ON THE OCCURRENCE OF A VARIETY OF TINGUAITE AT KOSCIUSKO, N. S. WALES.

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[With Plates I., II.]

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CONTENTS.

I. *Introduction.*—The rock described in this paper was discovered during a visit of two of the authors (Messrs. David and Guthrie) in company with Mr. Richard Helms, to the Kosciusko Plateau last February. Eruptive rocks, in which the felspathoid mineral nepheline replaces felspar, are somewhat rare in their distribution, and all the more interesting on that account. In England for example, nepheline rock of the nature of phonolite is known to occur only at the Wolf Rock, S.E. of the Land's End, Cornwall. The Wolf Rock is a Nosean Phonolite.[1]

[1] S. Allport, Geol. Mag. VIII., 1871, 247, and I., 1874, 462; also F.Z., Mikrosk. Besch. 1873, 397. "The Wolf Rock lies about nine miles S.E. of the Land's End, and is covered by the sea at high water. At low water spring tide it measures only 175 feet by 150 feet, and stands 17 feet above the sea. At high water it is two feet below the level of the sea. It consists of microporphyritic crystals of sanidine and nosean; and the groundmass which is holocrystalline consists of sanidine nepheline and a few of nosean and ægirine." British Petrography, with special reference to the igneous rocks, by J. J. Harris Teall, M.A., F.G.S., p. 367.

In Scotland a nepheline-bearing rock, described as a trachytoid phonolite, occurs at Traprain Law in the Garlton Hills.[1] This phonolite, which occurs in the form of a neck is remarkable for its high geological antiquity, being of Carboniferous Age. Borolanite (a rock formed of soda-orthoclase, a little plagioclase, melanite, biotite, a little pyroxene, nepheline as elæolite, apatite and a very little magnetite, with probably sodalite), occurs as intrusive dykes or sheets in older Palæozoic rocks near Lake Borolan, Elphin and Achiltibuie in Scotland.[2]

In France a number of interesting phonolite 'necks,' (over 100 in number) have been described in the neighbourhood of Velay, Cantal and Mount Dore, Central France. Nepheline is present only in some varieties, its place being taken mostly by nosean and haüyne. In some cases the felspars consist of kernels of anorthoclase, coated with sanidine.

In Saxony phonolites of the trachytoid type have been described from Obersdorf near Zittau, while numerous nephelinoid phonolites have been described from various parts of Bohemia, such as Teplitz, Schlossberg, etc.,[4] as well as from the Rhön region.

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[1] "It is essentially formed of a mass of little sanidine prisms, in which lie ragged crystals of bright green soda-augite. There are also present colourless patches which contain little crystals of nepheline with zeolitic decomposition products."

[2] Trans. R. Soc., Edinburgh, xxxvii., Nr. 11, 1892.

[3] Von Lasaulx, Phonolith vom Mont Dore N. Jahrb. f. Min. 1872, p. 351. Michel Lévy, Phonolithes des Mont Dore, Bull. Soc. Géol. (3) xviii., 1890, 795 – 821. Michel Lévy, Phonolithes vom Cantal, Comptes Rendus xcviii. 1884, Nr. 22. Fouqué et Lévy, Phonolithes des Cantal, Minéralog. Micrographique, 1879. Termier, Phonolithes des Velay, Comptes Rendus cx., 1820, 730.

[4] The literature is too extensive to quote in detail. The following may be mentioned :—Möhl, Nova Acta Leop. Carol. Acad. xxxvi., Nr. 4, 1873, and N. Jahrb. f. Min. 1874, 38. Boricky, Sitzgsbr. böhm. Ges. Wissensch. 19, April 1891, and Petrog. Stud. an den Ph.-Gesteinen Böhmens Archiv. d. Naturwiss. Landesdurchforschung von Böhmen iii. Bd., 2 Abth. 1 Prag. 1874. G. vom Rath, Phonolith von Zittau, Z. Geol Ges. viii., 1856, 291. Sandberger, N. Jahrb. f. Min. 1888, ii., 248; and Exc. N. Jahrb f. Min. 1881, ii, 211. F. Zirkel., Mikr. Besch. 394, 396, and Z. Geol. Ges. xi., 1859, 534. G. vom Rath, Correspondenz-Blatt naturh. Vereins, 1866, 46. K. Vogelsang, Z. Geol. Ges. xlii., 1890, 47, etc. For the above references as well as for many others in this paper, the authors are indebted to the great work of Ferdinand von Zirkel, "Mikroscopische Beschaffenheit der Mineralien und Gesteine."

Rosenbusch has described, in his magnificent work,[1] a variety of nepheline rock, which he refers to the basic group, from the Katzenbuckel, a dome shaped hill in the Odenwald, Baden. He terms this rock phonolitic nephelinite. In many respects it very closely resembles the Kosciusko nepheline rock, but the Katzenbuckel rock contains some olivine together with abundant häuyne, whereas these two minerals are wanting in the Kosciusko rock.

Professor Brögger has described nepheline rocks which though not definitely phonolites, are nevertheless as regards chemica composition, so closely allied to the Kosciusko rock, that they may be quoted here for comparison.

The rock described by him under the section of laurdalite from Lunde, Lougenthal, in the Christiania district is shown by its chemical composition to be not far removed from the nepheline rock of Kosciusko. A comparison however, of its chemical composition with that of the Kosciusko rock shows that the laurdalite is richer in lime than that of Kosciusko and correspondingly poorer in soda. Mineralogically it differs from the Kosciusko rock chiefly in having phenocrysts developed of potash felspar belonging to the varieties sanidine and orthoclase. In other respects, however, its minerals agree very closely with those developed in the Kosciusko rock.

The same author has described under the term nepheline-porphyry, also from the Lougenthal, a rock both chemically and mineralogically intimately related to that of Kosciusko. This nepheline-porphyry is richer in soda than the laurdalite, containing 11·36% of soda as compared with 8·18% in the latter. This alumina per centage in nepheline-porphyry is higher than that in the Kosciusko nepheline rock, and mineralogically it differs from the Kosciusko rock chiefly in having potash felspar developed as phenocrysts. The rock termed tinguaite, described by him from Hedrum, lithologically very closely resembles the Kosciusko rock.

[1] Microscopische Physiographie der Mineralien und Gesteine, dritte Auflage, Vol. II., p. 1260.

At S. Antão, however, in the Cape Verde Islands, Doelter[1] has described a phonolitic nephelinite which in mineral constitution appears to approximate closely to the Kosciusko rock. Rosenbusch (p. 1260) describes this rock as being conspicuously green in colour, the nepheline being present in sharply idiomorphic crystals, in which two generations can be distinctly recognised, whereas the sanidine occurs sparingly or more abundantly in small laths ("Leistchen"), the structure of the rock being evidently porphyritic.

Sauer[2] has described a nepheline—haüyne phonolite with pleochroic augite, a little hornblende and plagioclase from the Canary Islands.

Doelter[3] has also described a trachytoid phonolite from the volcano Mount Ferru, in Sardinia, varying from a rock poor in nepheline to one in which the nepheline is in excess of the sanidine. Haüyne occurs sparingly.

Deecke[4] has described phonolite dykes in the tuff of the crater walls of Vico in the Ciminian Hills of Italy. Nepheline, sanidine, augite, haüyne, plagioclase and titanite are present.

Professor J. W. Gregory, has described[5] nepheline-syenites, phonolite dykes and kenytè lavas from Mt. Kenia. The last mentioned consists of a glassy matrix very rich in soda, with granules of ægirine, felspar microliths and phenocrysts of anorthoclase.[6]

Rosiwal has described a nephelinite from the Maerú Mountains (Meru-Berg) from S. E. Africa.[7] This contains some brown

[1] Doelter (C), Die Vulkane der Capverden und ihre Produkte. Gratz, 1882.

[2] Sauer. Phonolithische Gest. Der Canarischen Inseln, Inaug.—Diss. Halle 1876—Ztschr. f. d. ges. Naturw., XLVII., 1876.

[3] Doelter, Phonolith von Sardinien, Denkschr. Wiener Akad. XXXIX., 1878, 59.

[4] Phonolith von Vico, Italien. N. Jahr. f. Min. Beilageb. VI., 1889, 239.

[5] Gregory (J. W.), Q.J.G.S., Vol. LVI., 1900, pp. 205 – 202 and pls. X., xi. and xii. *pars* "The Geology of Mt. Kenia," and Q.J.G.S., Vol. LVI, 1900, pp. 223 - 229 and pl. xii. *pars*. "The Nepheline-syenite and Camptonitic dykes intrusive in the Coast Series of British East Africa."

[6] See also Min. Mag. Vol. XII., July 1900, pp. 255 – 273. "Ægirine and Riebeckite anorthoclase rocks related to the Grorudite-Tinguaite Series, from the neighbourhood of Adowa and Axum, Abyssinia," by G. T. Prior.

[7] Rosiwal, Denkschr. Wien Akad. LVIII., 1891, 487.

akmite. He has also described phonolite from Mt. Kenia and its neighbourhood, containing anorthoclase, nephelīne, augite, ægirine and acmite.

G. Rose,[1] Rosenbusch, and van Werveke have described nepheline bearing rocks from Messid Gharian, from the great volcanic cone of Tekut, and from Mantrus, all situated in Tripoli. These are mostly dark grey phonolites with idiomorphic nepheline laths of sanidine and pyroxene; sodalite hornblende and haüyne with titanite, magnetite and apatite are present in some varieties.

J. Roth, has described a sanidine-augite-haüyne phonolite with a little nepheline from Kordofan.[2]

Vélain has deseribed a nepheline phonolite from the peninsula of Aden,[3] occurring in sheets, flows, and dykes. Nepheline, sanidine, plagioclase, green augite and magnetite compose it. Vélain considers these phonolites to be newer than the rhyolites and trachytes of the same neighbourhood.

Steinecke[4] has described a phonolite rich in biotite but poor in nepheline, from between Choi and Kosehkserai Marand in Persia.

In North America nepheline rocks of the nature of phonolites have been described from Dakota and Colorado.[5]

In South Dakota they form conspicuous conical hills, such as Mato Tepee, the core of a laccolith.[6]

A curious type of phonolite rich in hornblende, and terme apachite has been described by Osann, from the Apache Mountains.[7]

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1 G. Rose, Z. Geol. Ges. III., 1851, 105.

2 J. Roth, Allg. u. Chem. Geologie II., 262.

3 Vélain, Descript. Géol. de la presq 'île d' Aden, 1878, 35.

4 Steinecke, Phonolith aus Persien, Z. f. Naturw. 4, Folge, VI., 1887, 45.

5 Whitman Cross, Proc. Colorado Scientifi. Soc., 1887, 167.

6 Some of the principal phonolite localities in U. S. America, are Big Bull Mountain; Mitre Peak; Straub Mountain; Rhyolite Mountain; Florissant and Manitou; Bull Cliff; Washington Shaft, Victor.

