THE PROBLEM OF THE QUARTZ DOLERITES: SOME SIGNIFICANT FACTS CONCERNING MINERAL VOLUME, GRAIN SIZE AND FABRIC

By

GERMAINE A. JOPLIN

Australian National University, Canberra

(With 14 text figures and 5 tables)

Appendix

THE VARIATION OF DENSITY AND MAGNETIC PROPERTIES

By

J. C. JAEGER

Australian National University, Canberra

(With 5 text figures)

(*Communicated by Professor S. Warren Carey*)

INTRODUCTION

The problem of the quartz dolerites has been attacked by a number of methods, yet much remains to be discovered regarding the differentiation of these rocks.

Chemical methods and mineralogical studies, particularly with regard to the pyroxenes, have thrown much light upon the problem, but the extreme uniformity of the dolerites still remains unexplained, and makes the matter of attack on their genesis difficult.

The Tasmanian dolerites have been studied fairly exhaustively by chemical methods (Edwards, 1942), though little serious detailed work has yet been done on their mineralogy. Recently the problem has been attempted on a physical basis (Jaeger and Joplin, 1955) and measurements of magnetic intensity, magnetic susceptibility and density have indicated differences in rock type which are not readily apparent either in the field or by using the normal microscopic methods.

On the results of this physical work a method of differentiation was expounded, and though no detailed mineralogical work was attempted, microscope examination indicated that there was nothing to suggest that this type of differentiation could not have occurred. Whilst engaged on these examinations, however, the present writer was struck by differences in fabric and grain size within a single microscope section and it was thought that such observations were highly significant in discussing the cooling history. This communication, therefore, is a compilation of such data, together with a series of modal analyses, and a brief discussion on the significance of these observations with regard to magmatic differentiation.

The writer is indebted to Professor J. C. Jaeger for supplying the appended data on density and magnetic properties, and for much helpful discussion. She would also like to thank Messrs. A. Spry and R. Ford and Dr. Williams of the Department of Geology, University of Tasmania as well as Mr. G. Hale of the Hydro-electric Commission of Tasmania for taking her to many places of interest in the Hobart area and in the Upper Derwent Valley. The author also wishes to thank Professor S. W. Carey for his help for communicating the paper.

FIELD OCCURRENCE

Twelvetrees and Petterd (1899) and Edwards (1942) have remarked on the extreme uniformity of the Tasmanian dolerite sills in the field, although Edwards has mentioned the occurrence of chilled margins and of occasional pegmatites. Nevertheless, Edwards' own chemical work has shown that quite considerable differentiation has occurred, and, as noted above, physical measurements (Jaeger and Joplin, 1955) have also indicated marked differences. Furthermore, micrometric analysis reveals much variation of mineral volume among the limited number of constituent minerals.

Recent work by Tasmanian geologists indicates that many of the so-called sills show transgressive relations to the sediments and thus should be termed " sheets ".

Recently a short field trip was undertaken to examine quarry, road and shore sections in some detail in an endeavour to observe any field evidence of differences that had been noted in the laboratory. Most of the exposures examined occurred in and about Hobart and in the Upper Derwent Valley.

Brief notes on these sections are given below and it is concluded that the sills commonly show chilled margins of varying width, that pegmatites, occurring as discrete veins or schleirren or, more commonly, as elongated patches merging into the normal dolerite, are developed as a rule not far below the upper chilled margin. Pegmatites were not noted near lower contacts, but careful examination revealed finer grained veins or patches in some places. In general, the normal dolerite is extremely uniform. Calcite, and sometimes pyrite and zeolites are present along joint planes, especially in the region immediately below the upper chilled margin, and in one case fine basaltic veins were seen to intersect the upper marginal phase.

Unfortunately the cuttings on the road up Mount Wellington are somewhat weathered and in places covered by talus. Good exposures occur for the first 200 feet above the base and this is followed by about 80 feet covered by talus. In this latter section a junction betwen very fine dolerite and medium-grained dolerite was observed. The block showing this junction was not *in situ*, though the texture of the coarser type indicated that it had not travelled far and certainly had not come from the upper portion of the sill. The finer grained rock contained a larger proportion of ferromagnesian mineral, and as the junction was not sharp it suggested a vein-like mass injected before the host rock had completely solidified.* At 280 feet above the base the dolerite is exposed *in situ* in a steep cutting but is overlain by talus at a short distance from the road. From then on, the road section is covered intermittently to about 800 feet above the base, after which exposures are good to the summit of the mountain. There is a marked change in the texture of the rock above about 400 feet, the upper portion being much coarser and a little lighter in colour.

On the cliff section at Blackmans Bay the top of a sill is exposed. The marginal dolerite is fine to medium grained and is cut by small veins of very fine dolerite (basalt). At the base of the cliff a small storm beach is made up of large boulders of medium-grained dolerite which contain veins and patches of coarse pegmatite. It is assumed that these have been torn from a submerged rock-platform nearby and represent a slightly lower level of the sill.

In one of the quarries on Proctors Road, in the Mount Nelson sill, two coarse pegmatite veins, parallel to one another and connected by a small cross vein, intersect normal dolerite. These masses are presumably parallel to the upper contact which is not exposed in this quarry.

In the Upper Derwent area, near Tarraleah, several small quarries expose the upper contacts of sills. One of these shows small masses of pegmatite near the top of the sill, but in other quarries, and in the diversion tunnel through dolerite, the rock appears to be extremely uniform.

In the Great Lake area near the collar of bore 5001, it is reported that there is a good deal of pegmatite amongst surface exposures. Petrographical and magnetic evidence suggests that the collar is not far below the top of the sill, though there is no direct field evidence that this is so. It was stated by Jaeger and Joplin (1955) that sediments were *in situ* nearby, but unfortunately this statement was made in error and we would like to take this opportunity of correcting it.

MODAL ANALYSES

Bore cores provide most of the material for this study, and although they have been carefully logged the full thickness of the sills, or the exact part of the intrusion penetrated, is rarely known. In some cases upper or lower contacts have been encountered, but at present there is no record of any large sill showing both contacts. The mass examined by Jaeger and Joplin (1955) represents 1050 feet of dolerite, and although guesses were made as to the total thickness of the intrusion its exact thickness still remains in doubt; furthermore, some of the Tasmanian geologists now raise the doubt as to whether it is in fact a sill or a vertical feeding channel.

In an attempt to throw some further light on these questions, it is assumed that the well-documented Palisade sill represents the normal behaviour of such intrusions, and modal analyses from a number of sections (Walker, 1940) have been plotted in figs. 1-4. These show that there is a very definite and constant pattern, and that the amounts of pyroxene and plagioclase are nearly equal for the first 100 feet above the base. In the first 10 or 20 feet plagioclase may exceed pyroxene, but only by a comparatively small amount. Both minerals decrease in the region of the olivine ledge and pyroxene always exceeds plagioclase at this level. Immediately above the olivine layer both minerals increase again with pyroxene still a little in excess of felspar. Above 100 feet there is a sudden marked increase in plagioclase and a concomitant decrease in pyroxene until the level of from 500 to 700 feet is reached. Above this the amounts of the two minerals gradually approach one another again until they are equal, or only a few volumes per cent apart, at the upper contact.

Olivine occurs at both upper and lower contacts and reaches a maximum at the olivine ledge from 50-80 feet above the base. The mesostasis, which in this sill consists of a micropegmatitic intergrowth of quartz and felspar, is never abundant but gradually increases from immediately above the olivine-rich layer until it reaches a maximum of some 7 per cent within 50-100 feet of the upper contact. There is a slight enrichment of iron ore at the lower contact and a slight, though abrupt, decrease in the first few feet. The iron ores then slowly and steadily rise to a maximum at much the same position as that attained by the mesostasis.

* A similar vein occurs at 410 feet above the base of the borehole 5001 and is figured in fig. 12*c*.

