

opposition, and the winds blowing towards the Poles would be increased in strength and produce a still further rise of temperature on the earth's surface in high latitudes.

The change from the archipelagic to continental conditions occurred about the time when, for some reason or other, the whole of the troposphere, and probably the stratosphere as well, became colder and the snow-line was lowered. Glaciers, consequently, formed on high mountain ranges and in high latitudes when the snowfall was sufficient. With the passing away of the conditions which gave rise to the Ice Age, glacial conditions disappeared almost entirely from all except high mountain ranges of middle latitudes; but owing to the joining up of the islands on the continental platforms frigid conditions remained over the Polar areas.

The whole subject of the climatic conditions through which the earth has passed is full of interest and difficulty. I have no wish to appear dogmatic on the subject, for much will have to be learned before any theory can be considered as probably correct. One thing seems to be pretty clear, and that is that until a sound theoretical reason can be given to account for the general winds of the earth blowing as they do there is little chance of dealing satisfactorily with the climatic changes which might result from geographical changes.

VI.—THE CRAWFORDJOHN ESSEXITE AND ASSOCIATED ROCKS.

By ALEXANDER SCOTT, M.A., B.Sc.

INTRODUCTION.

ALTHOUGH the so-called Crawfordjohn essexite has been mentioned several times in petrographic literature, no detailed description of the occurrence has been given.¹ In 1888 Teall² described the main rock of the intrusion as an abnormal variety of the N. W.—S. E. Kainozoic dykes and noted the porphyritic augite and the abundance of feldspar, olivine, and apatite. Lacroix,³ in a general paper on the teschenites, mentioned the occurrence of nephelite in the same rock, which he described as an "olivine-teschenite, passing in structure to a tephrite". Bailey, in the Glasgow memoir,⁴ remarked on the close similarity between the Crawfordjohn and Lennoxtown rocks and classed them with the essexites on account of their chemical similarity to the Brandberget rocks,⁵ while Tyrrell,⁶ on account of this similarity and also of the resemblance to the Carclout essexite, included them in the late Palæozoic alkaline group.

The intrusion occurs on the west side of Craighead Hill,⁷ about one mile west of Abington Station and $2\frac{1}{2}$ miles east of Crawfordjohn.

¹ No mention of it is made in the Explanation of Surv. Scotland, 1871.

² *British Petrography*, 1888, p. 197.

³ *Compt. Rend.*, cxxx, p. 1273, 1900.

⁴ *Geology of Glasgow District* (Mem. Geol. Surv.), 1911, pp. 113, 130.

⁵ W. C. Brögger, *Quart. Journ. Geol. Soc.*, l, pp. 15-38, 1894.

⁶ *Geol. Mag.* [5], IX, p. 121, 1912.

⁷ The Craighead Hill, mentioned in *The Silurian Rocks of Britain* (Mem. Geol. Surv.), i, 1899, pp. 462-3, 501, lies in the Girvan Valley, Ayrshire.

The chief exposures are in Craighead Quarry, on the 1,000 ft. contour-line, and in a disused quarry 200 yards to the south-east. A number of isolated exposures are found further up on the hillside. The general trend of the exposures is a line running N.W. and S.E., which is apparently parallel to the northern contact with the sediments. The main rock is well exposed in both quarries, as is a fine-grained marginal facies, but although sediments are also seen the actual contact is usually obscured by drift or debris. The sediments, which are of Ordovician age, consist mainly of grits and shales, folded and lying almost vertical, and have undergone considerable metamorphism by the intrusion. The southern contact is nowhere exposed, but the grits occur in situ, in a small drift-covered quarry, 200 yards south of the large quarry. The main mass of the intrusion is a grey compact rock showing numerous phenocrysts of augite. In places, the porphyritic aspect is not so pronounced, and the rock is apparently more even-grained. As the edge of the intrusion is approached, the grain-size diminishes until at the margin the rock is thoroughly aphanitic, none of the minerals being distinguishable in the hand-specimen.

THE ESSEXITES.

