seen to consist of anhedral and subhedral grains, and the subhedral basal sections often show slight rounding of the (110) faces. The augite is pale grey or colourless or faintly brown, non-pleochroic and has fairly high relief.

(c) Composition.

Using the curves showing the relationship between chemical composition of the clinopyroxenes and the values of 2V and the refractive index along the Y crystallographic axis as published by Deer, Howie and Zussman (1963) the composition of the augite is found to be close to $\text{Ca}_{41}\text{Mg}_{31}(\text{Fe}^{2+} + \text{Fe}^{3+} + \text{Mn})_{28}$. The pyroxene shows no zoning and, unless altered, extinction is sharp thus showing that individual crystals are homogeneous.

(d) Twinning.

Twinning is not uncommon and the twin plane is most commonly (100), both simple and multiple twinning being found. "Herring-bone" structure is well developed in most crystals as a result of the combination of this (100) twinning and the good basal parting.

(e) Alteration.

The pyroxene is commonly altered to late magmatic hornblende and to secondary minerals such as chlorite, serpentine and iddingsite (?). These are described separately in the next section, and although termed "secondary", they may all be formed before complete consolidation of the magma. An example of the formation of hornblende around a pyroxene crystal is shown by figure 27. (See also figure 29.)

In the augite crystals the basal (salite) parting, which provides the attractive "herring bone" structure, also provides planes of weakness along which most of the alteration has taken place, or has,

at least, been initiated.

Where alteration has taken place the grains take on a mottled appearance with green, orange, and brown patches. The pyroxene itself is not pleochroic so the pleochroic chlorite and iddingsite are easily picked out. Between crossed nicols the chlorite is seen to consist of rosettes up to 0.05 mm. in diameter and has the characteristic anomalous Berlin blue interference colour. The honey-coloured mineral is pleochroic and between crossed nicols shows interference colours ranging from sensitive tint to second order green, and from other optical properties it is thought to be iddingsite.

(3) AMPHIBOLE.

(a) Occurrence.

Amphibole first appears in the dyke rocks to the west of the granophyric dolerite outcrops which make up the dyke immediately after the termination of the eastern part of the core. It occurs in small amounts in the granophyric dolerite of the Thomas River area and becomes increasingly more important eastwards. It is the predominant dark mineral of the acid veins in the granophyric dolerite which crops out in the bed of the Thomas River and here it occurs in long laths almost to the complete exclusion of pyroxene. As biotite becomes more abundant eastwards so the percentage of amphibole falls, and at the coast no hornblende is found at all. Here actinolite is the only amphibole present (12.65%) occurring as fibrous or brush-like acicular crystals in masses associated with pyroxene and chlorite.

The amphibole is considered to be late magmatic, crystallizing after the formation of the augite but before complete solidification of the magma. It occurs as subhedral crystals, as mantles surrounding altered pyroxene cores, or as fibrous needles sometimes penetrating other late minerals, such as quartz. It probably has an extended period of crystallization.

(b) Varieties Present.

There are two types of amphibole recognised in the dyke rocks: actinolite and hornblende. The hornblende itself has variable properties and may be divided into two varieties, green, and brown hornblende, although there appears to be complete gradation between the two. Hornblende is the predominant type throughout the dyke while actinolite occurs in very small amounts, but near the coast no hornblende is found in the rock and actinolite is the only amphibole.

(c) Properties.

(i) Actinolite.

This is fairly common but not abundant, except in the coastal variety of the "Transkei type" dolerite pegmatite, and should be regarded as an accessory mineral. It occurs as masses composed of fine needle-like crystals and is usually associated with chlorite and blebs of pyroxene. Sub-radiating "brushes" of actinolite are common. Fine hair-like inclusions in quartz crystals, sometimes passing into a mass of actinolite have been seen in some slides, but are not common. (See figure 28.). This could indicate replacement of quartz by late actinolite or else simultaneous crystallisation of the two minerals whereby quartz enclosed crystallites of actinolite thus preventing further growth. The actinolite is strongly pleochroic with:

α : pale yellow
 γ : green $Z/\gamma = 12^\circ$.

The larger needles enclosed in quartz have an extinction angle of between 10° and 15° . Difficulty was encountered in attempting to determine the refractive indices of the actinolite because a clean separation of crushed fragments under the microscope was virtually impossible.

The actinolite is either late magmatic or secondary, being an alteration product of either pyroxene or amphibole depending on the mineral with which it occurs in association.

(ii) Hornblende.

The commonest amphibole is hornblende which occurs in the following ways:

A) As subhedral crystals forming laths and showing basal sections with two cleavages at 56° and 124° . Such crystals may contain relict blebs of pyroxene or they may occur without pyroxene.

B) As a mantle around pyroxene, which may be present only as scattered grains forming a core to the amphibole.

C) As tiny patches in and around pyroxene crystals giving the pyroxene a mottled appearance.

These three modes of occurrence could be representative of three stages in the formation of amphibole after pyroxene in the later stages of the crystallisation of the magma. The pyroxene crystals react with a residuum to form amphibole, but at the same time amphibole of a similar composition is capable of crystallising from the magma without reaction being necessary. Because the residuum becomes enriched in alkalis with progressing crystallisation of the magma one would expect the hornblende which crystallises first to be comparatively rich in iron, while that which crystallises later to be comparatively rich in soda. This is confirmed by the fact that all subhedral basal sections are brown in colour, indicating iron, and by the presence of zoned laths which show brown centres grading into green or blue-green margins indicating a decrease in the amount of iron and an increase in the amount of soda with crystallisation. (See figure 29.). The boundaries between zones may be sharp or gradual. Thus, two varieties of hornblende are recognised which grade into one another.

The brown hornblende has the following properties:

$\alpha = 1.660$: pale yellowish-brown	
β	: deep brown	$\gamma - \alpha = 0.023$
$\gamma = 1.683$: dark brown, or dark green	
$2V_{\alpha} = 68^{\circ}$	$Z/\gamma = 17^{\circ} - 20^{\circ}$	

This is probably a variety of hastingsite.

Where associated with pyroxene the brown hornblende occurs nearest the pyroxene core and grades outwards into paler brown, green and finally blue-green amphibole. The boundaries may be sharp and not

EXPLANATION OF FIGURES 27 AND 28.

Figure 27: Photomicrograph showing the formation of subhedral, brown hornblende on a core of pyroxene. Plane polarised light.
(Magnification: x 38.)

Figure 28: Photomicrograph showing a subhedral crystal of brown hornblende, and actinolite. The actinolite occurs both as a mass of needle-like crystals, and as hair-like crystallites in quartz. Plane polarised light.
(Magnification: x 38.)

py = pyroxene

hb = hornblende

act = actinolite

qu = quartz

pl = plagioclase

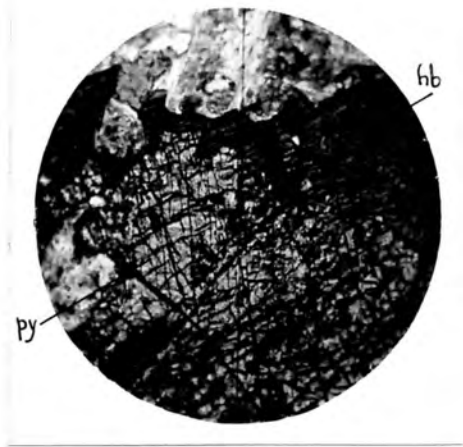


Figure 27

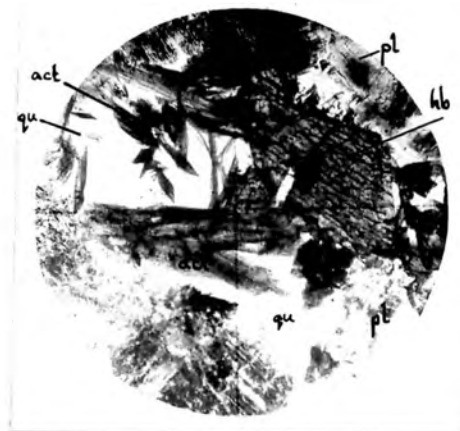


Figure 28

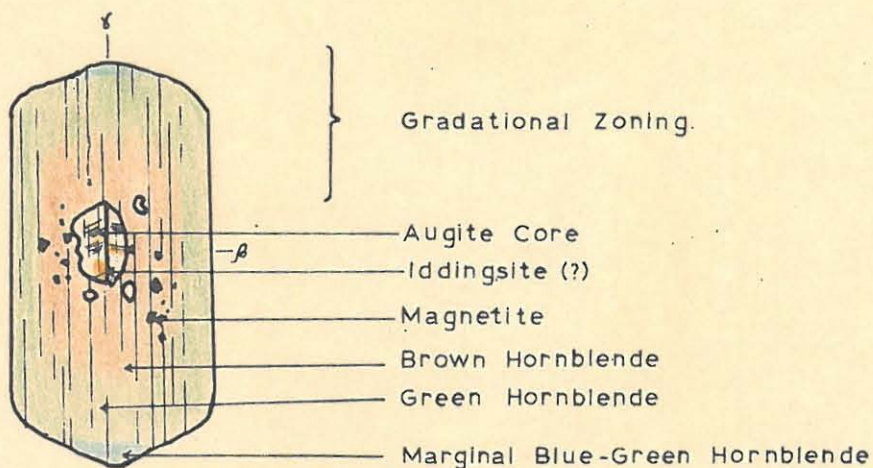
EXPLANATION OF FIGURE 29.

Diagrams drawn to show the types of zoning in hornblende, and to show the relationship between hornblende, pyroxene, iddingsite (?), chlorite and magnetite.

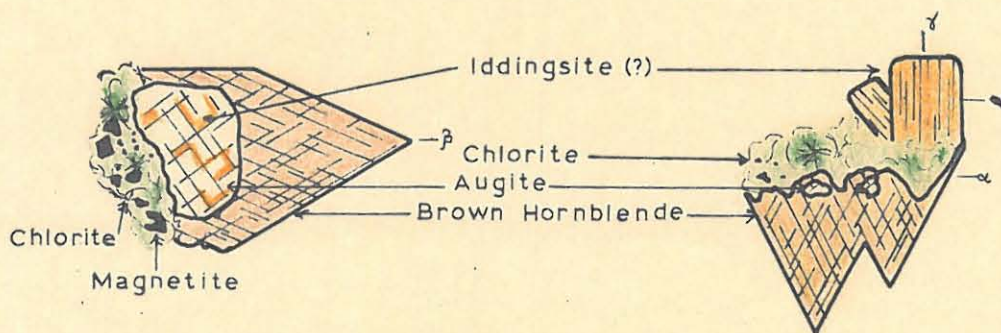
- (A) Ideal section, drawn parallel to (100).
- (B) Ideal section, showing a subhedral basal section of hornblende with a subhedral core of pyroxene which has slightly rounded (110) faces.
- (C) Camera lucida drawing showing the relationship between hornblende, pyroxene and chlorite, and the presence of crystals of iddingsite.
- (D) Camera lucida drawing of zoned hornblende to show the occurrence of sharp contacts between the zones.
- (E) Camera lucida drawing of a mantle of zoned hornblende around a corroded core of pyroxene.

In all cases the colours used are representative of the actual colours, but are not the same as the true colours of the crystals.

FIGURE 29

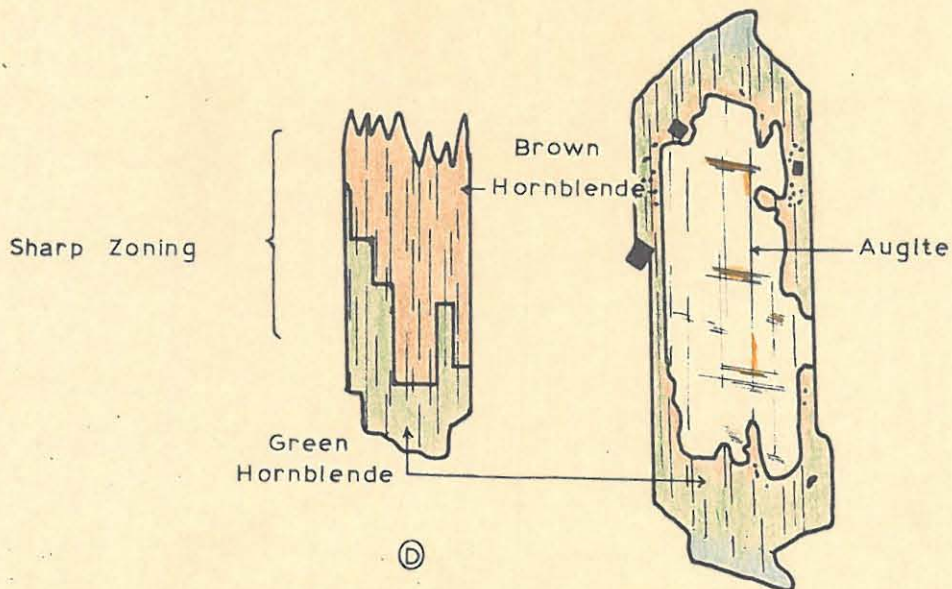


(A)



(B)

(C)



(D)

(E)

gradational. Where present the green or blue-green varieties form a zone which is widest at the extremities of the lath, parallel to the Z crystallographic axis. In sections parallel to (100) both varieties show straight extinction but in other sections there is a difference of a few degrees in the extinction angles of the green and brown varieties.

The green amphibole has the following properties:

$\alpha = 1.679$: pale yellow	
β	: pale green	$\gamma - \alpha = 0.019$
$\gamma = 1.698$: green or blue-green	
$2V_{\alpha} = 60^{\circ}$	$Z/\gamma = 12^{\circ} - 14^{\circ}$	

This is probably a soda-rich variety of hornblende.

Apart from its occurrence as the outermost part of the amphibole mantles to pyroxene the blue-green hornblende is also found as fibre-like crystals showing no apparent association with brown hornblende or pyroxene. Such crystals are quite anhedral. Both varieties of hornblende are frequently stained orange or brown when in contact with the ore minerals.

(4) MICROPEGMATITE.

(a) Definition.

The term micropegmatite is used, in this work, to define all micrographic intergrowths of quartz and feldspar, and includes intergrowths with geometric habit as well as myrmekite. The two varieties grade continuously into one another and it was found to be almost impossible to distinguish between them. The host mineral may be either orthoclase or plagioclase and, unless polysynthetic twinning is seen, it is almost impossible to distinguish between the two feldspars, even using the differences in refractive indices as a guide.

(b) Occurrence.

Micropegmatite occurs in small amounts in the granophyric dolerite flanking the core. In the granophyric dolerite east of the western part of the core it forms the major constituent of the rock and remains important, though falling considerably in percentage, throughout the granophyric dolerite found in the Thomas River area. It is very important in the acid veins of the Thomas River area, and is the major constituent of the metasomatized xenoliths. East of the Thomas River valley it declines rapidly in importance and east of Undula, in the "Transkei type" dolerite, it is either a minor constituent or absent altogether. No micropegmatite is found at all in the coastal variety rocks.

(c) Varieties.

Two distinct textures occur. The micropegmatite may be interstitial, in which case the intergrowth occurs radially around plagioclase laths and becomes coarser outwards. The plagioclase

lath is very often in optical continuity with feldspar of the intergrowth, but not necessarily all the way around the lath. Where the micropegmatite and the lath are in contact the boundary is sharp and there is little or no replacement of the plagioclase by micropegmatite; the latter mineral appears to be moulded around the former. Each section of the radiating micropegmatite intergrowth extinguishes uniformly and is in optical uniformity, but different sections of the same intergrowth extinguish in different positions, giving a mosaic effect with the orientations of the different sections differing by a few degrees. Near the lath the quartz component of the intergrowth frequently occurs as rods which are either geometric or vermiform in habit. Quite often these rods have a parallel or subparallel arrangement. Outwards they pass into blebs or triangular-shaped quartz areas in the feldspar host. This interstitial variety of the micropegmatite is generally associated with the plagioclase laths, but not necessarily so and is frequently found between crystals of other minerals.

The second variety may be described as a replacement texture, and is found where exceptionally large quantities of micropegmatite are present. In this replacement variety of micropegmatite there is ample evidence to show that the quartz-feldspar intergrowth has in fact replaced the plagioclase laths, even the most basic in composition. (See figures 23, 24 and 25). All stages of replacement have been observed, from incipient alteration along the margins between plagioclase and micropegmatite to almost complete replacement of the lath. In the first stages of replacement the micropegmatite replaces the lath along the margins and also along the composition planes. With further replacement the lath loses its outline and the radiating micropegmatite occurs in larger amounts both in and around the lath.

Quartz in the lath is in optical continuity with quartz in the micropegmatite surrounding the lath. The final stages of replacement are represented by large areas of micropegmatite with "ghosts" or relicts of plagioclase. Such relicts are recognisable only as patches of saussuritized feldspar and the former continuity of such patches is recognised only because their twin planes and extinction directions are aligned, or may be interpolated. Both varieties of micropegmatite may be found in the same microscope slide, but the interstitial type is more abundant in all areas except the Thomas River area.

(d) Alteration.

The micropegmatite has not undergone significant alteration and generally appears fresh. The feldspar of the intergrowth is normally turbid in ordinary light probably due to a certain amount of saussuritization. In weathered specimens of rock the feldspar has occasionally been replaced by brown serpentine forming a quartz-serpentine graphic intergrowth.

(5) OTHER MINERALS.

(a) Quartz and Orthoclase.

