THE VOLCANIC ROCKS OF SPRINGSURE, CENTRAL QUEENSLAND.

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(With 1 Plate and 6 Text-figures).

(*Read before the Royal Society of Queensland, 28th October, 1918.*)

Introduction.

In August, 1917, the writer visited Springsure for the purpose of examining the reported occurrence of alunogen on Vandyke Holding, sixteen miles south-west of Springsure, and also the volcanic rocks in the area, some of which were reputed to be alkaline trachytes.

The result of investigation of the alunogen deposit is given elsewhere in these Proceedings while the treatment of the volcanic rocks in particular is dealt with in this paper.

The area has been spoken of for some time past as containing representatives of the Cainozoic alkaline trachytes and as far as the author knows these rocks have not been examined and described hitherto.

The Agricultural Chemist (Mr. J. C. Brunnich, F.I.C.) kindly arranged for one of his assistants, Mr. G. R. Patten, to carry out three complete rock analyses of the three main types of volcanic rocks from the area, and a much more accurate knowledge of the rocks is gained thereby.

The similarity of the volcanic rocks in their lithological characters and in their arrangement with the volcanic rocks of south-eastern Queensland is very marked, as there is a three-fold development, with the alkaline trachytic rocks forming the middle representatives while basalts constitute the lower and upper divisions of the volcanic effusions.

Dr. Jensen and others have referred to the area as one containing alkaline trachytes and the area is regarded as being near the northern termination of a fairly definite line through Eastern Australia which connects the developments of Cainozoic alkaline trachytes*.

PREVIOUS LITERATURE.

In 1894, in the Annual Progress Report of the Geological Survey Dr. R. L. Jack gives a general account of the geology of the Springsure district. Among other things he states on page 9 : " The village of Springsure is very picturesquely situated in the centre of a volcanic region built up of successive beds of lava, sometimes trachytic, but for the most part consisting of basic rocks, varying from ordinary basalt (sometimes glassy) to highly augitic andesite." . " Both the basic and acidic rocks contain, on joints and faces and in cavities, immense quantities of hyalite and chalcedony." Dr. Jack also refers to the opal-bearing trachyte on a ridge just to the south of the town.

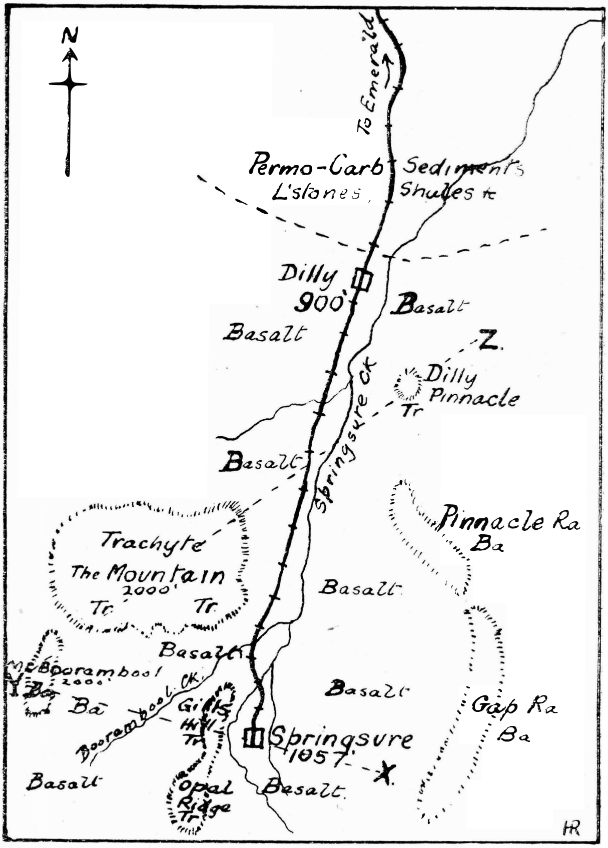
Mr. C. F. V. Jackson, in publication 177 of the Geological Survey of Queensland, gives an excellent account of the interesting development of opal in the trachyte, near Springsure. He writes : " The trachyte contains in many places large numbers of vesicular cavities, small thin veins and cracks, etc., filled with different varieties of opal which have been formed by infiltration of siliceous waters from the rock mass. The common forms are very plentiful, but occasionally the opal in the cavities is of the precious or noble variety, and gems so found are said to exhibit very brilliant colouring."