Microscopically, the porphyritic rock is seen to consist of numerous crystals of olivine and euhedral lath-shaped feldspars, accompanied by, and occasionally included in, large phenocrysts of augite. Ilmenite and apatite are fairly abundant, and sporadic flakes of biotite also occur. The interstices are filled with nephelite and analcite.

The olivine occurs in the usual rounded crystals and, as noted by Teall,¹ is generally fresh and distinctly greenish in colour. The crystals are often enclosed by the augite and are euhedral towards the feldspar. They contain a number of minute inclusions of a greenish-brown colour. These have no cleavage, are distinctly pleochroic, the colour varying from greenish-yellow to light-brown, and have a maximum extinction of about 35°. The refractive index is high, and the double refraction fairly strong. These characteristics agree with those of orthite, and the presumption that the inclusions are composed of this mineral is strengthened by the appearance of a reddish alteration product and by the fact that a trace of cerium oxide (and possibly thoria as well) was detected during the chemical analysis of the rock. In some of the more altered rocks, the olivine is replaced by pseudomorphs which closely resemble those in the Derbyshire Toadstones described by Bemrose.² The alteration commences along the cracks, and the pseudomorphs, which have a good cleavage, appear to have the same optical orientation as the original crystals. The pleochroism is very intense, and the colour varies from a blue-green (when the light is vibrating parallel to the cleavage-trace) to a deep red. The refractive index lies between that of olivine and feldspar, the double refraction is fairly high and the axial angle apparently large. Although similar pseudomorphs have been

¹ *British Petrography*, 1888, p. 197.

² H. H. Bemrose, *Quart. Journ. Geol. Soc.*, 1, pp. 603-42, 1894.

described from a number of localities,¹ in no case has the exact nature of the mineral been determined. It has generally been described as a mica or chlorite-like mineral. The optical properties resemble those of pennine, but the pleochroism is too intense and the double refraction too high for that mineral. The green colour of the olivine indicates a high content of fayalite, and it is probable that the pseudomorph is some type of iron-rich chlorite.

The olivine-crystals are often surrounded by an irregular border of strongly pleochroic mica, while sporadic flakes of the latter also occur throughout the groundmass. The mineral seems to have arisen through the resorption of the olivine by the water-rich residual magma which finally crystallized as analcite.

The augite occurs in large idiomorphic crystals, up to a centimetre in diameter, and has the purple colour characteristic of the so-called titanaugite of alkali-rich rocks. The crystals are often twinned on *a* (100), and irregular intergrowths and crystal-groups commonly occur. There are numerous inclusions of olivine, labradorite, apatite, and orthite (?), these being sometimes arranged parallel to the boundaries of the augite. Morphologically and optically, the mineral resembles the augite of the Bail Hill tuffs,² the hour-glass structure being very marked and a strongly-developed zonary banding being visible even in ordinary light. As determined in a number of twinned crystals, the extinction in the 'b-sector' of the hour-glass is 40° and in the 's-sector' 42½°. The mean refractive index is about 1.70 and the double refraction .030, the optic axial angle, as determined by means of the Federov stage, being 57½°. The dispersion of the bisectrices is fairly high, so that sections in or near the symmetry-plane do not extinguish in white light. The pleochroism is relatively strong, the scheme being *a* and *c* yellowish-brown, *b* reddish-purple (madder).

Some of the mineral was separated from the rock and analysed. This analysis, however, does not give the true composition of the mineral, as it is impossible to get rid of the numerous inclusions of olivine (sometimes occupying 20 per cent by volume of the augite). Column 6, table ii, gives the figures of the analysis made. It is certain that the ratio of lime to magnesia is too low on account of the amount of olivine present. The figures, however, could be used to determine the mode of the rock, as most of the inclusions are so small that they would be reckoned with the augite.

The plagioclase occurs as abundant lath-shaped crystals with the optical properties of 'basic' labradorite. These are sometimes sub-optimally enclosed by the augite and occasionally even penetrate the olivine, but in general they are arranged in characteristic aggregates surrounding these two minerals. Occasionally much larger equidimensional crystals with well-developed zonal structure are found, and these appear to be of early formation. The orthoclase, which is

¹ H. W. Monckton, *ibid.*, 1, pp. 40-1, 1894; H. H. Bemrose, *loc. cit.*; J. S. Flett in *Geology of East Fife* (Mem. Geol. Surv.), 1902, p. 392; R. B. Young, *Trans. Edin. Geol. Soc.*, viii, p. 327, 1903; S. H. Reynolds, *Quart. Journ. Geol. Soc.*, lxi, p. 508, 1908.

