PRELIMINARY NOTE ON THE NEPHELINE-BEARING ROCKS OF THE LIVERPOOL AND MOUNT ROYAL RANGES.

By W. N. BENSON, B.Sc.

[Read before the Royal Society of N. S. Wales, August 2, 1911.]

About two years ago, when first in the Nundle district, the writer noticed the great abundance, in the gravels of the Peel River, of pebbles of a remarkable coarse-grained basic rock with large dark purple-brown phenocrysts of augite. An examination of slices of these under the microscope showed that the augites were strongly zoned, sometimes having the hour-glass structure, and were highly titaniferous, while there were a number of large apatite prisms. The general facies strongly recalled the famous nepheline dolerite of the Löbauer Berg in Saxony. Nevertheless no nepheline was detected, the salic mineral being labradorite. Similar rocks were found later at Crawney, probably in situ, some fourteen miles further up the river than Nundle. Want of time prevented the investigation of their field relationships. While on a brief visit to Goonoo Goonoo, a small pipe of the rock was found forming a slight elevation (Currajong Hill) about a mile south-east of the station. A further large extension of these rocks was suggested by the following observation made by Mr. E. C. Andrews:—“At the Hunter and Manning River headwaters two distinct basaltic types occur, one a holocrystalline rock with large augite crystals so abundantly scattered throughout its mass as to obtain for it locally the name of ‘plum pudding stone.’ Other types found here are dense fine-grained vesicular olivine basalts.”

Some months later on examining a collection of rocks given by Mr. Eustace Wilkinson of Pokolbin near Maitland to Mr. R. E. Priestley, F.G.S., a similar porphyritic rock was found, and, on sectioning, abundant nepheline was clearly visible. In letters from Mr. Wilkinson I learn the following particulars: The rocks occur in a large series, stretching from Stewart's Brook to the Barrington Trigonometrical Survey Station, a distance of 10 miles. They appear everywhere to overlie a dense normal olivine basalt, and this in turn overlies steeply dipping cherts, sandstones, and shales, carrying such typically Carboniferous forms as Orthotetes crenistria, Spirifera striata, Orthonychia, Capulus cf. Oehlerti, De Kon., with abundant crinoid stems. The fossils were kindly determined by Mr. W. S. Dun in specimens forwarded by Mr. Wilkinson.

The section exposed on the Barrington Trig. as observed by Mr. Wilkinson, is shown in fig. 1. He remarked, however, that it was drawn from memory, and that it had been possible to devote but a short time to its examination. And further, that as it was chiefly rocks of rather unusual appearance that he collected, normal basaltic rocks were sometimes passed over. Nevertheless he is emphatic on the highly important observation that the coarse-grained dolerites overlie normal olivine basalts.

A final visit proved that rocks of this type occurred near Nundle. They cap Square Top Hill, which lies three miles to the west of the township, and under the microscope prove to contain abundant nepheline.

There is evidently here a field of great extent geographically, (Stewart's Brook and Nundle are more than forty miles apart), and of considerable interest petrographically, see fig. 2. In view of the writer's approaching departure for England, it was thought well to collect into a brief note the scanty data available on these rocks to direct attention to their occurrence.

I.—August 2, 1911.
Fig. 1. Sketch section of Barrington Trigonometrical Station Hill based on observations and collections made by Mr. Eustace Wilkinson.

A. Carboniferous sandstone slates, shales and conglomerates, dipping in a general easterly direction at from 20° to 86°.

B. Dense olivine basalt with large phenocrysts of olivine; about 500 feet thick (Rock No. 1).

C. Olivine dolerite (Rock No. 2) with natrolite. The most persistent rock of the district, always overlying the basalt. It merges into the theralites. About 300 feet thick.

D. Theralite of varying grain size and degree of zeolitisation (Rocks No. 3 and 4). It always overlies the finer grained No. 2 rock. About 200 feet thick.

E. Olivine dolerite (No. 2 Rock). About 100 feet thick.

F. Basalt, very decomposed, with vesicles filled with natrolite and analcrite. Made up of numerous flows. About 500 feet thick.