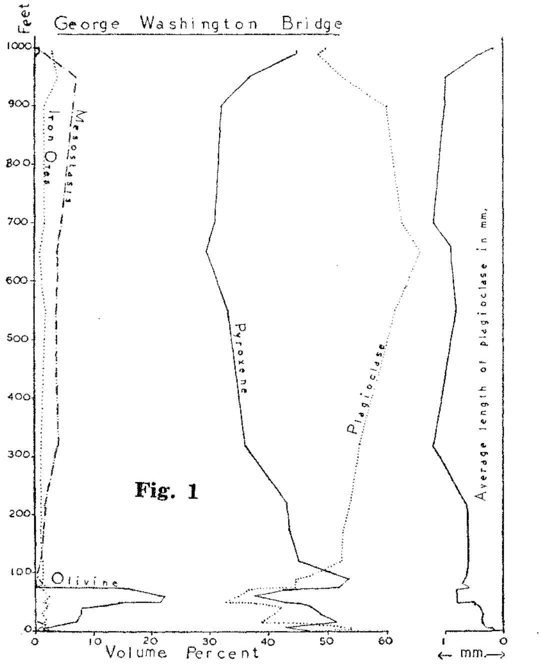

Fig. 1

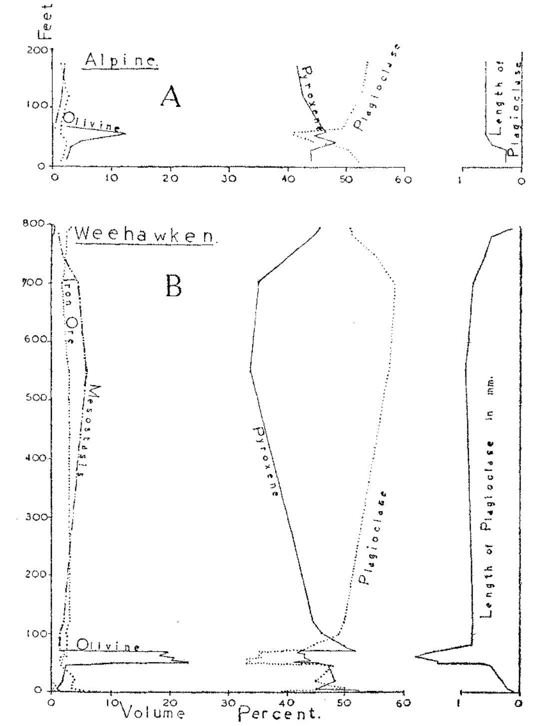

Fig. 3

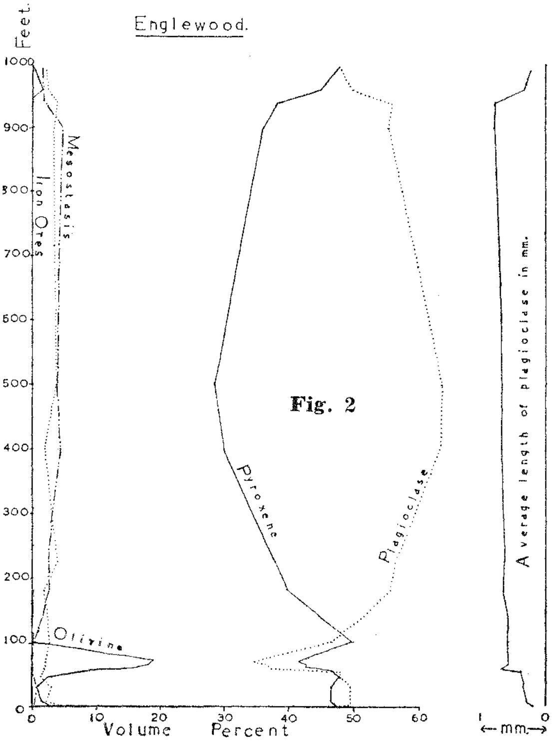

Fig. 2

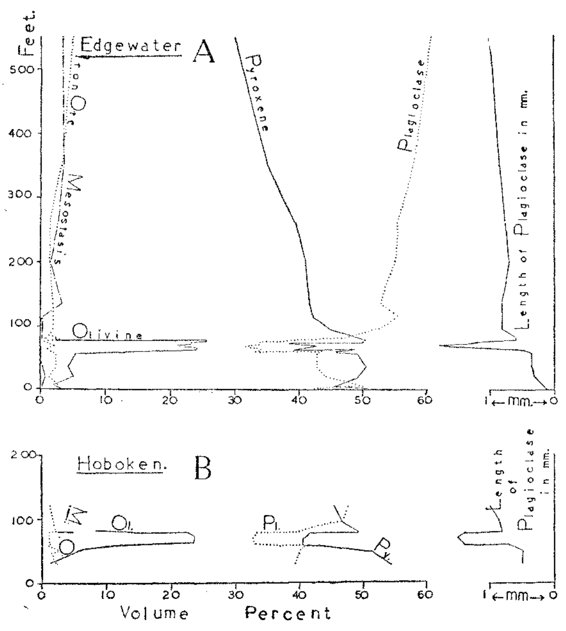

Fig. 4

FIGS. 1-4.—Plots of micrometric analyses of various sections of the Palisade sill, New Jersey.

TABLE I
Mount Wellington

Height above base of Sill	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Orthoclase	Iron Ores	Average length of Plagioclase		Average Diameter of Plagioclase		
1140′ ..	15.8	41.6	27.8	10.0	0.6	—	3.9	—	—	0.18	—	0.45
1120′ ..	16.3	44.7	25.0	6.9	1.9	—	5.1	—	—	0.18	—	0-72
1100′ ..	13.9	38.9	38.9	5.2	2.4	—	1.6 *e*	—	—	0.04	—	1.20
1095′ ..	23.7	38.3	24.4	6.5	—	—	2.9	—	—	0.22	—	0.54
1080′ ..	6.6	47.8	40.1	3.0	0.3	—	2.0	—	—	0.18	—	0.72
1065′ ..	12.6	43.4	29.2	9.9	nd	—	4.9	—	—	0-27	—	0.90
1050′ ..	14.2	47.3	27.4	8.7	0.5	—	1.9	—	—	0.29	—	0.77
1045′ ..	7.9	43.2	24.1	19.5	0.8	—	4.2 *e*	0.7	1.3	0.29	—	0.63
1025′ ..	20.7	41.6	26.5	7.6	1.4	—	2.1	0.7	1.2	0.29	—	0.72
1020′ ..	16.7 *a*	42.2	28.6	10.4	—	—	2.1	0.7	1.0	0.29	—	0.54
980′ ..	13.0	47.2	29.6	7.8	—	—	2.5	0.7	—	0.27	—	0.54
975′ ..	12.7	51.5	25.8	7.9	—	—	2.0	0.3	2.0	0.22	—	0.77
965′ ..	21.3	46.4	21.9	5.4	—	—	5.0	0.5	1.4	0.23	—	0.66
945′ ..	20.5	47.1	24.4	4.4	0.6	—	3.0	0.5	0.9	0.22	0.36	0.54
930′ ..	19.5	46.7	20.9	8.8	—	—	4.0	0.6	0.7	0.27	—	0.54
830′ ..	8.3	50.6	32.3	6.6	—	—	2.2	0.3	0.9	0.22	—	0.59
800′ ..	17.1	46.6	26.8	6.9	—	—	2.5	0.6	—	0.22	—	0.72
680′ ..	13.2	54.4	20.6	9.6	—	—	2.1	0.5	0.9	0.20	—	0.39
650′ ..	14.1	54.7	23.8	5.7 *b*	—	—	1.6	0.6	1.0	0.20	—	0.77
460′ ..	17.2	57.0	21.8	1.2	1.3	—	1.2	0.6	0.7	0.20	—	0.54
430′ ..	18.9	57.4	19.7	1.9	—	—	1.9	0.6	1.0	0.16	—	0.27
430′ ..	23.1	46.6	22.4	2.5	1.3	—	3 9	0.5	0.7	0.22	—	1.15 *c*
425′ ..	25.2	46.1	22.8	3.0	—	—	2.7	0.3	0.6	0.11	—	0.39
395′ ..	41.9	41.2	15.4	—	0.2	—	1.1	0.9	1.0	0.18	—	0.81
390′ ..	32.7	44.3	21.5	0.8	—	—	0.7	0.3	0.6	0.14	—	0.36
382′ ..	26.0	51.2	15.7	3.6	—	—	3.4	0.3	0.6	0.14	—	0.72
376′ ..	25.2	50.7	18.5	3.6 *b*	—	—	1.7	0.2	0.6	0.20	—	0.36 *c*
370′ ..	43.8	43.2	12.1	—	—	—	0.8	0.2	0.7	0.07	—	0.34
366′ ..	33.5	47.0	15.5	1.6 *b*	—	—	2.4	0.7	0.9	0.16	—	0.54
335′ ..	47.6	35.8	12.0	2.8	—	—	1.8	0.7	0.9	0.16	—	0.40 *d*
330′ ..	38.2	42.7	17.7	0.9	—	—	0.7	0.4	0.6	0.13	—	0.45 *c*
324′ ..	51.1	37.0	9.3	1.4	—	—	1.1	0.7	—	0.13	—	0.30 *c*
320′ ..	35.8	46.7	15.9	0.1 *b*	0.1	—	1.1	0.7	—	0.13	—	0.36 *c*
291′ ..	46.3	41.3	11.4	0.1 *b*	—	—	1.0	0.9	—	0.14	—	0.29 *c*
280′ ..	44.7	41.2	12.1	0.2	—	—	1.7	0.5	0.6	0.11	—	0.27
280′ ..	49.8	35.2	14.2	—	—	—	0.8	0.7	0.9	0.11	—	0.23
198′ ..	47.8	42.9	6.5	1.0	—	—	1.3	0.3	0.9	0.09	—	0.22
197′ ..	45.0	43.7	6.5	0.3	2.1	0.9	1.4	0.3	0.7	0.09	—	0.29
194′ ..	41.8	46.4	5.3	1.3	2.6	0.5	1.9	0.5	0.9	0.11	—	0.20
180′ ..	36.7	51.2	9.3	1.1	0.6	—	1.3	0.4	1.0	0.09	—	0.30
155′ ..	43.3	43.3	2.7	0.7	7.1	1.0	1.7	0.3	0 5	0.07	—	0.27
149′ ..	45.4	45.6	2.2	0.3	4.2	0.6	1.7	0.2	0.7	0.09	—	0.36
144′ ..	50.0	37 6	2.8	0.8	5.2	2.7	1.6	0.2	1.5	0.07	—	0.36
140′ ..	41.6	49.9	3.3	2.7 *b*	—	—	2.3	0.2	1.2	0.09	—	0.36
128′ ..	52.7	37.6	3.2	0.2 *b*	3.5	1.3	1.6	0.2	1.1	0.09	—	0.20
119′ ..	45.3	44.1	3.8	0.8 *b*	4.5	—	1.3	0.5	1.2	0.05	—	0.14
102′ ..	43.1	35.5	4.8	1.9	11.8	—	2.8	0.2	—	0.05	—	0.20
90′ ..	49.4	35.7	5.3	2.9	3.6	0.6	2.2	0.2	—	0.05	—	0.54
79′ ..	42.0	35.4	4.5	—	9.5	4.9	3.5	0.3	—	0.07	—	0.20
70′ ..	50.3	37.7	3.3	1.8	2.3	0.7	3.7	0.2	0.3	0.05	0.12	0.20
61′ ..	45.8	35.2	5.1	1.4	6.1	2.9	3.4	0.3	0.4	0.05	0.11	0.36
55′ ..	43.1	40.9	4.7	2.8	1.1	1.7	5.6	0.2	0.4	0.05	—	0.18
51′ ..	48.5	34.5	4.3	3.8	3.5	—	5.3	0.3	—	0.05	0.11	0.18
47′ ..	48.2	32.3	11.3	2.8	1.2	—	4.0	0.4	—	0.09	—	0.27
43′ ..	47.4	35.1	7.2	2.7	2.8	0.9	3.7	0.1	0.5	0.09	—	0.23
33′ ..	46.2	30.2	12.1	8.1 *f*	0.2	0.5	2.4	0.1	0.3	0.02	0.07	0.18
32′ ..	46.2	32.0	14.7	2.0	—	—	5.0	0.3	—	0.07	—	0.18
30′ ..	48.7	34.4	2.5	1.8	6.3	1.7	4.7	0.1	0.3	0.02	0.07	0.30
27′ ..	44.3	30.6	17.7	3.0	—	—	4.3	0.1	1.0	0.02	—	0.11
23′ ..	46.9	29.1	17.7	1.4	0.8	—	4.0	0.1	0.3	0.05	—	0.27
18′ ..	47.3	32.0	15.8	—	0.5	—	4.5	0.2	0.3	0.04	—	0.18
12′ ..	47.8	35.2	13.9	—	0.03	—	2.7	0.3	0.5	0.05	—	0.13
6′ ..	46.8	28.4	19.0	—	—	—	5.6	0.3	—	0.01	0.05	0.27
3′ ..	40.0	31.6	17.6	3.8 *f*	—	—	6.9	0.2	0.3	0.03	0.07	0.14
1′ ..	38.3	35.4	18.9	0.5	—	—	6.8	0.2	0.3	0.01	0.09	0.36
0′ ..	41.8	30.2	17.3	0.4	1.2	—	9.0	0.2	0.3	0.03	—	0.07

Anal. G. A. JOPLIN

a Small amount of Hornblende counted as Pyroxene.
b Small amount of Biotite, mainly chloritized, and counted as chlorite.
c Larger Plagioclase zoned.
d Larger Plagioclase tabular and interstitial.
e Including small amount of Pyrite.
f Pyroxene partly chloritized.