Both these minerals occur free in the granophyric dolerite with quartz being far more common than orthoclase. They occur as anhedral grains and frequently grade into the micropegmatite intergrowths. Under the microscope the orthoclase is generally turbid in ordinary light and seldom shows twinning. It occurs as crystals not exceeding 0.5 mm. in diameter and is found free only in the granophyric dolerite. East of Undula orthoclase is very rarely found free and is normally confined to the micropegmatite and to the irregular veins replacing plagioclase feldspar. The maximum amount of free orthoclase found in the "Transkei type" dolerite was 3%, at Toleni Bridge. East of this it is very rare and at the coast no orthoclase is seen at all.

The amount of free quartz in the dolerite varies considerably and is present only in very small amounts in the granophyric dolerite: in these rocks most of the quartz is in the form of micropegmatite. East of the Thomas River valley, where the amount of micropegmatite diminishes rapidly, free quartz becomes more common but is not abundant. It occurs as anhedral grains, sometimes containing hair-like or rod-like inclusions thought to be amphibole crystallites either replacing the quartz or, more likely, enclosed by the quartz during periods of overlapping crystallisation. Quartz, as anhedral crystals with very irregular boundaries, and as irregular veins replacing plagioclase laths continues to make up some 10% to 15% of the dolerite pegmatite of the "Transkei type" rocks. Near the coast there is a sudden decrease in the quartz content and where the dyke is exposed at the Jujura and Ngadla Rivers the rocks contain no quartz at all.

(b) Biotite.

Flakes of brown mica^{are} first noticed in freshly broken specimens of the "mottled rock" in the Thomas River valley. East of this biotite occurs in small quantities, sometimes less than 1% of the rock, until the dolerite pegmatite which crops out east of Undula is reached. The amount of biotite then gradually increases, but not significantly. Only east of Lujilo does it become common in the dolerite pegmatite, and throughout the Transkei it remains constant in amount forming about 4% of the rock. Where the dyke crops out at the Jujura and Ngadla Rivers the biotite forms about 7% of the rock.

Biotite often occurs in close association with hornblende where this mineral is present and, apart from the difference in extinction and the usually stronger pleochroism of the biotite, it is sometimes difficult to distinguish between it and brown hornblende. Particularly near the coast, where the amount of biotite present in the rock is large, there seems to be a close association between the biotite and the ore minerals. In places it appears as though the biotite is actually replacing the ore minerals. The biotite occurs as anhedral crystals often moulded around quartz or feldspar and also is often seen as dark brown, strongly pleochroic strips in green amphibole. Between crossed nicols crystals are sometimes seen to have a mottled appearance, which may be the result of incipient alteration. Crystals are unzoned and, apart from the slight mottling in some, they show straight extinction.

Green biotite is also present, but in very limited amounts, and the green and brown varieties may even grade into one another fairly sharply. The crystals are strongly pleochroic from very dark brown or green to pale yellowish-brown. Where green and brown varieties exist in the same crystal the colour has no effect on the

interference colour nor on the extinction position.

The properties of the brown mica are:

α : : pale yellowish-brown
 $\beta = 1.649$: light brown $\gamma - \alpha = 0.04$ ⁺₋
 γ : : very dark brown
 $2V_{\alpha}$: Small (10° to 15° .)

Because of the perfect basal cleavage only β could be satisfactorily determined.

The biotite, both green and brown, is exceptionally rich in pleochroic haloes which are dark grey or brown in colour. In places these are so intensely pleochroic that parallel to γ they appear opaque. The inclusions causing the haloes could not be identified, but are possibly tiny apatite crystals, or even tiny zircons.

(c) Ore Minerals.

Ore minerals are found in all specimens of the dyke rock and occur in three distinct habits. Most commonly the ore minerals occur as anhedral, and occasionally subhedral, grains. Such grains may be large, up to 2 mm. in diameter, or very small when the ore is found as dust. The grains are scattered irregularly throughout the rock, but with a definite tendency to be associated with the dark minerals, although they are found surrounded by all other types of mineral, including quartz and micropegmatite. Where pyroxene has partially altered to hornblende clusters of granular ore frequently occur scattered throughout both the pyroxene and the amphibole. Such granules are possibly a by-product of the reaction by which the augite was altered to hornblende. Ore minerals with this habit are considered to be either titaniferous magnetite or magnetite.

The second habit, by no means as common as the first, is that of skeletal crystals. All ore minerals found with this habit are ilmenite. The skeletal crystals vary in size from 0.5 mm. to 3 mm. across and, in places show a tendency towards a triangular arrangement of plates as shown in figure 30. Well developed triangular skeletal crystals are rare except in the acid veins of the Thomas River area. Elsewhere the skeletal crystals consist of a series of parallel rods or a number of aligned granules. As in the case of the anhedral grains the skeletal crystals show a tendency to be associated with ferromagnesian silicates. In all the crystals consisting of aligned rods or grains the interstitial material is chlorite or biotite, and occasionally prehnite and calcite are present as well. Although a few skeletal crystals were surrounded by, and sometimes enclosed in, other minerals such as micropegmatite, plagioclase, biotite and amphibole it does not appear as if the ore has actually penetrated these minerals.

The least common habit, also confined to ilmenite, is that of rod-like, or plate-like, crystals. Narrow plates, only 0.05 mm. thick, in thin section appearing as rods from 0.5 mm. to 3 mm. and more in length, were found in the coarse granophyric patches in the Thomas River area (See figure 12a) and in very small amounts in the granophyric dolerite. They may occur penetrating all other minerals and are not necessarily associated with the ferromagnesian silicates.

The ore minerals sometimes show the formation of greyish-brown leucoxene around them. Such ore minerals are ilmenite, and the greater number of opaque crystals in the dyke rock are ilmenite crystals, a fact borne out by the relatively high percentage of TiO_2 in the chemical analyses. The grains of ore are frequently found with rounded and indented margins, especially when in association with

EXPLANATION OF FIGURES 30 AND 31.

Figure 30: Photomicrograph showing the triangular arrangement of plates in a skeletal crystal of ilmenite. Plane polarized light. (Magnification: x 38.)

Figure 31: Photomicrograph showing crystals of the ore minerals with rounded and indented margins. They are associated with biotite and pyroxene, and the "caries" texture suggests that they might be replaced by the biotite and pyroxene. Plane polarized light. (Magnification: x 38.)

pl : plagioclase
m : micropegmatite
cl : chlorite
py : pyroxene
bi : biotite

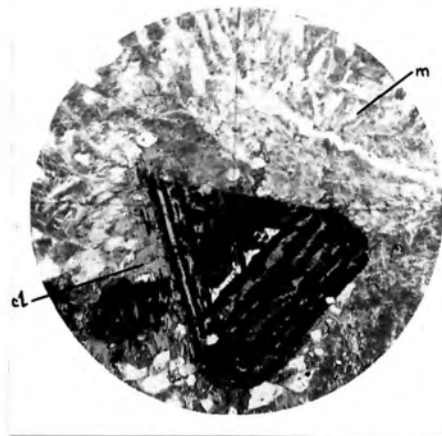


Figure 30

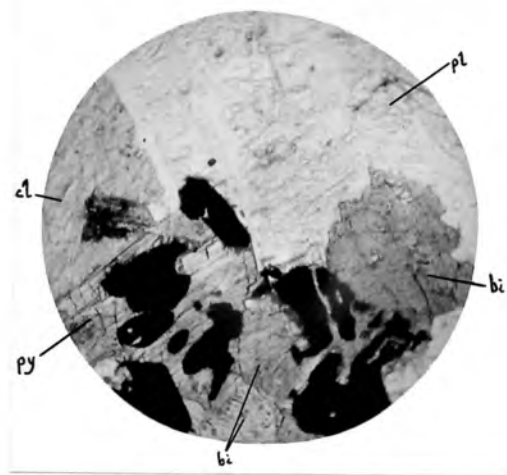


Figure 31

... the initiation of the crystallization of pyroxene and

biotite and pyroxene. This texture is suggestive of a replacement of the ore by biotite and pyroxene, although the "carries" texture is not conclusive proof. (See figure 31.). It may be the result of the reaction of residual fractions of the magma on early formed ore crystals.

A polished section of the dyke rock showed that by far the greatest percentage of the ore minerals is ilmenite, easily recognised by its anisotropism. All skeletal crystals and most of the anhedral grains are ilmenite. Isotropic magnetite was also seen in small amounts and such crystals are normally subhedral or euhedral cubes or octahedra, and showed no exsolution lamellae of ilmenite. A separation was carried out on a fairly finely crushed specimen of the "Transkei type" dolerite and the results were as follows:

Wt. of specimen (between 65 and 100 mesh)	= 5.9444 gms.
Wt. separated by a bar magnet (magnetite)	= 0.0190 gms.
Wt. attracted by an electromagnet	= 1.4968 gms.
of which wt. sinking in Clerici solution	= 0.0590 gms.
and the wt. floating in Clerici solution	= 1.4328 gms.
Therefore, weight of magnetite - 0.0190 gms.	= 0.32%
weight of ilmenite = 0.0590 gms.	= <u>0.99%</u>
Total	= <u>1.31%</u>

It was concluded that, of the ore minerals in the dyke, ilmenite and magnetite exist as distinct minerals. Ilmenite is the predominant ore mineral. A certain amount of TiO₂ may enter into the molecular structure of the magnetite, but not sufficient to form exsolution lamellae of ilmenite.

From textural evidence it seems difficult to believe that the magnetite and ilmenite were among the last of the minerals to crystallise, but rather that the ore started crystallising fairly

early, after the initiation of the crystallisation of pyroxene and plagioclase, and had a long period of crystallisation. Indications of early crystallisation are given by the presence of subhedral and euhedral magnetite crystals and, possibly, by the presence of skeletal crystals of ilmenite. It should, however, be noted that idiomorphic crystals are not necessarily a sign of early precipitation, especially in the case of magnetite and ilmenite which are known to have high crystallising powers. Late crystallisation is indicated by the presence of anhedral grains which may occur indiscriminately looped around other minerals. Lindgren (1933, p. 786.) states:

"Ilmenite with magnetite, is one of the earliest products of crystallisation in magmas...."

However, he also states, (p. 790):

"In basic rocks much iron remains in the residual magma and is separated at a late stage of the consolidation."
"... the tendency to form silicates is strong and sufficient silica is usually available to take care of all the iron in the form of ferromagnesian silicates."

although

"In the earlier stages of consolidation of igneous rocks some magnetite is crystallised, together with other accessories...."

Wager and Deer (1939, p. 311) state:

"This behaviour of the magnetite and ilmenite suggests that in a basic magma these minerals will be among the first to crystallise if the amounts of Fe_2O_3 and TiO_2 exceed about three and two and a half per cent respectively; if under these amounts there will be no primary precipitation until these values are attained."

As is seen in Table IX the percentages of Fe_2O_3 and TiO_2 are, in the case of the dolerites forming the north Gap Dyke, all below the values cited above. Wager and Deer were referring to the ferrogabbro and conditions may be quite different in the case of the Gap Dyke magma.

Pyrites was seen in very small amounts surrounding some magnetite crystals in the acid veins of the Thomas River area. No pyrites was observed in any other specimens.

(d) Apatite.

Apatite is a ubiquitous accessory mineral and occurs either as slender needles or as stumpy plates. In the granophyric dolerite it is not a conspicuous accessory and occurs in very small amounts as slender needles up to 0.05 mm. in length. East of the Thomas River area it becomes more noticeable and the needles are commonly found to have lengths of 0.75 mm. to 1.5 mm. Such needles penetrate all other minerals except ore, and are generally euhedral or subhedral in shape: hexagonal basal sections which remain dark between crossed nicols are very common. In spite of the euhedral habit and although acicular apatite crystals penetrate all other minerals, because there is a tendency for the majority of the needles to be associated with late stage micropegmatite and quartz, they are considered to be late in crystallising; Mountain (1937) states:

"....clusters of apatite needles are present, associated with the micropegmatite or interstitial orthoclase, so that, although idiomorphic, it seems as if the apatite were nevertheless one of the last minerals to crystallise."

Although the circumstances in the case of the north Gap Dyke are somewhat different from those described by Mountain, above, the argument still seems to be applicable, and it would appear that apatite crystallises late and has a strong crystallising power so that it is able to penetrate earlier formed crystals. This is not so easily understood in specimens from the north Gap Dyke where quartz and micropegmatite are rare, minor or even absent constituents, and idiomorphic apatite needles occur in the plagioclase and pass into

amphibole, biotite, and pyroxene.

The optical properties of the apatite were not determined because of the difficulties encountered in attempting to extract the fine needles from the crushed rock.

It is interesting to note that some apatite crystals show the presence of inclusions, which, when identifiable, are seen to consist of green serpentinous material and feldspar which are very similar to the surrounding groundmass. The inclusions, which are not pleochroic, occur as central rods in the apatite needles and in basal sections are seen to have a hexagonal outline. Assuming the crystals are late in genesis, the included material is likely to be the surrounding groundmass in the metasomatic skeletal crystals. (See figures 32 and 33.).

Apart from the apatite crystals with included serpentinous material, the inclusions are not comparable with inclusions in apatite as described by Groves and Maurant (1929) because they contain included material very similar to the surrounding matrix. Those described by Groves and Maurant contain distinct minerals, such as chlorite or biotite, and may also be zoned. Those in the Gap Dyke rocks are nearly all unzoned, but a few basal sections show clouding parallel to the hexagonal outline. (See figure 32.).

(e) Calcite.

Calcite commonly occurs in masses up to 2 mm. across their longest diagonal. It is often found replacing plagioclase, particularly the centres. Large masses, intergrown with epidote, occur in the cavities, up to 10 mm. across, in the "mottled rock" of the Thomas River area.

EXPLANATION OF FIGURES 32 AND 33.

Figure 32: Apatite crystal showing an idiomorphic basal section with concentric zoning and more or less hexagonal inclusion of feldspar and serpentine. Plane polarised light.
(Magnification: x 38.)

Figure 33: Section of an apatite needle containing inclusions of feldspar and serpentine. Plane polarised light.
(Magnification: x 166.)

pl = plagioclase

sp = serpentine

cl = chlorite

hb = hornblende

ep = epidote

q = quartz

Figure 33

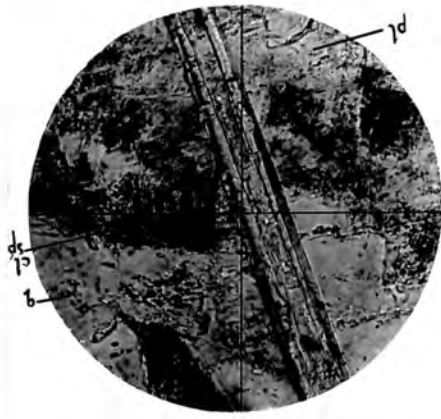
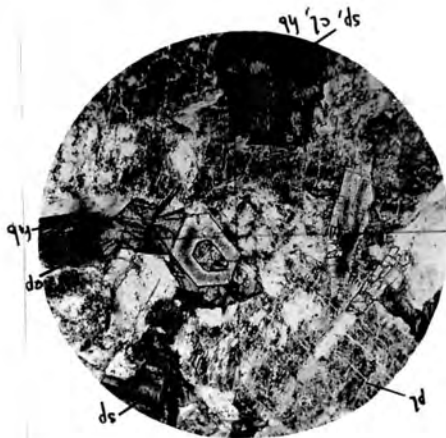


Figure 32



(f) Epidote.

Epidote is a common, but very minor, constituent of the north Gap Dyke dolerites and it occurs in crystals varying in size from 0.05 mm. to 2 mm. across. It is weakly pleochroic from pale yellow-green to pale green, and the colour is not uniform. It has fairly high interference colours, ranging from second order sensitive tint to green. It is slightly more abundant in the granophyric dolerite than in the "Transkei type" dolerite pegmatite and is particularly plentiful in the "mottled rock".

(g) Prehnite.

Only very occasionally are crystals of prehnite encountered in the dolerites found making up the north Gap Dyke and it occurs as colourless crystals up to about 0.5 mm. in diameter. It is found filling tiny cavities in the dolerite and is frequently associated with calcite. It has wavy extinction and high interference colours, up to yellow and sensitive tint of the second order. Prehnite is also found associated with chlorite and feldspar where it appears to be an alteration product of the plagioclase, possibly hydrothermal.

(h) Chlorite and Serpentine.

Both chlorite and serpentine, often intimately mixed, are very common and occur replacing pyroxene and amphibole, surrounding biotite, and as veins in plagioclase. The chlorite is strongly pleochroic, and the optical properties, determined with the aid of an oil immersion lens, are as follows:

α : : pale yellow
 $\beta = 1.653$: yellowish-green
 γ : : dark green
 $2V_{\gamma}$: Small

The interference colours vary from grey of the first order to the anomalous Berlin blue colour, and occasionally the natural green of the chlorite is so dark that it masks the interference colour. The chlorite is identified as closely as possible as daphnite, an iron-rich chlorite; (Winchell, 1951, pp. 381 to 385). Large areas of chlorite, up to 7 mm. in diameter, occur in some specimens, and these are composed of many chlorite "rosettes" each of which is about 0.1 mm. in diameter.

(i) Iddingsite (?).

Iddingsite is the honey-coloured mineral frequently found along the parting planes in several pyroxene crystals. It also occurs as distinct crystals (See figure 29) associated with hornblende, or around the margins of pyroxene crystals. The properties of this mineral were determined by the method of crushed fragments and Universal Stage measurements. The properties of several crystals were measured and found to be fairly consistent. The properties are:

$$\begin{aligned}\alpha &= 1.669 & \gamma - \alpha &= 0.041 \\ \gamma &= 1.710 \\ 2V_{\alpha} &= 50^{\circ} \pm\end{aligned}$$

Pleochroism is strong and the absorption is $\gamma > \alpha$.