7 Osann, Phonolite (Apachite) of the Apache Mountains, U.S.A.— Tschermak's Min. u. petr. Mitt., 1896, Vol. xv., p. 394. Rosenbush, Microscopische Physiographie der Mineralien und Gesteine, dritte Auflage 1896, p. 823.

Dr. F. Adams[1] and Mr. A. P. Coleman[2] have described a corundiferous nepheline syenite from Eastern Ontario. This remarkable rock is described as having a schistose structure, "so that at first sight it would be called gneiss. The darker layers contain much biotite and the lighter nepheline and plagioclase. Numbers of small crystals of corundum stand out on the weathered surfaces. Mr. Frank D. Adams has referred[3] to a rock formed of white felspar and orange-red grains of elæolite, described by Sir William Logan from Old Pic Point and Island, Lake Superior. It is thought to be probably related to the remarkable analcite rock called heronite, described by A. P. Coleman from Heron Bay, Lake Superior.[4] This rock, heronite, is considered to have the following mineral constitution :—

Analcite	47·00
Orthoclase	28·24
Labradorite	13·00
Ægyrite	4·04
Limonite	3·59
Calcite	1·96
	97·83

As regards the occurrence of nepheline rocks in the Southern Hemisphere, phonolites containing sanidine, nepheline, haüyne and hornblende, have been described from Fernando Noronha, off Cape S. Roche, Brazil;[5] and Renard[6] has described a volcanic

[1] Geol. Sur. Canada, 1892-3, Pt. J, p. 5; and also Amer. Journ. Sci., Vol. XLVIII., July 1894, pp. 10 - 18.

[2] Jour. of Geol., July - August 1899, Vol. VII., No. 5, pp. 437 - 444.

[3] Jour. of Geol., Vol. VIII., No. 4, May - June 1900, pp. 322 - 325, "On the probable occurrence of a large area of nepheline-bearing rocks on the north-east coast of Lake Superior.

[4] Jour. of Geology, Vol. VII., No. 5, July - August, 1899, p. 435.

[5] Gümbel, Phonolith von Fernando do Noronha, Brazilien, Min u. petr. Mitth. II., 1880, 188. Renard, Rep. on the petrology of Oceanic Islands, 1889, 33. Branner and Williams, Amer. Journ. of Sci., XXXVII., 1889, 145, 168.

[6] Renard, Phonolithe de l' îsle Nightingale (Tristan da Cunha), Bull. Acad. Royale de Belg. (3) XIII., 1887, 3. Renard, Report on the petrology of oceanic islands, 1889, 89.

conglomerate of considerable extent at Nightingale Island. The cement of this conglomerate is formed of phonolitic material. Nepheline is stated to occur in grains and crystals besides brown microlites of augite and sanidine etc.

In Brazil, Prof. O. A. Derby,[1] has described a nepheline-bearing rock from Serra de Tinguá. This, however, is perhaps more referable to the elæolite-syenite-porphyries, leucite-elæolite-syenite-porphyries or tinguaites than to the phonolites. Besides elæolite it contains abundant pseudomorphs in analcime after leucite. It was originally considered to be of Palæozoic Age, but Hussak[2] has shown that it intrudes Post-Carboniferous, perhaps Triassic, sandstones.

Kerguelen.—Phonolite has been described[3] at the above island at Greenland Harbour. It is stated to be a greenish-white rock forming cylindrical and columnar masses which rise above the general level of the surrounding sheets of augitic basalt. Much soda and sulphuric acid are present.[4] From the fact that angular enclosures of the phonolite are met with in the basalt, (whereas no basalt enclosures have been observed in the phonolite), and from the fact that the basalts which are typically porphyritic become less coarsely crystalline as they approach the dome-shaped masses of phonolite, it is argued that the Kerguelen phonolites are probably somewhat older than the basalts. Professor Roth[3] and Renard[5] have also described phonolite from Kerguelen.

Mr. Evelyn G. Hogg, M.A.,[6] has also described phonolites from Kerguelen, and the adjacent Howe Island. At the latter locality the minerals present in the phonolite are sanidine, augite, hornblende and nepheline. An analysis of this rock for comparison

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1 O. A. Derby, Q.J.G.S., XLIII., 1887, 457 ; XLVII., 1891, 251.

2 Hussak, N. Jahrb. f. Min., 1890, I., 166 ; 1892, II., 146.

3 Report Scientific Results, Voyage H.M.S. Challenger, Narrative, Vol. I., First Part, pp. 348 - 351, and p. 374. 2 *Op. cit.*, p. 350.

4 Roth, (Prof. J.) Ueber die Gesteine von Kergueland, Monatsber. d. K. preuss. Akad. d. Wiss. Berlin, 1875, pp. 723 - 735.

5 Bull. Musee roy. de Belge IV., 1886, 223, and Rep. on petrology of Oceanic Islands, 1889, 133.

6 Hogg, (E. G.) Proc. Roy. Soc. Victoria, Feb. 1899, Vol. XI., (New Series) Pt. 2, pp. 209 - 213.

with that of Kosciusko is quoted by us later on from Mr. Hogg's paper. From "Cat's Ears" on the main island, Mr. Hogg has described[1] a hornblende phonolite, (not unlike apachite, *authors*) containing sanidine, hornblende, nepheline, augite, apatite and a little sphene.

In the presence of hornblende some of these phonolites approach the apachite (Osann) of the Apache Mountains, and in the presence of olivine the phonolitic nephelenite, (bordering on the nepheline-basalts) of the Katzenbuckel in the Odenwald, Baden. In their low silica percentage, 51·15 – 52·30 they resemble the Kosciusko tinguaite, as will presently appear.

New Zealand.—The late Professor Ulrich of Dunedin, New Zealand has described[2] a very interesting group of phonolites from the neighbourhood of Dunedin at Portobello, and also at Pine Hill and Parakanui Cliffs, the first locality twelve miles east of Dunedin, and the second close to the town, and the third eighteen miles north of it. *Structurally*, Professor Ulrich differentiates them into (1) a coarsely porphyritic rock, and (2) a dense compact rock; and *mineralogically* into (*a*) nephelinitoid phonolites, and (*b*) trachytoid phonolites. Through accession of plagioclase, and either absence or presence of olivine, varieties of this rock graduate respectively towards tephrite on the one hand and basanite (Rosenbusch) on the other.

A. Wichmann[3] has described a nepheline rock under the name foyaite from Viti Levu, Fiji. This was collected by Kleinschmidt from Muanivatu and Koro Yalewa. This rock consists of orthoclase, a little plagioclase, fresh nepheline largely converted into zeolites, augite, apatite, biotite, magnetite, titanite, and titaniferous iron.

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[1] *Op. cit.*, p. 212.

[2] On the occurrence of nepheline-bearing rocks in New Zealand, by Professor George H. F. Ulrich, F.G.S., Director of the School of Mines, Dunedin.—Austr. Ass. Adv. Sci., Vol. III., pp. 127 – 150, pl. v.

[3] Tschermak's Min. u. petr. Mitth. v., 1882, 14.

W. H. Twelvetrees[1] and W. F. Petterd have described an exceedingly interesting series of nepheline, anorthoclase, nosean ægirine rocks in the neighbourhood of Port Cygnet, Tasmania. Melanite garnet and fluorite are present in some varieties: in some cases sanidine takes the place of anorthoclase. Messrs. Twelvetrees and Petterd class these as sölvsbergites nosean trachytes, and tinguaite porphyries.

As regards the occurrence of nepheline in Australia, it has hitherto been described only as an accessory mineral. Professor Ulrich has recorded[2] it in an "older basalt" (Eocene ?) at Phillip Island, Bass' Strait, Victoria. Analcime and natrolite occur in abundance as zeolites in this lava. F. M. Krause[3] also records nepheline from Victoria, at Western Port.

Recently Prof. J. W. Gregory[4] has described an interesting series of sölvsbergites and trachy-phonolites containing anorthoclase, nosean, ægirine, riebeckite, and in some cases cossyrite, from Mt. Macedon, Victoria.

In Queensland, Mr. Dunstan of the Geological Survey has referred[5] to a basalt rich in nepheline, at Mt. Beardmore, Dawson River, west, He states that this rock "occurs as an isolated peak surrounded by old sedimentary altered rocks and by tableland sandstones. The rock is fine grained and contains nepheline, augite, olivine, magnetite, etc.: no felspar present." He adds that it looks fresh.

In New South Wales, Prof. Liversidge[6] records the occurrence of nepheline in amygdaloidal porphyry at "The Pinnacles," Co., Forbes; Dowagarang and the Old Man Canobolas, near Wellington

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[1] Trans. Aust. Inst. Mining Engineers, 1898, Vol. v., p. 108, and also Papers and Proc. 1898-99, Roy. Soc. Tasmania, pp. 3 – 26, figs. 1 - 8.

[2] Quoted by R. M. Johnston, Geology of Tasmania, 1888, p. 249.

[3] "An Introduction to the Study of Mineralogy for Australian readers," F. M. Krause, 1896, p. 205.

[4] Proc. Roy. Soc., Victoria, Vol. xiv., (New Series) Pt. ii., pp. 185 – 217, Pls. xi. - xvii.

[5] Parliamentary Paper, No. C A. 9, 1901, Brisbane—Rep. Geol. Dawson and Mackenzie Rivers, 1901, p. 28. Preliminary Note.

[6] Minerals of New South Wales—A. Liversidge, M.A., F.R.S., 1888, p, 185.

(Orange ?) Co., Wellington. These spots were probably observed by the late Rev. W. B. Clarke.

Mr. G. W. Card, Assoc. R.S.M., F.G.S., Mineralogist to the Geological Survey of New South Wales, has informed us that he has lately observed nepheline in basalt from the following localities in New South Wales:—(1) at "The Peaks," Burragorang, where the lava occurs as a thin capping at the top of the mountain; (2) at Glen Alice, Capertertee; and (3) at Sapling Flat Creek, Capertee.

Mr. G. W. Card has also identified nepheline in large quantities in a rock just discovered by Mr. J. E. Carne, F.G.S., of the Geological Survey of New South Wales. The locality of the discovery is Portion 34 in the Parish of Barigan, about fourteen miles from the railway station Lue, on the Wallerawang to Mudgee Line, in N. S. Wales. In hand specimens the fine grained type of the Barigan rock is strikingly like that of Kosciusko. Mr. Card very kindly placed thin slices of this rock at our disposal, so that we might institute a comparison between it and that of Kosciusko. Since this, however, fresh discoveries on a much larger scale of highly interesting nepheline rocks, which Mr. Card considers allied to tinguaites, have been made in the same district by Mr. J. E. Carne.[1] Mr. Carne states that there are several mountains of nepheline rock in this locality over 1,000 feet high, from base to summit, and intrusive into the Permo-Carboniferous and Triassic rocks. Under these circumstances as the Barigan rocks will merit a special memoir, in all probability, it would be premature for us to attempt a description of them, except very briefly.