² A. Scott, *Min. Mag.*, xvii, pp. 100-10, 1914.

not abundant, also occurs in squat crystals, though sometimes it appears to border the plagioclase. The nephelite is fairly fresh and seldom idiomorphic, being usually found in irregular aggregates. The analcite is always interstitial and very fresh, and is distinguishable by its high relief and absence of double refraction. There are also numerous small eumorphic prisms of apatite. The iron-ore is apparently a titanomagnetite, and is generally surrounded by a narrow rim of deep-brown biotite.¹

The olivine is invariably the first mineral to crystallize after the accessory apatite and orthite(?) and the felspar the second, since they both occur enclosed in the augite. In some cases, the felspar has begun to solidify while the olivine crystals were still growing. The last-formed minerals are nephelite and analcite, the latter of which has not only filled the interspaces but has also, while still liquid, corroded the already formed phenocrysts with the production of biotite. The formation of the latter mineral is therefore to be ascribed to the action of the water-rich magmatic residuum on the already formed olivine and magnetite.

Although the porphyritic rock is fairly uniform, local differences in the relative amounts and grain-size of the various minerals are common. Column 1, table i, gives the mineralogical proportions, as determined by the Rosiwal method, of a rock from one of the exposures on the hillside, while column 2 gives those of a rock from the large quarry. The ratio of augite to olivine varies considerably, the variation being quite irregular so far as position in the intrusion is concerned. While one specimen from the large quarry is very poor in analcite and nephelite, the total amount of these minerals being about 3 per cent, others, within a short distance, contain as

TABLE I.

	1.	2.	3.	4.	5.
Plagioclase }					
Orthoclase }	32.2	30.9	35.2	23.3	32.3
Nephelite .	7.1	4.6	15.0 ²	{ 12.6	6.1
Analcite .	5.9	5.2			
Titanaugite .	27.4	41.0	34.5	36.1	25.9
Olivine .	23.8	13.8	9.7	18.6	27.9
Biotite .	.3	.4	1.5 ³	3.6	1.4
Ilmenite .	2.3	2.9	3.7	4.2	4.3
Apatite .	1.0	1.2	.4	1.6	.7
	100.0	100.0	100.0	100.0	100.0

1. Essexite (normal type), Craighead.

2. Essexite (augite-rich type), Craighead.

3. Essexite, Carclout, Patna.⁴

4. Theralite, Lugar.⁵

5. Kylvite (less femic type), Craigmark.⁶

¹ Cf. R. Campbell & A. G. Stenhouse, *Trans. Edin. Geol. Soc.*, ix, p. 126, 1907.

² Includes some turbid unidentified matter.

³ Includes a little hornblende.

⁴ Cf. G. W. Tyrrell, *GEOL. MAG.* [5], IX, p. 121, 1912. The writer is indebted to Mr. Tyrrell for the loan of slides of this rock.

⁵ *Ibid.*, p. 77.

⁶ *Ibid.*, p. 123.

much as 14 per cent. The distribution of the largest augites is also irregular, while it is curious that the very large crystals are often extraordinarily rich in inclusions. In the large quarry there are found several rocks which appear even-grained in the hand-specimen and some of which have pink felspar. In thin section, these are decidedly porphyritic, but the augite-phenocrysts are much smaller than in the rocks described above. The pink colour of the felspars is due to the fact that the latter are much 'analclitized',¹ being sometimes totally replaced by a dusty aggregate of analcite and other zeolites, although the interstitial analcite is often limpid and quite unaltered. In the neighbourhood of these rocks small clots, poor in ferromagnesian minerals but with abundant felspar and analcite, often occur.

TABLE II.