α : pale yellow, (antimony yellow)

γ : deep orange, (capucine yellow)

(The colours given in brackets are the colours in the Ridgway chart which most closely match those of the mineral.)

Between crossed nicols it shows fairly high interference colours, ranging from sensitive tint to second order green. It has straight extinction, and has one good cleavage, possibly (010). From these properties it is thought that this mineral is in fact iddingsite.

Iddingsite and bowlingite have usually been accepted as the products of late magnetic alteration of olivine or the orthopyroxene, hypersthene (Wager, 1929.). In the case of the north Gap Dyke it is clearly derived from the clinopyroxene. The iddingsite varies somewhat in character and may show crystalline form or it may be fibrous. It occurs as distinct crystals with well developed cleavage and has sharp boundaries against chlorite, amphibole or augite, or it may grade imperceptibly into any of these minerals.

MINERALOGY OF THE CORE MATERIAL.

Apart from the degree of recrystallisation, which increases from west to east, the nature of the granophyric quartzite core is very consistent. The minerals found are described below.

(1) QUARTZ.

Quartz is the predominant mineral in the core, and occurs as equigranular grains up to about 0.5 mm. in diameter, and these grains have highly irregular margins. The quartz with its crenulate margins is usually intimately intergrown with feldspar forming a type of "sieve" structure resembling micropegmatite. Several grains may link together to form areas up to 2 mm. in diameter and all show optical uniformity, although all the grains may not necessarily be physically continuous. The quartz has interference colours ranging from first order grey to yellow, and the extinction is usually wavy.

(2) FELDSPAR.

Both plagioclase and orthoclase occur, the former being more abundant, and both are usually highly altered to saussurite which gives them a turbid appearance in ordinary light. The feldspar is generally intergrown with quartz and, as a result, crystal outline is seldom seen, although lath-like crystals of plagioclase do occur. The plagioclase is easily distinguished by the presence of polysynthetic twinning. Extinction is normally wavy, but rough measurements show it to be a soda-rich variety (oligoclase) ranging from An₂₀ to An₂₅.

(3) CHLORITE AND SERPENTINE.

The chlorite is weakly pleochroic from pale green to yellowish-green. Between crossed nicols it shows the typical low interference colours. Serpentine is found both as green and brown thread-like masses, with low interference colours, and is distinguished from chlorite only because it occurs as fibrous, thread-like crystals. Both chlorite and serpentine in the core occur mainly as wisps disseminated throughout the rock. Apart from the fine wisp-like crystals chlorite is sometimes found forming radiating groups of crystals. It is also found as vermiform bodies enclosed in the quartz crystals and, between crossed nicols, such bodies sometimes show "rosette" structure.

The dark, angular inclusions contained in the feldspathic quartzite core material have too fine a grain for the minerals to be accurately identified, even under a high-power lens. However, it is clear that these inclusions consist chiefly of chlorite and serpentine with lesser quantities of very fine quartz and feldspar.

(4) OTHER MINERALS.

The commonest accessories of the core are highly rounded zircon crystals and spongy spheres, occasionally showing some crystal outline. Plate-like crystals of ilmenite are common, and often show alteration to leucoxene. Anedral grains of magnetite occur scattered throughout all the specimens collected. Calcite, in irregular masses up to 1 mm. across, is occasionally seen filling small cavities in the rock. Sericite (?), possibly muscovite, is seen in small quantities as scaly aggregates or shreds, and is usually either associated with the chlorite or occurs in the ground mass surrounding quartz-feldspar intergrowths. Colourless in ordinary light, it has

high interference colours ranging from second order yellow to sensitive tint. Far less common are pyroxene, garnet and rutile. In one slide a large, well-rounded apatite crystal measuring 0.75 mm. by 0.13 mm. was encountered. Mountain (1943) examined the heavy residue from 100 gms. of the core material from Stonehenge and found it consisted of:

Magnetite	0.438 gms.
Attracted by electromagnet	0.035 gms. (ilmenite)
Unattracted	<u>0.057 gms.</u>
Total:	<u>0.530 gms.</u>

The unattracted portion consisted of zircon (the predominant mineral of this portion), rutile, monazite, leucoxene, garnet and pyroxene. He noted these were identical with grains found in the heavy residues from ordinary Beaufort sandstone.

CHAPTER FOUR

PETROLOGY

ABSTRACT OF CHAPTER FOUR.

Micrometric analyses of the different types of rock show the variations in mineral composition along the length of the dyke, and these are plotted graphically.

The chemical analyses show the core is very similar in composition to the surrounding Beaufort sandstone, and that the dolerite types of the dyke may represent either a differentiation sequence or else hybridization followed by differentiation. The rock types of the Thomas River area may have been produced by more extreme differentiation or by assimilation of the core at this point.

PETROLOGY.

MICROMETRIC DATA.

The volume percentage of certain minerals was measured in each of a number of slides representing the dyke rock at various points along the length. This was done to obtain a better idea as to the type and amount of variation in mineral content along the length of the dyke. Measurements were carried out using a Ford Point Counter (Hallimond 1956, p. 204) with traverses 1 mm. apart. The total length of traverses across any one slide averages at about 225 mm. and, for the coarser grained rock, two or more analyses were made and a mean taken.

Graph 4 shows the variation in mineral composition, by weight, with distance across the dyke plotted from Table VIII. Because of the nature of the outcrops specimens across the entire width were not available, nor was one available from the margin. The width of the dyke is, however, fairly accurately known and, as seen by the graphs there is no marked variation in the mineral composition either near the margin or near the centre. Slight, but irregular variation is shown by the plagioclase, amphibole and pyroxene. The content of ore minerals and micropegmatite changes very slightly and could be regarded as constant. There is no antipathetic relationship shown by pyroxene plus amphibole and micropegmatite, quartz, and orthoclase plus ore minerals, so that the presence of volatiles, if present, has not influenced the mineral composition by preventing iron oxide from combining with silica to form pyroxene, as is the case in the Khale dolerite sheet (Eales, 1959, p. 69) and in the Palisade Diabase, New Jersey (Walker, 1940).

TABLE VIII.

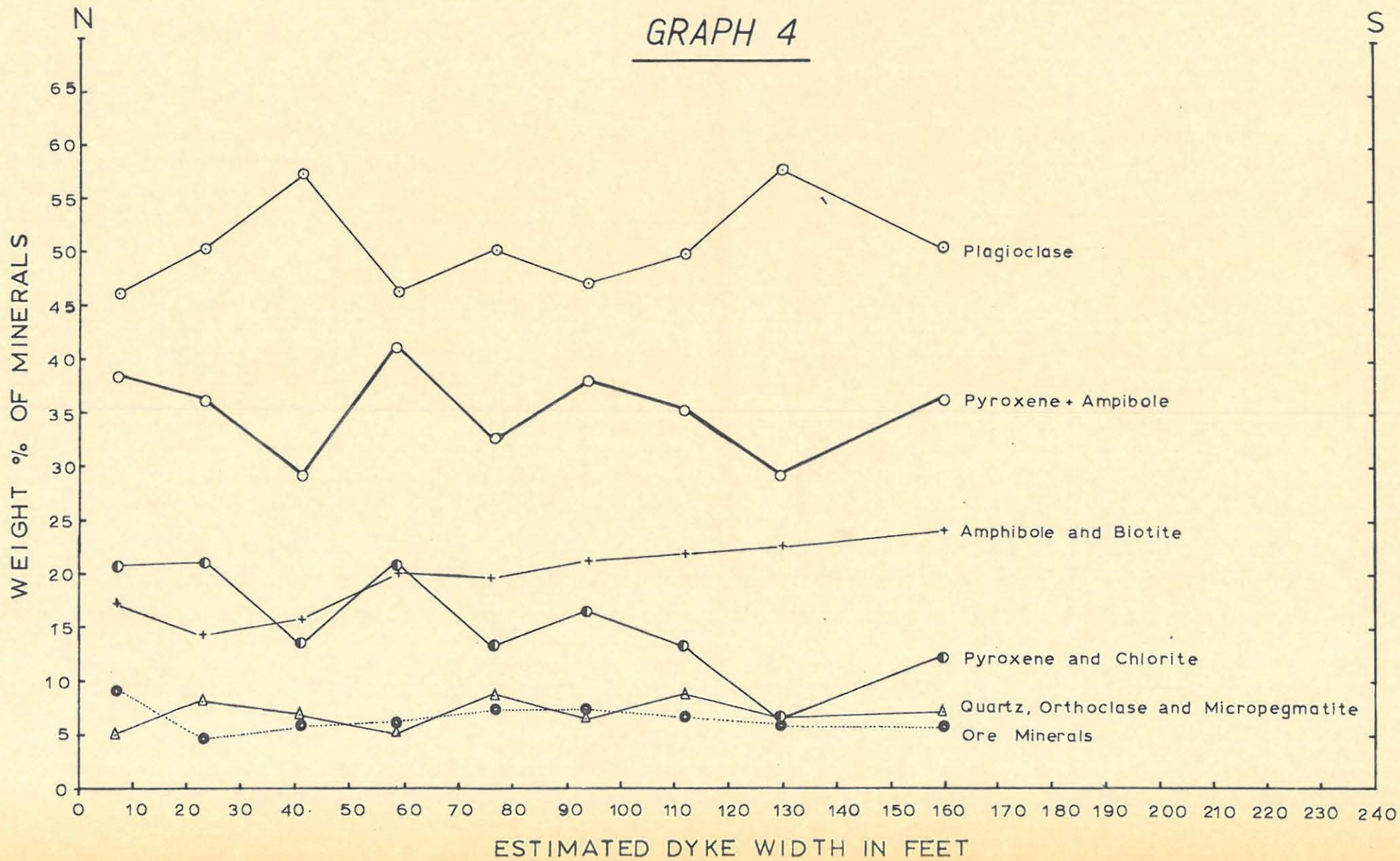
Weight per cent (Modes) of minerals across the dyke width at Undula. Recalculated from the micrometric analyses in Table VI.

	S.G. Used for calculation	Approx. distance from southern contact in feet.								
		7	23	41	59	76	94	112	130	160
Plagioclase		47.2	50.8	57.4	46.3	50.2	47.1	48.9	57.9	50.5
Pyroxene + Chlorite		21.2	22.1	13.6	21.0	13.3	16.6	13.3	6.7	12.2
Micropegmatite Quartz, Orthoclase		5.1	8.2	7.2	5.8	9.2	7.2	9.2	6.7	7.3
Ore minerals		9.2	4.7	5.9	6.5	7.4	7.5	6.5	6.0	5.7
Amphibole + Biotite		17.3	14.2	15.9	20.4	19.9	21.6	22.1	22.7	24.3

EXPLANATION OF GRAPH 4.

The graph shows the variation in mineral composition
across the dyke width at Undula.

GRAPH 4



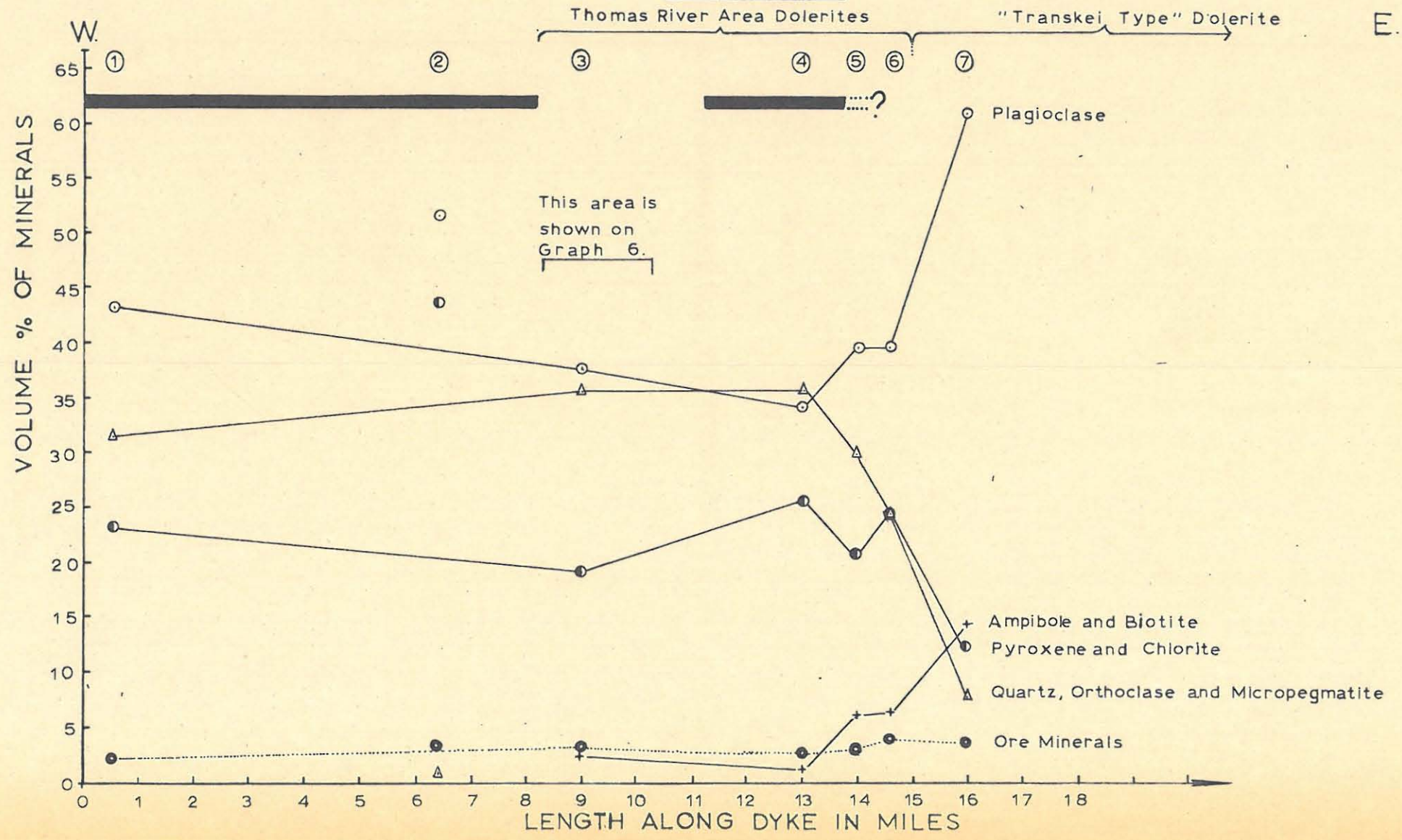
649

EXPLANATION OF GRAPH 5.

The graph shows the variation in mineral composition along the length of the dyke, from Stoneridge to Undula (16 miles east of Stoneridge.).

- (1) Granophyric dolerite flanking the core material on Stoneridge.
- (2) Subophitic dolerite flanking the core material. (Surbiton railway cutting).
- (3) Granophyric dolerite making up most of the dyke in the Thomas River area.
- (4) Rexfield.
- (5) East of the river on Rexfield.
- (6) South of homestead on Undula.
- (7) Eastern boundary of Undula.

GRAPH 5



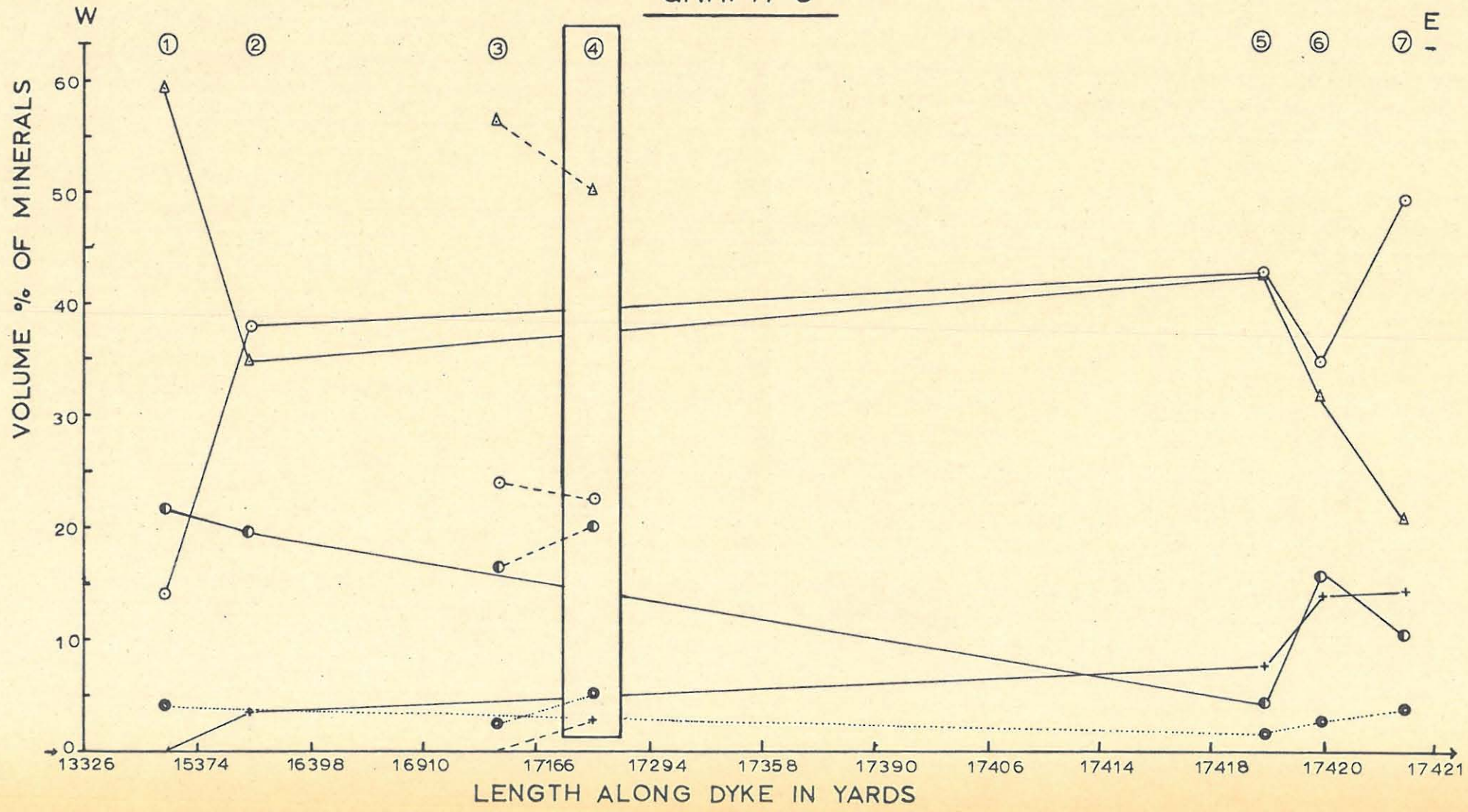
672

EXPLANATION OF GRAPH 6.