On comparing the sections of the fine grained variety of rock from Barigan with that of Kosciusko, one is struck at once with the absence from the former of inclusions of other rocks, the Kosciusko rock being remarkable for the amount of mineral matter, especially felspar, which it has borrowed from the surrounding gneissic granite. The Barigan rock does not exhibit under the microscope as numerous sharply defined sections of

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[1] Card, G. W.—Records Geol. Survey, N. S. Wales, Vol. VII., pt. 2.

nepheline as does the Kosciusko rock. The Barigan rock does not exhibit flow structure among its felspar microlites, whereas flow structure is well seen in the Kosciusko rock. The Barigan rock moreover has numerous clear streaks, of the nature perhaps of segregation lines, not seen in the Kosciusko rock. A subsequent examination of the Barigan area by Mr. Carne and Prof. David, shows that these lines are related to directions of pressure in the tinguaitic laccolites, the rock having a banded almost gneissic appearance the bands being approximately concentric to the general surface of the laccolites.

The Barigan rock is essentially composed of nepheline and ægirine, with numerous, irregularly distributed microlites of felspar and probably a little sodalite. Further information relating to the petrological character and mode of occurrence of this highly interesting rock from Barigan and the associated tinguaites will be published shortly by the Geological Survey of New South Wales.

II. *Occurrence at Mount Kosciusko.*—The tinguaite of Kosciusko occurs in the form of a dyke traversing granite. The dyke is about seven feet wide, is vertical or nearly so, as far as can be seen in the small section in the bank of the creek, and strikes in a direction E. 5° N. and W. 5° S. The height above sea-level is about 5,600 feet. The spot where the dyke crosses the creek [which flows from Lake Merewether (Blue Lake), and Hedley Tarn through Evidence Valley (Helms) to the Snowy River] bears about E. 47° N. from the Kosciusko Observatory, and is about four miles and thirty-nine chains distant. The spot is about a quarter of a mile up Evidence Valley Creek from its junction with the Snowy River.[1]

The rock on either side of the dyke is a slightly gneissic granite. The granite extends in a westerly direction from Evidence Valley, for about one mile, when it is replaced by a belt of phyllite and fine quartzite. This belt is from about a quarter of a mile up to

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[1] See *Plate* 2, for geological plan showing occurrence of dyke. See also Proc. Linn. Soc., N. S. Wales, New Series, 1901, Pt. 1, Pl. iii., and pp. 30-31.

over a mile in width; and beyond it the granite extends to a considerable distance further in a westerly direction. The eastern line of junction between the granite and the phyllite trends N. 15° E. and S. 15° W., while the western junction line is nearly meridional, so that there does not appear to be any relation between the strike of the tinguaite dyke and the junction line of the granite and phyllite. The same remark applies to the junction line of the granite with the radiolarian and graptolitic slates and cherts at twenty-nine miles in a direction E. 25° N. from Kosciusko. The folia of the granite strike N. 20° E. to N.N.E., and their prevalent dip is to E.S.E. at about 75°. The granite is strongly intrusive into both phyllites and radiolarian rocks. The age of the phyllites is unknown; but that of the latter is Lower Silurian (Ordovician). The tinguaite is strongly intrusive into the gneissic granite, and contains a large amount of included crystals of felspar, with a few of quartz and mica, derived from the granite.

An examination of the gneissic granite shows that it has been intruded by at least two distinct dyke rocks, other than the nephelinite, as well as by veins and irregular masses of a whitish euritic granite. The last mentioned is probably not much younger than the gneissic granite, as it has partaken of its foliation. The two dyke rocks referred to are respectively a pyroxene amphibolite, and an olivine basalt.

The nearest basalt dyke to the tinguaite, as far as we were able to observe, is one seen by us on the west side of Lake Merewether (the Blue Lake). It is about two feet wide and strikes in a direction from W.N.W. to W. 30° N. A much larger basalt dyke is developed on the Main Dividing Ridge to the west of Garrard's Tarn (Harnett's Lake, or Club Lake). This dyke is several yards in width and is perhaps a continuation of the dyke next to be described, viz., that at Russell's Tarn near Mount Townsend (Müller's Peak). This dyke is forty yards wide, is strongly laminated and strikes in an E.N.E. direction, whereas the laminæ trend N.N.E. and S.S.W. This dyke is rendered porphyritic by augite and olivine, and contains numerous enclosures of granite an inch or more in diameter. A further description of one of the local basalts is given later in this paper.

There is thus nothing in these basalt dykes, except their fresh state of preservation, strong intrusion into the granite and approximate parallelism of strike (with that of the tinguaite) which connects them with the last mentioned rock. It is, however, possible that the dykes may be complementary to one another.

The tinguaite of Kosciusko is brownish-grey in colour with a faint tinge of green, and in this respect differs from the "conspicuously green" phonolitic nephelinite of S. Antão. The Kosciusko rock has not the sonorous ring of some phonolites. It breaks readily under the hammer with an uneven to sub-conchoidal fracture, and has a somewhat greasy lustre. Macroscopic whitish-grey to pale reddish-grey crystals of nepheline can be seen on freshly fractured surfaces, giving the rock a somewhat pseudo-porphyritic appearance, though probably the rock is not really porphyritic in the strict sense of that term as used by Rosenbusch.

III. *Microscopic Character.*—The specimens in the following description were taken from the following portions of the dyke:—No. 1 from northern side of dyke within six inches of its plane of junction with the granite. No. 3, from the centre of the dyke. No. 4, from the southern side of the dyke within six inches of its plane of junction with the granite.

No. 1. In thin section the rock is seen to possess a hyalopilitic texture. A considerable amount of residual glass is present. It is colourless, but contains fairly numerous dusty crystallites. A very marked flow structure is apparent. None of the minerals show definite evidence of occurring in more than one generation, though the rock is rendered pseudo-porphyritic by occasional largely developed nephelines. The reasons for considering these large phenocrysts of the same generation as the small individuals of the base are:—(*a*) there is a perfect gradation from the largest crystals to those of sub-microscopic dimensions; (*b*) there is no distinction in microstructure between the large and the small crystals; (*c*) there is a total absence of any trace of resorption; (*d*) the larger nephelines are surrounded by ægirines more densely packed than in other parts of the base, pointing to the fact that these nephelines have grown in size in the place where they are now found, pushing the ægirines aside in the process. If we accept Rosenbusch's definition for "porphyritic structure," that term cannot therefore be applied to the rock under consideration.

The most obvious and important mineral constituent is nepheline. This occurs as occasional, fairly large, idiomorphic crystals in stumpy hexagonal prisms with basal planes. These vary in size up to 3 mm. in length, the breadth being about the same. Mr. G. W. Card states that he has observed well developed pyramid faces modifying the rectangles, but such faces appear to be exceptional. The mineral is clear and colourless and its refractive index and double refraction are characteristic. In places, grey, yellow and brownish decomposition products are abundant. The large nepheline crystals have a marked zonal structure, the central zones possess a higher refractive index than those near the periphery, as proved by testing them by Becke's method.

In the small crystals a similar arrangement can be made out under the high power. The individualised inclusions are mainly referable to ægirine, similar to that occuring as an essential constituent of the rock. It is recognisable by its marked and characteristic pleochroism. Occasional grains of magnetite also occur. Besides these, there are indeterminate dusty inclusions of a greyish colour. In one very large crystal is included a fragment of the felspathic material to be described later. Another large, almost basal, section shows a very remarkable inclusion. The nepheline is about 1·58 mm. in diameter, in it is a crystal of sanidine, ·53 mm. long by ·118 mm. broad. The sanidine is singly twinned, and has given rise to cleavage cracks (parallel to $[10\bar{1}0]$) in the host (*Plate* I, fig. 4). This occurrence is remarkable, as the crystallisation of sanidine is usually subsequent to that of nepheline. The essential felspar is present in small quantity, and is inconspicuous.

It occurs in exceedingly slender lath-shaped sections about ·125 mm. long by ·007 mm. broad. Some of these are distinctly singly twinned, as observed with a $\frac{1}{8}$th inch objective, have a refractive index somewhat lower than that of Canada balsam, and exhibit the characteristics of sanidine. On the other hand, as observed by Mr. G. W. Card, some of the felspar microlites extinguish at an angle of about 10° measured from the clinodiagonal or brachy-diagonal, on the assumption that the microliths have been elongated in the direction of that axis. This points to the probability that some, if not all, of the felspar microliths are not normal sanidine. They may be soda-bearing varieties or even albite. The principal ferromagnesian constituent of the rock is ægirine. In reflected light most of the pyroxene is seen to be somewhat decomposed, possessing a light greenish-yellow colour, but where undecomposed it is blackish-green. In transmitted light the colour is dark green. Many of the individuals are almost opaque owing to decomposition products. The habit is prismatic, the larger prisms being conspicuously frayed out at the ends. Besides the prisms, there are numerous tufty aggregates with a slight tendency towards radial spherical arrangement. The pleochroism is very strong in brown and dark blue-green tints. The extinction angle is small, not more than 4° or 5° from the axis of the prism, but exact measurements are rather difficult to make. The maximum length is about ·25 mm., and the smallest individuals sink to microlitic dimensions. A very small quantity of biotite is also present of same order of size as the larger ægirines, and its pleochroism is in dark greenish bronze to opaque. A little magnetite is scattered through the section. Mr. G. W. Card suggests that some of the curved microlites may be melilite.

The most remarkable feature of the rock is the abundance of included fragments. In ordinary light these are colourless but somewhat clouded by decomposition products which appear opaque white in reflected light. The double refraction of these is stronger than that of nepheline. The refractive index is lower than that of Canada balsam in the cases where a comparison is possible

(Becke's method). These facts indicate an acid felspar. These felspar fragments are much broken up through mechanical and chemical agencies, and polarize as a mosaic. Extensive corrosion has gone on, many of the grains having been almost entirely dissolved, but no difference in the character of the rock can be seen in the neighbourhood of the enclosure. One idiomorphic crystal was found having the outline of a clinopinacoidal section of felspar with [001] extensively developed, and [110] and [201] less so. Owing to the extent of decomposition and alteration no exact determinations of this felspar are possible. These inclusions are almost certainly derived from the granite through which the dyke has been intruded. If this is so, the occurrence of such felspathic material in the larger nephelines is additional evidence *against* the intratelluric origin of the latter. In the large amount of enclosed granitic material the Kosciusko nepheline rock resembles some of the other dyke rocks of this district, the olivine basalts being particularly rich in granite enclosures.

No. 4 does not differ essentially from No. 1, except that it is considerably more decomposed. As a result of this decomposition several new minerals have made their appearance, namely, analcite, calcite, and natrolite. They possess a pseudo-amygdaloidal arrangement. The analcite is slightly greenish in colour, owing to chloritic stains, but is perfectly isotropic and characteristic in every other particular. The calcite also calls for no particular remark. The mineral we have called natrolite occurs in the form of little tufty aggregates with a tendency towards spherulitic arrangement, and is included in the analcite. These fibres possess a refractive index not distinguishable from that of the analcite. The double refraction is quite noticeable, even though the fibres do not extend through the whole thickness of the section, the colours being greyish-white. The extinction is parallel and at right angles to the length of the needles.