It seems obvious that Walker made micrometric measurements of normal types of dolerite only and that schleirren and veins were deliberately excluded.

If the same method and scale is used in plotting the modal analyses of some of the Tasmanian dolerites a very similar pattern emerges. Actually a greater number of analyses have been used in the Tasmanian sections, they are more closely spaced and the material was not selected to illustrate the magmatic differentiation but rather to study odd magnetic properties, so it is probable that slides have been made of schlieren and veins which are not very apparent in the small bore core (diameter $\frac{3}{8}$"). As indicated by the work of Edwards (1942) there is no evidence of any ferromagnesian ledge, though in the Mount Wellington sill there is an enrichment of magnesian pyroxene at the 280 foot level.

Apart from the scarcity or absence of olivine in the Tasmanian sills the greatest difference between them and the Palisade lies in their greater abundance of mesostasis, which attains a value of about 30 per cent of the total volume in a rock near the top of Mount Wellington. The mesostasis of these rocks consists either of a micropegmatic intergrowth of quartz and felspar, of small quartz grains surrounded by chlorite, of chlorite alone or most commonly of indefinite felspathic material. Much of this felspar is potassic and it may occur as irregular grains or as radiating masses (figs. 11*c*, 12*b*, 13*a*) often pierced by long slender needles of plagioclase which appear to be outgrowths from adjacent plagioclase laths (fig. 11 *c*). Small quantities of biotite and grains of iron ore commonly occur in the mesostasis, the latter being more abundant in the upper more acid region of the sill and occurring as minute grains around the bordering minerals or in larger grains moulded on felspar and pyroxene. (Figs. 11 *b*, and *c*, 12 *b* and *c*, and 13 *b*.)

As the base of the Mount Wellington sill is exposed and the mass is of comparable thickness to the Palisade sill, it was thought desirable first to compare this section with the New Jersey example. Most of the material was collected by Professor Jaeger using an aneroid barometer, and though at the time of collecting there were no bench-marks on the mountain and no exact corrections were made for barometric variations, the relative positions of specimens are quite definite.

Reference to fig. 5 shows that the general pattern of what is taken to be the typical example (the Palisade) is apparent, though slightly masked by minor variations. Examination shows that the amounts of plagioclase and of pyroxene remain fairly close together until the level of 400 feet is reached, but more critical examination reveals that, except for three analyses which may represent veins, there is a falling off of pyroxene and an increase of plagioclase at about the 300 foot level. It may be significant that the magnesian-rich dolerite, which Edwards regards as the most basic part of the sill, occurs at 280 feet and that immediately above the ultrabasic olivine ledge of the Palisade sill plagioclase becomes excessive over pyroxene. Unlike the Palisade Sill, however, pyroxene exceeds plagioclase at the actual contact, though this may be exceptional since Mr. A. Spry of the University of Tasmania reports that a micrometric measurement made by one of his students showed the reverse and Edwards found 45 per cent of plagioclase at the margin. Immediately above the magnesia-rich layer there is a general decrease of pyroxene and an enrichment of plagioclase, although this is not clearly indicated until the 400 foot level is reached. As pointed out in the notes on the field occurrence a fine grained darker vein was encountered in a boulder below this level and it is possible that the three rocks which appear abnormal between 280 feet and 400 feet may represent such veins or segregation patches.

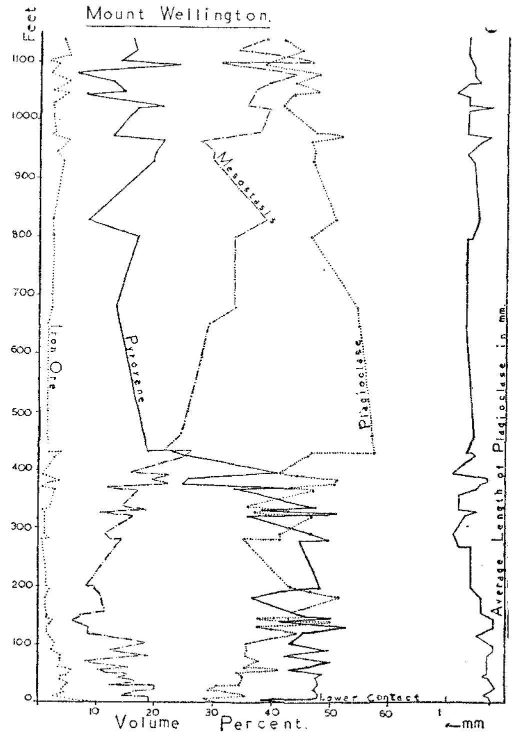

FIG. 5.—Plot of micrometric analyses of Mount Wellington sill, Tasmania.

Above 400 feet the amounts of pyroxene and plagioclase diverge and their behaviour is exactly similar to that of the minerals of the Palisade sill, except that both tend to be slightly lower as the amount of mesostasis increases sharply above 200 feet. The quantity of iron ores is greater in the Tasmanian rock, though the behaviour of the curve is exactly similar. Chlorite, quartz and orthoclase have been added to the mesostasis in plotting these graphs except where it is indicated that chlorite is replacing pyroxene.

Reference to fig. 6 shows that Bore 5001 follows the same general pattern, and, except for a greater number of possible veins and segregations (deliberately chosen because of their magnetic properties) * is closely comparable to the Mount Wellington sill above the 300 foot level. Furthermore, the amounts of pyroxene and plagioclase are drawing closer together near the top of the bore, thus suggesting that this level may be a higher one than that represented by the top of Mount Wellington, and is in fact near the actual top of the intrusion. These observations suggest that 5001 is a normal sill and that its base may be reached at another 300 feet.

* Reference to Jaeger and Joplin (1955) figs. 1 and 3, shows that there is a peak in the intensity of magnetization and in the magnetic susceptibility at 949 feet, that is at 101 feet above the base of the bore. Figure 6 of the present paper shows a marked increase in the amount of mesostasis at this point. The mesostasis usually carries minute grains of iron ore too small for measurement as such.

TABLE II
Bore Core 5001

Height above bottom of bore	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Iron Ores	Average length of Plagioclase		Average diameter of Plagioclase		
1049′	1′	33.2	41.0	21.6	2.6	—	1.7	0.6	0.7	0.05	—	0.39
1032′	18′	28.1	43.6	21.1	1.8	2.5	2.7	0.4	0.6	0.14	—	0.36
1000′	50′	28.9	31.8	23.8	10.0	—	5.3	0.2	—	0.45	—	0.80
944′	106′	33.5	43.0	19.2	1.9	—	2.3	0.5	1.5	0.18	0.54	1.37
902′	148′	15.7	46.3	24.9	6.0	3.1	3.8	0.6	—	0.11	—	0.54
897′	153′	6.0	43.7	37.0	8.7	—	4.8	0.3	0.4	0.09	—	0.27
850′	200′	21.5	45.8	18.6	10.7	—	3.3	0.4	1.0	0.18	—	0.72
769′	281′	16.6	44.5	18.3	9.2	—	9.2	0.6	1.0	0.18	—	0.72
754′	296′	16.4	46.9	26.1	7.4	—	3.0	0.5	0.7	0.20	—	0.48
741′	309′	17.7	36.7	23.6	12.1	1.5	8.2	0.7	—	0.25	—	1.71
707′	343′	27.7	39.3	17.5	11.5	—	3.8	0.6	—	0.29	—	0.90
653′	397′	27.7	34.3	19.5	13.8	—	4.5	0.5	—	0.25	—	0.54
650′	400′	20.8	35.7	23.7	12.7	—	7.0	0.3	0.7	0.21	—	0.37
639′	411′	26.0	35.2	26.8	6.8	—	5.1	0.5	0.6	0.22	—	0.37
570′	480′	24.7	45.6	20.5	6.5	—	3.0	0.3	0.5	0.23	—	0.90
537′	513′	12.8	50.6	25.5	5.2	—	5.8	0.5	—	0.22	—	0.27
450′	600′	6.4	56.7	21.5	13.7	—	1.5	0.3	1.0	0.13	—	0.36
438′	612′	24.4	49.3	19.3	3.8	—	3.1	0.6	—	0.14	—	0.54
426′	624′	11.8	48.9	31.7	4.3	—	3.3	0.3	0.9	0.27	—	0.39
409′	641′	20.6	47.2	20.6	—	—	11.6	0.6	0.7	0.22	—	0.66
383′	667′	33.5	42.1	19.9	1.8	—	2.5	0.5	0.6	0.23	—	0.45
371′	679′	27.1	49.6	20 6	—	—	2.6	0.3	—	0.23	—	0.36
359′	691′	35.9	42.4	16.0	1.4	—	4.3	0.5	—	0.23	—	0.54
348′	702′	33.3	38.7	17.6	4.8	—	5.4	0.5	1.0	0.16	—	0.38
337′	713′	37.1	35.8	20.0	3.8	—	3.1	0.5	1.0	0.27	—	0.38
324′	726′	34.0	40.3	20.9	—	—	4.7	0.4	1.0	0.21	—	0.38
313′	737′	28.8	40.5	23.2	3.7	—	3.8	0.5	1.0	0.19	0.21	0.38
297′	753′	24.2	41.6	28.8	2.2	—	3.2	0.6	1.0	0.15	—	0.32
285′	765′	38.2	29.5	22.8	3.5	—	5.6	0.6	1.0	0.14	—	0.32
273′	777′	28.9	46.6	20.3	0.8	—	3 3	0.3	—	0.13	—	0.27
266′	784′	27.9	48.4	19.6	1.7	—	2.5	0.2	0.7	0.13	—	0.20
250′	800′	41.6	43.8	10.7	0.5	—	3.4	0.3	1.0	0.13	—	0.27
186′	864′	28.6	55.4	13.4	1.0	—	1.4	0.3	0.4	0.11	0.18	0.70
154′	896′	39.6	40.2	16.5	1.8	—	2.0	0.4	0.5	0.09	—	0.54
103′	947′	19.6	65.1	12.5	0.4	—	2.3	0.2	0.5	0.09	—	0.27
101′	949′	22.3	57.0	17.6	—	—	2.7	0.2	—	0.07	—	0.23
91′	959′	40.8	43.4	12.2	0.7	—	2.8	0.2	0.3	0.07	—	0.14
50′	1000′	30.0	53.3	10.5	2.5	—	3.6	0.3	1.0	0.07	—	0.27

