the patience of the readers of the GEOLOGICAL MAGAZINE I should like some day to make an attempt to show how the trick is done, and how ripple-mark concerns geologists, not as a mere unimportant detail of rock-structure, but as an important factor and index in the great problem of marine erosion. In the meantime I may refer to Dr. Nansen's admirable epitome of the evidence of marine erosion in his work above referred to, and also to Dr. Cornish's papers in the *Geographical Journal*.

VII.—CONTRIBUTIONS TO THE GEOLOGY OF CEYLON :

III. THE BALANGODA GROUP.

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THE name 'Balangoda group' is proposed for a series of granitic and pegmatite-like rocks, intrusive in, but distinct from, the Charnockite series; first met with in the Balangoda district, but evidently widely distributed over a large area between Balangoda and Hatton. The rocks are best described as granites, but occur most often in rather narrow dykes, after the manner of pegmatites. Yet there is no reason for separating the smaller from the larger masses, and the term granite is applied to both. The group (of which a more detailed account will ultimately be needed) includes in particular zircon granite, allanite granite, magnetite granite, and granite without conspicuous accessory minerals; as well as the probably similar rocks in which the hitherto unlocated minerals geikielite, baddeleyite, rutile, fergusonite, thorite,¹ thorianite, etc., may be looked for; and the vein of pegmatite at Gampola, which consisted of quartz, feldspars, and biotite, with apatite, ilmenite, tourmaline, and the new mineral described as thorianite² as accessory minerals.

These granites are intrusive in the Charnockite series, and though frequently occurring in lenticular masses (Denagama) with a disposition parallel to that of the foliation planes of the charnockites, have often been observed to transgress these foliation planes and to behave as intrusive rocks. Contact phenomena have not, however, been observed, except perhaps in a slight tendency to a peripheral fineness of grain in the intrusive rocks. At the junctions granite and charnockite are usually welded together, there being no absolutely hard line of separation, although the junction may be called sharp; in the case of the larger masses no good junctions have been seen.

A description of the rocks is given below, with special reference to the localities where they can be seen :—

Zircon granite.—This rock was seen *in situ* at several points, and is the best known member of the group. The finest and longest exposure is on Massena estate, six miles from Balangoda; here a considerable mass of granite, fully two miles in length and

¹ W. Dunstan, *Nature*, 1904, p. 510.

² "Spolia Zeylanica," vol. i, pt. 4 (1904), p. 112; and *Nature*, loc. cit.

averaging perhaps a hundred yards in width, runs, parallel to the Charnockite foliation-strike, along the trough-like strike valley of the Massena Oya, in which the main part of the estate is found. The rock occurs in enormous masses, both *in situ* and in great boulders, amongst which the Massena Oya finds its way. Two rows of curiously weathered masses stand out of the swamp below the bungalow; good specimens very rich in zircon can be collected here. The rock usually shows no trace of foliation in small specimens; but foliation (vertical, with strike about 15° N. of W.) is evident in an exposure *in situ* near the middle of the estate, near the 'lines.'

The rock consists essentially of quartz, felspar, and biotite, with zircon and ilmenite as characteristic accessory minerals, and apatite as a microscopic constituent. The content of zircon varies greatly from specimens in which a crystal can hardly be found to others

FIG. 1.—Rough sketch-map of zircon granites near Denagama Oya bridge, near Balangoda, Sab, Ceylon. $\times \times \times$ zircon granites; $+$ zircon granites well foliated. Scale, 5 inches = $1\frac{1}{2}$ miles.

in which it forms a noteworthy proportion of the rock. The zircon occurs in moderately good, idiomorphic, stumpy, prismatic crystals, generally terminated, the forms m (110), a (100), p (111), e (101) being certainly present; the colour is hair-brown, often quite pale; in thin section no colour is seen; the longest individuals exceed $\frac{3}{8}$ inch in length, but most are somewhat smaller. The rock itself is relatively fine-grained, the quartz and felspars rarely exceeding in diameter the length of the longest zircons. The felspars include orthoclase (sometimes micropertitic) and an acid plagioclase with s.g. near to that of orthoclase. The biotite occurs in ragged crystals, macroscopically nearly black, but brown in thin section, and with pleochroism from warm brown to pale straw colour. Ilmenite is common, occasionally moulding the zircons, and generally partly altered to 'leucoxene.' Apatite is fairly abundant in six-sided terminated prisms about $\frac{1}{16}$ inch in length. The general structure is hypidiomorphic, only the zircon and apatite occurring in well-developed crystals.