The felspathic inclusions are, if anything, more abundant here than in No. 1, but possess similar characters slightly modified by the greater amount of decomposition. In addition to the felspathic inclusions there are one or two included fragments of greenish-brown biotite, which are corroded though not to the same extent as the felspar. These fragments, derived probably from the granite, intruded by the dyke, are to be distinguished from the accessory authigenic biotite of the dyke rock. The chemical analyses given below show the presence of some chlorine. This indicates sodalite as a constituent mineral, but there is no confirmatory microscopic evidence as to its presence. It is quite probable that some of the material noted as "glass" should be referred to this mineral.

No. 3 specimen from the centre of the dyke. This rock is so distinct from those hitherto studied as to belong to quite a different rock-type. It is *holocrystalline*, though finely so. Flow structure, if present, is very obscure. Nepheline is apparently absent. By far the most abundant mineral in the rock is the felspar, which occurs in the form of irregular sections, which are not twinned. It is exceedingly difficult to determine which felspars belong to the dyke rock proper, and which to the included granite. Some definite laths of sanidine occur, but the greater part is distinctly a plutonic acid felspar. With this felspar is associated abundant muscovite in large irregular plates. Quartz is also present in small quantities. The ægirine here differs from that already described only in its habit and in the comparative absence of decomposition.

The section as a whole is very difficult to interpret. We are inclined to think it does not represent a fair sample of the dyke rock, but rather belongs to a part of it which has had its characters entirely altered by almost complete solution of a large fragment of included granite. The plutonic character of such a large percentage of the minerals, and the occurrence of abundant muscovite is in favour of this hypothesis. The fragments which can be definitely made out to be inclusions are very numerous. Others, exceedingly like them, shade off insensibly into the groundmass. The peculiar habit of the ægirine, namely, its occurrence with the ends of the prism round or conical as if due to solution is suggestive of a very marked change in the composition of the magma after their formation. The change must have taken place after the crystallization of the ægirine, but prior to that of most of the sanidine and before any nepheline had started to form. The evidence as to the nature and date of this change is we think, quite conclusive.

A short description is given here of the eruptive rocks associated with the phonolitic nephelinite:—

Granite—Three miles from Jindabyne towards Cooma, on road. Typical hypidiomorphic texture rather coarsely crystalline. Evidence of dynamical metamorphism in the undulose extinction of many of the minerals, bending of biotite flakes, the bending and faulting of twin lamellæ of felspar and the peripheral shattering of all the minerals. Quartz is abundant in irregular grains, generally much shattered at the edges. It contains plentiful liquid and gaseous inclusions arranged in very definite planes, which, at any rate in some cases, pass from grain to grain without interruption. In addition to enclosures of the older segregations which occur abundantly as rock constituents, the quartz also contains straight and curved trichites which are apparently opaque. These are in some cases at any rate arranged very regularly. In one section nearly perpendicular to the optic axis, they lie in lines making angles of 60° with one another, and therefore in all probability parallel to the faces of the primary rhombohedron. The largest of these trichites reach the dimensions of very small acicular crystals. Some of these are certainly apatite, others are probably rutile. The quartz is considerably cracked, the cracks being roughly parallel throughout the rock.

The Felspar, which in some cases exhibits traces of crystalline form, is apparently most of it plagioclase. It is twinned after the albite law, and in most cases after the Carlsbad law too. The peripheral shattering and decomposition render R.I. determinations difficult, but apparently the R.I. is higher than that of quartz, indicating a rather basic variety of plagioclase. The sections are not suitable for measurement of extinction angles. One whose shape and the absence of albite twinning indicate a plane parallel to M (010) gives an extinction angle of 22° in a positive sense from the trace of the cleavage parallel to P 001. Another section nearly in the zone ⊥ M (010) gave extinction angles for the albite lamellæ 16° and 18° on opposite sides of the plane of composition of the twin. The felspar probably lies between a basic andesine and an acid labradorite probably the latter, as the measurements in the section parallel to M (010) are the more reliable. A small quantity of a second felspar is present, which from its low R.I. (less than that for balsam) and untwinned character is probably orthoclase. The enclosures in the felspar are zonally arranged. The trichites mentioned in the quartz do not appear to be represented, but otherwise they are similar.

Biotite is very abundant. It occurs in ragged sections which give very marked evidence of the crushing to which the rocks have been subjected. In ordinary light the colour is bright yellow on vertical sections to reddish-brown on sections near the base. Basal sections are practically opaque. The pleochroism is very intense, absorbtion of light vibrating parallel to the cleavage being almost complete. (In the thick slice this gives rise to a remarkable appearance where a thin film of biotite overlaps a section of quartz and felspar. The biotite acts as an analyser and the polarisation colours of the other mineral appear even though the upper nicol is out of the axis of the tube). The biotite flakes are fairly free from decomposition. In one or two places a little greenish chloritic material is present. One of the remarkable features of the rock is the presence of numerous aggregates of faintly bluish-green talc or sericite. These represent the decomposition products of some previously existing mineral. In one of the aggregates there is apparently a kernel of greenish-yellow epidote, showing that whatever may have been the character of the primary mineral, epidote was one of the alteration products. The aggregates are parallel tufted and irregular. It is obvious that there has been an increase of bulk during the process of decomposition which gave rise to the talcose mineral, since the surrounding minerals have been very much broken up by cracks radiating from the aggregates and the talc (?) has been injected irregularly through these cracks.

Among the accessory minerals other than the rutile and apatite already mentioned, are apatite (in larger prisms) zircon and pyrites.

The apatite is fairly abundant, particularly as inclusions in the biotite. In one case an apatite, itself an inclusion in the biotite, includes a well developed zircon.

Zircon is remarkably abundant, especially in the biotite, where it produces very strongly marked pleochroic halos.

Pyrites occurs in two distinct habits, (i.) as small dusty grains which accompany the regularly arranged fluid and gaseous enclosures of the quartz; (ii.) larger tufts and perfect cubical (pyritohedral) crystals scattered through the rock.

Basalt from between Boggy Plains and Pretty Point Kosciusko. This rock has a pilotaxitic base, with marked flow structure composed of felspar and brownish augite microlites with a lot of minute crystals of magnetite. There is no glass present. The felspar microlites are somewhat basic, the refractive index, as tested by Becke's method being distinctly higher than that of Canada balsam, and in some sections they have extinction angles up to about 30°, measured from the Carlsbad twinning plane. Colourless augite is present in idiomorphic stunted prisms with pyramids. They have a small opti-axial angle and good cleavage. They decompose into light green products, apparently chlorite. There are also present more or less kaolinised and much corroded fragments of felspar with an occasional granule of quartz, both being evidently derived from rocks intruded by the basalt dyke, so that they may be considered to be enclosures. A granular greenish-yellow epidote is present with a pleochroism in grey to deep greenish-yellow. It probably represents an intermediate stage of alteration between the colourless augite and the chlorite. In one slide the basalt contained a small enclosure of kaolinised felspar with a flake of biotite intercrystallised with it. This enclosure was obviously derived from the local granite.

IV. *Chemical Composition.*—The chemical nature of the rock is shown in the accompanying table which exhibits the result of analyses (made by one of the authors, Mr. Guthrie), of the three specimens taken from different portions of the dyke, the microscopic characteristics of which have been just described. Specimen No. I. was taken from the northern side of the dyke, and represents a thickness of the dyke of six inches, measured at right angles to the plane of junction of the dyke rock with the granite. No. IV. represents a similar portion of the dyke on its southern side, and No. III. was taken from the centre of the dyke. As already stated, the dyke is about seven feet wide.

Composition of nephelinitic tinguaite from Kosciusko.

	I.	III.	IV.
Water at 100° C.	0·23	0·78	0·32
Water above 100° C.	3·54	5·25	3·29
SiO_2	52·40	50·15	51·98
Al_2O_3	19·93	18·45	20·61
Fe_2O_3	3·83	4·71	4·08
FeO	1·51	1·24	1·32
MnO	0·45	0·26	0·40
CaO	1·34	1·39	1·12
MgO	0·32	0·37	0·38
K_2O	4·10	4·65	4·42
Na_2O	11·71	12·02	11·69
SO_3	none	none	none
Cl	0·05	traces	0·09
P_2O_5	traces	traces	traces
CO_2	0·21	0·52	0·44
	99·62	99·79	100·14
Oxygen equivalent for Cl	0·01		·02
	99·61		100·12
Specific Gravity ...	2·499	2·434	2·492
Decomposible by HCl	66·0	60·0	66·0

Composition of portion decomposed by HCl.

	I.	III.	IV.
SiO_2	51·84	53·90	53·16
Al_2O_3	28·74	26·86	27·08
Fe_2O_3	2·68	3·02	2·74
CaO	1·83	1·92	1·85
K_2O	1·98	1·77	2·45
Na_2O	12·93	12·53	12·72
	100·00	100·00	100·00

A few remarks with regard to the analysis are appended. The water above 100° C. was determined by heating the powdered rock in a hard glass tube, the water being collected and weighed in a small bulb-tube containing calcium chloride. The mass after fusion with sodium carbonate was in all cases of a bright green colour, dissolving in acid to a pink-coloured solution. The iron and alumina were separated from the manganese by precipitation as basic acetates, and the manganese determined by the method described in Bulletin 148 of the United States Geological Survey by W. F. Hillebrand. The ferrous iron was determined by treating the rock with hydrofluoric and sulphuric acids in an atmosphere of carbon dioxide.[1] We are indebted to Mr. Mingaye, Assayer and Analyst to the Mines Department, Sydney, for a sample of hydrofluoric acid of almost absolute purity.

The portion of the rock decomposed by hydrochloric acid was attacked in the following manner : 1 gramme of the finely powdered rock was digested with strong hydrochloric acid (sp. gr. 1·1) for a few minutes. The solution was diluted with about four times its volume of water, boiled for 10 minutes, and filtered. The filtrate, which contained dissolved SiO_2, was evaporated to dryness, ignited on the water-bath and taken up with hydrochloric acid, the separated SiO_2 being filtered off, ignited and weighed ; the iron, alumina, lime and alkalies being determined in the filtrate. The residue originally insoluble in hydrochloric acid and which

[1] J. H. Pratt—Amer. Journ. Sci. (3) 48, 149.

contains deposited silica from the decomposition of the nepheline, was treated with 30 cc. of 10 per cent. solution of NaHO. It was boiled for about two minutes, diluted, and filtered through a weighed filter-paper. The residue dried at 100° C. and weighed, gives the amount unattacked by hydrochloric acid. The alkaline filtrate was acidified, evaporated to dryness and the silica determined in the usual way. We thus obtain the proportion of silica separated out when the rock was attacked by HCl as well as the proportion which went into solution in the acid. These were added together and entered in the analysis as SiO_2 decomposable by HCl. If stated separately they are as follows:—

	I.	III.	IV.
Separated SiO_2 ...	46·73	46·88	46·91
Dissolved SiO_2 ...	5 11	7·02	6·25
	51·84	53·90	53·16

With regard to the distribution of the different minerals in the rock, Mr. Card has kindly given us the results of his calculation. He finds the following to represent roughly the percentage mineral constitution of the rock according to the analytical data, taking as a basis the mean of the three analyses:—

Felspar (orthoclase and albite = soda-orthoclase)...	45·4
Nepheline	33·6
Ægirine-augite	21·0
	100·0

The assumptions made are the following:—

1. The whole of the Fe_2O_3 is contained in ægirine.
2. The FeO and MgO are contained in a pyroxene together with the CaO.
3. A MnO SiO_2 molecule is present.