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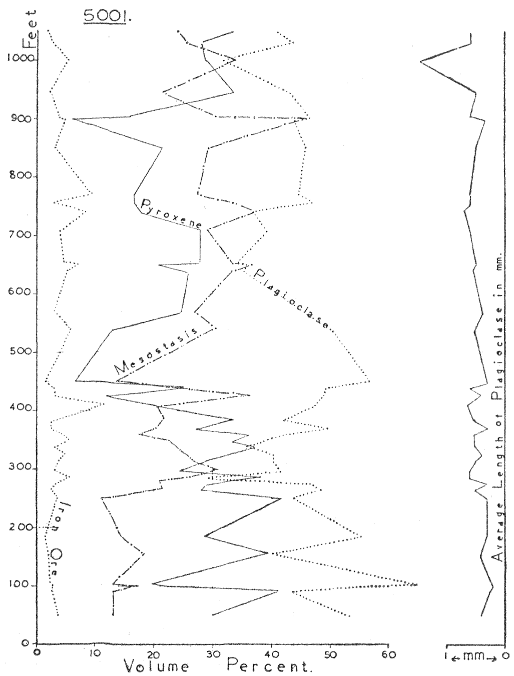

FIG. 6.—Plot of micrometric analyses of Bore Core 5001, Tasmania.

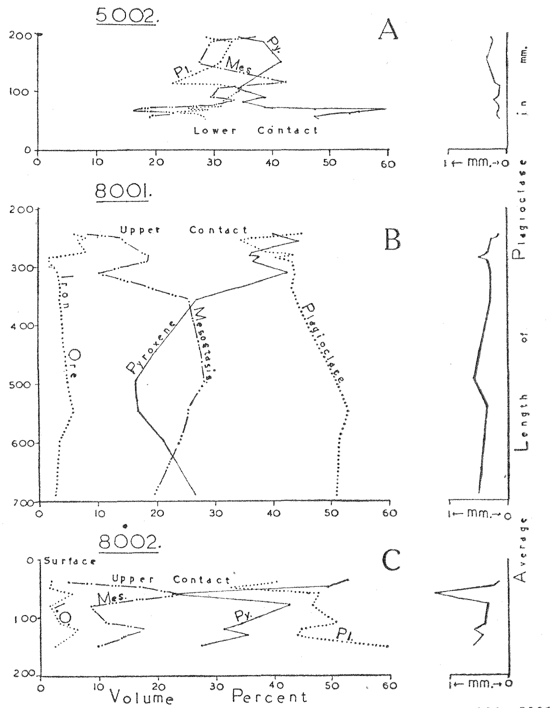

FIG. 7.—Plots o mic ometric analyses of Bore Cores 5002, 8001 and 8002, Tasmania.

TABLE III
Bore Core 5002

Height above base of bore	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Average length of Plagioclase	Predominating width of Plagioclase
138′	8′	34.2	28.7	37.1	0.30	0.07
133′	13′	38.6	33.0	28.4	0.24	0.08
97′	49′	41.3	31.1	27.6	0.30	0.08
59′	87′	35.2	22.6	42.2	0.24	0.08
54′	92′	34.3	34.9	30.8	0.30	0.08
37′	109′	38.2	32.3	29.5	0.32	0.08
30′	116′	34.9	31.5	33.6	0.25	0.08
22′	124′	38.7	31.2	30.0	0.25	0.07
17′	129′	47.5	25.7	26.8	0.20	0.05
15′	131′	59.2	23.5	17.2	0.18	0.04
14′	132′	54.9	28.9	16.2	0.18	0.05
11′	135′	53.5	23.4	23.0	0.18	0.04
9′	137′	50.1	26.9	23.0	0.20	0.04
5′	141′	47.2	33.2	19.2	0.20	0.05
2′	144′	47.9	33.4	18.7	0.28	0.06

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The Bore 5002 penetrates about 150 feet of dolerite and exposes the base of the sill. The modal analyses are plotted in fig. 7 *a* where it is seen that pyroxene and plagioclase are of similar amount, with the former in excess at the contact. Unfortunately iron ores have been counted with the mesostasis, so that the only reliable comparison that can be made with the other diagrams is on the basis of the pyroxene and plagioclase curves.

Figure 7 *b* shows an upper contact and a comparison with the standard pattern indicates that here the marginal zone is about 70 feet in width, since both pyroxene and plagioclase are very close together in amount, below this there is a sudden increase in the amount of plagioclase and of mesostasis and a concomitant decrease in pyroxene. To the present writer such a pattern indicates a sill of thickness comparable to the Palisade, Mount Wellington and 5001. Figure 7 *c* also shows an upper contact, the marginal zone being about 50 feet in thickness. This, together with the marked deviation of the curves for plagioclase and pyroxene below this level, also suggests a sill of somewhat similar dimensions.

TABLE IV
Bore Core 8001

Depth from upper contact	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Iron Ores	Averag length of Plagioclase	Predominating width of Plagioclase		
1′	245′	39.9	45.1	—	6.9	1.9	6.2	0.20	0.01	—	0.04
6′	250′	42.2	36.0	10.3	3.4	—	8.0	0.20	0.20	0.04	0.09
11′	255′	44.7	34.2	12.4	2.1	—	6.6	0.30	0.03	0.05	0.12
30′	274′	36.3	38.8	14.6	3.1	—	8.1	0.36	0.04	0.11	0.16
36′	280′	36.0	43.5	13.7	4.4	0.2	4.4	0.42	0.05	—	0.20
41′	285′	37.6	40.3	16.0	1.8	0.8	1.8	0.49	0.13	—	0.45
46′	290′	36.4	43.3	17.5	0.3	0.5	1.9	0.36	0.07	—	0.27
66′	310′	42.5	43.5	9.4	1.0	—	3.4	0.29	0.05	0.12	0.22
91′	335′	34.2	43.3	16.7	1.9	0.2	3.6	0.30	0.05	—	0.15
110′	354′	26.8	44.1	22.9	2.5	0.1	3.4	0.29	0.03	—	0.13
200′	444′	19.8	48.3	22.4	4.1	0.9	4.3	0.48	0.09	—	0.23
250′	494′	16.5	50.9	23.5	4.6	—	4.5	0.59	0.06	0.18	0.38
300′	544′	16.7	52.3	21.9	3.4	—	5.6	0.36	0.07	—	0.13
350′	594′	21.0	51.6	17.6	6.5	—	3.3	0.42	0.07	0.13	0.23
446′	690′	26.3	51.1	16.1	3.7	—	2.7	0.50	0.13	—	0.30

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TABLE V
Bore Core 8002

Depth from upper contact	Depth from surface	Pyroxene	Plagioclase	Mesostasis	Chlorite	Quartz	Orthoclase	Iron Ores	Average length of Plagioclase	Predominating width of Plagioclase		
5′	37′	52.7	40.3	4.5	0.4	—	—	2.0	0.15	0.04	—	0.0[illegible]
16′	48′	49.1	32.3	14.4	2.4	—	—	1.9	0.30	0.07	0.10	0.30
29′	61′	22.9	47.6	16.2	4.6	3.3	—	5.2	1.25	0.36	—	0.72
49′	81′	42.4	46.9	3.5	3.3	2.0	—	1.8	0.35	0.09	0.13	0.21
79′	111′	34.6	50.7	6.1	3.8	1.4	—	3.3	0.40	0.13	—	0.21
89′	121′	31.3	44.6	14.0	2.0	1.5	—	6.3	0.60	0.14	0.18	0.39
99′	131′	35.4	44.1	5.0	7.0	2.8	—	5.3	0.45	0.13	—	0.45
117′	149′	27.3*a*	59.2	5.7	1.7	2.5	0.9	2.6	0.60	0.11	0.16	0.36

a Little Hornblende counted as Pyroxene.

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GRAIN SIZE

Walker (1940) quotes the average length of plagioclase at different levels in the Palisade sill and these are plotted in figs. 1-4. To make the comparison of the Tasmanian sills with the New Jersey intrusion as complete as possible the length of plagioclase crystals were also measured in all slices from which a micrometric measurement was made and these are plotted in figs. 5, 6 and 7.

The Palisade examples all show that the crystals are shorter at the lower contact and steadily increase in length to about the 50 foot level and then rapidly attain a maximum in the olivine ledge, above which there is a sharp fall and then a steady slow rise to within about 100 feet of the upper contact above which a marked diminution in length is apparent.

Many of the Tasmanian rocks contain plagioclase crystals of two predominating lengths as shown in tables I-IV, but there is usually some gradation in size and an average is plotted in most cases, though in a few instances the predominant size has been taken. A comparison of the lengths plotted in figs. 5, 6 and 7 with those in figs. 1-4 will show a general similarity and the many small variations indicate possible veins and schlieren as noted above.