This graph shows the variation in mineral composition along the length of the dyke in the Thomas River area. Because some of the specimens are collected from points close together and others are from points fairly distant a logarithmic scale is used along the abscissae.

- (1) Granophyric dolerite found making up the entire width of the dyke where the eastern end of the western section of the core dies out.
- (2) Granophyric dolerite found making up most of the dyke in the Thomas River area.
- (3) Metasomatized xenoliths in the granophyric dolerite.
- (4) Metasomatic granophyre: quoted from Walker and Poldervaart (1949, p. 619).
- (5) Acid veins.
- (6) Granophyric dolerite in the bed of the Thomas River, where the river cuts the dyke for the first time.
- (7) "Mottled rock".

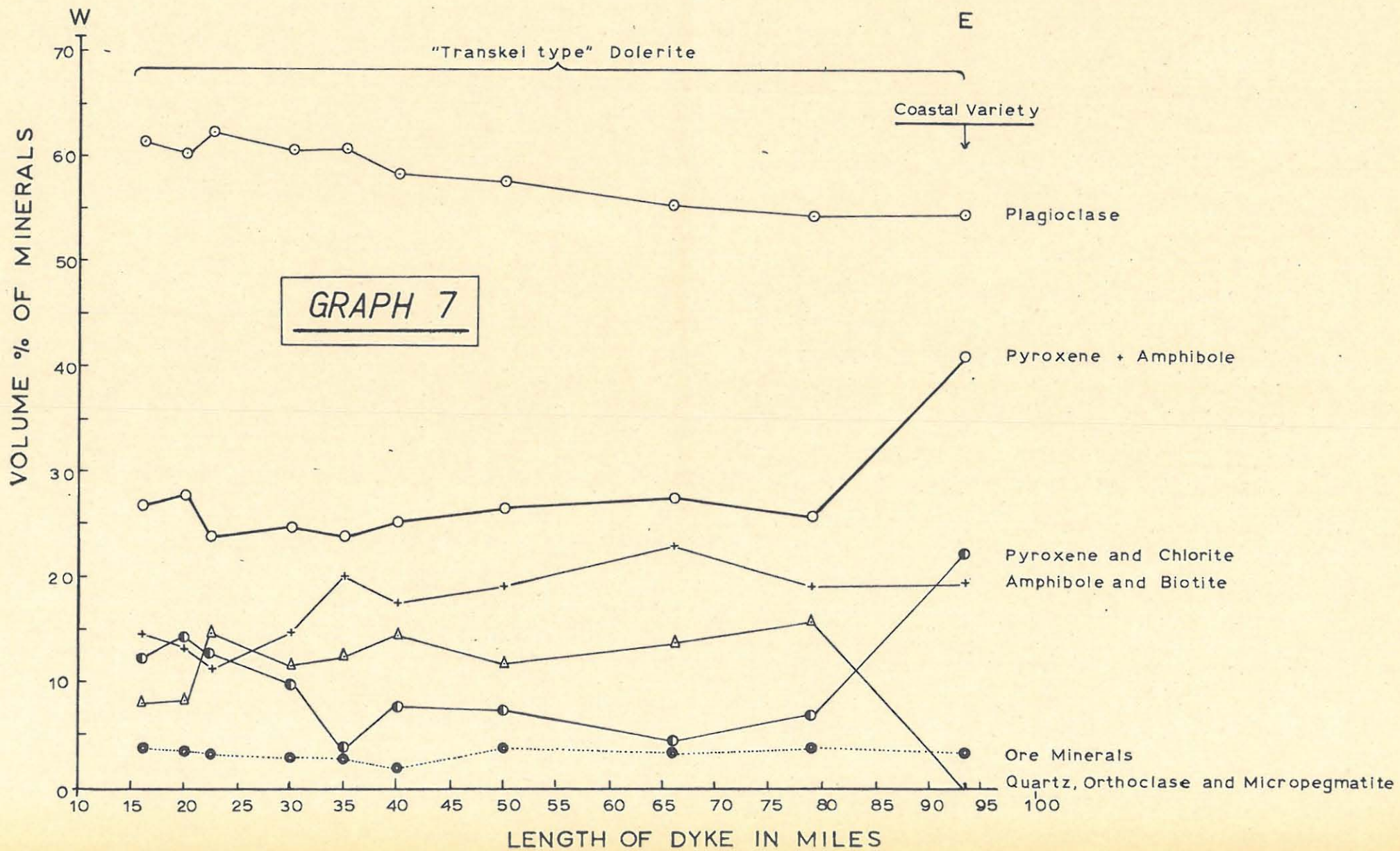
GRAPH 6



679

EXPLANATION OF GRAPH 7.

Graph showing the variation in mineral composition along the greater length of the dyke. There is little variation except at the eastern end, where the coastal variety of the "Transkei type" dolerite is recognised.



649

The shape of the graph does not change whether volume or weight percentages of the minerals are used, only the relative positions are affected. For this reason the volume percentage of minerals present in the slides was used for further graphical representation.

Graph 5 shows the variation in mineral composition along the length of the dyke for the first 16 miles, from the western end. Apart from the complex Thomas River area it is seen that there is little variation in the mineral composition of the predominant type of rock, which is the granophyric dolerite. Only the granophyric dolerite at the termination of the core differs from the rest. The composition of the subophitic dolerite flanking the core is markedly different from all the other types of rock plotted. Amphibole remains a minor constituent becoming more important eastwards, a trend continued in the "Transkei type" dolerite. Once more neither sympathetic nor antipathetic relationships are shown between the minerals present.

Because the different types of rock found in the Thomas River area occur so close together they could not be plotted on Graph 5, which has the length of the dyke in miles as abscissae. Therefore, these rocks are plotted separately on Graph 6, which has the volume percentage of minerals plotted vertically and the abscissae are plotted on a logarithmic scale representing the length of the dyke in yards. On this scale the most westerly point is 13326 yards east of the first outcrops of core material on Stonehenge. The most easterly point is 17421 yards from the same point, and at 17420 yards the Thomas River cuts the dyke for the first time. The rocks are then plotted in their correct positions along the length of the dyke. Included in the graph are plots representing the metasomatic granophyre quoted by Walker and Poldervaart (See Table IV, No. 7) to

show the similarity between this rock and the coarse patches with rod-like, criss-cross crystals in the granophyric dolerite (Table IV, No. 3). Only plots representing rocks of definitely igneous origin are linked. The plots of the coarse patches are, therefore, not linked since it is thought these represent metasomatized xenoliths.

Graph 7 is a continuation of Graphs 5 and 6 and shows the variations in mineral composition in the "Transkei type" dolerites. It shows at a glance that there is no significant variation in the dolerite forming this part of the dyke, except for the area near the coast. Even here the change in composition is confined to two minerals: quartz, which disappears altogether, and pyroxene, which increases to over 20%. The dyke, therefore, has a basic eastern section, which possibly becomes even more basic out to sea, if the general trend continues.

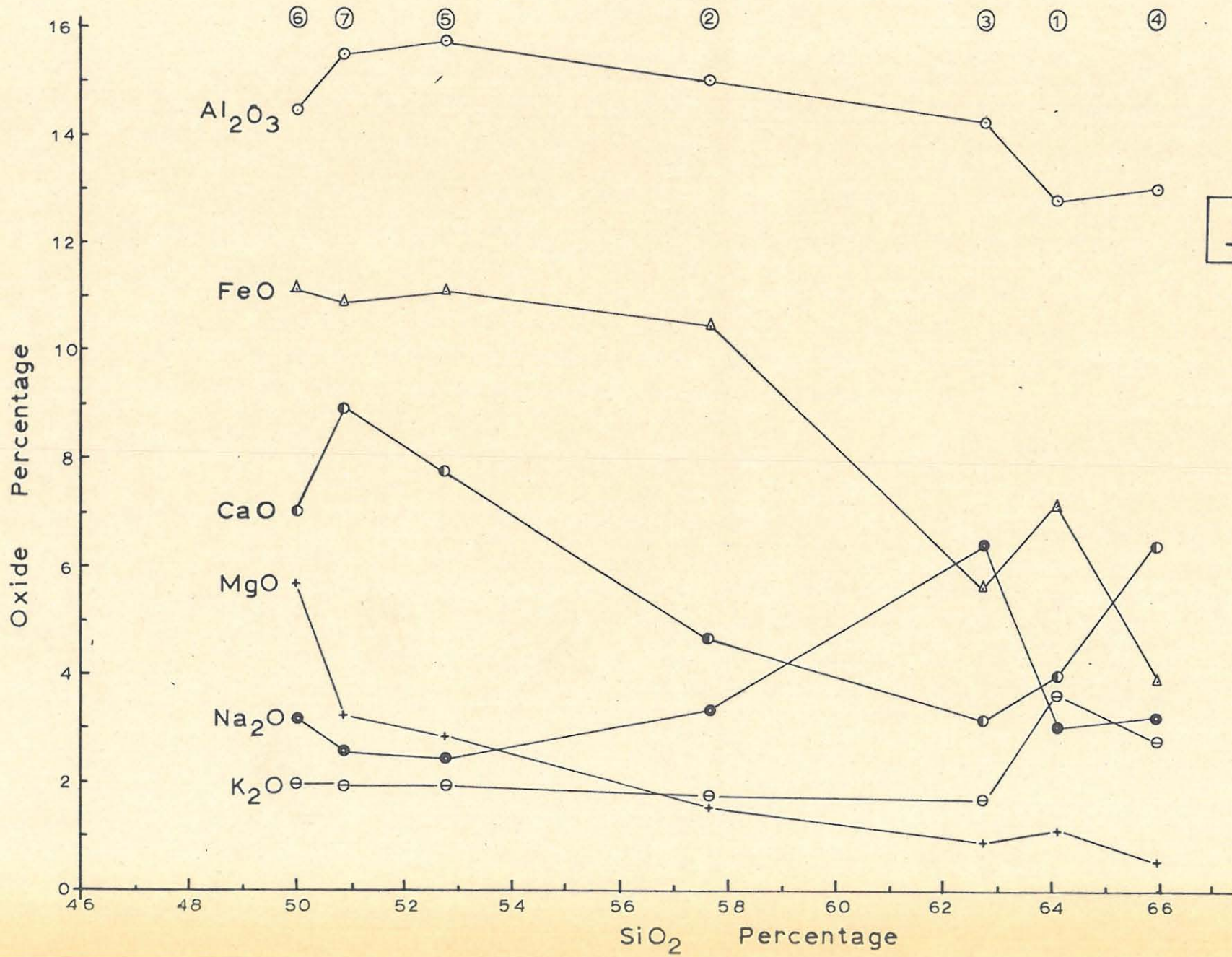
Graphs 5, 6 and 7 make no attempt to show a progressive variation sequence but merely represent the type of variation in mineral composition along the length of the dyke, so that the values recorded in the various micrometric analyses may be more easily compared.

TABLE IX.

Chemical Analyses.

	(1)	(2)	(3)	(4)	(5)	(6)
SiO ₂	64.13	57.65	62.75	65.92	52.77	49.96
Al ₂ O ₃	12.81	15.02	14.27	13.01	15.79	14.49
Fe ₂ O ₃	0.77	1.95	1.07	1.42	1.82	1.23
FeO	7.16	10.52	5.69	3.92	11.13	11.19
MgO	1.19	1.57	0.92	0.52	2.84	5.66
CaO	3.97	4.66	3.15	6.38	7.78	7.04
Na ₂ O	3.08	3.37	6.44	3.20	2.42	3.17
K ₂ O	3.64	1.75	1.65	2.74	1.91	1.95
TiO ₂	1.70	1.85	1.37	0.85	1.29	2.38
P ₂ O ₅	0.22	n.d.	n.d.	0.38	0.83	0.67
MnO	0.13	n.d.	n.d.	0.05	0.09	0.15
CO ₂	0.15	n.d.	n.d.	0.00	0.08	0.10
H ₂ O ⁺	1.45	1.48	2.46	1.78	1.17	1.59
H ₂ O ⁻	0.18	0.39	0.30	0.34	0.21	0.39
Total	100.58	100.21	100.07	100.53	100.13	99.87
S. G.	2.75	2.79	2.69	2.65	2.82	2.89
f(norm)	117				107	105
<u>Norms.</u>						
Q	19.98	12.72	9.72	24.78	7.26	---
Or	21.13	10.56	10.01	16.12	11.12	11.67
Ab	26.20	28.82	54.49	27.25	20.44	27.24
An	10.29	20.29	5.00	12.79	26.69	19.17
C	---	---	---	---	---	---
Ol	Fa	---	---	---	---	5.30
	Fo	---	---	---	---	2.80
Wo	3.25	1.23	3.13	5.57	2.67	4.64
Di	En	0.80	0.30	1.20	1.30	0.90
	Fs	2.64	1.06	5.15	4.62	1.85
Hy	En	2.20	3.60	1.10	---	6.20
	Fs	7.39	13.33	5.15	---	13.73
Wo	---	---	---	1.28	---	---
Mt	1.16	3.02	1.62	2.09	2.55	1.85
Il	3.19	3.65	2.74	1.67	2.43	4.56
Ap	0.34	n.d.	n.d.	1.01	2.02	1.68
Cc	0.30	n.d.	n.d.	---	0.20	0.20
Total	98.87	93.63	99.31	98.48	98.06	99.27

- (1) Granophyric dolerite, at end of western section of core. Quoted from Mountain (1943, p.61). Analyst: Prof. E. Mountain.
- (2) "Mottled Rock", Thomas River. Analyst: A. Moore.
- (3) Acid veins, Thomas River. Analyst: A. Moore.
- (4) Metasomatized xenoliths, Thomas River. Analyst: P. Ginn.
- (5) "Transkei type" dolerite, Toleni Bridge. Analyst: A. Moore.
- (6) "Transkei type" dolerite; coastal variety, Ngadla River mouth. Analyst: M. Johnson and A. Moore.



GRAPH 8

699

EXPLANATION OF GRAPH 8.

Chemical variation diagram of the north Gap Dyke rocks. The numbers refer to the numbers of the chemical analyses in Table IX.

TABLE IX Continued:

Chemical Analyses.

	(7)	(8)	(9)	(10)	(11)	
SiO ₂	50.83	72.75	71.96	52.3	52.5	
Al ₂ O ₃	15.50	13.98	14.37	16.0	15.4	
Fe ₂ O ₃	1.09	0.04	0.32	1.2	1.2	
FeO	10.91	2.80	2.24	10.3	9.3	
MgO	3.22	1.01	0.70	4.2	7.1	
CaO	8.96	2.05	0.82	8.6	10.3	
Na ₂ O	2.58	2.50	2.80	2.7	2.1	
K ₂ O	1.92	2.64	3.79	1.8	0.8	
TiO ₂	3.34	0.71	0.46	2.4	1.0	
P ₂ O ₅	0.19	0.06	0.05	0.3	0.1	
MnO	0.08	0.03	0.03	0.2	0.2	
CO ₂	0.10	tr.	0.00	--	--	
H ₂ O ⁺	1.24	1.49	1.69	--	--	recalculated
H ₂ O ⁻	0.14	0.41	0.53	--	--	to 100.0: water
						free
Total:	100.10	99.97	99.76	100.0	100.0	
S. G.	2.92	2.65	2.60	--	--	

Norms:

Q	2.76	40.02	37.70
Or	11.12	15.57	22.24
Ab	22.01	20.96	23.58
An	25.02	10.29	3.06
C	--	3.26	4.59
Wo	7.54	--	--
En	2.90	--	--
Di	Fs	4.75	--
Hy	En	5.20	2.50
	Fs	8.84	3.96
	Mt	1.62	--
	Il	6.38	1.37
	Ap	0.34	--
	Cc	0.20	--
Total:	98.68	97.93	98.48

(7) South Gap Dyke, Eagle's Nest, district Butterworth. Quoted from Mountain (1943, p. 61). Analyst: Prof. E. D. Mountain.

(8) Core material, Stoneridge. Quoted from Mountain (1943, p. 61). Analyst: Prof. E. D. Mountain.

(9) Beaufort sandstone, Thomas River area. Quoted from Mountain (1943, p. 61). Analyst: Prof. E. D. Mountain.

(10) Average "Kentani type" dolerite. Quoted from Walker and Foldervaart (1949, p. 669).