	1.	2.	3.	4.	5.	6.
Si O ₂	44.37	45.03	43.65	43.10	40.87	43.94
Ti O ₂	2.37	2.30	4.00	2.80	2.85	4.38
Al ₂ O ₃	14.19	14.82	11.48	13.94	16.23	7.01
Fe ₂ O ₃	3.12	2.77	6.32	4.92	1.31	4.36
Fe O	7.28	8.71	8.00	6.93	7.37	9.68
Mn O	.24	.37	—	.14	.64	tr.
Mg O	7.84	7.79	7.92	8.86	9.83	10.81
Ca O	12.68	9.83	14.00	14.65	11.13	14.95
Na ₂ O	3.86	4.33	2.28	2.50	2.78	3.76
K ₂ O	1.92	1.51	1.51	.89	.53	.57
H ₂ O +	1.23	1.71	1.00	.55	1.35	.04
H ₂ O -	.24	.24	—	.15	4.28	not found
P ₂ O ₅	.83	.58	tr.	.27	.52	.41
CO ₂	not found	.22	—	.64	.38	not found
(Ba . Sr) O	tr.	—	—	.06	—	—
	100.17	100.21	100.16	100.40	100.07	99.91

1. Essexite, Craighead, analyst A. Scott.
2. Essexite, Lennoxtown, analyst W. Pollard.²
3. Essexite, Brandberget, analyst L. Schmelk.³
4. Essexite, Mt. Royal, Montreal, analyst B. J. Harrington.⁴
5. Theralite, Barshaw, analyst E. G. Radley.⁵
6. Essexite (with inclusions), Craighead, analyst A. Scott.⁶

A sample of the fresh rock from one of the exposures on the hillside has been analysed and the results are given in column 1, table ii, several other analyses being included for comparison. The composition of the Craighead rock is very similar to that of the Lennoxtown essexite, and both resemble closely the Brandberget type. It was on account of this chemical resemblance that Bailey⁷ classed the two former rocks as essexites. The name essexite was given

¹ Cf. J. S. Flett in *Geology of Edinburgh* (Mem. Geol. Surv.), 1910, p. 295.

² Summary of Progress of Geological Survey for 1907, 1908, p. 55; E. B. Bailey, loc. cit., p. 130.

³ W. C. Brögger, loc. cit., p. 19.

⁴ F. D. Adams, Geological Congress, Canada, 1913, Guide-book No. 3, p. 39.

⁵ E. B. Bailey, loc. cit., p. 134.

⁶ Another analysis of more impure material is given by G. W. Tyrrell, *Geol. Mag.* [6], II, p. 363, 1915.

⁷ Loc. cit.

by Sears¹ to an olivine-free soda-gabbro from Essex Co., Mass. Rosenbusch² expanded the term to include olivine-bearing types of the same rock, and also applied it to the Norwegian rocks which Brögger³ had termed 'olivine-gabbro-diabase'. Owing to the fact that the amount of nephelite may vary widely, while olivine and hornblende may be absent or may be prominent constituents, the term *essexite* has been very loosely used, and rocks ranging from gabbro to theralite have been included in this class. The name should be restricted to those gabbroid rocks in which the felspar is strongly sodic and the nephelite small in amount. Where nephelite (or analcite) is a prominent constituent, the rocks should be classed as theralites, while the name *essexite-theralite* could be used for intermediate types. Where olivine or hornblende is present in notable amount, the terms 'olivine-essexite' and 'hornblende-essexite' could be used. Thus some of the specimens from Craighead could be included under the former name, while the latter could be applied to the dominant type in the Monterey hills.⁴

That the Craighead rock is related chemically to the theralites may be seen by a comparison of columns 1 and 5, table ii, while the mineralogical connexion is evident from a consideration of columns 1 and 4, table i. This type, therefore, might be fitly termed an *essexite-theralite*, and the rock generally may be said to vary from a normal *essexite* to an olivine-*essexite* and *essexite-theralite*. Some of the olivine-rich varieties have obvious affinities with the less femic types of kyllite (cf. column 5, table i), and it is apparent that by an increase in the amount of olivine a continuous sequence may be traced from *essexite* through olivine-*essexite* to kyllite and finally kyllite-picrite.

