6.—SOME BASALTS FROM THE NORTH KIMBERLEY, WESTERN AUSTRALIA.

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INTRODUCTION.

The following notes are intended to supplement our meagre knowledge concerning the petrology of the basalts of the North Kimberley region of Western Australia (Fig. 1). They are based on an examination of two small collections, one of which was made by Messrs. A. Gibb Maitland and C. G. Gibson, in 1901, when they were attached to the Brockman Exploring Expedition (Brockman and Crossland, 1901), and the other by Mr. W. V. Fitzgerald, who accompanied the Crossland Expedition in 1905. (Fitzgerald, 1907).

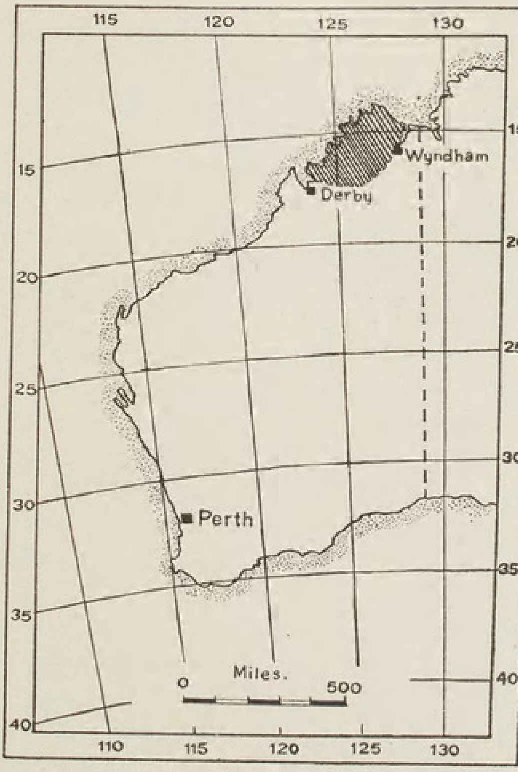

Figure 1.
Locality Map, showing the position of the North Kimberley (shaded).

Maitland and Gibson explored the country in the neighbourhood of Wyndham ; the gorge of the Isdell River ; the land to the west, north-west and north of the Synnott Tableland, including the Synnott Creek, the Charnley

River Gorge, and the Calder River Gorge ; the vicinity of Mount Kitchener, Mount Lyell, and Mount Trevor ; the upper reaches of the Prince Regent River, and Mount Hann ; and some of the hills overlooking Napier Broome Bay (Fig. 2).