The whole forming an ægirine-augite of the composition—

$$\left\{\begin{array}{l} Na_2O.\ Fe_2O_3.\ 4\ SiO_2. \\ (FeO.\ MgO)\ CaO.\ 2\ SiO_2. \\ MnO.\ SiO_2 \end{array}\right.$$

4. The proportion of K_2O to Na_2O in the nepheline is 1 : 5.

On these assumptions the whole of the material in the rock is exactly accounted for with the exceptions that there remains a residue of about 1 per cent. Na_2O, and that 0·2 per cent. CaO is required above that present in the rock. This is shown by the table on the next page, in which the percentage amounts of the different ingredients are accounted for, taking the following formulæ for the minerals present :—

Orthoclase and sanidine ($K_2O.\ Al_2O_3.\ 6\ SiO_2$)

SiO_2	64·75
Al_2O_3	18·35
K_2O	16·90
	100·00

Albite ($Na_2O.\ Al_2O_3.\ 6\ SiO_2$).

SiO_2	68·70
Al_2O_3	19·47
Na_2O	11·83
	100·00

Nepheline ($K_2O.\ 5\ Na_2O.\ 6\ Al_2O_3.\ 12\ SiO_2$).

SiO_2	41·48
Al_2O_3	35·25
Na_2O	17·85
K_2O	5·42
	100·00

Ægirine ($Na_2O.\ Fe_2O_3.\ 4\ SiO_2$).

SiO_2	51·95
Fe_2O_3	34·63
Na_2O	13·42
	100·00

$RSiO_3$ (MgO. 2 FeO. 3 CaO. 6 SiO_2).

SiO_2	50·56
FeO	20·22
MgO	5·62
CaO	23·60
	100·00

$MnSiO_3$ (MnO. SiO_2).

SiO_2	46·15
MnO	53·85
	100·00

The last three minerals forming an ægirine-augite, and the first two a soda-potash felspar.

Mean percentage composition of the rock.

SiO_2	51·51
Al_2O_3	19·66
Fe_2O_3	4·21
FeO	1·32
MgO	0·36
CaO	1·28
Na_2O	11·81
K_2O	4·39
MnO	0·37
Distributed as follows:—	94·91

	Mean Percentage.	Soda-potash Felspar. Orthoclase.	Albite	Nepheline.	Ægirine.	$RSiO_3$	$MnOSiO_2$	Total.
SiO_2	51·51	9·88	17·84	13·85	6·32	3·30	0·32	51·51
Al_2O_3	19·66	2·80	5·06	11·77	...	...	...	19·63
Fe_2O_3	4·21	...	...	...	4·21	...	...	4·21
FeO	1·32	...	...	...	...	1·32	...	1·32
MgO	0·36	...	...	...	...	0·36	...	0·36
CaO	1·28	...	...	...	...	1·54	...	1·54
Na_2O	11·81	...	3·07	5·96	1·63	...	...	10·66
K_2O	4·39	2·58	...	1·81	...	...	...	4·39
MnO	0·37	...	...	...	...	...	0·37	0·37
	94·91	15·26	25·97	33·39	12·16	6·52	0·69	93·99

The difference (0·92) between the totals as calculated in the last column and the amounts present in the rock being due to the excess of Na_2O (1·15) and Al_2O_3 (0·03) and to the deficiency of CaO (0·26).

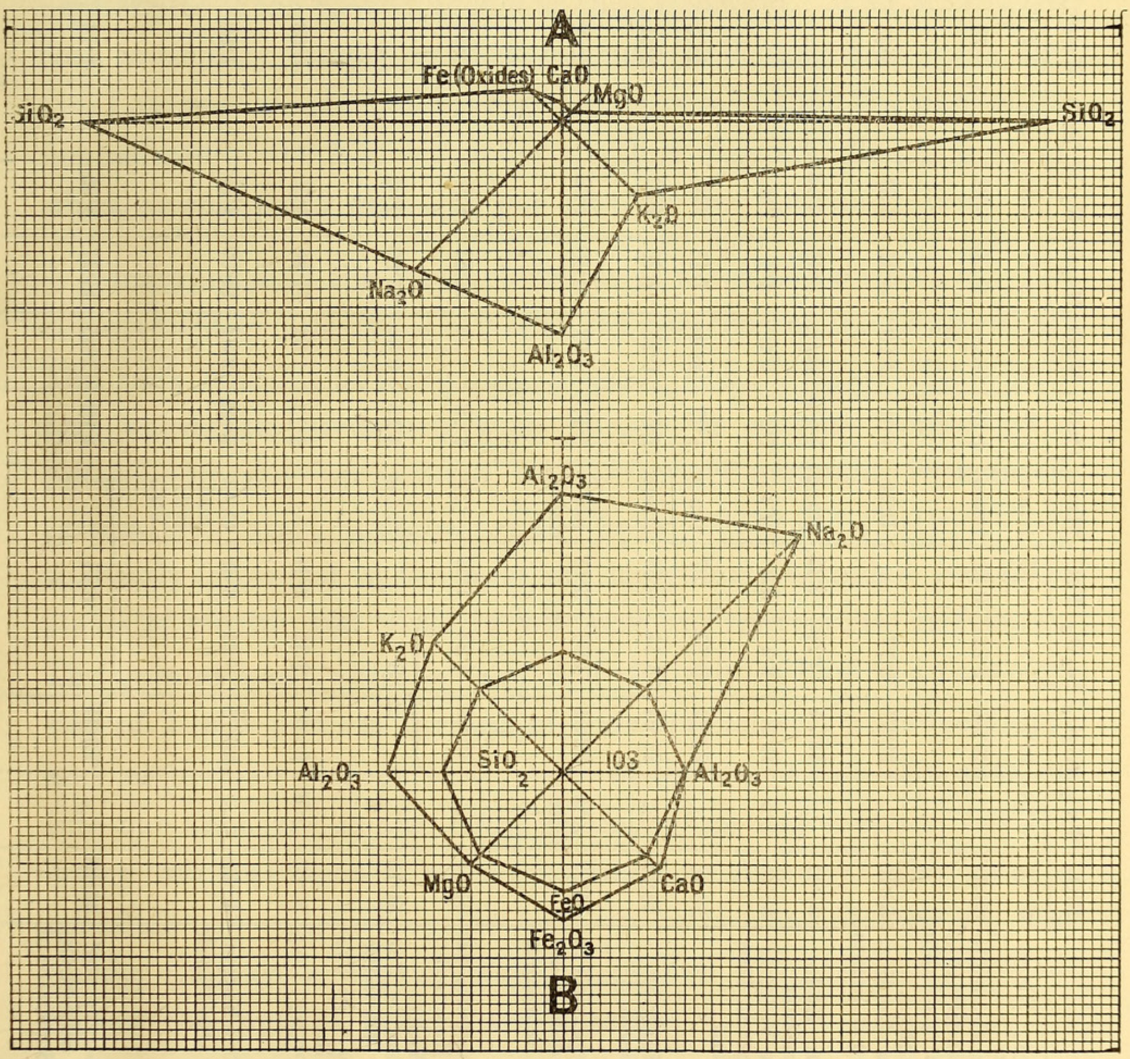
Reducing these figures to percentages we get the following as the approximate composition of the rock:—

Orthoclase and sanidine ...	16·2	43·8 soda-potash felspar
Albite	27·6	
Nepheline...	35·6	
Ægirine	13·0	20·6 ægirine-augite
$RSiO_3$	6·9	
MnO SiO_2	0·7	
	100·0	

A result which agrees fairly closely with Mr. Card's calculation.

No attempt has been made to distribute the minerals in the portion soluble in HCl. Nearly the whole of the iron in the original rock has apparently gone into solution, and if this is all contained in the ægirine as has been assumed in the above calculation, the ægirine must have undergone a selective decomposition, as the figures do not permit of the assumption that the soluble part consists of nepheline with some ægirine.

Mr. Card has also very kindly prepared for us the following diagrams, to express graphically the molecular constitution of the rock.



A. is a Brögger diagram as modified by Hobbs, (Journ. Geol. VIII.)
B. is a Mügge diagram (N.J.B., 1900, Vol. I.)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	BaO	Water	Loss.	Cl	So_3	P_2O_5	Co_2	
Phonolite Rock, Black Hills, Dakota.	61·08	0·18	18·71	1·91	0·63	trace	1·58	0·08	8·68	4·63	0·05	2·21	...	0·12	trace	...	...	L. V. Pirsson, Amer. Journ. Sci., [3] XLVII, p. 341.
Phonolites from Colorado Florissant, Pasolty Co., Colorado. 25°/₀ soluble in HCl=nepheline.	60·02	...	20·98	2·21	0·51	trace	1·18	trace	8·83	5·72	...	0·70	...	trace	...	trace	...	100·15. L. G. Eakins, (v. W. Cross) Jahr. f. Min., 1890, 1 Ref Sci. Soc, 1887, II., 167
Phonolite from Teplitz-Schlossberg in Bohemia	58·16	...	21·57	2·77	...	0·24	2·01	1·26	5·97	6·57		2·03	...	...	0·16	...	...	100·58. Rammelsberg, Z. Geol. Ges. XIV., 1862, 751; XX., 542.
Tinguaite from Edda Gijorgis, Abyssinia.	57·81	...	18·74	5·76	0·42	trace	1·28	trace	9·35	4·52	...	...	1·50	...	...	...	...	99·38. G. T. Prior, Min. Mag. XII., 57, 269, July 1900.
Phonolite of the Volcanic Vent of Traprain Law at East Lothian.	56·8	0·5	19·7	2·2	3·5	0·2	2·2	0·4	4·3	7·1	...	...	2·5	...	...	...	..	F. H. Hatch, Trans. Roy. Soc. Edinburgh, 1893, XXXVII., p. 115.
Wolf Rock	56·46	...	22·29	2·70	·97	trace	1·47	trace	11·13	2·81	...	2·05	...	...	...	trace	...	Phillips, by Allport, Geol. Mag. VIII., 1871, p. 249.
Greenland Harbour, Kerguelen Island.	54·87	...	21·64	3·31	0·89	trace	1·63	0·37	9·26	4·02	...	3·61	...	...	...	...	...	99·60. Clement, in Renard's Report of the Petrology of Oceanic Islands, 1889, 134.
Laurdalite. Type rich in nepheline, Lunde, Lougenthal, Christiania District.	51·90	not deter.	22·54	4·03	3·15	not deter.	3·11	1·97	8·18	4·72	...	0·22	...	...	...	not deter.	...	99·82. G. Forsberg, Zeitschr. f. Kryst. B. 16, I., 33. See also Die Eruptiv-Gesteine des Kristiania-Gebietes W. C. Brögger, III., p. 19.
Nephelinitic tinguaite *var* Muniongite, Kosciusko, New South Wales.	51·51	...	19·66	4·21	1·36	·37	1·28	·36	11·81	4·39	...	·44	3·52	·05	trace	trace	·39	F. B. Guthrie, Journ. Roy. Soc., New South Wales, XXXV., 1901.
Nepheline-phonolite, Purakanui, near Dunedin New Zealand. 51·8°/₀ soluble in HCl.	51·15	...	29·38		...	trace	4·59	0·34	13·80	0·95	...	...	...	...	...	...	...	100·21. F. B. Allen and P. Fitzgerald, Austr. Assoc. Adv. Sci., Chrischurch, 1891, III., 136.
Nepheline-porphyry, Lougenthal.	50·63	0·90	24·00	2·33	2·21	...	2·13	1·54	11·36	4·39	...	0·63	...	...	...	0·28	...	100·40. W. C Brögger, Die Eruptiv-Gesteine des Kristiania-Gebietes, III., p. 235.
Nephelinite of the Katzenbuckel in the Odenwald.	48·24	...	20·72	6·24	3·58	CoO and NiO 0·22	2·88	2·32	11·00	4·43	...	1·50	...	...	0·18	...	...	H. Rosenbusch, "Der Nephelinit vom Katzenbuckel.' Inaug. Dis. Freiburg 1869; Neues Jahr. f. Min. 1869; S. 487.
Nepheline-porphyry of Beemerville, Sussex Co. N. Jersey. (Sussexite of Brögger).	45·18	...	23·31		6·11		4·62	1·45	11·17	5·95	...	1·14	...	...	...	...	...	98·93. J. F. Kemp, "The Elæolite Syenite near Beemerville, Sussex Co., N.J." Trans. New York Acad. Sci., II., 60, 1892.