G. Olivine dolerite with a little theralite.
Petrologically the rocks may be termed dolerites, using the term in its widest possible sense. They are holocrystalline aggregates of augite and plagioclase with large ilmenite crystals occasionally developed, but owing to the presence or absence of olivine, orthoclase, and nepheline, and the variation in texture, they may fall into the more strictly defined divisions of the olivine dolerites, the essex-
ites, the theralites and the basanites. The most remarkable rocks are the theralites (Nos. 3 and 4 of Mr. Wilkinson's figure) that occur on the slopes of Barrington Trig. These two rocks differ only in grain size and amount of zeolite developed. They are very coarsely granular with exceedingly well marked zonary structure in their deep purple augites. The predominant salic mineral is a labradorite in tabular crystals, and there are also large crystals of ilmenite and prisms of apatite. In addition to this, there is a certain amount of clear nepheline. All these different minerals can readily be distinguished with the naked eye in the slide of No. 4, of which Plate 6, fig. 1 is a photograph. In addition, there is a small amount of zeolite developed by alteration of the nepheline.

The most interesting feature, perhaps, is the occurrence of a second generation of augite of a more greenish tint than that of the phenocrysts, and this forms a granophyric intergrowth with the nepheline, either in little hooked-like pieces fig. 3 (a), or in peculiar arrow-head shapes fig. 3 (b).¹

Fig. 3. Graphic intergrowths of augite shaded, and nepheline clear, in theralite.

(a) from Stewart's Brook, magnified 80 diameters.

(b) from Barrington Trigonometrical Station hill, magnified 22 diam.

This is an enlarged drawing of the large nepheline grain visible in the centre of fig. 1, Plate 6.

¹ Cf. Fig. 89 B, A. Harker, The Natural History of Igneous Rocks, p. 271.
This intergrowth of augite and nepheline, though not unknown, is a very rare petrological feature. It is developed in the Löbauer Berg rock above mentioned to a finer degree than here figured. In the Stewart's Brook rock there are small aggregates of chlorite, probably pseudomorphous after olivine, but these are absent from the Barrington rock. This type of rock seems best classed as a theralite. The low percentage of silica suggested by the abundance of nepheline is confirmed by the fact that a determination of silica showed the presence of 42.54% only.

No. 2 of the Barrington series, which Mr. Wilkinson remarks appears to pass by transitions into the other types (3 and 4), has a very different fabric, the tabular plagioclases having a more parallel arrangement (fig. 2, Plate 6). There seems to be no definite nepheline, but there are present, interstitially, cloudy areas of a very low refractive index, which may represent altered orthoclase, though the occasional presence in them of spherulites of natrolite suggests the possibility of the derivation from nepheline. The augite occurs in large irregular grains with a slight development of the ophitic structure. The presence of numerous small inclusions of olivine and felspar gives it a curiously pitted appearance. Olivine also forms numerous large idiomorphic crystals. Ilmenite is abundant in small plates, but apatite is rare.

In the majority of the doleritic pebbles of the Peel River gravels, the structure is rather intermediate between those of the rocks described above. The tabular felspars have not much parallel arrangement, the augites are varied in the extent to which they show ophitic structure or idiomorphism, but are always purple. Olivine is abundant, ilmenite frequent in small grains, and apatite is not very common. In one instance orthoclase is present, forming interstitial intergrowths with plagioclase, and occasionally
occurs in individual grains. It is in very small amount however. Nepheline does not seem to be present in any of the slides I have examined.