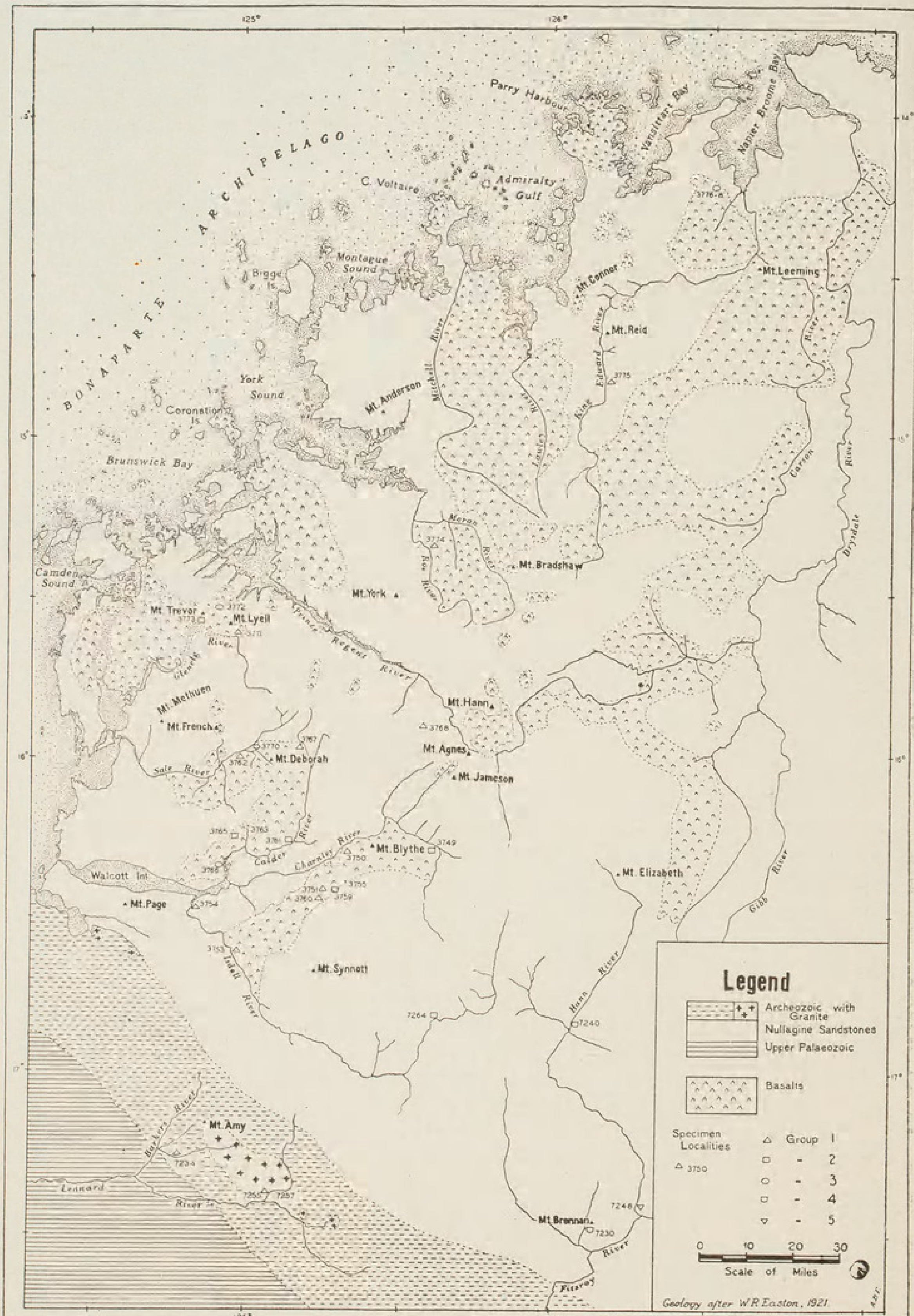

Figure 2.

2. Geological Sketch Map of the North Kimberley, showing the localities from which the specimens were obtained.

Fitzgerald examined the country along the May, Lennard, Barker, Adcock, Throssell, Upper Fitzroy, Hann, Barnett, Isdell, Sprigg, Lower Charnley, and Lower Calder Rivers.

The localities from which the specimens were obtained are shown in Figure 2, which is copied from Easton's (1922) geological map of the region, as reprinted, to accompany Jutson's " Physiography of Western Australia " (Jutson, 1934). No information is available as to the field occurrences of most of the specimens, and, as will be indicated, this is a matter to which any future expedition might give attention.

The collection is the property of the Geological Survey of Western Australia, and my thanks are due to Mr. H. A. Ellis, who was Acting Government Geologist in 1939, and who, at the instance of Professor E. de C. Clarke, not only gave me permission to examine it, but went, personally, to much trouble to put it in order and to collect all the field notes regarding the specimens which could be found in the official records. Mr. Ellis also allowed me to make use of a manuscript report on these and other rocks from the North Kimberley, which was written many years ago by R. A. Farquharson. The present study has been carried out in the Geology Department, University of Melbourne, by kind permission of Professor E. W. Skeats.

GENERAL GEOLOGY.

The North Kimberley District of Western Australia lies between longitudes 124° and 128° and between latitudes 14° and 18° (Fig. 1), and is an inaccessible, and therefore little known, part of Australia. Our knowledge of its geology is based chiefly on the accounts and collections of the parties led by the surveyors Hardman (1885), Brockman and Crossland (1901), Fitzgerald (1907) and Easton (1922).

Over the greater portion of this region the outcropping rocks consist of lava flows interbedded with massive sandstones of Nullagine age, which are either horizontally bedded, or only gently folded. The sandstones appear to overlie the lava flows to a large extent, but Maitland (1902) indicates that some of the igneous rocks occur as sills. He refers to them briefly as "a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase," sometimes accompanied by beds of volcanic ash and breccias. In places he reports that "the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of igneous rock," while some sections "indicate quite clearly that the igneous rocks have (in these localities) found an easy passage along the bedding planes of the sedimentary beds and . . . . occur in the form of sills."