V. *Relation to allied rocks.*—The foregoing table shows the relation of the Kosciusko rock, from the point of view of its chemical composition, to various nepheline-bearing rocks from other parts of the world.

It is obvious from the preceding table that (if we omit, on account of its deficiency in potash, the phonolite of Purakanui near Dunedin, New Zealand), there are three nepheline rocks in the table to which the Kosciusko rock is, chemically, closely allied, viz., (1) The nepheline-porphyry (Brögger) of the Lougenthal, Christiania District. (2) the type of Laurdalite (Brögger) rich in nepheline, from Lunde in the Lougenthal, and (3) the phonolitic nephelinite of the Katzenbuckel in the Odenwald. The Kosciusko rock is slightly poorer in alumina, lime and magnesia than the two Lougenthal rocks, and is slightly more acid than the phonolitic nephelinite of the Katzenbuckel which contains 48·24 per cent. of silica, as compared with 51½ per cent. in the Kosciusko rock.

Mineralogically the characteristics of these three rocks may be summarised as follows:—(1) Nepheline porphyry of the Lougenthal[1] The rock consists of a medium grained ground-mass, with a perfect eugranitic structure with larger or smaller phenocrysts (einspringlingen) up to 3 cm. in diameter of nepheline in stunted prismatic crystals, bounded by the faces (0001) and $(10\bar{1}0)$. Very sparingly imbedded in the base are irregularly bounded poikilitic plates of biotite and slightly idiomorphic individuals of felspar. The ground-mass, which is composed of granules having an average size of 2 to 5 mm., is formed of soda-orthoclase (cryptoperthite) and orthoclase-microperthite, both of the same size and passing into one another : it also contains nepheline and sodalite, but the latter mineral occurs more sparingly. Amongst the darker minerals are ægirinediopside with an outer zone of ægirine, and biotite (it may be lepidomelane) together with accessory titaniferous iron, pyrites, sphene and apatite.

[1]Description abridged by us from Brögger's "Die Eruptivgesteine des Kristianiagebietes," Vol. III., pp. 155 - 161.

Brögger calculates *(op. cit.*, p. 161) the mineral constitution of this nepheline porphyry to be as follows:—

$40\frac{1}{4}$	Alkali-felspar
$32\frac{1}{4}$	Nepheline
11	Sodalite
8	Pyroxene
5	Lepidomelane
2	Iron oxides
1	Sphene
$\frac{1}{2}$	Apatite
100	

The nepheline porphyry therefore of the Lougenthal differs from the Kosciusko nepheline rock in being (1) much more coarsely crystalline, being eugranitic in texture, in which respect as Brögger remarks, it approaches the nepheline syenites to which he has applied the name of ditroite. (2) In containing some phenocrysts of felspar. (3) In containing more sodalite. (4) In containing more mica. (5) In containing sphene, which does not appear to be present in the Kosciusko rock. (6) In containing less nepheline than the Kosciusko rock.

A remark of Brögger with reference to this nepheline-porphyry is so applicable to the Kosciusko rock, and bears so directly on the question as to whether the Kosciusko rock can truly be termed porphyritic or not, that we think it well to quote it here *(op. cit.*, p. 157):—

"Wenn oben, wie in früheren Publicationen, das Gestein als Nephelin-porphyr bezeichnet ist, muss ich hier eigentlich eine Reservation einschalten, Es is nämlich offenbar, dass die scheinbaren grossen Einsprenglinge *Keine Scharf getrennte ältere Generation im Vergleich mit den Nephelinkörner der Grundmasse darstellen. Sowohl die scheinbaren Einsprenglinge als die Nephelinkörner der letzteren sind nämlich gewiss im wesentlichen gleichzeitig gebildet."*

Also *(op. cit.*, p. 157) "Uberhaupt is diese structur, welche ganz analog auch bei dem Laurdalit selbst wiederkehrt, keine echte Porphyrstructur mit zwei getrennten Generationen, Sondern nur *eine porphyrähnliche eugranitische Structur."* The italics in the above two quotations are ours.

As regards laurdalite (Brögger) this rock is characterised in its type localities (Brögger, *op. cit.*, p. 15) by large hypidiomorphic felspars having a subparallel arrangement and large hypidiomorphic granules of elæolite. In another variety the nephelines are small, fairly idiomorphic and enclosed in the felspars, or intergrown with them so as to form a micropegmatitic structure. In another variety of laurdalite olivine is present in some quantity, so that Brögger applies to the rock the term olivine-laurdalite. While therefore the laurdalite of the type rich in nepheline (type III., Brögger, *op. cit.*, p. 19) differs chemically from the Kosciusko nephelinitic tinguaite in containing less soda but more lime and alumina, it differs distinctly mineralogically (1) in containing much felspar (up to over 62% in the leading type). (2) In containing little nepheline, only 13% in the leading type, though no doubt more in variety III., which is described as rich in nepheline. (3) In containing more mica. The Kosciusko rock cannot therefore be classed with nepheline-laurdalite. As the nepheline-porphry of Beemerville, Sussex Co., N.J. ("Sussexite" of Brögger) is rather too basic to be closely allied with the Kosciusko rock, there remain only the "Phonolitic nephelinites" (Rosenbusch), and certain nepheline-bearing types of tinguaite, to which the Kosciusko rock may be referred.

The phonolitic nephelinite of Rosenbusch is a trifle more basic than the Kosciusko rock, as already remarked having 2% less silica, about 4% more iron oxides, over 1% more lime, and about 2% more magnesia. Unfortunately we have not access to Doelter's paper on the phonolitic nephelinite of S. Antão. The petrological description of it, however, given by Rosenbusch[1] leads us to suppose that it must be very closely allied to the Kosciusko rock, though more basic in composition. As mentioned by Rosenbusch, the rock described by Doelter is remarkable for the absence of augite, the want of coloured minerals as constituents, the abundance of ægirine, in the form of microliths, and of sharply idiomorphic nepheline, belonging to two distinct generations. Sanidine occurs sparingly or more abundantly in small laths. The structure is decidedly porphyritic and the rock is

[1] Mikroskopische Physiographie der Massigen Gesteine.—H. Rosenbusch Bd. II., 2nd Edit, pp. 734-795.

conspicuously green. This description exactly fits the Kosciusko rock with the exception that (1) it is doubtful whether two generations of nepheline are present in the Kosciusko rock, though at first sight there appear to be. Brögger's remark about the nepheline-porphyry of the Lougenthal, we think, is applicable to the Kosciusko rock, in which we are of opinion, in spite of its porphyritic appearance, that only one generation of nepheline is present. (2) The Kosciusko rock is rather brown tinged with green, like a typical phonolite, than "conspicuously green."[1]

As the microliths of felspar present in the Kosciusko dyke rock belong to an alkali felspar rather than to a lime-soda or lime felspar the rock cannot be classed with the nepheline tephrites, and it is too basic to be grouped under grorudite or sölvsbergite. The nepheline-tinguaites, however, have much closer affinities with the Kosciusko rock. At the same time as regards structure the rock is rather nephelinitic than tinguaitic. Some tinguaites which when rich in nepheline approach in character to the Kosciusko rock have been described by G. T. Prior[2] from the neighbourhood of Adowa and Axum in Abyssinia. The Abyssinian tinguaites are, however, more acid than that of Kosciusko containing nearly 58% of silica as compared with the 51½% in the Kosciusko rock.

The provisional conclusion arrived at by us is that this Kosciusko rock does not exactly resemble any definite type of rock known to us from other parts of the world with the exception of the nepheline-ægirine-alkali-felspar rock of Barigan in New South Wales.

As the rock is distinctly hypabyssal and intermediate between the (plutonic) nepheline-syenites and the (volcanic) phonolites we have decided to group it provisionally with the tinguaites rich in nepheline, and propose to call it nephelinitic tinguaite, *var.*

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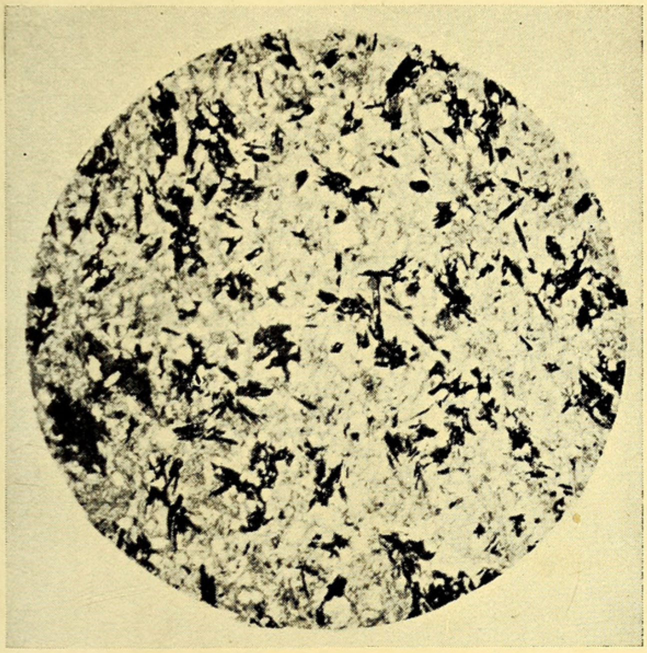
[1] Recent observations in the Barigan district near Lue, N. S. Wales, convince us that the brownish tinge of the Kosciusko rock is simply due to weathering and that the rock at a slight depth would be distinctly green.