THE MARGINAL ROCKS.

Although several types of aphanitic rock can be recognized under the microscope, these generally exhibit a monchiquitic habit. One type, which occurs in the large quarry and may be distinguished in the hand-specimen by the 'spotted' appearance of the weathered surface, is rather less aphanitic than the others. In thin section it is seen to consist of abundant microphenocrysts of olivine and augite with scarcer felspar in a fine-grained matrix. The augite, though a titaniferous variety, is somewhat less pleochroic than the mineral of the *essexites*, while the olivine is usually replaced by an aggregate of fibrous serpentine. The ferromagnesian minerals are often poecilitically enclosed in the labradorite, a structure strikingly in contrast to that of the *essexites*, where augite is the enclosing mineral. The matrix consists of small granules of augite and magnetite in a dusty base of analcite and nephelite with locally a number of small felspar laths. Mineralogically the rock might be termed a nephelite or analcite basalt, but on account of its association

¹ Bull. Essex Inst., xxiii, p. 146, 1891.

² *Mikroskopische Physiographie*, 4th ed., 1908, II, i, p. 404.

³ Loc. cit.

⁴ F. D. Adams, loc. cit.; also *Journ. Geol.*, xi, pp. 239-82, 1903; J. A. Dresser, *Geol. Surv. Canada*, Mem. No. 7, pp. 14-18, 1910; J. J. O'Neill, *ibid.*, Mem. No. 43, pp. 28-84, 1914, etc.

with the essexites and its intermediate texture, it may be included in the essexite-monchiquites. Lacroix¹ has applied this term to those monchiquites in which felspar predominates over nephelite and which have, in addition, an isotropic (presumably analcitic) groundmass. The Madagascar rocks differ from the one under consideration only in the presence of barkevikite and in a greater scarcity of olivine. The name is appropriate in the case of the Craighead rock, since, by an increase in the grain-size of the minerals, a gradual passage may be traced to a normal essexite.

Another 'spotted' rock represents a more felspathic and finer-grained type than the one described above. The phenocrysts are not so abundant, and the olivine rivals the augite in size. As before, both these minerals are poecilitically enclosed in felspar, which, however, also occurs as laths, of varying dimensions and often arranged in a radial fashion. The phenocrysts, together with a second generation of augite and numerous prisms of apatite, are enclosed in a matrix which is mainly analcite. In both of these rocks, local patches of a more acid nature occur. Olivine and porphyritic augite are absent, and the 'clots' consist of phenocrysts of labradorite in a groundmass of analcite, with subordinate nephelite and granular augite. These seem to be of late formation and to arise through the crystallization of a residual magma rich in water and alkalis.

(To be concluded in our next Number.)

VII.—ON A NEW GENUS AND SPECIES OF THE THECIDIINÆ (BRACHIOPODA).

By J. ALLAN THOMSON, M.A., D.Sc., F.G.S.

THE subfamilies Thecidiinæ, Dall, and Leptodinæ, Schuchert, constitute the family Thecidiidæ, Gray, which is regarded by Schuchert as a near relation of the Strophomenidæ. The chief external characters of the Thecidiinæ are the smallness of the shells, the absence of the foramen, attachment by the ventral valve, the presence of a nearly straight hinge-line and of a prominent area with a solid deltidium. The shell substance, with the exception of the deltidium, is punctate. Internally the ventral valve bears in its hollow beak a small median septum on which is sometimes superposed a small muscular plate. The dorsal valve bears a so-called cardinal process, formed by the median union of the socket ridges, and this plate is strong, subrectangular, and hollow at its base, and projects beyond the hinge. In most of the genera two lateral spurs unite mesially to form a bridge just in front of the cardinal process, over the visceral cavity. There are no free brachial arms, but the brachial supports are represented by an anterior septum, frequently branched, and lamellæ rising from the floor of the valve in the spaces between the septum and its branches, the margins, and the bridge. The septum runs back from the anterior margin towards the bridge, and like the margins and the bridge, is more or less covered with granulations.

¹ *Nouvelles Archives du Museum* [4], i, p. 142, 1903.