In figure 8 curves representing the frequency of distribution of plagioclase crystals of varying width are plotted for rocks at 18 feet and at 102 feet above the base of the Mount Wellington sill. The widths of 400 separate plagioclase crystals were measured in each slide by following parallel lines across the slide and measuring every crystal on the line. In the case of the 18 foot level it will be seen that there is a marked peak at 0·04 mm. and a smaller one at 0·18 mm. The curve for the rock at 102 feet shows a peak at 0·05 mm. and a minor one at 0·20 mm. The larger crystals are prominent but less abundant, but as they are often tabular there is a spread in the widths and their frequency is probably greater than is apparent.

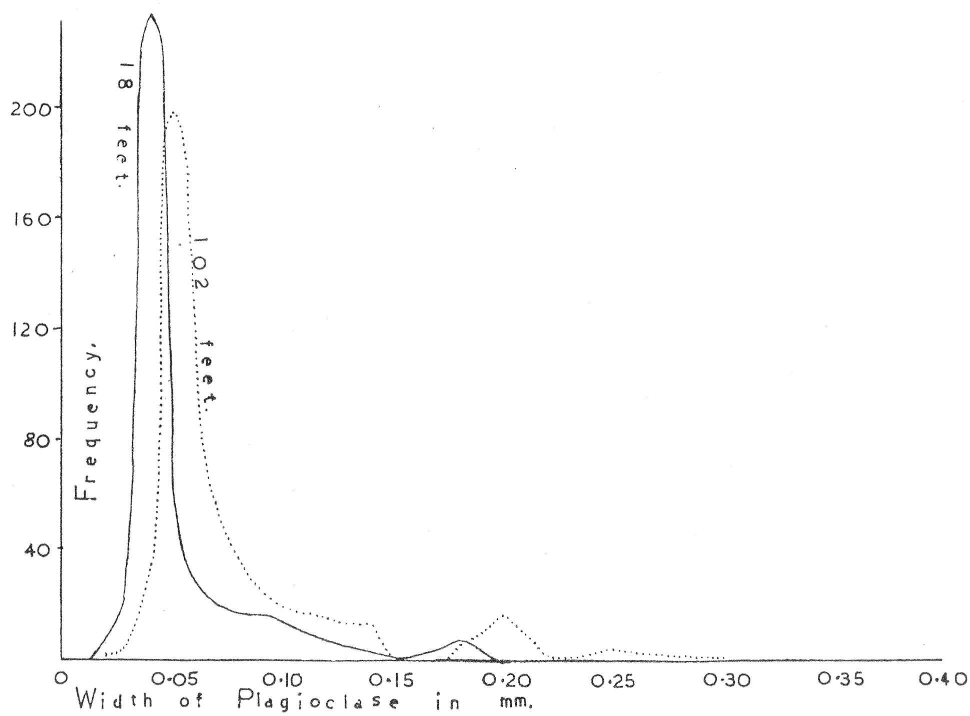

FIG. 8.—Plots of frequency distribution of widths of plagioclase crystals at 18 feet and 102 feet, Mt. Wellington.

In other slides measurements were made on a far smaller number of crystals, so the measurements listed in tables 1-5 and plotted in fig. 9 cannot be taken as absolutely accurate, though they are regarded as fair approximations. In some rocks three distinct widths of crystal are apparent and such are listed in the tables. In fig. 9, however, only the most frequent smaller crystal widths are plotted since it is believed that these grew *in situ* and may therefore be plotted in relation to depth, whereas the thicker ones possibly cooled in a different environment and may have come from a different level. Reference to fig. 9 *a* shows a steady increase in width from the lower contact to the top of the section, with a possible pegmatitic facies at about 1100 feet in the Mount Wellington sill. The adjacent fig. 9 *b* shows a very similar form indicating again that 5001 is behaving like a sill from which the upper contact has been removed and the lower not yet exposed.

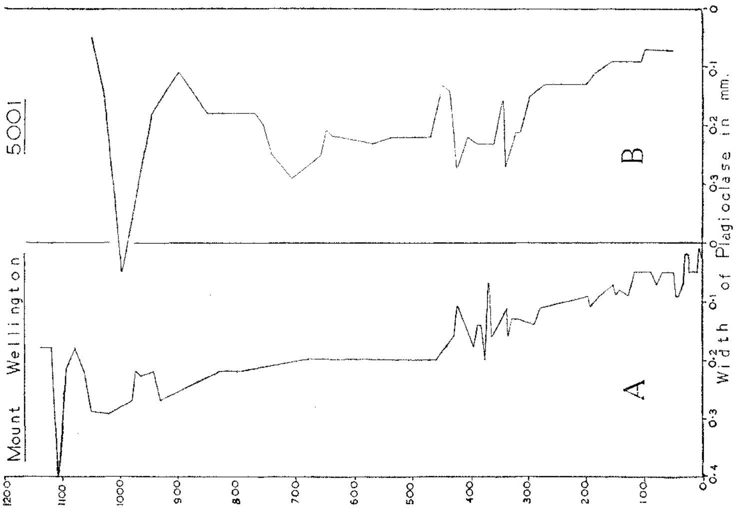

FIG. 9.—Plot to show width of smaller plagioclase crystals in relation to depth in the Mount Wellington sill and Bore Core 5001.

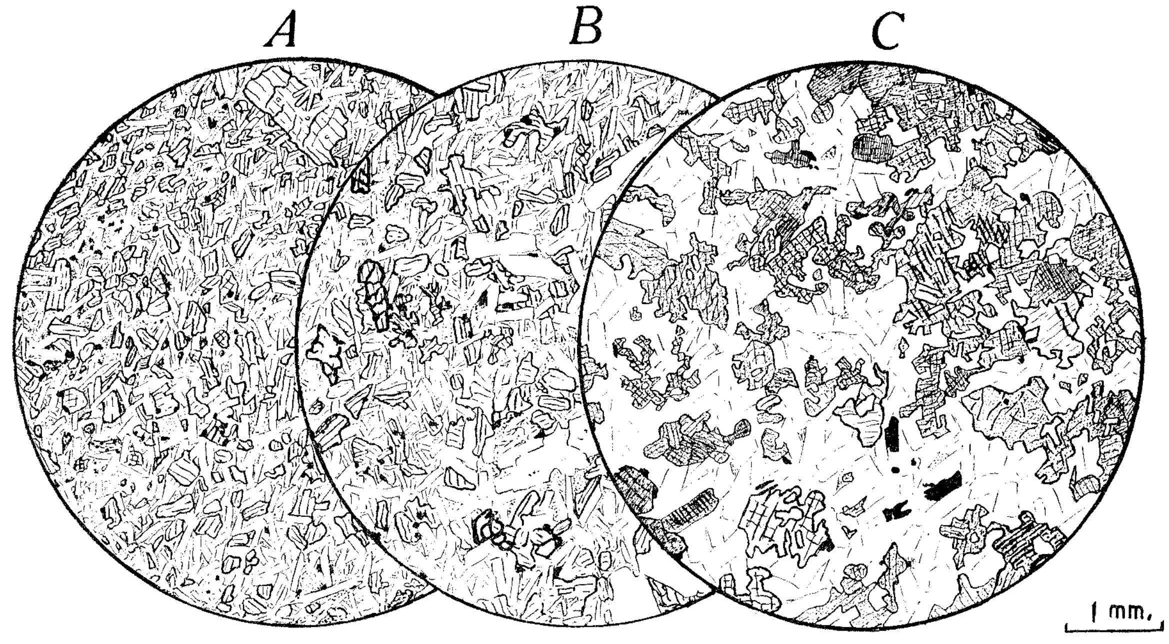

FIG. 10.—Mount Wellington. X 13

A. At contact. Fine-grained dolerite showing phenocryst of enstatite slightly moulded around small felspar laths. The remainder of the rock is intergranular, intersertal and slightly subophitic.

B. At 12 feet above basal contact. Phenocrysts of plagioclase and of partly resorbed orthopyroxene in an interstitial, intergranular and subophitic groundmass.

C. At 280 feet above basal contact. Ophitic dolerite, slightly intersertal. Note independent crystals of orthopyroxene (bottom left) and one partly moulded by clinopyroxene (middle right), also interstitial iron ore.

Winkler (1949) used the size of crystals in his discussion on the cooling of a basaltic magma, but his observations were made on rocks close to the margin and in this case it is hardly applicable when differentiation and accumulation of deuteric solutions have played so important a role.

FABRIC

So far as the present writer is aware the matter of differentiation has not been approached by a consideration of fabric. Yet it is significant, since an understanding of fabric leads to an understanding of order of crystallization and this in turn to an interpretation of the cooling history.

Most of the writers who discuss the quartz dolerites have mentioned that the marginal and fine grained varieties have an intergranular fabric whilst the coarser types are characterized by the ophitic and intersertal, but there appears to be no discussion as to the distance from the margin where this change of fabric takes place, how gradually it takes place, nor are there any observations on peculiarities of texture apart from the common development of phenocrysts.

At its lower contact the Mount Wellington dolerite is mainly intergranular and intersertal, but an occasional moulding of pyroxene on plagioclase suggests the subophitic fabric. Enstatite phenocrysts occur at this level and reference to fig. 10 *a* shows one of these moulded on small laths of felspar, thus suggesting that it grew rapidly *in situ* at the chilled margin, rather than that it represents an intratelluric crystal. It might be argued, however, that they were emplaced as embryo crystals and grew larger in their present position.

At 12 feet above the contact small phenocrysts of both plagioclase and enstatite occur. The enstatite shows resorption (fig. 10 *b*) and the fabric of the rock is partly intergranular, partly subophitic and markedly intersertal, and porphyritic. Professor Jaeger* has shown that at 12 feet from the contact the magma could be expected to take

* Personal communication. With reasonable values of the thermal properties of the magma the time for complete solidification is about four years if the magma is intruded at 1100°C and its range of solidification is 1100-800°C, and about two years if the magma is intruded at 1000°C, and the range is 1000-800°C.