Another exposure (Map, Fig. 1) is seen near the bridge over the Denagama Oya, about 6 miles from Balangoda on the Haputale road. Small idiomorphic zircons ($\frac{1}{16}$ inch) are scattered sparingly in the rock, which resembles that of Massena estate, but is of somewhat coarser grain. Ilmenite is common, the zircon quite scarce. Other exposures are found along the line of strike on the left bank of the stream. The granite seems to form a series of lenticular masses. At one point the rock becomes well foliated (as if by pressure), the small crystals of biotite being closely packed and sweeping round the augen orthoclase. Well-formed zircons $\frac{3}{8}$ inch in length are to be found.

A similar foliated zircon granite is exposed by the roadside $1\frac{1}{2}$ miles further on, just beyond the 91st milepost; the zircons vary from $\frac{1}{16}$ to $\frac{1}{8}$ inch in length, and are of the usual light-brown colour.

No junctions were observed in the instances above referred to.

Near Haldummulla and about 18 miles from Balangoda a small granitic dyke was seen in the Weli Oya valley about half a mile above the road, crossing foliation in the Charnockite series and containing a few minute zircons just visible to the naked eye.

In the Bamberabotuwa district a large number of small intrusive pegmatites or granite dykes were examined on Hopewell estate (15–16 miles from Balangoda), where they are well exposed, and cross the foliation of the Charnockite series in all directions; only two were found to contain minute crystals of zircon sparingly distributed. Zircon may occur in others, but so rarely as to be overlooked. This exhausts the list of localities where macroscopic zircons have been seen *in situ*.

Zircons of all sizes (up to $1\frac{1}{2}$ inches or more) occur abundantly in every stream and river gravel, and are found in quantities when gemming operations are carried on, joining a large proportion of the heavy residue (*nāmbu*¹) at the bottom of the gemming-basket: the clear-coloured varieties are of value as gems; the remainder is rejected. The irregular zircons described by Mr. Spencer² occur in this way in various parts of the Balangoda and Bamberabotuwa districts. Near Kondrugala zircon is very abundant in large individuals. Well-developed twins on *e*(101) are found. With the zircon are associated 'thorianite,' thorite, ilmenite. Large zircons have also been found in gemmings from the Hatton district. Zircon is also abundant over a wide area in the Southern Province in the Galle, Matara, and Morawaka districts, and no doubt also at Rakwana; the same rocks may be expected to be met with in these districts.

Allanite granites.—Allanite granites are well exposed in two places in the Balangoda districts. It is some years since Mr. W. D. Holland discovered a granite or pegmatite dyke, crossing foliation in the Charnockite series, in the bed of the Wewel Dola near the lower end of his estate of Dik Mukulana, and containing allanite in some abundance. The determination of allanite was confirmed

¹ A Sinhalese term which may with advantage be adopted.

² *Nature*, April 14th, 1904, p. 575.

by a partial analysis made for Mr. Holland, and by Mr. G. T. Prior, to whom a sample was submitted. The granitic dyke is composed of quartz, felspar, hornblende, allanite, biotite, pyrite.

The felspars include porphyritic orthoclase and also a series of smaller individuals of orthoclase and plagioclase (some of the latter are porphyritic like the orthoclase), forming with quartz the finer-grained portions of the dyke. Allanite and hornblende occur in varying amount, both being locally very abundant. Biotite is scarce. Pyrite occurs chiefly in secondarily deposited films.