According to Jutson (1934), the North Kimberley is an extensive plateau which is undergoing rapid dissection by a number of streams. These streams are arranged radially about Mount Hann (2,800 feet), which lies near the centre of the plateau, and rises about 800 feet above it. The "ranges" marked on most maps of this region are really the ridges or plateau remnants forming the interfluves between the deep narrow gorges occupied by these streams. In their lower tracts the river valleys broaden, but they retain their steep walls throughout their courses. The coastal region has undergone submergence, giving rise to an extremely broken coastline of the rias type, the harbours being flanked by precipitous cliffs, often several hundreds of feet high.

PETROLOGY.

In the hand specimen the basalts can be divided into two distinct varieties, a group of relatively coarse-grained rocks, and a group of extremely fine-grained rocks. Examination of thin sections under the microscope shows that the coarse-grained rocks are a uniform group of ophitic two-pyroxene dolerites. The fine-grained rocks, on the other hand, comprise basalts of several varieties that can be distinguished mineralogically and texturally.

1. *Two-pyroxene dolerites.*

[3750],* from Camp F. B. 31, Charnley River.
[3751], from Camp F.B. 32, Charnley River (analysed).
[3753], from the Isdell River (analysed).
[3760], from Camp F.B. 32, Synnott Creek, Charnley River (analysed).
[3762], from a large hill between Camps F.B. 37 and 38.
[3767], from a "pocket" near Camp F.B. 47.
[3769], from a hill near Crossland's Wart, Prince Regent River.
[3771], from 3 miles south-east of Mt. Lyell (analysed).
[3775], from Camp F.B. 73.
[7234], dyke in granite, from the right-hand branch of Barker River.
[7255], dyke in the Lennard River, 10 miles below Mt. Eliza.

Similar, but with granophyric intergrowths of quartz and felspar :—

[3754], from Camp C. 5, Isdell River.
[3768], from gorge below F.B. 52 (analysed).
[3774], from 4 miles south-west of F.B. 66 (analysed).

This group comprises 14 of the 35 specimens forming the collection, and includes the freshest specimens. As will be seen from Figure 2, the localities from which the specimens come are widely scattered over the North Kimberley, so that there can be little doubt that this variety of basalt is one of the widespread types of the region.

Two sub-varieties can be recognised, a slightly more acid group with intersertal patches of granophyric quartz and orthoclase (*quartz-dolerites*), and a more basic one in which such granophyric intergrowths are lacking. Apart from this minor difference, the rocks appear to be identical. They are coarse-grained (Plate I, Fig. 1), and consist essentially of pyroxene and basic plagioclase, with some chloritized biotite, and iron ore. The pyroxene is the coarsest-grained constituent, and forms crystals about 1 to 2 mm. across, which are in ophitic relation with the felspar laths.

Two varieties of pyroxene are present, in intimate association. One shows a (+) 2V of about 50°, so that it is a diopsidic augite, while the other shows a (+) 2V of about 0°–10°, so that it is a pigeonite. The extinction angles show a general maximum of 35°, with an occasional 40°. Using the data given by Deer and Wager (1938), this suggests that the compositions of the two pyroxenes are approximately as follows :—

$$\text{Augite} \quad \begin{cases} CaSiO_3 = 35 \\ MgSiO_3 = 55 \\ FeSiO_3 = 10 \end{cases}$$

$$\text{Pigeonite} \quad \begin{cases} CaSiO_3 = 15 \\ MgSiO_3 = 75 \\ FeSiO_3 = 10 \end{cases}$$

* Numbers in brackets [ ] refer to specimens in the collection of the Geological Survey of W.A.