(11) Average Karroo dolerite. Quoted from Barth (1952, p. 181).

CHEMICAL DATA.

The most convenient method of describing the conclusions derived from the chemical analyses is to subdivide the dyke into arbitrary divisions, as was done in the section on petrography. A total of 5 new analyses is presented; three of which are complete analyses and two partial. The other analyses are quoted from published papers and are used for comparative purposes.

(i) The Core.

An analysis, made on material fairly free of the dark mudstone inclusions, is quoted in Table IX, (No. 8). As shown by Mountain (1943) this analysis and the analysis of a typical Beaufort sandstone from the Thomas River area (analysis No. 9) differ in composition:

".....by more than 1% only in the case of CaO and K₂O, and that both these figures would be reduced if the original rock contained a certain proportion of mudstone".

The similarity between the core material of the dyke and the surrounding Beaufort sandstone is thus seen to be very close, not only as regards mineral composition and grain size, but with respect to chemical composition. Some of the CaO in the core may have been introduced from the flanking dolerite magma, as suggested by Mountain (1943):

"..... in view of the calcification so commonly effected by dolerite magma in general".

(ii) The Thomas River Area.

The granophyric dolerite found extending across the entire width of the dyke at the east end of the western section of the core is a rock extremely rich in quartz and micropegmatite. It is, therefore, not surprising to find that it has a high SiO_2 content (analysis No. 1). If the analysis is compared with that of the core (analysis No. 8) and with that of the dolerite pegmatite from Toleni Bridge (analysis No. 5), which is typical of the material forming the greater part of the dyke, it is seen that the granophyric dolerite is intermediate in composition. There are, however, appreciable discrepancies, such as the low Al_2O_3 content and the high K_2O and Na_2O contents. Such differences could be explained by a certain amount of metasomatic exchange between the core and dolerite pegmatite, as suggested by Mountain (1943, p. 70).

When plotted on a triangular diagram with MgO , FeO , and $(\text{Na}_2\text{O} + \text{K}_2\text{O})$ as used by Walker and Poldervaart (1949, p. 657) to illustrate differentiation of Karroo dolerites, the plot of this granophyric dolerite falls very close to other plots on a line approximately parallel to the $\text{FeO} - (\text{Na}_2 + \text{K}_2\text{O})$ side, (see figure 34). This could indicate that the rock has formed as the result of fractional crystallisation and represents the second part of the normal differentiation trend, as shown by Karroo dolerites. However, because of the restricted occurrence of this rock type, and because of its close association with the core it is considered unlikely that it is produced by differentiation alone. As shown by the micrometric analyses (Tables III and IV) it differs markedly from the granophyric dolerite flanking the core and from the granophyric dolerite which is found making up the dyke in most of the Thomas River area. This granophyric dolerite, found only at the western side of the section where the core is missing,

is rich in quartz and micropegmatite and very limited in extent. Similar rock types are not found anywhere else along the length of the dyke.

Comparing this rock with both the average Karroo dolerite and the average "Kentani type" (analyses Nos. 10 and 11) it is seen that Al_2O_3 , FeO, MgO and CaO are low while SiO_2 , K_2O and Na_2O are high, which is in accordance with the normal process of differentiation. It seems unlikely, then, that this granophyric dolerite was formed simply by assimilation of the core material. However, the core may have aided the advanced degree of differentiation in some way, possibly by providing volatiles.

The chemical analysis of the coarse patches in the granophyric dolerite near the west bank of the river (analysis No. 4) shows that:

Na_2O is higher than in either the dolerite pegmatite at Toleni Bridge, which is close to the "Kentani type" (analyses Nos. 5 and 10) or the Beaufort sandstone at the Thomas River area. (analysis No. 9).

K_2O is slightly higher than in the dolerite pegmatite and nearly the same as in the Beaufort sandstone.

CaO and $(FeO + Fe_2O_3)$ are intermediate between those of the dolerite pegmatite and the sandstone.

MgO is only slightly lower than that of the sediment and appreciably lower than that of the dolerite pegmatite.

Apart from the MgO, the resemblance between the oxide differences, as explained above, and those explained by Walker and Poldervaart (1941 p. 446) concerning the metasomatic granophyre of the Hangnest dolerite still, is very close. It appears, then, that

these coarse patches in the granophyric dolerite have gained Na_2O and some CaO , FeO and Fe_2O_3 from some magmatic source, probably the surrounding granophyric dolerite.

This evidence, together with the textural evidence, modal similarity to a described metasomatic granophyre (see Table IV) and the minerals present, especially the occurrence of rutile, garnet and serpentine pseudomorphs after pyroxene (?) laths, leads one to believe these coarse patches are not magmatic differentiates but that they can only be metasomatized sediment, whether mobilized or not. Fluxes, although released over a prolonged period, reach a culmination during the later stages of crystallisation of the dolerite magma. (See Lindgren, 1933, p. 115, figure 11, and pages 114 to 117.) In this case the granophyric dolerite probably represents the final stage reached in the differentiation, and thus emanations, reaching a maximum during this stage, could metasomatize included Beaufort sandstone xenoliths.

A sample of this rock was crushed and a heavy mineral separation carried out in the hope of finding rounded zircon crystals. It was thought that the presence of zircon, whether rounded or not, might be conclusive proof of a sedimentary origin. However, although zircon appears to be absent from the Karroo dolerite magma, it is not necessarily absent from all basaltic magma as shown by J. Teall (1888, p. 168, 169).

"Zircon is now known to be a widely distributed mineral in all kinds of igneous rocks. It is however, more common in the acid than in the basic series. It occurs, as a rule, in short well formed prisms."

"Professor ROSENBUSCH mentions the occurrence of beautiful crystals of zircon in the Whin Sill of Upper Teesdale."

Eales (1951, p. 64) found pleochroic haloes in the hornblende and biotite of the Khale dolerite sheet to be formed around small zircons.

The acid veins found in the granophyric dolerite in the bed of the Thomas River are not unusual in chemical composition, apart from the very high Na_2O content. They may have been caused by the concentration of volatiles which would reduce viscosity locally and thus promote the growth of large crystals. These veins are composed of acid plagioclase, quartz and micropegmatite, a small percentage of hornblende and very little pyroxene. They are irregular in their trend, whereas schlieren are of a stratiform or lenticular habit. Because of their habit they may be residual injection veins, representing a locally more differentiated magma than that which crystallised to produce the granophyric dolerite. These acid veins are similar to the dolerite pegmatite residual injection veins described by Walker and Poldervaart (1940) in the dolerite sill of the Downes Mountain, but differ in the proportion of pyroxene to plagioclase.

Also contained in the granophyric dolerite in the bed of the Thomas River is a xenolith of fine grained dolerite. This is surrounded by a zone of coarse grained dolerite varying in thickness from 2" to 4". This surrounding dolerite appears to be identical to the material forming the acid veins. However, this comparison was based on poor quality slides, the poor quality being due to the difficulty experienced in collecting samples from the flat, weathered surface. The dolerite of the xenolith itself is comparatively fresh and, apart from the somewhat irregular margin, shows no signs of assimilation. If this xenolith is derived from an earlier dolerite intrusion intersected by the Gap Dyke it may have contained ground

water which would have stimulated the formation of the surrounding dolerite pegmatite. It is more likely that there has been a certain amount of reaction between the dolerite of the xenolith and the surrounding granophyric dolerite which has produced the coarse zone. Such reaction must have been limited for some reason as the xenolith remains almost unaltered and the dolerite pegmatite zone is rather narrow. Alling (1936, pp. 247 to 248) emphasises that the development of pegmatite phases is stimulated by assimilation.

On the east bank of the river the peculiar "mottled rock" (analysis No. 2) is encountered. This rock has a composition fairly similar to that of typical Gap Dyke dolerite, such as at Toloni Bridge (analysis No. 5). The SiO_2 per cent is much higher and Na_2O is slightly higher, while FeO , MgO , CaO and K_2O are all slightly lower. Therefore, although it has the general appearance of a contaminated rock it cannot be regarded as such considering the criteria for distinguishing between acid dolerite produced by contamination and that produced by differentiation, as stated by Mountain (1958, p. 219); (See also Figure 38). When plotted on the $\text{MgO} - \text{FeO} - (\text{Na}_2\text{O} + \text{K}_2\text{O})$ triangular variation diagram, (see Figure 34) the plot falls on the second part of the differentiation sequence, on a line parallel to the $\text{FeO} - (\text{Na}_2 + \text{K}_2\text{O})$ side and fairly close to the FeO apex, indicating a stage after iron enrichment in the magma.

If the "mottled rock" is to be regarded as the product of assimilation or contamination then the most likely material to be assimilated is the granophyric quartzite core which is absent at this point. The rock which most nearly approaches the composition of the "mottled rock" is produced by 10 parts of dolerite pegmatite (analysis No. 5), the normal Gap Dyke rock, assimilating 4 parts of

core material (analysis No. 8) shown in Table X. Differences up to 1.83% (in FeO) are recorded and this does not support the idea that the rock is caused by assimilation.

From Graph 9 it is seen that the most siliceous material which could be added to the dolerite pegmatite of the "Transkei type" to produce the "mottled rock" has the following composition:

SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O
63.8	14.1	9.7	0.0	0.8	4.5	1.5

This is quite unlike the analysis of the core of mobilized sediment or the Beaufort sandstone (analyses Nos. 8 and 9). It seems therefore, that the assimilation of foreign material by the magma is an unlikely cause of the production of the "mottled rock".

(iii) The "Transkei type" Dolerite.

The analysis of the rock which crops out near Toleni Bridge (analysis No. 5) is very similar to that of the average "Kentani type" dolerite (analysis No. 10) of Walker and Poldervaart (1949, p. 669), and fairly similar to that of the south Gap Dyke at Eagles Nest (analysis No. 7). It represents the type of dolerite found along the greater length of the north Gap Dyke, and is, in this work, termed the "Transkei type" dolerite.

When plotted on the MgO - FeO - (Na₂O + K₂O) triangular variation diagram (figure 34) the plot falls close to that of the "mottled rock" and amongst others following the general differentiation trend of all Karroo dolerites.

The ratio $\frac{(\text{FeO} + \text{Fe}_2\text{O}_3) \times 100}{\text{MgO} + \text{FeO} + \text{Fe}_2\text{O}_3}$ is equal to 82.02 which is

close to the range (70 to 80) indicating the third stage of the crystallisation period of Karroo dolerite, as defined by Walker and Poldervaart (1949, p. 654).

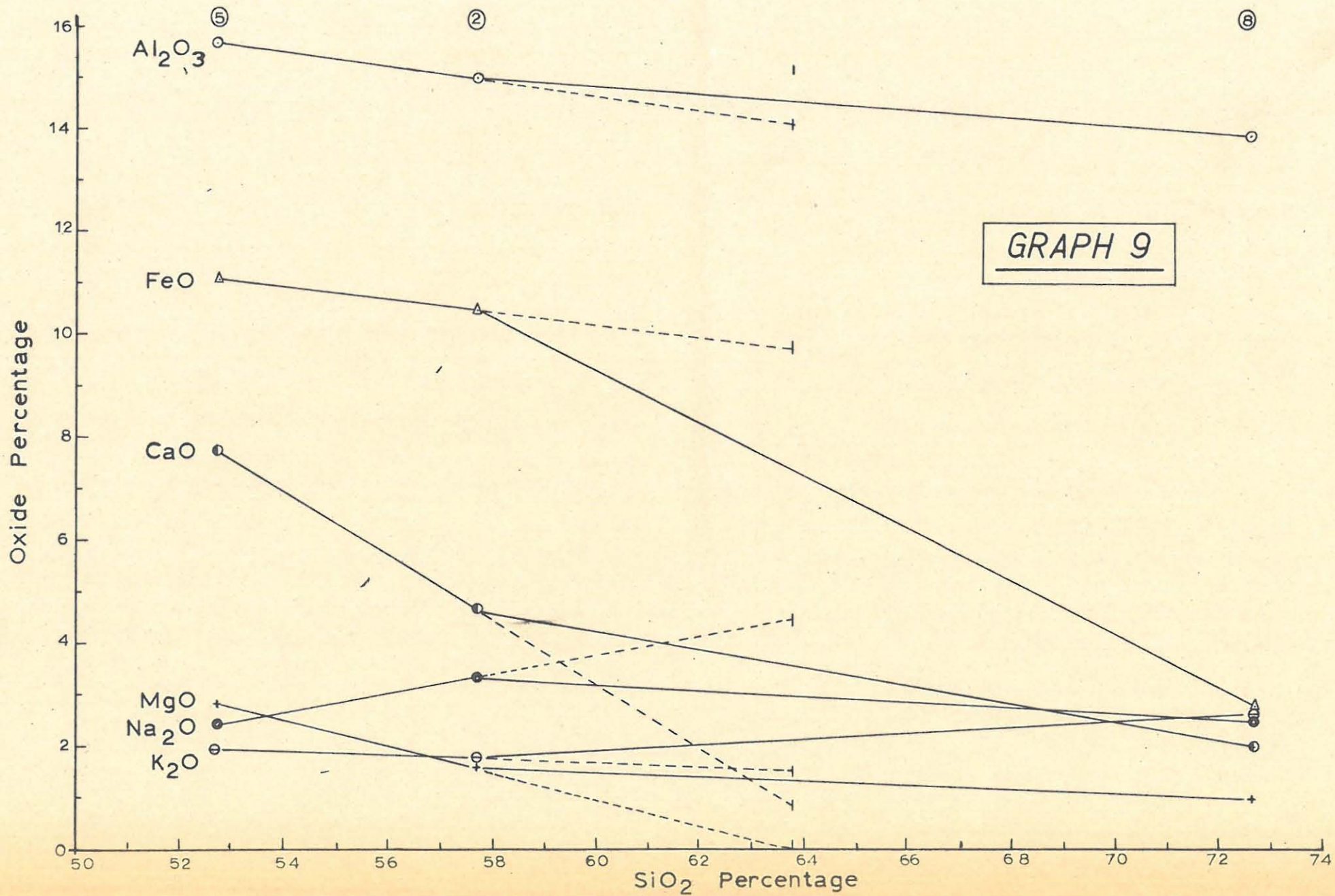
TABLE X.

Showing the amount of core material which the "Transkei type" dolerite pegmatite must assimilate in order to produce the "mottled rock".

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
(i) Dolerite pegmatite (5)	52.77	15.79	1.82	11.13	2.84	7.78	2.42	1.91	1.29
(ii) Core material (8)	72.75	13.98	0.04	2.80	1.01	2.05	2.50	2.64	0.71
(iii) 10 parts dolerite pegmatite	527.7	157.9	18.2	111.3	28.4	77.8	24.2	19.1	12.9
(iv) 4 parts core material	291.0	55.92	0.16	11.20	4.04	8.2	10.0	10.56	2.84
(v) Sum of (iii) and (iv) and reduced to 100%	58.47	15.27	1.31	8.69	2.31	6.14	2.44	2.12	1.13
(vi) "Mottled rock" (2)	57.65	15.02	1.95	10.52	1.57	4.66	3.37	1.75	1.70
Difference between (v) and (vi)	+0.82	+0.25	-0.64	-1.83	+0.74	+1.46	-0.93	+0.37	-0.57

EXPLANATION OF GRAPH 9.

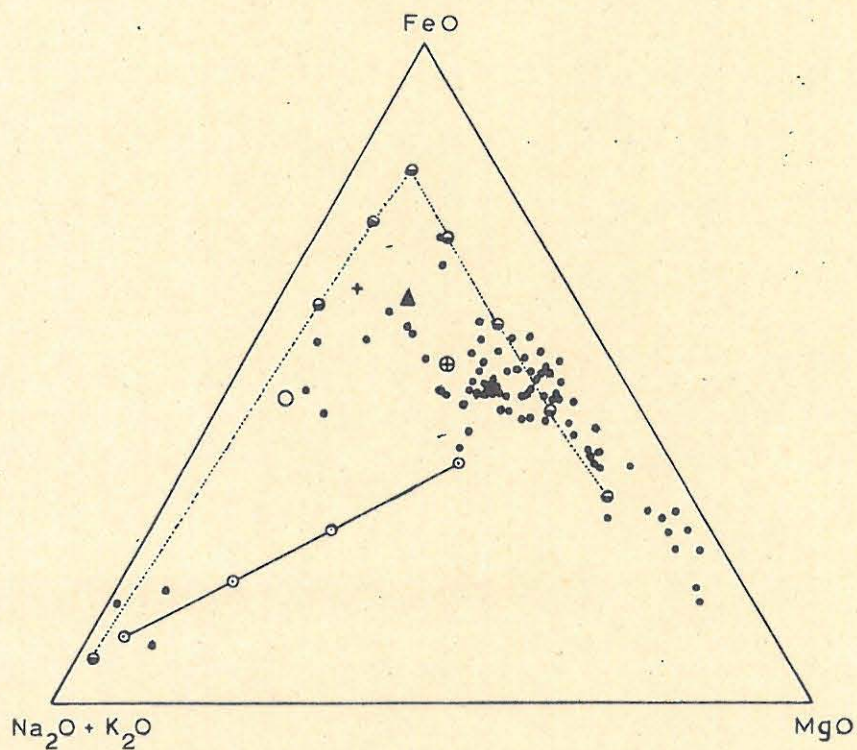
The graph shows the most siliceous material which could be added to the "Transkei type" dolerite pegmatite, represented by the analysis of the dyke rock at Toleni Bridge, in order to produce the "mottled rock". The numbers refer to the numbers of the analyses in Table IX.



EXPLANATION OF FIGURE 34.