Two extreme types call for special notice. The exceedingly coarse-grained rock illustrated in Plate 7, is composed of large crystals of augite up to two centimetres in diameter, with smaller crystals of olivine and plagioclase. There are also small crystals of ilmenite and apatite. Between the large crystals is a little fine-grained ground-mass composed of tiny felspar laths, some of them possibly sanidine, and pale yellow-brown masses of a platy zeolitic material, the precise nature of which must be left for future examination. Here and there are aggregates of very minute graphic crystallisations and rods of brown-grey augite of the second generation. This is very similar in many respects to the augite that is intercrystallised with the nepheline of the rocks described above. The rock must provisionally be classed as a porphyritic olivine dolerite. The same name is to be applied to a rock of a very different appearance, namely, that figured in fig. 3, Plate 6. It consists of large phenocrysts, up to 4 millimetres in diameter, of augite and olivine, set in an almost basaltic ground-mass composed of abundant small grains of ilmenite and purple augite with felspar laths. A little of the yellowish zeolite is present, and a very few small olivines. There appears to be a third generation of minute brown-grey arrow-heads and needles of pyroxene developing interstitially.

The only definitely nephelinic rock yet found near Nundle is that from Square Top. It forms a capping two hundred feet thick on the summit of the hill, but its mode of occurrence was not proved. There were apparently no underlying Tertiary gravels. In hand specimens the rock is dark grey, with dark purple-brown augites, and on weathered surfaces white felspar laths can be distinguished. Its microscopical
appearance is shown by fig. 4, Plate 6. It is seen to contain large, perfectly developed, phenocrysts of purple augite which have often an exterior zone full of minute inclusions of ilmenite, olivine, and scraps of plagioclase, giving a very pitted appearance. Usually the colour changes from strong purplish pink on the inner portion of this zone, to greenish-grey on the outer portion. These phenocrysts are up to three millimetres in diameter. There are numerous smaller phenocrysts of olivine. The ground-mass consists of short felspar laths, many of which are sanidine, and abundant hexagonal prisms of nepheline. A good deal of this has been changed into natrolite. As this rock has a much finer grain than any of the others and a far more volcanic habit, it may be termed a nepheline basanite. The small amount of plagioclase present prevents it from falling directly under the nepheline basalts, using the term in its strict sense.

A mile south-east of Goonoo Goonoo Station and about twenty miles north-west of Nundle is a small knoll, Currajong Hill. On a very hasty examination it appeared to be a neck about ten yards (from memory) in diameter composed of a coarse grained rock of granite texture with dark purple black pyroxene. On section, this proves to be also closely related to the rocks above described. It is a remarkably fresh rock, and contains large purple augites, clear olivines, large labradorite tabulae, with a fair amount of interstitial orthoclase. Numerous small crystals of ilmenite are present, often surrounded by bright red-brown pleochroic biotite. Apatite prisms are well developed. The rock is best termed an essexite.

Here attention should be drawn to the similarity, several times remarked upon by Dr. Jensen, between these rocks and the essexites, described by him, which occur as rolled

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pebbles in Bullawa Creek in the Nandewar Mountains, over one hundred miles N.N.W. of Nundle and Goonoo Goonoo.

With the exception of Mr. Wilkinson's important discovery that these rocks overlie the normal Tertiary olivine basalt, and the writer's discovery of them at Nundle capping a high hill, we have little direct evidence of their mode of occurrence. Nevertheless an observation made by Dr. Woolnough is of importance in this question. He ascended Mount Warrawalong thirty miles W.S.W. of Newcastle and over a hundred miles south of the occurrences described above. He there found the Tertiary basalt cap penetrated by dykes of coarse-grained olivine dolerite. He has generously handed specimens of this rock to me for description.