The plagioclase occurs as laths which range up to 1 mm. in length, when they appear to be porphyritic, but they average about 0·3 mm. They show extinction angles as high as 33° in the symmetrical zone, and are optically positive, so that they are labradorite, of a composition about Ab40. Small areas of chlorite, pleochroic from green to pale straw, are of frequent occurrence. They show straight extinction parallel to a single, widely-spaced, but perfect cleavage, so that they appear to represent altered biotite. Sometimes the chlorite is fibrous, with a plumose structure ; and sometimes, as in [3750], it appears to be pseudomorphous after small crystals of olivine. The iron ore occurs as sporadic coarse, irregular shaped grains of ilmenite and ilmenite-magnetite intergrowths, moulded on the pyroxene, and ophitic towards the felspar. There is also a certain amount of interstitial felspathic base, which has been altered to sericite ; and occasionally, as in [3745], [3768], and [3774], there are intersertal areas which consist of a granophyric intergrowth of quartz and orthoclase. The chemical analyses, Table I., Nos. 1–4, suggest that the specimens showing these micrographic intergrowths are slightly more acid than those in which they are lacking. The possible significance of this is referred to later. The nearest analogue to these rocks in Western Australia is provided by the dolerites and the quartz dolerites which intrude the Nullagine formations in the vicinity of the Upper Ashburton and Upper Gascoyne Rivers, in the North-Western Division (Maitland, 1909 ; Talbot, 1920). An analysis of one of these dolerites is quoted in Table I., A., for comparison.

In most of the specimens the plagioclase is considerably altered, having been changed to sericite or saussurite, and more rarely to epidote, as in [3753], when the change is reflected in the chemical composition of the rock (Table I., No. 5). The pyroxene has generally resisted alteration, or become slightly chloritized.

In one specimen, however, [3760] from Synnott Creek, the alteration of both felspar and pyroxene is more striking. The original plagioclase has been completely altered to lemon-yellow epidote, which retains to some extent the lath-like form of the felspar, and to albite and quartz. The albite, which is dusted with epidote granules, occurs as allotriomorphic crystals 0·2 to 0·5 mm. in diameter, interlocked with allotriomorphic, and sometimes idiomorphic, crystals of quartz of similar size. The quartz predominates.

Much of the soda set free during the alteration of the labradorite to epidote has attacked the pyroxene, and converted it to a soda-amphibole, presumably glaucophane, which is intensely pleochroic, with X = pale violet, Y = deep violet, Z = deep blue-green. It shows a good cleavage parallel to (110), and extinguishes at 30° on this cleavage. Remnants of the original pyroxene are sometimes enclosed within the glaucophane. Some of the pyroxene, on the other hand, is intimately intergrown with the yellow epidote. The amount of glaucophane present is considerably less than the probable amount of pyroxene present in the original dolerite, and the analysis of the rock (Table I., No. 6) suggests that the glaucophane is rich in iron, and possibly magnesia. It seems probable that the augite of the original rock has altered, in part at least to epidote, while the pigeonite has changed to glaucophane. A little pyrite has been introduced, together with veins and patches of calcite. When the chemical analysis of the rock is compared with the analyses of the less altered rocks of Table I., it is seen that there is a considerable general resemblance, as would be expected, but that K_2O, MgO and TiO_2 have been leached out to a considerable degree during the alteration, while Na_2O has been removed in lesser degree. On the other hand, SiO_2, CaO and CO_2 have been introduced.

Glaucophane is recorded chiefly from metamorphic rocks, and its occurrence as an alteration product of a dolerite is unusual, particularly since the dolerites in this region are for the most part fresh and un-metamorphosed. The presence of pyrite and carbonates in the rock suggests that it has undergone local metasomatism, or possibly autopneumatolysis.

2. *Two-pyroxene andesine-basalts.*

[3749], from 1 mile north-west of Camp F.B. 28, junction of Maurice Creek and Charnley River (analysed).
[3761], from the Calder River, 5 miles west of F.B. 34.
[3763], from the Harding Range, 800 feet below the summit, and 1 mile from F.B. 43.
[3765], from the Harding Range, 1,100 feet below the summit, and 1 mile from F.B. 43.
[3773], from the summit of Mt. Trevor.
[7264], from a dyke in sandstone, Upper Isdell River.

This small group of glassy basalts has a distinctive appearance under the microscope (Plate I., Fig. 2). Both pyroxene and plagioclase occur as elongated laths 0·5 to 1·0 mm. long and 0·02 to 0·05 mm. wide, and show a tendency to form stellate clusters in the dark glassy base. The pyroxene sometimes occurs in radiating sheaves. Two varieties are present. One has (+) 2V = 0°–10°, so that it is a pigeonite. The other has (+) 2V greater than 45°, and is probably augite. In most of the specimens the pyroxene laths were just beginning to crystallize when the rock was chilled, and indistinct trichytes of pyroxene can be made out in the dark glassy base. These trichytes tend to a radial arrangement, suggestive of colourless hornblende fibres, but are proved to be pyroxene by their large extinction angles, which range up to 40°.