MgO - FeO - (Na₂O + K₂O) triangular variation diagram showing the differentiation trend of Karroo dolerites (88 analyses), the trend of the Skaergaard liquid, Daly's average basalt, andesite, dacite and rhyolite, and some of the rocks of the north Gap Dyke.

FIGURE 34



O: Granophyric dolerite found at the eastern end of western section of the core.

+: "Mottled Rock".

▲: "Transkei Type" ("Kentani Type") dolerite.

⊕: "Transkei Type" —Coastal variety.

—○—○: DALY'S average basalt, andesite, dacite and rhyolite.

⋯●⋯●: Skaergaard liquid.

●●: Karroo dolerites.

The dolerite which is found near the coast and which marks the most easterly limit of the dyke available for examination has been shown to differ considerably from the dolerite pegmatite making up the rest of the dyke in the Transkei. This difference is further emphasised in the chemical analysis (No. 6) which shows a much lower SiO_2 content and an increase in MgO . In spite of this increase in MgO no orthopyroxene was found in any of the slides examined. The plot of this coastal variety of dolerite falls on a line parallel to the $\text{MgO} - \text{FeO}$ side of the triangular variation diagram in figure 34, indicating that it could have formed during the first stage of crystal differentiation.

The ratio $\frac{(\text{FeO} + \text{Fe}_2\text{O}_3) \times 100}{\text{MgO} + \text{FeO} + \text{Fe}_2\text{O}_3}$ for the coastal variety is

equal to 68.69. This indicates that it belongs to the second stage of the crystallisation period and thus, according to the classification of Walker and Poldervaart (1949, p. 654), cannot belong to the "Kentani type" dolerite. It is, in fact, similar to the "Blaauwkrans type" dolerite, but for the absence of magnesian pigeonite and olivine, and the plagioclase present is in amounts greater than 50% by volume, being 54.6% of the rock.

The f(norm).

Barth (1952, p. 123) uses the sum $ab' + 2di' + 2.3hy'$, called the f(norm), to indicate the nature of the first crystallisation products separating from a basaltic melt. The normative minerals ab, an, di and hy are recalculated to 100 per cent and the symbols thus formed are called ab' , an' , di' and hy' respectively. If the sum of the f(norm) equals 123 (approximately) then the basalt lies on the boundary surface which separates those magmas precipitating plagioclase first from those which precipitate pyroxene first, in

the tetrahedron illustrating the approximate composition of basaltic lavas. (Barth, 1952, p. 121, figure 36.) In this case both plagioclase and pyroxene crystallise together. If this sum is smaller than 123 plagioclase crystallise first, and, if greater, pyroxene crystallise first. This equation is very useful when considering the crystallisation of basaltic magma, but the results may be misleading when considering the rocks of the north Gap Dyke which are more acid than those formed by crystallisation of normal basaltic magma. However, in all cases considered the $f(\text{norm})$ is less than 123, suggesting that plagioclase crystallised first. This is in accordance with the textural evidence which shows occasional tiny plagioclase laths entirely enclosed in anhedral pyroxene, and a tendency towards a subophitic texture. Pyroxene seldom occurs as subhedral crystals, although it may be found as such in some cases, while the plagioclase is almost always lath-shaped.

ORIGIN OF THE CORE.

There can be no doubt that the granophyric quartzite core found at the western end of the north Gap Dyke was originally a sediment. The present writer can only confirm the views expressed by Mountain (1943, pp. 70 to 71) who states:

"The following considerations support a sedimentary origin for the material of the western end of the N. dike;-

1. The appearance of the rock in the field is practically identical with much of the invaded sediments in that area.
2. Certain portions of the rock under the microscope look like an almost unaltered feldspathic sandstone and grade continuously into the remainder of the rock, the general equigranular texture of which is not inconsistent with such an origin.
3. The chemical composition of the rock" (analysis No. 8) "is very similar to that of a specimen of Beaufort sandstone from the same area.
4. The analysis shows over 3 per cent of normative corundum.
5. Heavy residues from the rock include a number of highly rounded grains, especially of zircon, which appear to be of water worn origin.
6. The dark angular inclusions under the microscope resemble metamorphosed mudstone and nothing that is known to be of magmatic origin."
9. The abrupt transition between the granophyric quartzite and the granophyric dolerite suggests the possibility of a different origin for the rocks on either side of this transition zone.
10. The feldspathic quartzite on Stoneridge is in all respects comparable with the material of rheomorphic veins of Karroo dolerite elsewhere, the origin of which can be established beyond dispute in the field."

This evidence can surely leave no doubt that the core, which exists in two distinct sections, is of sedimentary origin. The material found at Stoneridge is not as highly recrystallised as that at Surbiton and Rexfield but already the individual grains show a certain amount of intergrowth. The degree of recrystallisation of the core increases from west to east and has reached a maximum at

Surbiton. The material on Rexfield is identical to that at Surbiton. Although the dark angular inclusions, which are undoubtedly metamorphosed fragments of mudstone or shale, show no alignment and the granophyric quartzite is massive, without any signs of flow structure or bedding, it is quite likely that the core is a mobilized sediment. Unless it is assumed that this body was mobilized there appears to be no possible explanation as to how the mudstone fragments arrived in their present positions. These fragments are not at all comparable with the thin shale lenses occasionally found in Beaufort sandstone. The Beaufort sandstone is known to contain thin shale bands and if, in the process of mobilization, one or more of these bands was broken up then the fragments so formed could be scattered through the core while it was in a plastic state.

The granophyric quartzite core is by no means constant in width, but varies from 200 feet on Stonehenge to 26 feet in the Surbiton railway cutting. It disappears altogether in the Thomas River valley. Apart from the great length of this body (over 8 miles) it is unique in that no other mobilized sediments have been described from dykes of Karroo dolerite. All other occurrences have been in sills, and all such mobilized sediments have been comparatively small in size. (See figures 19 and 35).

There is no evidence that the granophyric quartzite of the core gradually passes into the granophyric dolerite found across the entire width of the dyke where the western section of the core dies out. On the contrary, although there is no contact exposed and although the exact eastward limit of this part of the core cannot at present be fixed, the likelihood of a gradation between the two rock types is small. This is thought to be so because the

EXPLANATION OF FIGURE 35.

Hypothetical diagrams showing possible shapes
of the mobilized sediment core at the western end of the
north Gap Dyke.

(A)

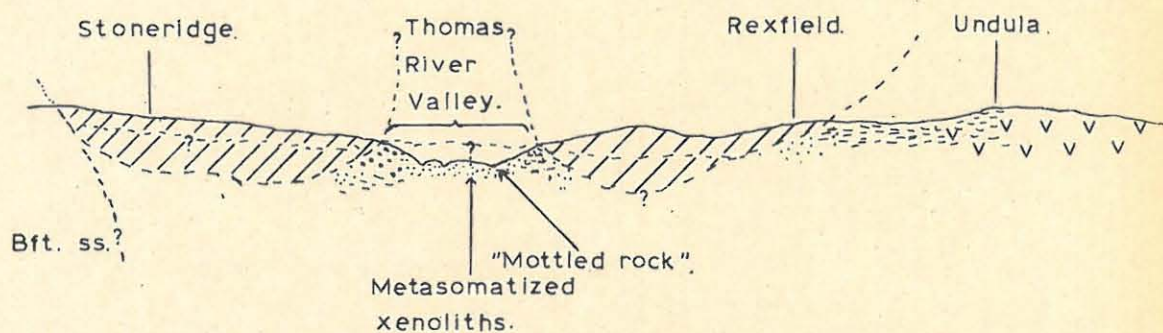
If the core is floored by dolerite.
(Section along the middle of the dyke.)





(B)

If the core is capped by dolerite.
(Section along the middle of the dyke.)

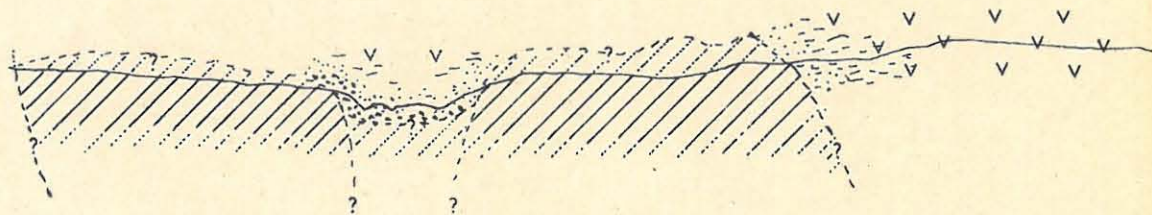
FIGURE 35

(A)



- | | | | |
|---|------------------------------|---|---|
|  | Core. |  | Dolerite pegmatite—rich in micropegmatite and quartz. |
|  | Granophric dolerite (types). |  | Dolerite pegmatite—rich in quartz. |

(B)



contact between the core and the granophyric dolerite flanking the core is sharp. It should be remembered, however, that the granophyric dolerite flanking the core and that at the eastern limit of the first part of the core are quite different, as shown by the micrometric analyses.

Because of poor outcrops the precise western limit of the core, and the dyke, is unknown. It appears to taper out against the Beaufort sandstone east of the Cathcart - Alice main road. It is possible that the core actually passes into the sediments here but this cannot be proved unless better outcrops are exposed. The supposed shape of the core, as shown in the diagrammatic sketch of figure 19, is deduced from the occurrence of outcrops and by interpolation. It may, however, be in more than two sections. There may also be more variation in the width but not enough outcrops occur for exact variations to be shown. For the following two reasons the gradual thinning eastwards of the western section of the core is thought to occur:

(i) Outcrops become more sparse than ever east of the farm Stonehenge.

(ii) The core obviously affects the grain size of the flanking dolerite (See Graph 2). A gradual thinning of the core could explain a gradual increase in grain size east of Stonehenge.

The core is undoubtedly derived from the Beaufort sandstone and the problem as to how it was emplaced arises. Any hypothesis must necessarily be speculative, but in any discussion it should be remembered that genesis probably took place at a depth greater than its present elevation, relative to the walls, in the dyke. This is because:

(i) The core is almost certainly mobilized, as shown by the presence of the angular mudstone fragments.

(ii) If produced at its present elevation in the dyke, relative to the walls, the metamorphic effect on the core material would be similar to that on the wall rock. The core, however, shows a very high degree of recrystallisation, increasing in degree eastwards from Stoneridge to Surbiton and Rexfield, while the wall rock is recrystallised to a very limited degree and only for a few feet on either side of the dyke. Even if allowance is made for the fact that the core is in contact with the dolerite on two, three, or possibly even four sides, while each wall is in contact on only one side, it still seems hard to believe that the metamorphic effect on the wall rocks would be so much less than on the core, if the core was formed at the same elevation in the dyke, relative to the present walls.

The problem of how the core was emplaced does not appear to have any really satisfactory solution because of the volume of mobilized sediment involved. It is because of the great length of core material that it is considered unlikely that it was sucked into the cooling dyke from the western end. One possible solution is that a long block of Beaufort sandstone was detached from the walls during intrusion of the dyke and then, because of temperature and depth, became mobilized. It may have been squeezed into its present position as the result of lateral pressure while in a semi-plastic state, or it may have risen upwards into this position because of the lower specific gravity of the core compared with that of the dolerite. All this must have taken place before complete solidification of the dolerite magma so that volatiles, released from the core during recrystallisation, could influence the course

of crystallisation of the dolerite immediately next to it. (See figure 36).

A second possible solution is that during intrusion the dyke split into two in depth, each section following a plane of weakness in the massive, jointed Beaufort sediment. The semi-central sedimentary material between the two sections then rose upwards in a semi-plastic state as a result of lateral pressure, or because of its lower specific gravity, or because it was carried up with the rising dolerite magma. It eventually came to rest in the position in which it is now found. (See figure 36.) Its presence caused rapid cooling of the magma near it, hence the fine grain and undifferentiated nature of the subophitic dolerite. At the same time it may have provided certain elements which changed the composition of the dolerite immediately next to, and surrounding, it, hence aiding the formation of the granophyric dolerites.

THE EFFECT OF THE CORE ON THE DOLERITE.

That the presence of the mobilized sediment core has definitely affected the dolerite is shown by the presence of the granophyric dolerite immediately flanking the core, by the decrease in grain size of the dolerite where the core is present (See Graph 2), and by the variation in the anorthite content of the plagioclase crystals (See Graph 3). The precise manner in which the core has affected the dolerite is uncertain: if it provided volatiles for the production of the granophyric dolerite one would expect a coarse grain, but the reverse is true.

It seems as if the core has, in some way, provided an escape for the heat of the dyke and promoted rapid cooling, as shown

by the relatively small grain of the flanking dolerite. At the same time a certain amount of transfusion of elements has taken place to produce the granophyric dolerite which is found immediately flanking the core. Unless chemical analyses of fresh subophitic dolerite are obtained and the K_2O and SiO_2 contents of these rock types compared, no definite conclusions may be reached. However, if the granophyric dolerite of Stoneridge is the same as that at Surbiton then there has been a marked increase in the amount of micropegmatite in the granophyric dolerite as compared with the subophitic dolerite, and this would mean a possible introduction of K_2O and SiO_2 from the core. The rate of cooling of the dolerite flanking the western section of the core must have been so rapid that any differentiation of the magma was prevented, resulting in the formation of a subophitic dolerite with very little quartz.

The core is absent in the Thomas River valley, although it is found both to the east and west of the valley. However, it has apparently affected the dolerite of the dyke in this area because it is between the western and eastern core outcrops that the peculiar rock types of the Thomas River area occur, and nowhere else along the length of the dyke are similar rock types found. Wholesale assimilation of the core material in this area is discounted, but the core may have influenced the course of crystallisation by the transfusion of certain elements, particularly volatiles, into the dolerite. If a certain amount of transfusion of elements has taken place the granophyric dolerite of the Thomas River area, particularly that found at the western end of the area, could be an acidified dolerite comparable with those found at Coedmore Quarries, Durban. (Mountain, 1958).

The nature of the plagioclase in the dyke also indicates that the core has influenced the crystallisation of the dolerite. (See Graph 3.) The plagioclase in the subophitic dolerite flanking the core is An_{60-64} , which is the same as that in the granophyric dolerite of the Thomas River area, and that in the "Transkei type" dolerite pegmatite. However, for the granophyric dolerite flanking the core, and the granophyric dolerite at the eastern end of the western section of the core the anorthite content of the plagioclase is An_{55-58} . Apart from the "mottled rock" (An_{53}) and the metasomatized xenoliths (An_{35}) these are the lowest anorthite values recorded for the centres of plagioclase crystals found in the different types of dolerite making up the dyke. It is significant that they occur only where there is a gap between the two sections of the core material. East of the "mottled rock" there is a gradual increase in the anorthite content in the centres of plagioclase crystals, as seen in Graph 3.

By what means the core has influenced these features is not certain, but it has promoted the crystallisation of more acid plagioclase than is found elsewhere in the dyke. These acid plagioclase crystals (An_{53}) in the "mottled rock" occur in rocks with a comparatively high SiO_2 content and this acidity may be actual or relative; i.e. it may be caused by hybridization of the rock or by the removal of early formed crystals by fractionation. The core could have assisted either method: the first by providing material to allow for hybridization, and the second by providing volatiles which would decrease the viscosity of the magma. The very acid plagioclase (An_4 to An_{30}) found in the pale patches of the "mottled rock" and in the acid veins of the granophyric dolerite in the bed of the Thomas River, is most likely to be the result of crystallisation of residual magma. The first crystals to form would

EXPLANATION OF FIGURE 36.

Diagrammatic representation of the origin of the mobilized sediment core.

(A)

Detachment of a sandstone block from the walls during intrusion, later to be squeezed, or to rise upwards.

(i) Block becomes detached from the wall.

(ii) Block is carried to the centre of the rising dyke magma.

(iii) Due either to lateral pressure or to the lower specific gravity of the block it is carried upwards, and becomes mobilized. In this semi-plastic state any included shale bands could be fragmented and so form the dark, angular inclusions.

(iv) The core in the position in which it is found today.

(B)

Bifurcation of the dyke forming a core of sedimentary origin.

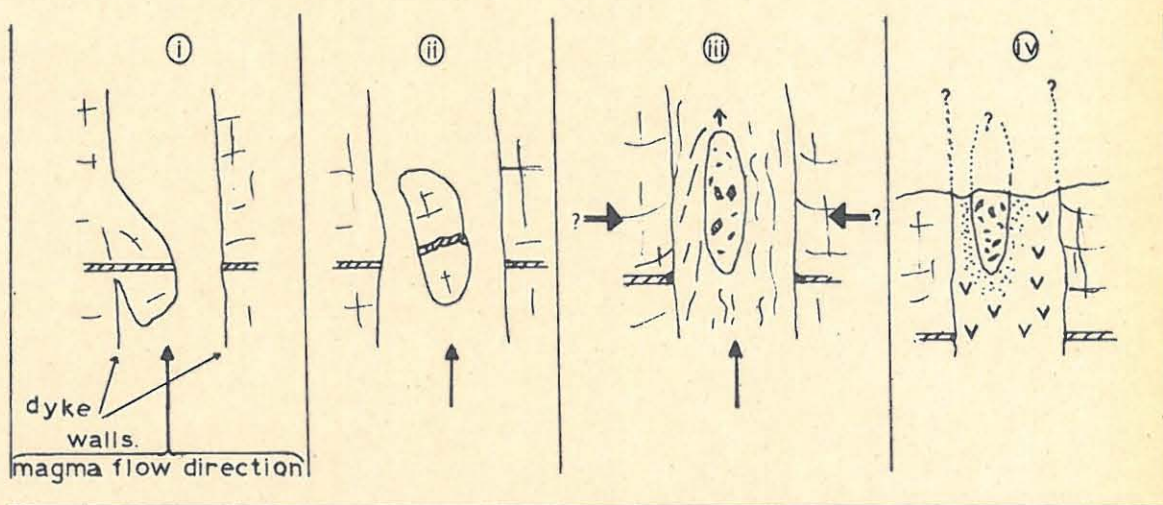
(i) Bifurcation of the dyke causes a block of sandstone, with included shale band(s), to be separated from the walls.