A better exposure of allanite granite is found in the lower part of Denagama estate, about seven or eight miles from Balangoda. A conspicuous dyke, three to four feet thick, crosses the left branch of the stream, which runs through the tea below the path, and forms a conspicuous ledge inclined at a low angle to the foliation. The granulites are inclined at a very similar angle, but it can be seen clearly that the dyke does not keep strictly to the foliation planes; moreover, a few short processes, six inches to a foot in width, project into the rock underlying the dyke, clearly showing the intrusive character of the latter. The dyke is coarse-grained, and consists mainly of orthoclase (porphyritic idiomorphic individuals often about 3×1 inches), quartz, and biotite, the latter in long thin crystals (measuring e.g. $9 \times 1 \times \frac{1}{4}$ inches) scattered in all directions through the rock.

In these two dykes the allanite is very unevenly distributed, being in places very abundant, and elsewhere almost or quite absent. The allanite forms thin tabular idiomorphic as well as more irregular individuals; the largest attain a length of three inches, those of medium size measure about $1 \times \frac{1}{2} \times \frac{1}{4}$ inch. A curious point is that the allanite seems to form a centre for radiating cracks in the rock, giving it a rather conspicuous appearance, of which a diagram is given in Fig. 2 (Denagama).

The allanite is macroscopically black (in thin section brownish olive-green), and has a resinous lustre and conchoidal fracture; hardness about 6; sp. gr. 3.2 to 3.5; before the blowpipe it intumesces strongly.

Magnetite granite.—A small dyke 2 inches wide and of the usual character, but containing irregular individuals of magnetite about $\frac{3}{4}$ inch in diameter, was seen in the bed of the Wewel Dola at Dik Mukulana. Another dyke 6 inches wide, containing similar magnetite, was observed on Hopewell estate.

*The Gampola pegmatite.*¹—This rock consisted mainly of orthoclase, quartz, and biotite, and contained apatite, tourmaline, ilmenite, and uraninite ('thorianite') as accessory minerals.

Granites without conspicuous accessory minerals.—These are of fairly general distribution in the Balangoda district, sometimes occurring in the form of dykes (usually less than three feet in width) in very considerable abundance. It is possible that a much more extended search might reveal the presence of macroscopic zircons in some of these rocks; for the most part, however, they

¹ "Spolia Zeylanica," vol. i, pt. 4 (1904), p. 512.

are similar to the granitic rocks described above, but without the characteristic accessory minerals. There is a considerable exposure of reddish granite on the Ratnapura road about a mile below Balangoda, and this is known as a locality for 'graphic granite.' A tendency to graphic structure was noticed in many of the rocks already described. Smaller masses (dykes) are common at Dik Mukulana (11 miles from Balangoda) and on Hopewell estate,

FIG. 2.—Structure of allanite granite; Denagama estate, Balangoda. *A*, allanite; *B*, biotite; *O*, orthoclase; remainder quartz and felspar. Present scale, $\times 5\frac{1}{2}$ times.

15 miles from Balangoda, and at many other points. These granites (as well as others containing zircon) are also well exposed on Herimitegala estate, about 8 miles from Balangoda.

The list of types of rock belonging to the Balangoda group actually met with is now exhausted. There can be no doubt that many other varieties will be found, and it is evident that some are likely to be of great interest. Since, however, detrital zircon is exceedingly abundant, yet is known *in situ* in a few localities only, it is clear that the chance of finding any particular one of the other and rarer minerals *in situ* must be rather small.

REVIEWS.

I.—DR. FRIDTJOF NANSEN'S RESEARCHES INTO THE BATHYMETRICAL FEATURES OF THE NORTH POLAR SEAS.¹

THIS elaborate volume is the outcome of Dr. Nansen's Arctic Explorations, of which we have narratives in his "First Crossing of Greenland" (1890) and his "Farthest North" (1897), both

¹ Published by the Fridtjof Nansen Fund for the Advancement of Science (with 29 plates). Christiania, 1904.