The plagioclase laths began to crystallize before the pyroxene, and some of them are of microphenocryst size. They are largely altered to white mica, chlorite, and sometimes epidote, but occasionally they still show broad lamellar twinning, with an extinction angle in the symmetrical zone of about 20°, so that they consist of andesine of a composition about Ab60. In each section there are one or two microphenocrysts of altered olivine, which retain their idiomorphic outline to some extent (Plate I., Fig. 2). The abundant glass is greyish and opaque, but under high magnification it resolves into a network of pyroxene microlites. Iron ores are generally absent.

Texturally these rocks have considerable affinity with tholeiites, but mineralogically they are related to the andesites. A chemical analysis of [3749] (Table II., No. 1) indicates that the rocks are basaltic in composition, but midway, as it were, between the tholeiites proper and the andesites. The Al_2O_3, Na_2O and K_2O contents are too high for tholeiites, just as the andesine felspar is too acid. These features also distinguish this group of basalts from the two-pyroxene dolerites of Group 1.

3. *Andesine-basalts.*

[3766], from the edge of tidal water, 6 miles south-west from F.B. 44.
[3770], from Camp F.B. 53, south side of the Cole River.
[3772], from a hill near Mt. Lyell, and 3 miles north-east of F.B. 57.
[3776], from 3 miles north of F.B. 79, at Napier Broome Bay (analysed).
[3777], an epidositized specimen from the same locality as [3776] (analysed).
[3778], from the same locality as [3776].
[7246], from the Hann River.
[7271], a dyke, from near Mt. Joseph.

The specimens comprising this group are coarser grained than the basalts of Group 2, and contain less glass (Plate 2., Fig. 3). The felspar is a more acid andesine, about Ab_{70}, occurring in laths that lie at all angles to one another, and are often partially micacised. They are associated with laths of clinopyroxene, so altered to chlorite that the composition of the pyroxene cannot be gauged. These laths are set in a base of dark glass with which are associated numerous areas of apple-green chlorite, showing ultra-blue polarization colours. It is this chlorite, presumably, which accounts for the high MgO content in the chemical analysis of [3776] (Table II., No. 2). In some of the specimens, notably [3777], the felspar has been extensively altered to epidote, which occurs in irregular areas through the sections. An analysis of this extensively altered specimen (Table II., No. 3) shows that SiO_2, MgO, Na_2O, K_2O and TiO_2 have been leached out of it, while the FeO has been oxidised, and a large quantity of CaO has been introduced.

In the absence of an analysis, these rocks would be regarded as basic pyroxene-andesites, but their chemistry indicates their basaltic character, and their affinity with the other rocks from this region. Specimen [3772] appears to be intermediate between these andesine-basalts and the two-pyroxene andesine-basalts of Group 2. The pyroxene in it forms colourless microphenocrysts, with (+) 2V greater than 45° so that it approaches augite in composition. The plagioclase is too much altered to secondary mica for its composition to be determined, but it shows a pronounced stellate arrangement, and the interstitial spaces are filled with a dark glass containing trichytic crystals of pyroxene. In [7246] the groundmass consists of a lattice work of chloritized pyroxene microlites in a dark glass. In places this structure is replaced by granular calcite.

Another specimen difficult to classify, but having affinities with this group is [7271], a dyke rock from near Mount Joseph. It consists of small stumpy laths of much altered andesine ophitically intergrown with areas of partially altered pyroxene, which shows a large optic axial angle, and appears to be augite. The glassy base is much altered, and patches of chlorite occur scattered throughout the rock. Associated with the chlorite are small areas of glaucophane, intensely pleochroic from deep-green to pale-brown, pale violet, or nearly colourless.

4. *Microcrystalline andesine-basalts.*

[3759], from the Synnott Tableland, north-east of Camp F.B. 32.
[7230], a dyke at the base of Mt. Brennan, intruding Nullagine sandstone (Fitzgerald). (Farquharson suggests it may be an interbedded lava or a sill.)
[7240], from the Hann River, near its junction with the Barnett River.