[2] Min. Mag., XII., 57, pp. 268-269, July 1900.



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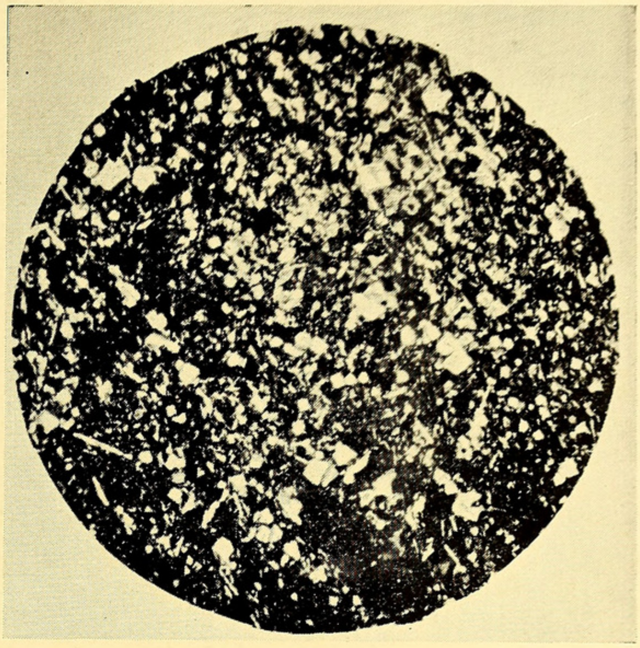
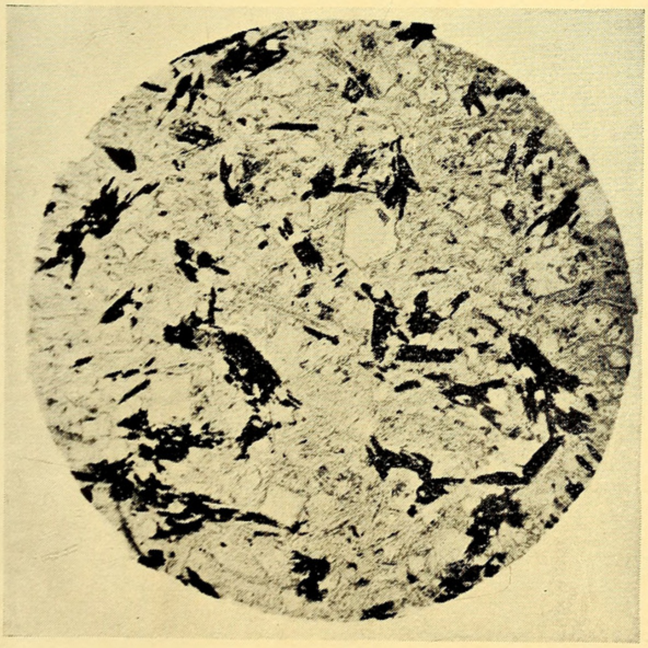


2

Fig. 1. General aspect of the nephelinitic tinguaite of Kosciusko in ordinary light. The dark aggregates are ægirine-augite. The white rectangular or hexagonal patches are nepheline. × 17 diameters.

Fig. 2. The above rock seen under crossed nicols. × 17 diameters.



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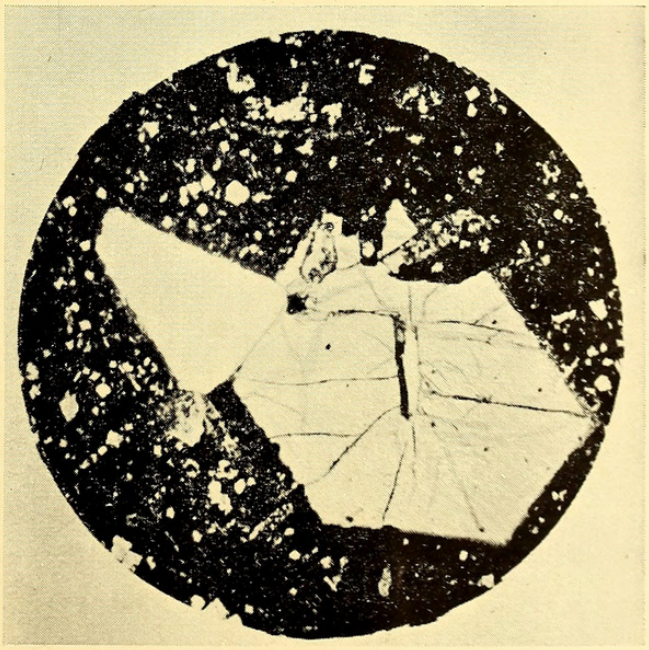
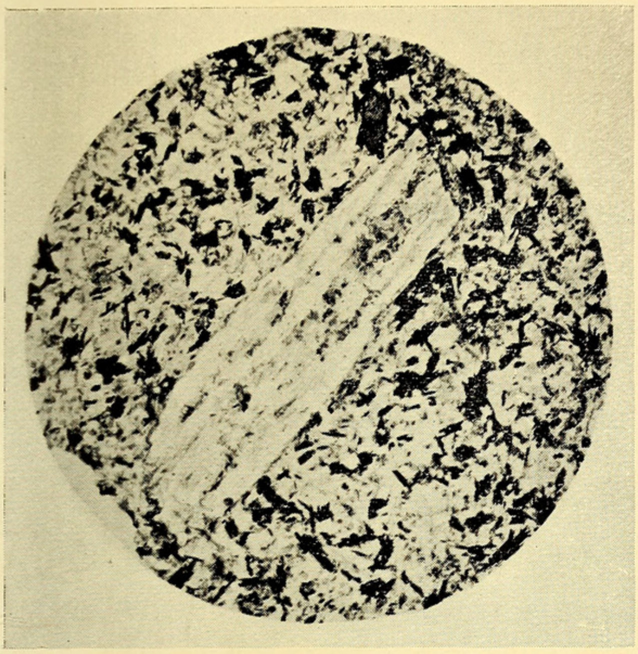


4

Fig. 3. Similar to Fig. 1 but × 35 diameters.

Fig. 4. Twinned crystal of sanidine ·53 mm. × 118 mm. Enclosed in a pseudoporphyritic crystal of nepheline, in the nephelinitic tinguaite of Kosciusko.



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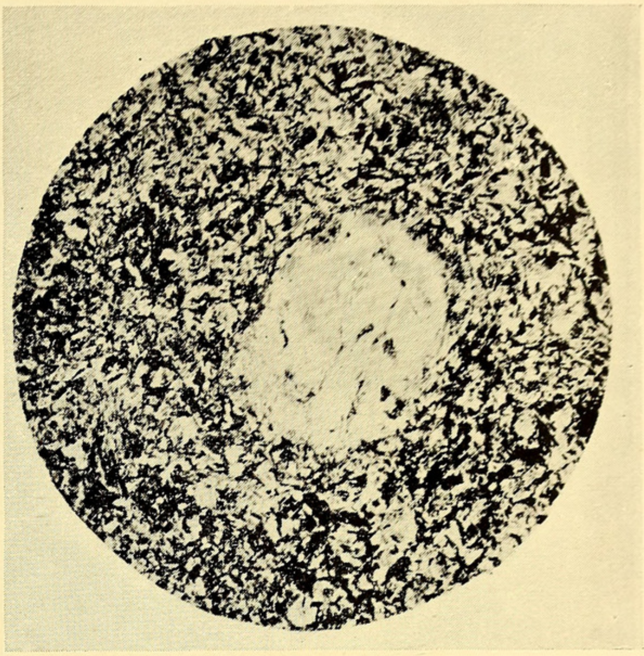

2

Fig. 1. Felspar crystal, derived from granite, enclosed in the nephelinitic tinguaite of Kosciusko. × 17 diameters.

Fig. 2. Granule of quartz, derived from granite, enclosed in the nephelinitic tinguaite.

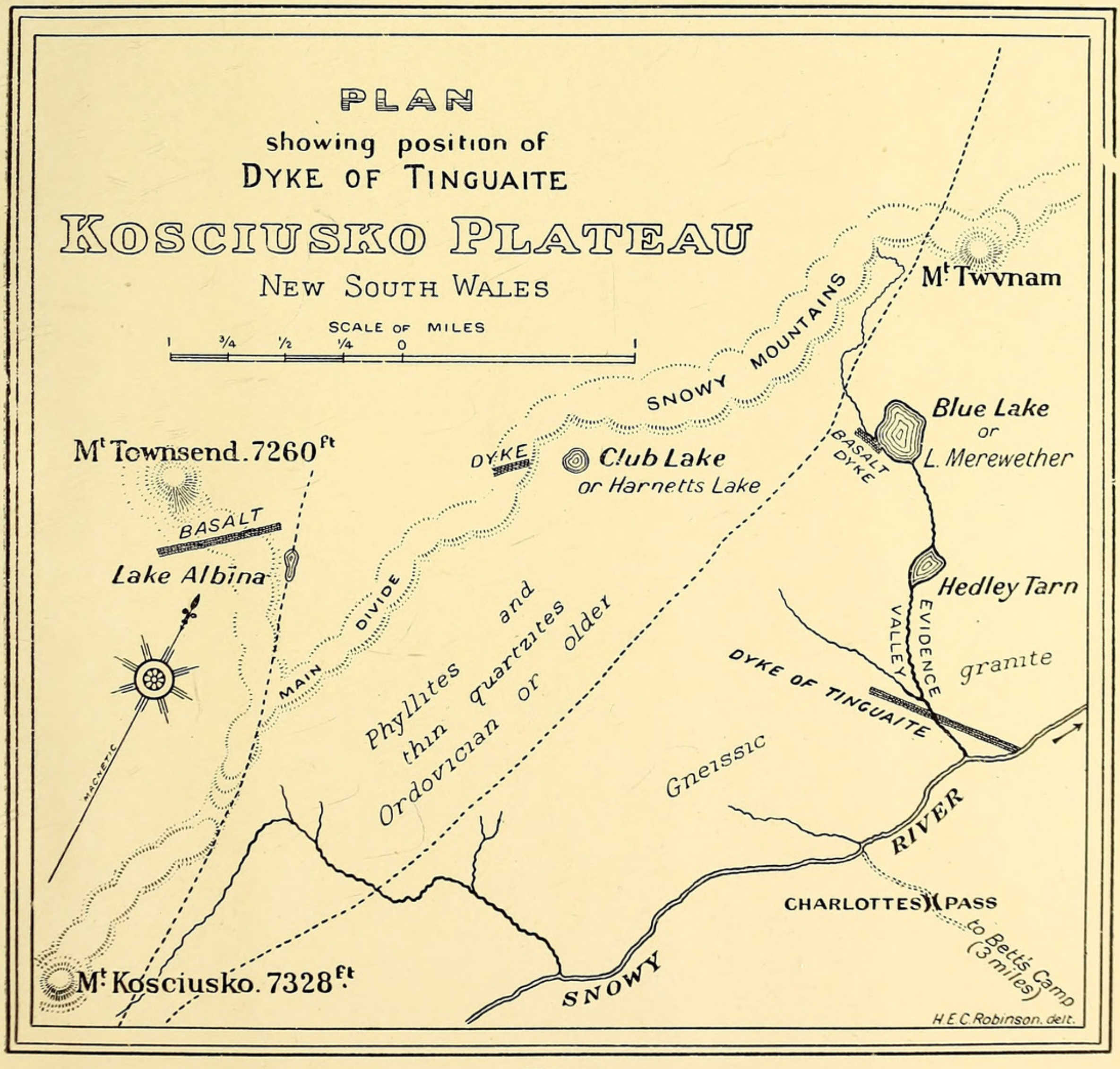

Fig. 3.