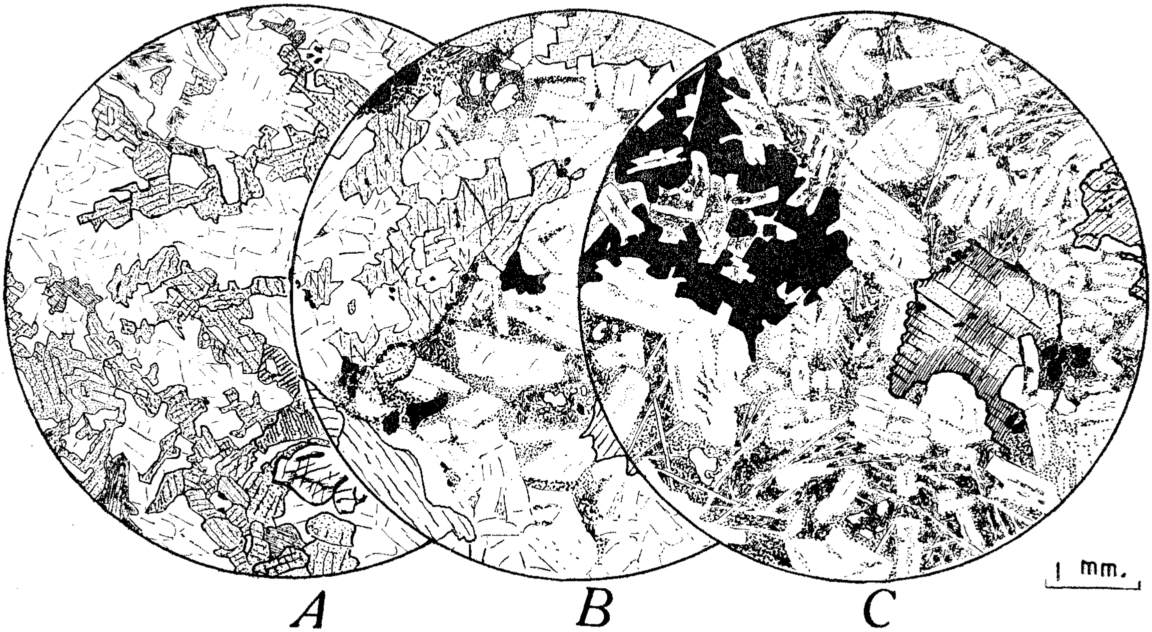

FIG. 11.—Mount Wellington. X 13.

A. At 335 feet above basal contact. Ophitic dolerite, intersertal in places. Note (bottom right), orthopyroxene partly resorbed and moulded by clinopyroxene, and (top) large zoned tabular felspar moulding felspar laths and pyroxene and idiomorphic against felspathic mesostasis.

B. At 945 feet above basal contact. Coarse ophitic dolerite highly intersertal. Note granules of iron ore bordering pyroxene around interstice, also group of smaller felspar laths (bottom, right).

C. At 1045 feet above basal contact. Coarse intersertal dolerite. Note iron ore moulded around felspar (the two smaller grains in the middle of the large grain are pyrite) also felspathic mesostasis containing patches of dark chlorite and long needles of plagioclase some of which are outgrowths from felspar laths. The pyroxene shows schiller inclusions of iron ore.

several years to consolidate, thus leaving ample time for a partial resorption of either intratelluric enstatite or of crystals that had cooled quickly near the contact and later disturbed by currents and brought up to a slightly higher level. The larger felspar crystals and the small patches of pyroxene moulded on felspar needles also suggest a disturbance of environment.

At 280 feet the fabric is fairly definitely ophitic (fig. 10 *c*) to subophitic and it is at this level that Edwards finds an enrichment of magnesia. At this level the pyroxene consists of both hypersthene and augite, and it is difficult to envisage a sinking of earlier-formed magnesia-rich pyroxene crystals when they mould the plagioclase. If the pyroxene were zoned it could be argued that additional growth took place in their present position, for the fabric certainly suggests growth *in situ*; zoning, however, is not apparent.

At 335 feet, and thereabouts, remnants of hypersthene are moulded by clinopyroxene, there is a well-marked ophitic and intersertal fabric and two generations of plagioclase occur, the larger felspars being slightly zoned and forming subidiomorphic tabular crystals which mould felspar laths and pyroxenes and themselves show idiomorphic relations towards the felspathic mesostasis (fig. 11 *a*).

Reference to table 1 shows that many of the larger felspars between 290 and 430 feet are zoned and fig. 8 indicates that the smaller felspars show much variation in size in this part of the section.

Towards the upper part of the sill the mesostasis plays a very important role and is commonly rich in iron ores and dark chlorite. The relation between pyroxene and plagioclase is ophitic and the rocks are highly intersertal (fig. 11 *b* and *c*).

Most of these fabrics and peculiarities of crystallization can be matched in 5001 though the intergranular fabric is present only in a few finer types that may represent veins, or inclusions of the marginal facies. The intersertal and the ophitic fabrics are persistant throughout (figs. 12 and 13), the former becoming more prominent at higher levels as in the case of the Mount Wellington sill.

Bore 5002 is intergranular for a short distance above the base, but rapidly becomes intersertal and ophitic.

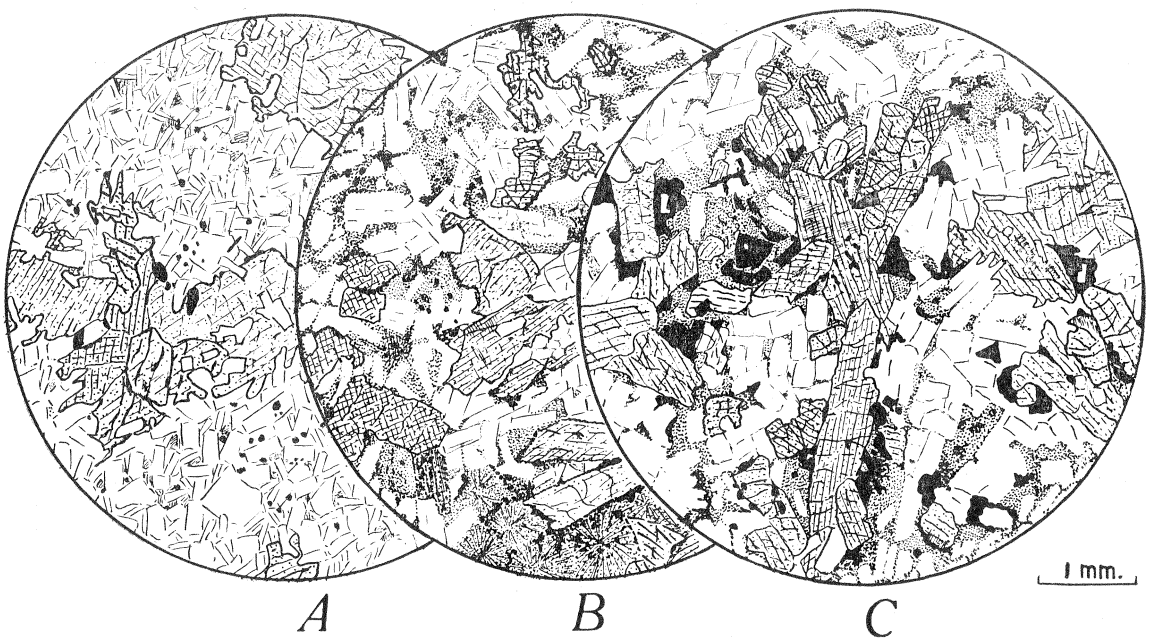

FIG. 12.—Bore Core 5001. X 13.

A. At 50 feet above base of bore. Ophitic dolerite partly intersertal, showing stout laths and small tabular crystals of plagioclase and large irregular grains of pyroxene.

B. At 285 feet above the base of bore. Ophitic dolerite highly intersertal showing subidiomorphic to idiomorphic columnar crystals of pyroxene. and mesostasis with radiating felspar.

C. At 410 feet above base of bore. Narrow mafic vein through optic dolerite. Elongated columnar crystals of pyroxene are approximately parallel to the length of the vein and adjacent felspar shows similar slight parallelism. The vein merges gradually into the ophitic dolerite and there is no sharp contact. Iron ore is interstitial.

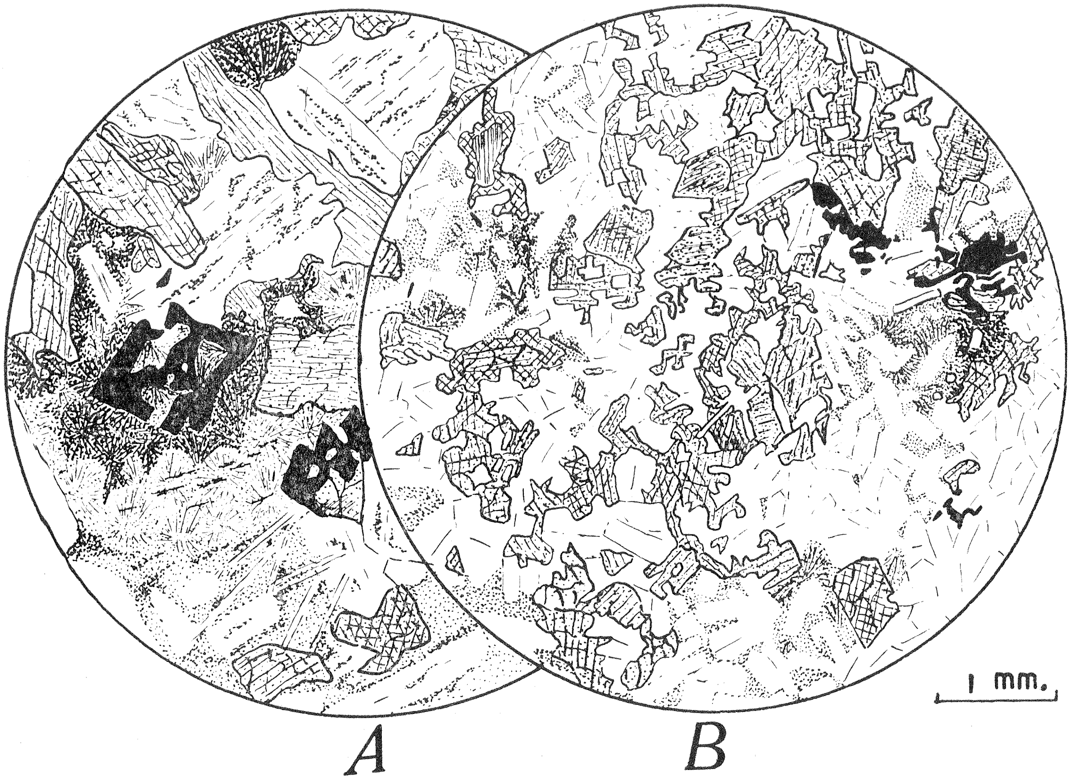

FIG. 13.—Bore Core 5001. X 16.