As will be seen from Figure 2, two of these rocks come from the south-east portion of the region, away from the main areas of basalt, as mapped by Easton, while the third occurs in the south-central part, associated with other basaltic types.

[7240] consists of minute laths of plagioclase accompanied by small grains of iron ore, in an abundant groundmass of glassy material that has been altered to pale-green chlorite. The felspar laths lie at all angles to one another, with no suggestion of parallelism, and show extinction angles up to 12° in the symmetrical zone when twinned, and almost straight extinction when microlitic, indicating that they consist of acid andesine, of a composition about Ab_{70}. Small patches of calcite occur throughout the rock, in the glass ; and calcite fills a number of small amygdules in the rock, when it is associated with small amounts of radially fibrous chlorite and finely granular quartz. Similar granules of quartz occur through the rock in the vicinity of the amygdules. Occasionally an amygdule is completely filled with chlorite.

In [7230] the plagioclase laths are coarser-grained, though still small, and despite partial kaolinisation, show extinction angles up to 12° in the symmetrical zone, indicating that they consist of acid andesine (Ab_{70}). The amygdules in this rock are filled (i) with chlorite ; or (ii) with quartz and untwinned felspar, stained with iron oxide, and sometimes accompanied by chlorite ; or (iii) with quartz and chlorite. In other respects, however, the rock is identical with [7240].

The same texture is preserved in [3759] from the Synnott Tableland, but in this rock the felspar is so altered to mica and kaolin material that its composition cannot be made out. In addition the rock, which contains numerous amygdules of chlorite, is stained deeply with limonite.

In the absence of a chemical analysis, these rocks might be regarded as basic andesites, but they have been classified as andesine-basalts in view of their general resemblance to the other rocks of the region, which when analysed prove to be basalts.

5. *Hornblende-oligoclase-basalt.*

[7248], from the Hann River, near its junction with the Fitzroy River (analysed).

This variety, which is represented by a single specimen from the south-eastern part of the area, is a micro-crystalline rock consisting of laths of plagioclase and idiomorphic micro-phenocrysts of pyroxene, set in a dark mesostasis of groundmass which has partially crystallized as radiating sheaves of a grey-brown hornblende that shows almost straight extinction. The plagioclase is largely altered to secondary mica, but lamellar twinning can be made out in some crystals, and gives extinction angles up to 10° in the symmetrical zone, so that the felspar appears to be basic oligoclase of a composition Ab_{70}–Ab_{75}. The pyroxene is completely altered to chlorite, so that its composition cannot be determined. In places it is ophitic towards the plagioclase. The hornblende fibres are sometimes interleaved with green chloritic material, representing original glass, and less frequently with fine felspar laths. In view of the acid nature of the plagioclase, and the abundant hornblende, the rock resembles an andesite, but a chemical analysis (Table II, No. 4) indicates that it is a basalt. The fine texture of the rock is shown in Plate 2, Fig. 4.

6. *Volcanic Tuff.*

[3755], from the Synnott Tableland, north-east of Camp F.B. 32.

This specimen is from a much weathered rock consisting of angular fragments, up to 1 cm. across, of highly chloritized material which contains a few small laths of altered felspar, cemented together by material consisting chiefly of limonite, chlorite, and fine mosaics of secondary quartz. The rock is almost certainly a weathered tuff.

DISCUSSION.

The outcrops of basaltic rocks in the North Kimberley region cover an area estimated by Easton (1922) as about 6,250 square miles. The inadequacy of any generalisations concerning these rocks, based on an examination of a collection of only 35 specimens is manifest. However, the specimens display a marked uniformity in their general petrological character, which, coupled with the wide scatter of the localities from which they were obtained, justifies some suggestion as to the probable petrological character of the North Kimberley basalts as a whole With the exception of [3771] (Table I

No. 4) all the unaltered specimens that have been analysed are either saturated with respect to silica, or nearly so ; and chemically, they have many features in common with the tholeiitic basalts (Kennedy, 1933) or plateau-basalts (Washington, 1922) as distinct from the olivine-basalts (Kennedy, 1933), as is shown by Table III, in which the averaged analyses of the more or less unaltered North Kimberley rocks are compared with averaged analyses of the East Kimberley basalts, the tholeiites of south-western Western Australia, and the theoretical tholeiite magma type. This resemblance is particularly marked with the North Kimberley dolerites. The basalts tend to be rather more andesitic in composition.