(ii) The block is mobilized and, for some reason, carried upwards.

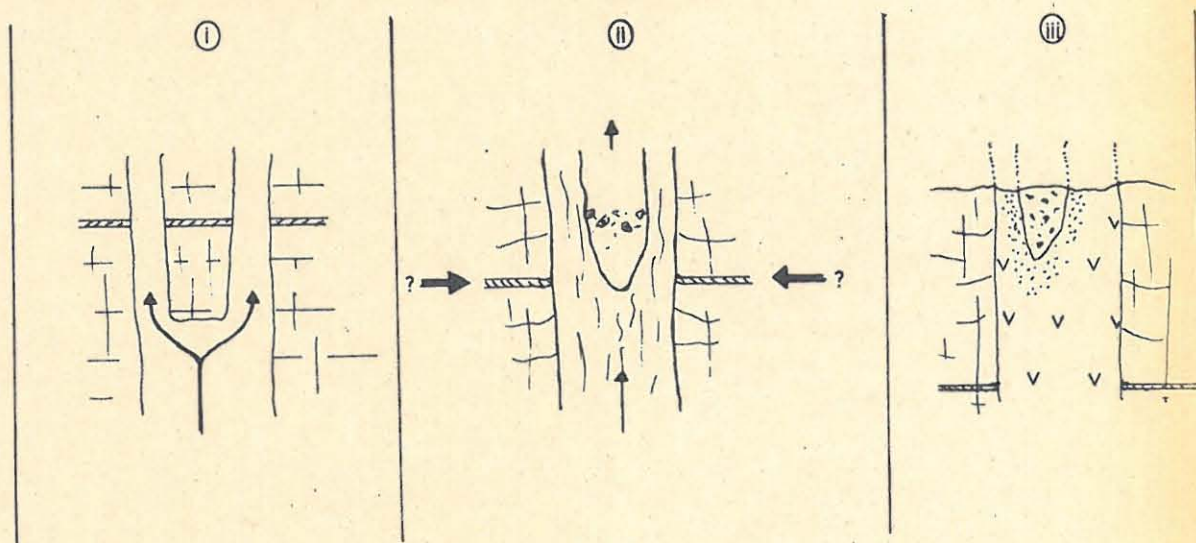
(iii) The core in the position in which it is found today.

FIGURE 36

(A)



(B)



be anorthite-rich, and if these were effectively removed either by sinking or failing to react with the residual magma the plagioclase forming from the residual magma would be albite-rich.

CLASSIFICATION OF THE "TRANSKEI TYPE" DOLERITE.

The writer's "Transkei type" dolerite of the north Gap Dyke is, except for the more basic coastal variety, the same as the "Kentani type" of Walker and Poldervaart (1949). However, it is not really necessary to classify this dolerite as a distinct type, because it is, in fact, a dolerite pegmatite. This classification as a dolerite pegmatite is based on Walker's (1953, p. 44) definitions:

"Dolerite pegmatite contains practically the same range of minerals as ordinary* dolerite, with two exceptions: Orthopyroxene is completely absent and greenish-brown amphibole is generally a major constituent."

And also:

"Dolerite pegmatite lies on the normal differentiation trend of dolerite magma on the liquid line of descent and is close to the stage of maximum iron enrichment...." (See figure 34.)

Du Toit (1956, p. 363) writing about the Gap Dyke, states:

".... they are composed of coarse-grained gabbroidal rock which, through ready weathering, has been eroded into longitudinal valleys.

Varying appreciably in composition and texture in various parts, the rock is normally olivine-free and composed of labradorite feldspar, reddish biotite, and clinopyroxene, the latter being partly converted to brown hornblende. Having a silica percentage of 50 - 52, the name 'DOLERITE PEGMATITE' is more fitting than 'diomite', as originally stated."

* What is meant by "ordinary dolerite" is not quite certain. It may mean the commonest type of dolerite in the Karroo suite, which is the "Perdekloof type" (28.4%) (Walker and Poldervaart, 1949, p. 615.)

The coastal variety of the "Transkei type" dolerite represents the most basic type of dolerite encountered along the north Gap Dyke. From west to east the dyke becomes progressively more basic in character and it would be in keeping with this trend for a more basic dolerite to occur beyond the coastline.

THE ORIGIN OF THE MAGMA.

Because complete assimilation of sediment by basaltic magma and crystal fractionation tend to lead to the same end product there can be no certain decision as to whether the north Gap Dyke magma is the product of differentiation or assimilation.

Walker and Poldervaart (1949, p. 671) consider that the dolerite pegmatite forming the Kentani Gap Dykes represents an advanced stage of differentiation of the Karroo magma, emplaced after the main period of injection of Karroo dolerite. Their reasons are as follows:

1. In chemical composition the average Kentani type is very similar to a quartz diabase from the upper part of the Palisade sill. The average Palisade diabase shows a very close chemical correspondence with the average Karroo dolerite, and the Palisade magma was notably inert in its behaviour toward the associated sediments.

2. The composition of the average Kentani type reflects all the changes expected in the fractionation of the Karroo dolerite magma. Thus, the relative impoverishment in MgO and CaO and the enrichment in FeO, Fe₂O₃, TiO₂, Na₂O and K₂O, when compared with the average Karroo dolerite, are explained by normal fractionation of the Karroo magma.

3. Mineralogically the Kentani type resembles the dolerite pegmatites of the Karroo, though the latter are generally more mafic. There is no need for an appeal to the metasomatism of sediments to explain the origin of the dolerite pegmatites, which were considered by Tomkeieff (1929) to be due to the segregation of aqueous portions of the magma.

4. Metasomatic granophyres of the Karroo are characterised by an elongated habit of the pyroxene generally pseudomorphed in

yellow-green serpentine, and by the occurrence of relict minerals and structures. The Kentani type dolerite bears no resemblance to these granophyric rocks of demonstrably metasomatic origin."

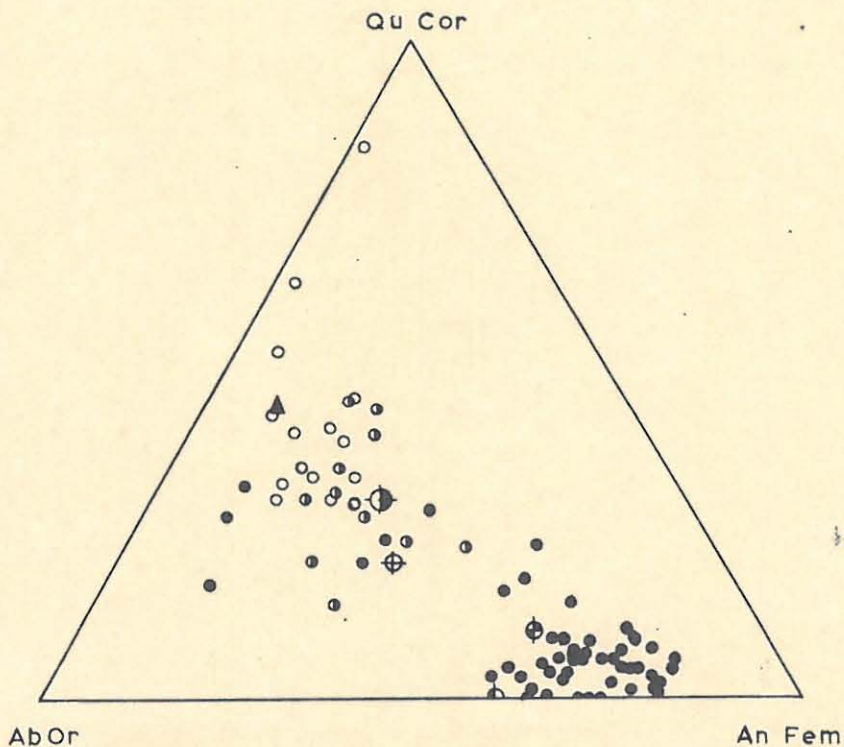
The water which causes the formation of the dolerite pegmatite, as explained in point 3 above, need not necessarily come from segregated portions of the Gap Dyke magma. Water derived from sediments would have the same effect. If the magma was in fact generated by association, in depth, of normal Karroo magma with deeply buried sediments, with the transfusion of certain elements only, as suggested by Mountain (1943), then a typical metasomatic granophyre would not necessarily result, as implied in point 4, above.

The dyke may be differentiated vertically: the lowermost point is exposed at the coast where the most basic rocks crop out while inland the rocks become progressively more acid. The most westerly part of the dyke is also the highest exposed part, and should, therefore, be represented by the most highly fractionated residue. This residue would also be the most active towards the mobilized sediment core. Such activity might account for the production of the silica-rich granophyric dolerite at the eastern end of the first section of the core, and for the metasomatized xenoliths in the granophyric dolerite of the Thomas River area. Both of these rocks show a tendency to approach the composition of the dolerite pegmatite. (See figure 37). If the north Gap Dyke is differentiated vertically then, in the west, the core complicates the normal differentiation sequence. Thus, the "mottled rock" and granophyric dolerite of the Thomas River area, although they still lie on the normal differentiation trend (Figure 34), are possibly due to the presence of the core. The subophitic dolerite would then represent magma in which

EXPLANATION OF FIGURE 37.

Analyses of Karroo dolerites, dolerite
pegmatites, granophyres and sediments, and of some
of the north Gap Dyke rocks plotted on a triangular
diagram with variables An Fem; Qu Cor; Or Ab.

FIGURE 37



- : Dolerites.
- : Metasomatic granophres.
- : Sediments.
- ▲ : "Transkei Type" dolerite — Coastal variety.
- ⊕ : "Transkei Type" ("Kentani Type") dolerite.
- ⊕ : Metasomatized xenoliths in Thomas River area.
- ▲ : Beaufort sandstone in the Thomas River area.
- ⊕ : Granophyric dolerite found at the eastern end of the western section of the core.

differentiation has been inhibited because of chilling by the core.

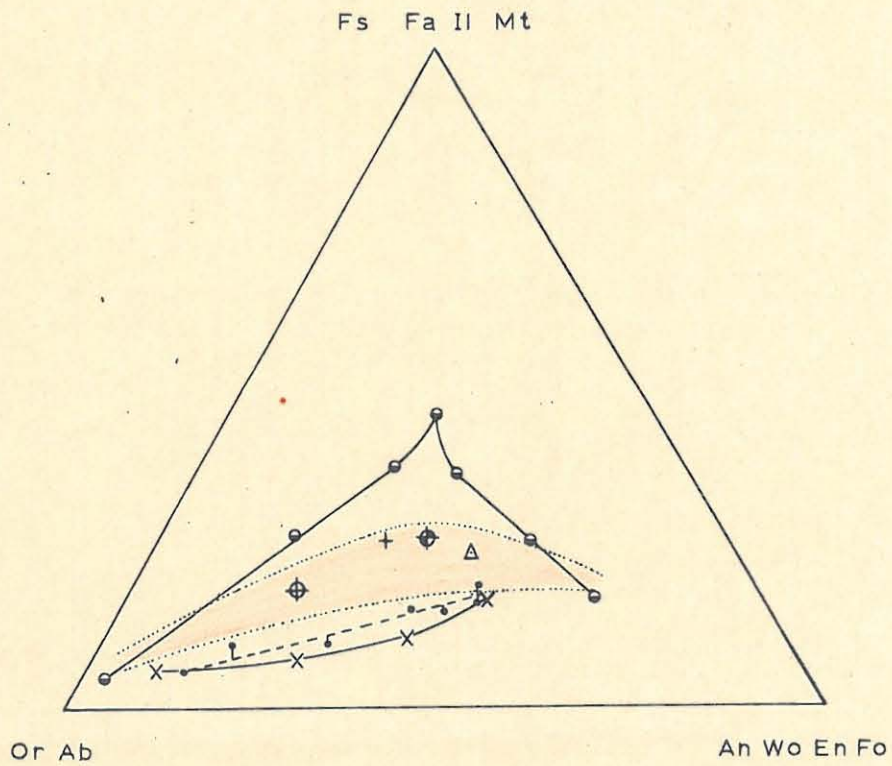
The magma from which the granophyric dolerite of the Thomas River area crystallised was relatively acid in character and the question arises as to why this magma metasomatized included xenoliths of Beaufort sandstone, or core, but did not react with a xenolith of dolerite. In accordance with the Reaction Principle of Bowen (1956, pp. 54 to 62, and p. 197), the dolerite xenolith is basic compared with the surrounding granophyric dolerite, and hence higher in the reaction series so that some reaction would be expected. There appears to be no reaction other than the formation of the dolerite pegmatite in a narrow zone around the xenolith. The only possible explanation is that there was not enough time for complete reaction to occur before solidification of the granophyric dolerite. The xenolith may be from a nearby dyke or sill cut by the north Gap Dyke, or it may represent autobrecciation of an unexposed chilled margin. Exposures in the Thomas River area are very poor and merely because a significant chilled margin was not found in the weathered dolerite in the Surbiton cutting, nor in the outcrops east of the Thomas River, it does not mean that there is no chilled margin to the granophyric dolerite of the Thomas River area.

Considering the origin of the normal calc-alkaline series of rocks, Wager and Deer (1939) used a triangular diagram showing the more refractory, medium refractory and less refractory normative minerals to illustrate the trend of the Skaergaard liquid and other rock series. This diagram is reproduced in figure 38 with plots of certain of the north Gap Dyke rocks added. All of these plots fall within the shaded area representing the differentiation trend of Mull and Ardnamurchan lavas and hypabyssal rocks. Because of the similarity of the trends shown by the Mull rocks and the north Gap

EXPLANATION OF FIGURE 38.

Some of the north Gap Dyke analyses, and other rock suites, plotted on a triangular diagram of normative compounds.

FIGURE 38



- : Skaergaard liquid.
- : Mull and Ardnamchuran lavas and hypabyssal rocks.
- - -○ : Carsphairn calc-alkaline hybrid suite.
- △ : "Transkei Type" dolerite — Coastal variety.
- ⊕ : "Transkei Type" ("Kentani Type") dolerite.
- +
- ⊕ : Granophyric dolerite found at the eastern end of the western section of the core.

rocks the possibility exists that these may have a similar origin: an origin which involves both contamination of the magma and then crystal fractionation, as suggested by Wager and Deer. However, this evidence should not be regarded as proving a hybrid origin for the Gap Dykes. The Lugar Sill (Tyrell, 1916) and Shiant Sill (Walker, 1930) have been plotted on a similar diagram (Wager and Deer, 1939, p. 319) and straight line graphs were obtained which are close to those produced by the Carsphairn calc-alkali suite, which is regarded as the product of hybridization, and Daly's average basalt, andesite, dacite and rhyolite. Yet these two sills are formed as the result of "a selective gravitational effect due mainly to the sinking of olivine."

Mountain (1943) considers that the dolerite pegmatite forming the greater part of the Gap Dykes could have been generated in depth, by association with deeply buried sediments. He states:

"If this is the case, then it is clear that the resultant magma was the result not merely of an intermingling of the original magma and the sediment, which would have given rise to a somewhat acidified product, but rather some form of transfusion between the two involving the selective transference of certain constituents only."

Whichever theory is favoured the problem arises as to why such intrusions of dolerite pegmatite are not more common. The answer may perhaps be found in the extraordinary size of the dyke. As pointed out by Wager and Deer (1939, p. 321):

"If convection currents may exist in a relatively small intrusion like that of the Skaergaard, then with greater probability they may exist in larger masses of basic rock, in existence for longer periods of time."

The volume of material contained in the long north Gap Dyke must indicate a large reservoir of magma, and if both Gap Dykes are derived from the same magma chamber, as is likely, then it indicates

an even larger reservoir. Thus, the probability of convection currents existing in such a reservoir is high. These currents provide an excellent means whereby effective mixing of sialic rocks and basic Karroo magma could have taken place. This could have taken place over a comparatively long period of time, as the intrusion was relatively late since it cuts all earlier intrusions. Once this hybrid magma was emplaced a certain degree of differentiation could have taken place.

In spite of a careful examination of the dyke outcrops no remnants of any earlier dyke could be found along the margins of the north Dap Dyke. In the Thomas River area only a few outcrops of a slightly darker material were found near the margins of the granophyric dolerite. When sectioned, specimens of these rocks were found to be very similar to the granophyric dolerite, but contained slightly less micropegmatite and more pyroxene and chlorite. It may be that much nearer the wall rock a chilled margin exists, and that this darker rock may grade into such a margin. However, more exposures would be necessary to prove this. The magma of the dyke does not appear to have been very reactive, and, in fact, where it encloses a dolerite xenolith there is no significant reaction. This is in direct conflict with a statement made by Walker and Poldervaart (1949, p. 671):

"Apparently the 'acid' Kentani magma was exceedingly mobile and active in its behaviour towards the associated rocks. It followed the course of two earlier dolerite dikes, remnants of which are still preserved along the margins of the dikes. The original dolerite was converted to granophyric dolerite, rich in biotite, by normal reaction with the Kentani magma, in accordance with the reaction principle (Bowen, 1928, pp. 197 - 201)."

SUMMARY.