A. At 1000 feet above the base of bore. Pegmatite showing long columnar pyroxenes and large tabular felspars with much mesostasis. Note clusters of radiating felspar, dark chlorite and skeleton crystals of iron ore in the mesostasis.

B. At 1049 feet above base of bore. Ophitic dolerite, intersertal in places. Clinopyroxene moulded on pigeonite. Note decrease in grain size.

Bore 8001 shows an upper contact, and the rock against the tuffaceous sandstone contact is so fine grained that no micrometric analysis was attempted. The minute felspars appear to be plagioclase and tend to form radiating groups. The fabric is porphyritic, intergranular and intersertal, the minute grains of iron ore being confined to the intersticies (see fig. 14 *a*). A little xenocrystal quartz occurs. The phenocrysts are completely altered into bright green iddingsite, and their form in most cases suggests original pyroxene, though one or two sections resemble the form of olivine and it is possible that both minerals may have occurred. One foot below this type the rock resembles a normal fine-grained dolerite, though there is still a slight tendency towards a radial grouping of the plagioclase (fig. 14 *b*). Quartz is prominent in the intersticies throughout the marginal zone and is probably due to contamination with the overlying sandstone.

NOTES ON DIFFERENTIATION

The difficulties regarding the acceptance of crystal settling by gravity have been discussed by Jaeger and Joplin (1955, 1956) and in his discussion on the latter paper Hess (1956) concludes that this mechanism does not occur to any appreciable extent in the differentiation of the quartz dolerites as they are typically unlaminated. Many of the points noted above add to this difficulty, but they also present difficulties regarding the sinking of large blocks as postulated by Jaeger and Joplin.

Until further data is available it is not proposed to enter into a full discussion on differentiation, but at this stage it might be pointed out that the sinking and *shattering* of blocks with an accompanying disturbance of the bottom "sediment" may account for many of the observed phenomena.

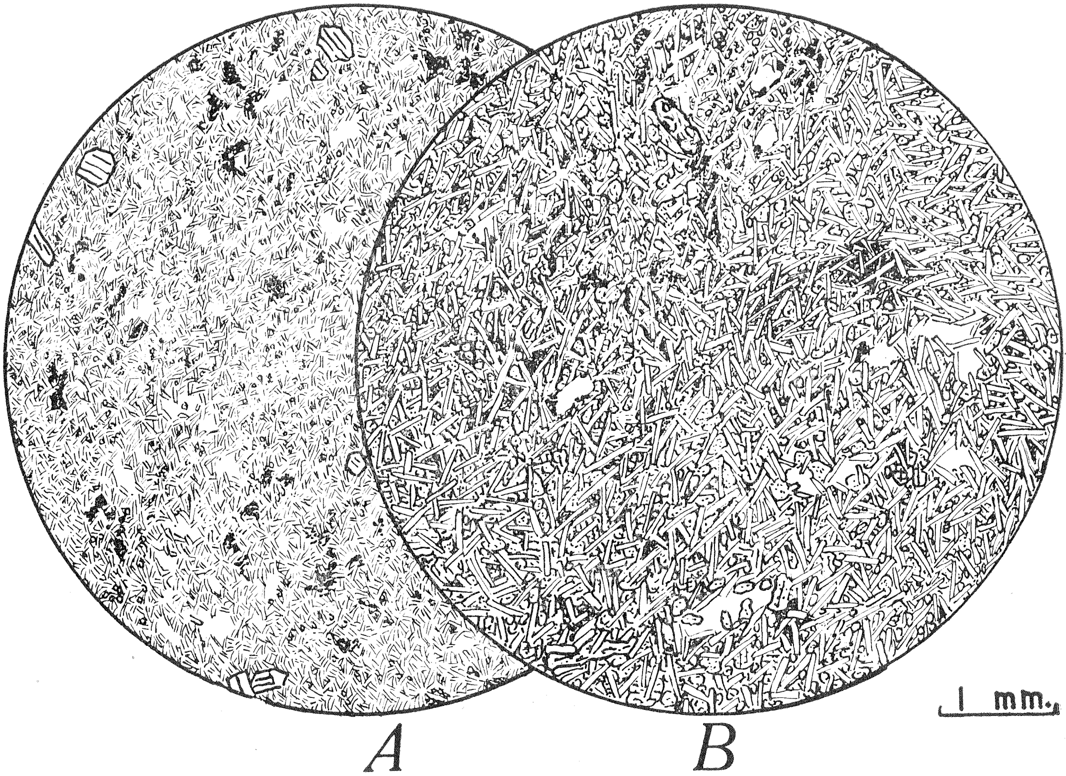

FIG. 14.—Bore Core 8001. X 16.

A. At contact. Extremely fine basaltic phase showing pseudomorphs of iddingsite, after hypersthene or (?) olivine in a base of felspar and intergranular pyroxene.

B. At 5 feet below contact. Fine intergranular phase showing small altered microphenocrysts of enstatite, few microphenocrysts of plagioclase and numerous small areas of quartz. Iron Ore is present in minute grains forming patches in the mesostasis.

If the falling blocks were not completely solid but consisted of a crystal mush and interstitial liquid, they would tend to fragment on their way to the bottom and might be accompanied by a shower of small fragments which may or may not reach the floor. As the larger fragments reached this floor, which would be strewn with only partly consolidated material, further breaking up might occur and turbidity current set up. Some of the felspar might tend to rise, and in the new environment become zoned, felspars of different size would become mixed either as individual crystals or as little clots of similar sized crystals giving rise to fabrics that have been observed in the lower part of the Mount Wellington sill.

As noted above the ophitic fabric in the magnesia-rich layer of Mount Wellington suggests crystallization *in situ*, yet it is known that magnesian pyroxene crystallized before iron-rich varieties and it has thus been assumed that this rock represents a gravity accumulation of early-formed crystals. Unfortunately exposures on the mountain are not good enough for this rock-type to be traced any distance horizontally, but if it is of local occurrence, which it might well be, then it seems not impossible that this was a fairly large block, which formed at an early stage near the roof and fell to its present position without much disintegration since its fabric is only slightly interstitial and the felspar and pyroxene are closely welded.

In general, however, the field evidence and above observations do not favour the final preservation of large settled blocks, but rather suggests that much of the early material started to drop as large units that shattered into a shower of crystals or minute fragments when they reached the floor, where they continued to grow or were enclosed by more rapidly cooling magma from which crystals of smaller grain size were separating.

As noted above, the chief point of difference between the Palisade sill and the Tasmanian sills is the presence of abundant olivine in the former. Accumulation of crystals seems to be the only means of accounting for the olivine ledge and Walker (1940, 1956) considers these were of intratelluric origin and that there was no hotter magma for them to melt in at the time of their settling. The presence of the olivine ledge therefore indicates that the magma was supercooled at the time of injection. Recently Jaeger and Joplin (1956) have discussed Walker's comments and have pointed out that certain magmas are not supercooled at the time of injection and that small phenocrysts may develop at the margin owing to sudden cooling. The fact that there is no accumulation of enstatite crystals to form a ledge in any of the Tasmanian sills, seems to support this view. Thus, apart from the slightly more basic composition of the initial magma in the case of the Palisade sill, the main point of difference between it and the Tasmanian sills is that the first was intruded in a super-cooled state and contained suspended crystals and that the Tasmanian magma was not super-cooled at the time of injection.

CONCLUSION

Reference to the appendix will show that the densities plotted in figs. A (*a*, *b* and *c*) are consistent with plots of modal composition, thus the peak at about 300 feet in fig. A (*a*) is the point suggested by fig. 5 as the place where the true deviation of plagioclase and pyroxene really occurs. Furthermore, a comparison of figs. A (*a*) and A(*b*) suggests, as does figs. 5 and 6, that the base of 5001 is possibly about 250 to 300 feet below the present level of the bore and that the Mount Wellington sill has been denuded to a level slightly below that of 5001. The same observations can be made with regard to the magnetic susceptibilities in figs. 9 B (*a* and *b*).

Apart from their possible use as a means of interpreting magmatic differentiation, it seems to the present writer that these data may have an economic application in predicting the approximate thickness of a sill. As many of the drill holes put down by the Hydro-Electric Commission pass through these sills, it would probably be of value to know what thickness of dolerite might be expected in the bore and whether the present level of boring is near the top or the bottom of the sill. The study of fabric and grain size and a series of micrometric measurement should give a fair approximation and although the method is not conclusive, the detailed study of a number of sills may help to make it a more reliable tool.

REFERENCES

EDWARDS, A. B., 1942.—Differentiation of the Dolerites of Tasmania. *Journ. Geol.*, 50, 451-480, 579-610.

JAEGER, J. C. AND JOPLIN, G. A., 1955.—Rock Magnetism and the Differentiation of Dolerite Sill. *Journ. Geol. Soc. Aust.*, 2, 1-19.

————————, 1956.—Discussion *Amer. Journ. Sci.*, 254, 443-446.

HESS, H. H., 1956.—Discussion, *Ibid.*, 254, 446-451.

TWELVETREES, W. H. AND PETTERD, W. F., 1899.—The Mesozoic Dolerite and Diabase in Tasmania. *Pap. and Proc. Roy. Soc. Tas.*, 47-55.

WALKER, F., 1940.—Differentiation of the Palisade Diabase, New Jersey. *Bull. Geol. Soc. Amer.*, 51, 1059-1106.