Mineralogically, also, the North Kimberley rocks are related to the tholeiites and their derivatives. They tend to form a distinctly calc-alkaline suite, grading towards andesites, rather than towards the more alkaline types which accompany olivine-basalts.

As indicated, the North Kimberley rocks resemble, in their chemical composition, those of East Kimberley (Edwards and Clarke, 1940), but the varieties of basalt known to occur in the two regions cannot be matched. This is not surprising if the North Kimberley rocks are of Nullagine age, while the East Kimberley basalts are Cambrian, or even post-Cambrian in part. The relative abundance of dolerite specimens in the collection suggests that this rock is the most widespread in the region, and, since it is also the most basic found there, it may approximate to the composition of the parent magma. Whether it bears such a relation to the basalts, also, must remain doubtful, for reasons given below.

As pointed out by Farquharson (in his unpublished manuscript), the dolerites from North Kimberley bear considerable resemblance to the dolerites described by Maitland (1909), and by Talbot and Farquharson (1920), from the drainage basin of the Ashburton, Gascoyne, and Oakover Rivers, and the Hammersley-Ophthalmia Plateau, in the North-West Division. The significance of this resemblance is that the latter dolerites occur largely in the form of sills, up to 300 feet thick, intruded into flat-lying beds of Nullagine age (the Carawine Limestones and others). In view of Maitland's observations referred to above (Maitland, 1902), this raised the question as to whether some or all of the dolerites in the North Kimberley may not occur as thin sills, rather than as lava flows. If this should prove to be so, it may be found that the sills have undergone some degree of differentiation in situ, and that the quartz-dolerite facies is a product of this differentiation.

Talbot and Farquharson (1920) showed that the dolerites in the district described by them were younger than the basalts in that region, because dykes of dolerite cut through sedimentary series with which the basalts were interbedded. This raises the further question as to whether the basaltic rocks of the North Kimberley may not also be of two ages—earlier, interbedded basalts, and later intrusive dolerites. This may well be so, but, since there are no details as to the mode of occurrence of the specimens in the collections examined, except an occasional description of a specimen as "from a dyke" (and these occur in four of the five groups established above), and in the case of one dolerite specimen [3771] a note ("laccolith ?"), it is a matter that must be left for future explorers in the North Kimberley to decide.

TABLE I.

	1	2	3	4	5	6	A
SiO_2	51·15	50·70	50·98	46·90	54·44	56·34	49·42
Al_2O_3	15·16	14·02	11·06	14·12	7·72	12·80	14·95
Fe_2O_3	2·00	0·90	5·72	0·07	8·22	4·11	1·38
FeO	11·52	12·70	10·67	12·50	11·20	8·98	10·76
MgO	5·88	3·66	5·88	6·96	4·00	1·16	6·16
CaO	9·70	8·66	8·09	10·92	6·68	12·96	9·85
Na_2O	1·46	3·01	2·75	2·85	3·14	1·11	2·70
K_2O	1·14	1·37	2·11	1·67	1·91	tr	0·72
H_2O+	0·41	0·20	0·28	1·24	0·20	0·06	0·77
H_2O-	0·36	1·35	1·73	0·22	2·01	0·62	0·09
CO_2	tr	...	...	*nil*	*nil*	0·08	*nil*
TiO_2	1·19	1·84	0·70	1·88	1·48	0·34	1·95
P_2O_5	0·01	...	...	...	...	...	0·55
MnO	0·19	0·90	0·65	0·29	0·22	0·36	0·47
FeS_2	n.d.	0·90	0·43	tr	0·16	0·16	0·26
	100·17	99·94	101·06	99·62	101·38	99·08	100·03

Explanation.