The origin of the dolerite pegmatite magma forming the greater length of the north Gap Dyke remains uncertain. It may be the result of normal differentiation, or it may be the result of hybridization and differentiation. Westward the dyke becomes more acid in character and eventually contains a semi-central core of mobilized sediment, which is in two sections. This core may have influenced the course of crystallisation and aided differentiation of the magma. Although absent in the Thomas River area the core may have played a part in the formation of the unusual rock types found there. The dolerite bordering the western section of the core is of two types: granophyric dolerite contiguous with the core and subophitic dolerite lying between the granophyric dolerite, which varies in width, and the walls, which are of massive, Beaufort sandstone.

If the western end of the dyke represents the most acid stage in a differentiation sequence then, unless the presence of the core has prevented differentiation in the dolerite flanking it rather than promoted differentiation, possibly by chilling, no explanation can be offered for the presence of the subophitic dolerite.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

SUMMARY.

CHAPTER ONE: FIELD RELATIONSHIPS.

By mapping with the aid of aerial photographs the north Gap Dyke is found to be a vertical intrusion $93\frac{1}{2}$ miles long. It extends from a point about $4\frac{1}{2}$ miles south of Cathcart to the coast where it enters the sea about 100 yards north of the Ngadla River mouth. The strike is more or less east-west but there are some variations near the coast, and it changes near Cathcart. The width is greatest at the coast, 250 yards, and westward it gradually thins, eventually tapering out altogether south of Cathcart. In the Transkei the dolerite pegmatite of the dyke weathers more readily than the surrounding Beaufort sandstone, which undisturbed by the intrusion, and so it forms longitudinal valleys termed "gaps". These valleys are absent at the western end, and outcrops are in the form of boulder-like joint-blocks. There is a mobilized sediment core in the far west which varies in width, and is not continuous. The metamorphism produced by the dyke is very slight and has recrystallised the wall rock only to a limited extent. The absolute age of the dyke is thought to be similar to that of the south Gap Dyke, which is 171 million years. It penetrates all other dolerite intrusions which it intersects.

CHAPTER TWO: PETROGRAPHY.

The petrography of the dyke is most conveniently dealt with by describing separately the different rock types making up the intrusion.

(i) The Core. The core is a mobilized sediment, very similar in appearance to the surrounding Beaufort sandstone, which is highly recrystallised and contains small, angular, shale-like fragments. It occurs in two sections at the western end of the dyke and varies considerably in width.

(ii) The Dolerite Flanking the Core. This is of two types: a granophyric dolerite contiguous with the core, and a subophitic dolerite between the granophyric dolerite and the walls of the dyke. Both varieties vary in width. Exposures are poor and only the core tends to crop out. The only good exposure occurs in the Surbiton railway cutting where, as elsewhere, the dolerite is very highly weathered.

(iii) The Thomas River Area. Here a variety of rock types occur, including a granophyric dolerite very rich in micropegmatite. The predominant rock type is a granophyric dolerite which has enclosed in it metasomatized xenoliths of sedimentary origin, acid veins and a dolerite xenolith. Further east this passes fairly sharply into a mottled-looking dolerite. The core material is absent in this area but crops out both to the west and east of the valley.

(iv) The "Transkei type" Dolerite. This is a dolerite pegmatite which shows hardly any variation throughout the Transkei. At the coast a more basic variety occurs which contains no quartz, orthoclase or micropegmatite.

(v) The Sediments. Throughout the length of the dyke the sediments are Beaufort sandstone. The sandstone shows very little change but becomes slightly less feldspathic east of Cathcart.

CHAPTER THREE: MINERALOGY.

(A) Mineralogy of the dolerite types making up the north Gap Dyke.

(i) Plagioclase. Grain size measurements of the plagioclase laths show there is considerable variation in crystal size along the length of the dyke but very little across the width. The plagioclase crystals tend to be small where the core is present and increase in size where it is absent. The anorthite content also varies, the more acid plagioclase being found near the core. Progressive zoning of the crystals is conspicuous, as is the typical polysynthetic twinning. Alteration to saussurite and replacement by micropegmatite, where this is present in large amounts, ~~is~~ ^{are} common. Irregular veins of quartz and orthoclase may also be found penetrating plagioclase crystals.

(ii) Pyroxene. In all the dolerite types the pyroxene is augite with a composition, determined by optical properties, approximating to $\text{Ca}_{41}\text{Mg}_{31}(\text{Fe}^{2+} + \text{Fe}^{3+} + \text{Mn})_{28}$. It is quite often twinned on (100) and, because of well developed basal parting, attractive "herring-bone" structure is common. The pyroxene is frequently altered to brown hornblende and other minerals, such as chlorite, serpentine and iddingsite (?).

(iii) Amphibole. Both actinolite and hornblende are recognised. Actinolite is common and occurs as acicular crystals or "brushes". Hornblende, which is green or brown, or even both colours in a single zoned crystal, occurs either surrounding relict grains of pyroxene or as subhedral crystals.

(iv) Micropegmatite. This term includes myrmekite. The texture may be either interstitial or replacement, usually depending on the relative amount of micropegmatite present.

(v) Other Minerals. These include: orthoclase, quartz, biotite, ore minerals, apatite, calcite, epidote, prehnite, chlorite and iddingsite (?).

(B) The mineralogy of the mobilized sediment core is simple and fairly constant. The core is composed essentially of quartz and feldspar, very often intimately intergrown, and has in smaller amounts chlorite, sphene, ore minerals and some apatite.

CHAPTER FOUR: PETROLOGY.

The micrometric analyses of the different rock types show only the variation in the mineral composition.

The most convenient method of describing the chemical analyses is to subdivide the dyke into arbitrary divisions.

(i) The Core. The analysis of the core material is very similar to that of the surrounding Beaufort sandstone.

(ii) The Thomas River Area. An analysis of the granophyric dolerite found extending across the entire width of the dyke in the western side of the section where the core is missing shows it to be very rich in SiO_2 . The chemical analysis itself does not show whether this rock is the product of assimilation or differentiation. The evidence of the coarse patches in the granophyric dolerite found predominating in the area seems to confirm the belief that these patches are metasomatized xenoliths of a sedimentary origin. Other analyses include one of the acid

veins and one of the "mottled rock".

CONCLUSIONS.

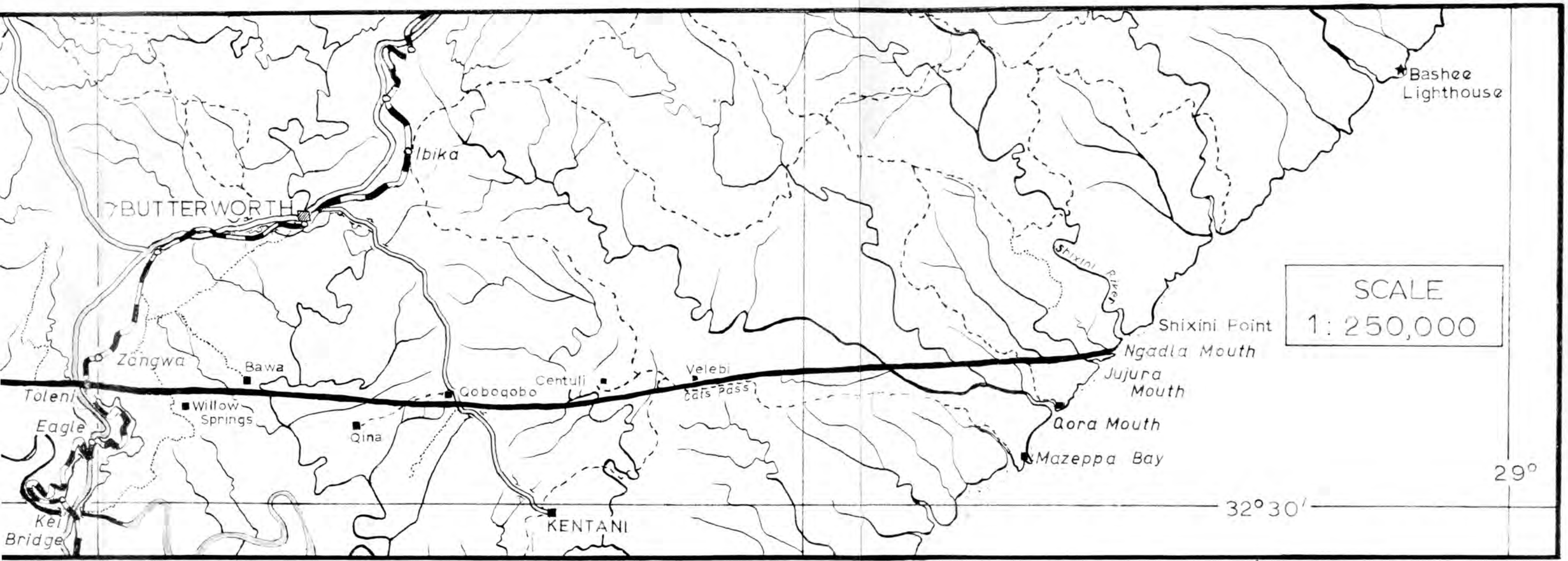
Origin of the Core. From all the evidence compiled there seems to be no doubt at all that the core material has a sedimentary origin, and very little that it has been mobilized. The problem as to its emplacement, however, remains without a satisfactory solution.

Origin of the Magma. No definite conclusion can be reached and there remain two possibilities: either the magma represents the product of differentiation of dolerite magma, or else it was formed as the result of hybridization possibly followed by differentiation. The subophitic dolerite flanking the core may represent the contaminated but undifferentiated magma and exists only because differentiation was inhibited by the rapid cooling promoted by the core. The Thomas River valley is a critical area. It is here that the core is absent although it crops out both to the east and to the west of this area. The peculiar rock types found there almost certainly owe their existence to some influence exerted by the core. Further research in this area might lead to some very interesting results, and show whether the rock types were produced as the result of an advanced degree of differentiation, aided by the core, or whether they were produced by assimilation of the core at this point.

REFERENCES.

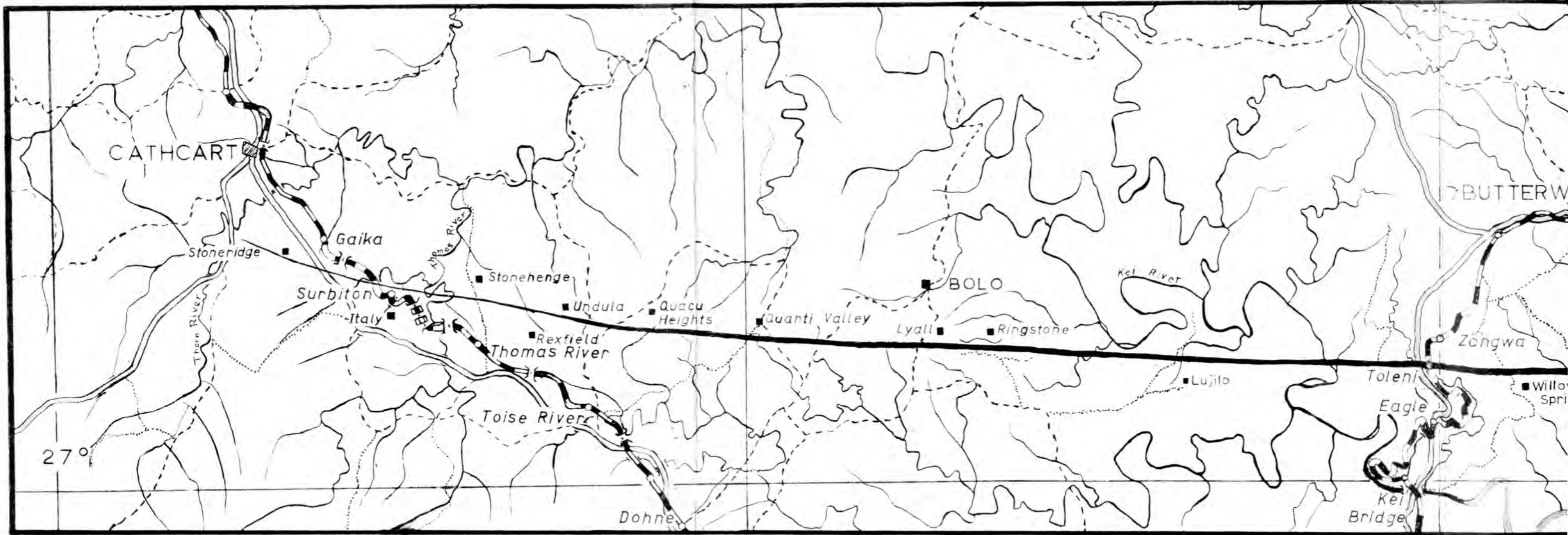
- ALLING, H. L. (1936) Interpretative petrology of the igneous rocks, 1st. Ed. McGraw-Hill, New York. 353 p.
- BARTH, T. F. W. (1952) Theoretical petrology, John Wiley and Sons, Inc., New York. 387 p.
- BORDER REGIONAL SURVEY, (1957) The Border region, Geology. by E. D. Mountain. (Map). University Press, Oxford.
- BOWEN, N. L. (1956) The evolution of igneous rocks, Dover Publications, Inc., New York. 332 p.
- CHUDOBA, K. and KENNEDY, W. Q. (1933) The determination of the feldspars in thin section. Thomas Murby, London. 61 p.
- DU TOIT, A. L. (1956) The geology of South Africa, 3rd. Ed., Oliver and Boyd, Edinburgh. 611 p.
- DEER, HOWIE and ZUSSMAN (1963) Rock forming minerals, Volume 2 -- chain silicates, Longmans, London. 379 p.
- EALES, H. V. (1953) The Khale sheet. Thesis presented for the degree of Master of Science, to Rhodes University, Grahamstown. 100 p.
- GROVES, A. W. and MOURANT, A.E. (1929) Inclusions in apatite of igneous rocks, Mineralog. Mag., Vol. XXII, No. 125, pp. 92 - 99.
- HALLIMOND, A. F. (1956) The polarizing microscope, 2nd. Ed., Cooke, Troughton and Simms, Ltd., York. 219 p.
- HESS, H. H. (1949) Chemical composition and optical properties of common clinopyroxenes, Part 1, Am. Mineralogist, Vol. 34, Nos. 9 and 10, pp. 629 - 666.
- LINDGREN, W. (1933) Mineral deposits, 4th. Ed., McGraw-Hill, New York. 930 p.
- MOUNTAIN, E. D. (1937) Anatectite veins at Gonubie river mouth, South African Jour. Sci., Vol. XXXIII, pp. 248 - 253.
- (1943) The dikes of the Transkei gaps, Trans. geol. Soc. S. Afr., Vol. XLVI, pp. 55 -73.
- (1945) Problems of Eastern Province geology, Anniversary address, Proc. geol. Soc. S. Afr., Vol. XLVIII, pp. xxi - xxxvii.
- (1958) Acidification of dolerite at Coedmore quarries, Durban, Trans. geol. Soc. S. Afr., Vol. LXI, pp. 209 - 219.

- McDOUGALL, I. (1963) K - A Age measurements on dolerites from Antarctica and South Africa, Jour. of Geophysical Research, Vol. 68, No. 5, pp. 1535 - 1545.
- ROGERS, A. W. and SCHWARZ, E.H.L. (1904) The Transkei Gap, Trans. S. A. Phil. Soc., Vol. 14, pp. 66 -75.
- TEALL, J. J. H. (1888) British Petrography, Bemrose and Sons, London. 469 p.
- TYRRELL G. W. (1916) The picrite - teschenite sill of Lugar (Ayrshire), Geol. Soc. London, Quart. Jour., Vol. LXXII, pp. 84 -131.
- WAGER, L. R. (1929) Metasomatism in the Whin Sill, Geol. Mag., Vol. 66, pp. 223 - 225.
- and DEER, W. A. (1939) Geological investigations in East Greenland, part III. The petrology of the Skaergaard intrusion, Kangerdlugssuaq, East Greenland, Meddelser om Grønland, Bd. 105, No; 4.
- WALKER, F. (1930) The geology of the Shiant Isles (Hebrides), Geol. Soc. London, Quart. Jour., Vol. LXXXVI, pp. 355 - 398.
- (1940) The differentiation of the Palisade diabase, New Jersey, Bull. Geol. Soc. Am., Vol. 51, pp. 1059 - 1106.
- (1942) The origin of the Kentani gap-dykes of the Transkei, Cape Province, Trans. Roy. Soc. S. Afr., Vol. 30, pp. 79 - 83.
- (1953) The pegmatite differentiates of basic sheets, Am. Jour. Sc., Vol. 251, pp. 41 - 60.
- and POLDERVAART, A. (1940) The petrology of the dolerite sill of Downes Mountain, Calvinia, Trans. Geol. Soc. S. Afr., Vol. XLIII, pp. 55 - 64.
- (1942) The metasomatism of Karroo sediments by dolerite, Trans. Roy. Soc. S. Afr., Vol. 29, pp. 285 - 307.
- (1949) Karroo dolerites of the Union of South Africa, Bull. Geol. Soc. Am., Vol. 60, pp. 591 - 706.
- WINCHELL, A. N. and WINCHELL, H. (1951) Elements of optical mineralogy, part II. Descriptions of minerals, 4th. Ed., John Wiley and Sons, Inc., 551 p.
- WINKLER, H. G. F. (1949) Crystallisation of basaltic magma as recorded by variation of crystal size in dykes, Mineralog. Mag., Vol. XXVIII, No. 205, pp. 557 - 574.
-



SCALE
1: 250,000

F THE NORTHERN GAP DYKE



THE COURSE OF THE NORTHE