————, 1956.—The Magnetic Properties and Diffentiation of Dolerite Sills—A Critical Discussion. *Amer. Journ. Sci.*, 254, 433-443.

AUTHOR'S NOTE.—Since the completion of this manuscript, a paper by J. F. Truswell (*Trans. Roy. Soc. S. Africa*, 1955, 34, 409-416) has come to the writer's notice. Modal analyses of Karoo dolerite in an 820 foot sill are plotted, and the diagram is very similar to figs. 1-7 of the present paper. Variations in modal composition, and the presence of veins near the base of the sill, are accounted for by a later injection of undifferentiated magma. This explanation was considered in the case of some Tasmanian sheets.

APPENDIX

THE VARIATION OF DENSITY AND MAGNETIC PROPERTIES

In Jaeger and Joplin (1955) the general variation of magnetic susceptibility and intensity of magnetisation in the sill 5001 were discussed in detail and were compared with observations of the density and petrography. These were found to form a pattern consistent with differentiation in the sill. This pattern is followed in the additional sills now examined by Dr. Joplin and may be taken as the characteristic behaviour of sills of this type. Only the average values of density and magnetic properties will be reported here: as remarked in Jaeger and Joplin (1955), the latter, in particular, show a fine structure which is believed to be significant, but this will not be discussed.

The Density

In figure A (*a*) the variation of density in Mt. Wellington is shown. Each value is the average of all samples in a 50 foot interval; 20 or more samples have been taken in each of the lower intervals, but only two or three in each of the upper ones, so that the values given for the upper part of the sill may differ considerably from the true mean value which may be regarded as following the dotted curve. The density is seen to increase slowly to a maximum at about 300 feet from the lower contact, followed by a rapid decrease around 400 feet—this is the point at which the rapid falling off in the volume percentage of pyroxene appears in fig. 5.

The behaviour of the density in 5001, taken from Jaeger and Joplin (1955), is shown in fig. A (*b*) and is seen to be very similar to that of Mt. Wellington. Combining the two, it may be suggested that the typical variation of density in a thick sill of magma of this type consists of a rapid fall in density setting in 50 or 100 feet below the upper margin, the density having its minimum value some hundreds of feet below; there is then a rise to a maximum some hundreds of feet above the lower contact, with a subsequent slight decrease towards the lower contact. The behaviour of the other three incomplete cores examined fits into this pattern. In 5002, the density increases from 2·90 near the lower contact to 2·93 over the remaining 120 feet (this relatively uniform density would also be shown if the sill were a thin one). The sill 8002 has an average density of 2·90 with little fluctuation in the first 100 feet below the upper contact; below this there is a considerable fall in density as well as great fluctuations in it, values between 2·67 and 2·80 having been measured. The sill 8002 shows similar behaviour, in this case the density is relatively constant at 2·90 for only 20 feet from the upper contact after which a rapid fall takes place, values between 2·62 and 2·81 having been measured.

The behaviour of the Palisade sill (George Washington Bridge and Edgewater sections), fig. A (*c*), is very different, the change being attributable to the olivine layer and to the presence of olivine near the upper margin. In the regions in which olivine is not present, the curve of fig. A (*c*) is not very different to figs. A (*a*) and A (*b*); this lends some support to the suggestion of Jaeger and Joplin (1956) that the olivine ledge is formed by a fall-out of intra-telluric olivine crystals, subsequent differentiation having followed very much the pattern of the sills described in this paper.

Magnetic Properties

Susceptibilities have been measured by the method described in Jaeger and Joplin (1955). The reversible susceptibility of a number of samples from Mt. Wellington has also been measured accurately by Mr. D. W. Smellie in an apparatus similar to that of Bruckshaw and Robertson* (1948), using a peak field of 0·25 oersted at 50 cycles. Values obtained in this way are consistently about 10 per cent higher than those measured by the simple apparatus described in Jaeger and Joplin (1955) which is thus shown to be completely adequate for comparative work of the present type.

Values of the average susceptibility of samples taken in 50 feet regions from Mt. Wellington are shown in fig. B (*a*), and those for 5001 in fig. B (*b*) for comparison. Mt. Wellington shows a rapid fall from the marginal values to a very low value 200 feet above the lower contact, followed by a steady rise. Comparison with fig. B (*b*) suggests that this minimum may be below the lowest level measured in 5001; also, it may be expected that, as the upper contact of Mt. Wellington is approached, the susceptibility would fall towards a marginal value. Of the two upper contacts measured, 8001 shows relatively constant values for 100 feet from the margin, followed by an increase, while 8002 shows constant values for 40 feet followed by an increase: both these results show variations consistent with those of the density and petrography. 5002, however, is to some extent anomalous, values in the regions 20-80 feet being lower than the value at the contact.

* Bruckshaw, J. McG., and Robertson, E. I., *J. Sci. Inst.*, Vol. 25, p. 444.

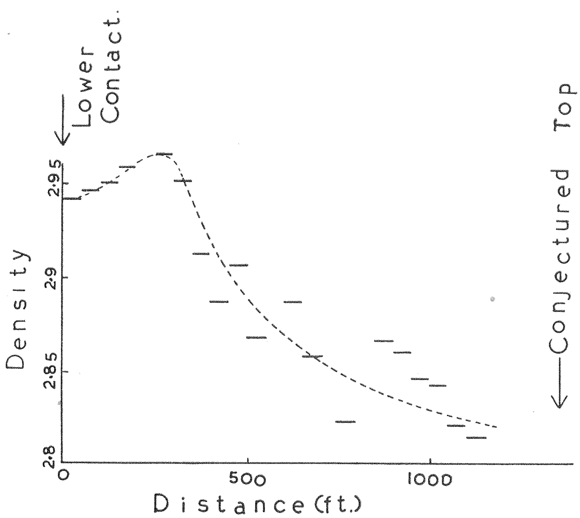

Fig. A (a)

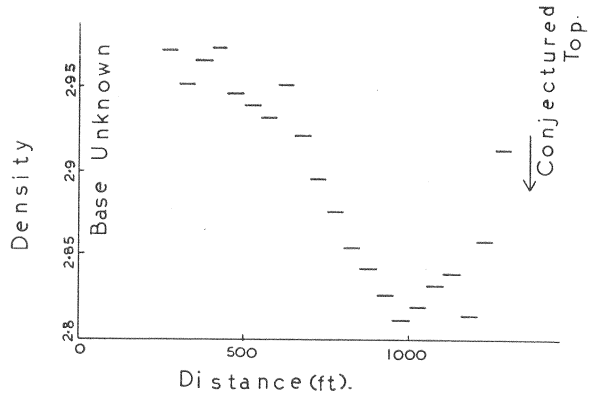

Fig. A (b)

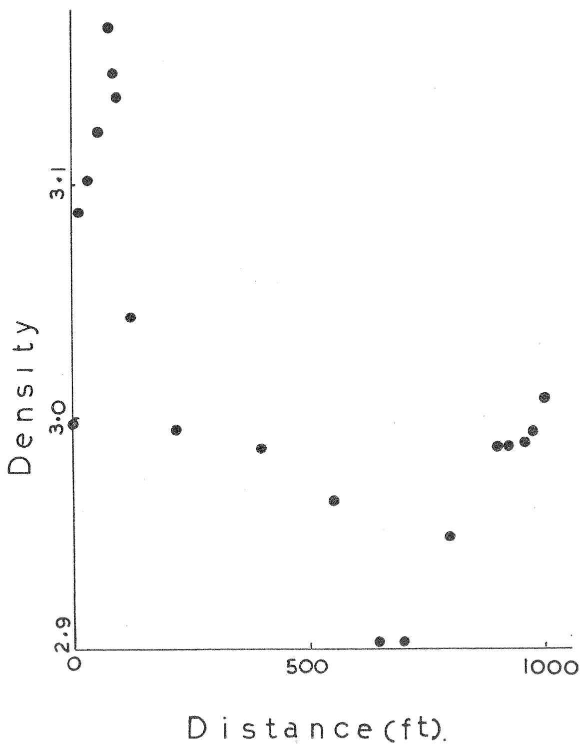

Fig. A (c)

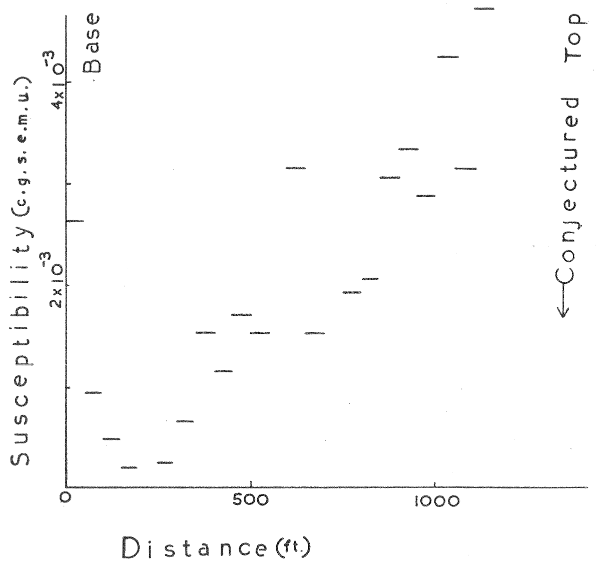

Fig. B (a)

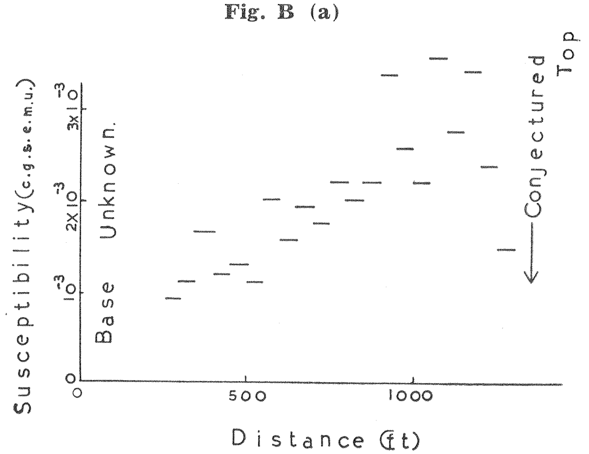

Fig. B (b)