1. [3774], two-pyroxene quartz-dolerite, from 4 miles south-west of F.B. 66. *Analyst*—A. B. Edwards.
2. [3768], two-pyroxene quartz-dolerite, from the gorge below F.B. 52, north of Mt. Shadford, Upper Prince Regent River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
3. [3751], two-pyroxene dolerite, from Camp, F.B. 52, Synnott Creek, Charnley River. *Analyst*—C. C. Wilson. *Bull.* 67, *Geol. Surv. W.A.*
4. [3771], two-pyroxene dolerite, from 3 miles south-east of Mt. Lyell, Glenelg River (laccolith). *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
5. [3753], altered two-pyroxene dolerite, from the Isdell River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
6. [3760], Epidote-glaucophane rock (altered two-pyroxene dolerite), from Camp, F.B. 32, Synnott Creek, Charnley River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*

A. [7728], dolerite, sill or flow, Irregully Creek, Upper Ashburton River, North-West Division. *Analyst*—H. Bowley. *Bull.* 33, *Geol. Surv. W.A.*, pp. 1694, 169.

TABLE II.

	1.	2.	3.	4.
SiO_2	51·40	51·04	45·59	49·50
Al_2O_3	16·38	13·60	13·54	17·29
Fe_2O_3	1·26	2·08	9·39	3·95
FeO	12·78	8·40	4·87	7·78
MgO	2·30	7·94	3·01	7·24
CaO	7·32	5·68	20·19	7·75
Na_2O	3·14	4·30	0·57	3·25
K_2O	1·72	1·83	0·06	0·67
H_2O+	0·12	0·36	0·28	0·27
H_2O-	1·99	2·64	0·68	1·11
CO_2	...	*nil*	*nil*	tr.
TiO_2	1·06	1·36	0·68	0·87
P_2O_5	...	...	...	0·01
MnO	tr.	0·34	0·37	0·13
FeS_2	*nil*	...	0·17	n.d.
	99·47	99·57	99·40	99·82

Explanation.

1. [3749], two-pyroxene andesine-basalt, from 1 mile north-west of Camp, F.B. 28, junction of Maurice Creek and Charnley River. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
2. [3776], andesine-basalt, from 3 miles north of F.B. 79, Napier Broome Bay. *Analyst*—C. G. Gibson. *Bull.* 67, *Geol. Surv. W.A.*
3. [3777], epidositized andesine-basalt, from the same locality as 3776. *Analyst*—C. C. Wilson. *Bull.* 67, *Geol. Surv. W.A.*
4. [7248], hornblende andesine-basalt, from the Hann River, near its junction with the Fitzroy River. *Analyst*—A. B. Edwards.

TABLE III.

	1.	2.	3.	A.	B.	C.
SiO_2	50·3	49·9	50·5	52·2	50·5	50
Al_2O_3	14·5	13·6	15·8	14·5	14·8	13
FeO, Fe_2O_3	13·2	14·0	12·1	11·2	11·5	13
MgO	5·7	5·6	5·8	5·0	6·0	5
CaO	8·3	9·3	6·6	7·3	10·9	10
Na_2O	2·8	2·5	3·6	2·9	2·9	2·8
K_2O	1·5	1·6	1·4	2·0	0·5	1·2

1. Average of North Kimberley basalts and dolerites (7 analyses).
2. Average of North Kimberley dolerite (4 analyses).
3. Average of North Kimberley basalt (3 analyses).

A. Average East Kimberley basalt (7 analyses), A. B. Edwards and E. de C. Clarke, *Jour. Roy. Soc. W.A.*, xxvi, 1939–40, p. 93.

B. Average Tertiary tholeiite from south-western Western Australia (3 analyses). A. B. Edwards, *Jour. Roy. Soc. W.A.*, xxiv, 1937–38, p. 7.

C. Tholeiitic Magma Type. W. Q. Kennedy, *Amer. Jour. Sci.*, Ser. 5, 25, 1933, p. 239.

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PLATE I.

Fig. 1. Microphotograph of typical two-pyroxene dolerite. In ordinary light. ×15.

Fig. 2. Two-pyroxene andesine-basalt, in ordinary light, showing the pyroxene laths in the glassy base, and an olivine microphenocryst. ×15.

Plate I.

PLATE II.

Fig. 3. Andesine-basalt, in ordinary light, showing patches of chlorite. ×15.

Fig. 4. Hornblende-oligoclase-basalt, in ordinary light, showing its extremely fine-grained texture. ×15.

Plate II.