Microscopically the rock is seen to contain large elongated ophitic crystals of dark purple augite up to two centimetres in length, with felspar tabulæ and interstitial white zeolite. The microscope shows that the augite is strongly titaniferous, and has the hour-glass structure developed to some extent. A peripheral zone of a greenish colour is sometimes developed, the colour-change being usually gradual, though in some instances quite sharp, as though the crystal had grown by secondary enlargement during a later epoch of pyroxene crystallisation. The felspar is chiefly orthoclase, in large or smaller prismatic crystals, idiomorphic against a yellowish zeolitic ground mass. It is mostly glassy and untwinned, but decomposition is commencing along the cracks. Plagioclase tabulæ are also present. The refractive index is distinctly above that of the Canada balsam. There are large crystals of olivine, irregular plates of ilmenite, slightly leucoxenised, and numerous large apatite prisms. Interstitially there is a considerable amount of an almost isotropic yellowish zeolitic material, (analcite?), like that in the northern rocks. Imbedded in this are minute graphic fragments of green augite, similar
to that on the periphery of the phenocrysts. There are also, interstitially, patches of minute plagioclase laths with ophitic green pyroxene. This feature also is exhibited in some of the northern rocks. There are a few large patches of a zeolite of moderate birefringence. This rock is clearly an essexite. A second rock from the same locality and occurrence differs in the almost complete absence of orthoclase. The plagioclase is labradorite, and there is a little yellowish interstitial material with minute felspar laths and augite of the second generation; apatite is rare. This is an olivine dolerite. It is possible, of course, that the essexite is not a distinct occurrence, but that the section examined chanced to pass through a locality of orthoclase segregation in the essexitic dolerite.

It will be seen that the specimens bear features strongly recalling the northern rocks and may be considered to belong to the same series. Their intrusive character into Tertiary basalts supports Mr. Wilkinson’s statement that the latter overlie these at Stewart’s Brook. The extreme coarseness of grain of the majority of the rocks makes it in the highest degree improbable that they were flows. Might it not be suggested that they will be found to form sills in the Tertiary basalt, and to be comparable to the dolerite sills in the Tertiary igneous series of Skye? It may further be pointed out that the range of mineralogical composition of these rocks is almost paralleled by that of the Tertiary basalts themselves. Some are purely felspathic, some strongly nephelinic.

I have to thank Mr. Eustace Wilkinson for the pains he has taken in supplying me with information and specimens from Stewart’s Brook and the Barrington Trig., and Dr. Woolnough for the opportunity of examining the Warrawalong material. To Mr. A. B. Walkom, B.sc., I am indebted for kindly consenting to correct the proofs in my absence.
EXPLANATION OF PLATES.

Plate VI, fig. 1—Theralite from Barrington Trigonometrical Station. Note the zoned augite, large ilmenites, cloudy felspar and clear white nepheline × 4. An enlarged drawing of this white patch is shown in text fig. 3.

2—Olivine dolerite from the above locality, with plagioclase, augite, olivine, and natrolite × 12.

3—Olivine dolerite from the Peel River gravels showing basaltic ground-mass × 11.

4—Nepheline basanite, Square Top, Nundle, showing augite phenocrysts, with peripheral zone full of inclusions, olivine, and hexagonal nepheline crystals in the ground mass × 18.

Plate VII, Specimen of porphyritic olivine dolerite from the Peel River gravels near Nundle, with large phenocrysts of titaniferous augite. Scale one half natural size.

Corrigendum to paper entitled "The Volcanic Rocks of Hornsby and Dundas," this Journal, Vol. xlv, pp. 495–555, 1910. The analysis of the Hornsby basalt, pp. 544–545 was made simultaneously with analyses of several other rocks, and it has since been discovered that the wrong figure for titan oxide was entered through oversight, in the Hornsby analysis. A redetermination has been completed and the correction must be made as under.

Pages 544 and 545, substitute for the figures given:—

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\begin{align*}
\text{Al}_2\text{O}_3 & \quad 17.94\% \\
\text{TiO}_2 & \quad 2.64\%
\end{align*}
\]

and the following recalculated norm.:—

<table>
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<th>Amount</th>
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<tr>
<td>Albite</td>
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<tr>
<td>Anorthite</td>
<td>24.74</td>
</tr>
<tr>
<td>Nepheline</td>
<td>1.14</td>
</tr>
<tr>
<td>Diopsode</td>
<td>9.95</td>
</tr>
<tr>
<td>Olivine</td>
<td>4.54</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{Magnetite} & \quad 4.64 \\
\text{Ilmenite} & \quad 5.02 \\
\text{Apatite} & \quad 1.34 \\
\text{CO}_2 & \quad 7.1 \\
\text{Water} & \quad 4.12 \\
100.98 & \quad 100.98
\end{align*}
\]

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