Muniongite, "Muniong" being the native name for the Kosciusko Plateau.[1]

VI. *Age.*—Lastly as regards the age of the nephelinitic tinguaite of Kosciusko, it is obvious that it is of newer date than the gneissic granites which it intersects, and that it is much newer also than the sedimentary rocks containing radiolaria and graptolites, which have been intruded by the granites. These sedimentary rocks, as already stated, are of Lower Silurian (?) (Ordovician) age. The granite therefore, is Post-Ordovician, and it is obvious that the tinguaite is very much newer than the granite. This is proved by the fact that the minerals in the nepheline dyke rock are mostly remarkably fresh and free from decomposition, and in the second place by the fact that there is an entire absence of planes of foliation or cleavage from the dyke rock.

As already stated these nepheline dyke rocks of Kosciusko appear to be of approximately the same age as the basalt dykes of the same neighbourhood. There can be little doubt that the latter belong to some part of the Tertiary Era. If, as seems not improbable, the eruptions which produced the nepheline rocks of Kosciusko were synchronous with those which produced the sölvsbergite lavas of Mount Macedon, Victoria, they would then slightly antedate or be nearly contemporaneous with the "older basalts," so called, of Victoria, as according to Professor Gregory, the latter are near in age to perhaps a little newer than the Mount Macedon nepheline rocks.[2]

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[1] Since the recent important discoveries by Mr. J. E. Carne of at least eleven mountains of nepheline-orthoclase-ægirine rocks in the neighbourhood of Barigan, near Lue, it has become apparent that the Kosciusko rock is more or less closely related mineralogically and chemically to these rocks of Barigan. The Barigan rocks pass, at their margins, into a fine-grained selvage very similar to the Kosciusko rock, Possibly at a depth the Kosciusko rock would also pass into 'Bariganite.' For the present, however, we think it better to retain for it the name given above.

[2] Proc. Roy. Soc. Vict., Vol. xiv., (New Series) Pt. ii., pp. 185 – 217, Pls. xi. - xvii., 1901 [published 1902.]

The older basalts of Victoria are in part of Eocene age, and in part, according to Messrs. Hall and Pritchard,[1] perhaps older, possibly Upper Cretaceous. The nepheline rock of Kosciusco may therefore, be also of Cretaceous, or at all events of Upper Mesozoic age. This conclusion is rendered the more probable by a comparison of the age of the trachyte lavas of the Canoblas near Orange, and of the Warrumbungle Mountains near Coonabarabran in New South Wales. These last appear to be slightly older than most of the Tertiary basalts of New South Wales, perhaps Eocene or older.[2]

Moreover, the relations of the soda-syenite of the Gib Rock near Bowral, New South Wales, to the Tertiary basalts of the same neighbourhood appears to be somewhat similar, the soda rock being somewhat older than the basalts. Evidence is as yet wanting as to the exact age of the rock in New South Wales, which above all others hitherto described mostly closely resembles the nepheline rock of Kosciusko, viz. that of Barigan. It is clear however, from Mr. Carne's account that the nepheline rock of Barigan has intruded the Triassic Hawkesbury Series as well as the underlying Permo-Carboniferous coal measure formation, and is therefore Post-Triassic in age.

In Queensland the trachyte lavas and trachytic volcanic necks of the Glass House Mountains, between Brisbane and Maryborough and the trachyte agglomerates of the district west of Port Mackay appear to be slightly older than most of the Tertiary basalts of Queensland. As described in the report by Mr. A. Gibb Maitland[3] the trachytic agglomerates of the Port Mackay district are to be referred to the geological horizon of the Desert Sandstone, the age of the latter being considered to be either Upper Cretaceous or Cretaceo-Tertiary.

Messrs. W. H. Twelvetrees and F. W. Petterd in their interesting account of the Port Cygnet soda-bearing rocks of Tasmania

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1 Proc. Roy. Soc. Vict., Vol. VII., pp. 188 and 195, 1894.
2 Proc. Linn. Soc. N. S. Wales, 1896, Pt. 2, June 24th, p. 265.
3 Geological Features and Mineral Resources of the Port Mackay District—Parliamentary Paper C.A. 93, 1889.

have shown that these rocks have intruded the strata of Permo Carboniferous age. It is probable that they are older than the Tertiary basalts of Tasmania, but definite evidence on this point as well as on the exact relation of this soda series to the vast intrusive masses of diabase of the same island has not yet been obtained. On the whole, until more accurate evidence is available, it may be concluded that the nephelinitic tinguaite of Kosciusko is probably of Upper Mesozoic age, but may possibly be Eocene.

VII. *Summary.*—The evidence so far collected proves that a highly interesting nepheline rock, for which we propose the name nephelinitic tinguaite *var.* muniongite, is developed as a dyke rock at Kosciusko. Its chemical composition proves that it is on the border line, as regards silica percentage (51½%), between the intermediate and the basic groups of eruptive rocks, and tested rigidly by its silica percentage it falls within the latter group. At the same time it is obvious that its general physical characters ally it more to the phonolites than to the nephelinites. We should have no hesitation in classing it at once as a phonolite were it not for the absence of distinct and well formed crystals of potash felspar and for the fact that it is hypabyssal. As already stated minute lath-shaped crystals of soda-sanidine or soda-orthoclase are present in some numbers in the base, but they are of the nature of microliths. They constitute perhaps about 42% of the whole rock. Nepheline is very abundant, occurring in sharply idiomorphic crystals varying in size up to about 3 mm. in length by nearly the same in breadth; in one case a crystal of sanidine was observed to be enclosed in the centre of one of these nepheline crystals. (See *Plate* I, fig. 4.)

Ægirine is also very abundant, and forms over 13% of the whole rock as compared with the 35% formed by the nepheline. The presence of 0·07% of chlorine implies that a little sodalite is also developed. The analcite observed was in every case of secondary rather than of primary origin. The same remark obviously applies to the tufted aggregates of natrolite. A little biotite is present, but much at all events is of derivative origin.

A distinct feature of this rock is the large amount of derived fragments, chiefly quartz felspar and mica, which the rock contains and which it has caught up from the gneissic granite forming the walls of the dyke. In this respect the nepheline rock of Kosciusko closely resembles the basalt dykes of the same neighbourhood. The latter contain a vast number of enclosures of granite, individual fragments being in many cases several inches in diameter. The fact of occasional crystals of sanidine being enclosed in the nepheline crystals is, we think, an argument against the intra-telluric origin, in this case, of the larger crystals of nepheline, which we therefore consider pseudo-porphyritic. The Kosciusko rock is also remarkable for the large proportion, 64%, soluble in HCl. The fact that 2·81% of the soluble portion is ferric oxide shows that part of the ægirine must have been attacked by the HCl.

On comparing the nepheline rock of Kosciusko with the soda-series of Port Cygnet, Tasmania, one is at once struck with the fact that melanite garnet, so abundant in the Port Cygnet rocks, is absent from those of Kosciusko. A possible explanation of this is afforded by the experiments of MM. F. Fouqué and Michel Lévy.[1] They state that, in their experiments in the artificial production of rocks, a mixture of 3 parts of nepheline and of 1 . 3 of augite after fusion and cooling extended over two days, (following their system No. 4) produced microlites of nepheline and augite. The augite crystallised out just after the nepheline. When the proportion of pyroxene was diminished, pyroxene no longer formed. For example, a mixture of 10 parts of nepheline and 1 of augite yielded beautiful crystals of nepheline, small octahedra of spinel, and brownish isotropic rhombic-dodecahedrons of melanite garnet. Evidence is as yet insufficient as to whether or not the nepheline dyke rocks of Kosciusko are complementary to the basic dyke rocks of the same neighbourhood.

As regards age, the Kosciusko basic rocks are probably Tertiary, whereas the nepheline rocks are perhaps somewhat older, Cretaceo-

[1] Synthesè des Mineraux et des Roches. Paris, 1882, pp. 63-64.

Tertiary or Upper Cretaceous. It would appear to be more than an accident that the chronological relations of the chief nepheline and younger soda-rocks to the Tertiary basalts are so similar throughout Australasia, for example, in Queensland near Port Mackay and at the Glass House Mountains; in New South Wales at the Warrumbungle Mountains, the Canoblas, the Gib Rock and Barigan; in Victoria at Mount Macedon; and in Tasmania at Port Cygnet, the nepheline and other younger soda-rocks appear in every case to be a little older than the "older Tertiary" basaltic lavas. It may be mentioned also that at Kerguelen Island the phonolites are thought to be a little older than the basalts, the latter being considered to belong to some part of the Tertiary Era, perhaps to the Miocene. It has occurred to us that there is possibly a fine field for research in studying the distribution of soda-bearing rocks (such as these nepheline rocks of Kosciusko), in relation to areas of subsidence, elevation, or stable equilibrium. So far it would appear that the extrusion of such soda rocks in Australasia has taken place chiefly along the *edges* of great subsidence areas.

It would appear then that in Australasia magmas rich in soda have risen chiefly from the septa of folds in the earth's crust rather than from the tops of ge-anticlines or from the deep seated portions of geo-synclines. The latter in Australasia have mostly yielded either basic or ultra-basic lavas or massive hypabyssal dykes, sheets, or bosses of diabase, while the former (the ge-anticlines) have produced acidic rocks such as granites and rhyolites. At the same time the fact should not be lost sight of that even the basic dyke rocks which have risen from beneath the centre of the geo-syncline under Sydney contain a good deal of soda, primary analcime being present in some of these dykes.

We are specially indebted to Mr. G. W. Card, A.R.S.M., F.G.S., for the kind help and advice he has given us of which we have freely availed ourselves. We are also indebted to him for the Mügge and Brögger diagrams. Our thanks are also due to Mr. W. S. Dun, F.L.S., for assistance in studying the bibliography of the subject. For this portion of the paper we would specially express our obligation to the works of F. von Zirkel and H. Rosenbusch. We also desire to thank Mr. A. J. Peterson, B.Sc., and Mr. L. C. Green for their kind assistance. Our thanks are also due to Mr. E. F. Pittman, Assoc. R.S.M., the Government Geologist, for placing the Geological Survey Library at our disposal.