*Jensen, H.I., Proc. Linn. Soc., N.S.W., xxxiii, 1908, p. 585, text-fig. 10.

Physical Features.

Springsure is situated at the termination of a branch line 40 miles long, running south from Emerald which is 166 miles west of Rockhampton.

The basal rocks of the area are sediments of late Palæozoic age and piled on these are accumulations of volcanic rocks. These have been weathered down and very much dissected but they act as a divide between the Comet River on the east and the Nogoa River on the west which join further to the north to form the MacKenzie River.



Text-Fig. 24.—Sketch-Map of Springsure to show the location of the volcanic masses west and north-west of the town. XY and YZ are the lines along which the sketch-sections in Figs. 25 and 26 were taken. *Scale* : 2 miles to one inch.

In the immediate vicinity of Springsure the volcanic series of rocks have not been denuded through to the underlying Palæozoic sediments. These sediments are believed by the Geological Survey* to be of Lower Bowen age and to be part of a belt about 10 miles wide which extends from the south of Springsure in a northerly direction a little to the west of Emerald and east of Clermont. To the west of this belt the Star Series outcrops and the alunogen deposit at Vandyke, 16 miles south-west from Springsure, is in sandstones belonging to that series. To the east of the belt the Upper Bowen Series outcrops.

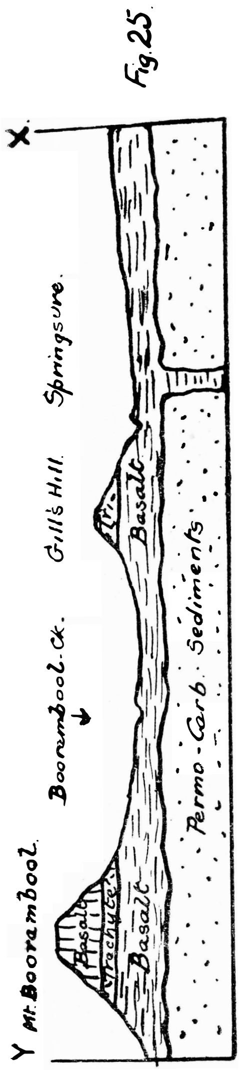
Springsure railway station is 1,057 feet above sea-level and the height of the volcanic accumulations reaches approximately 2,000 feet in the case of Mt. Boorambool which is about two miles west of the town.

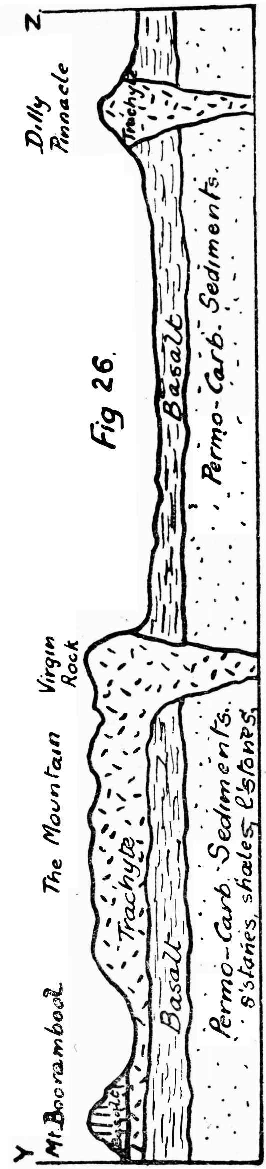
The immediate approach to Springsure by rail is along the valley of the Springsure Creek which runs north between the ridges of volcanic rocks. Boorambool Creek which joins Springsure Creek a little to the north of Springsure flows between Gill's Hill and Mt. Boorambool and around the southern flank of the Mountain. These creeks have denuded through the upper and middle series of volcanic rocks but have not cut through the basal volcanic series of basalts and basaltic agglomerates.

The investigations of the author were restricted almost entirely to the volcanic masses to the west and north-west of the town and these are the Opal Ridge running north to Gill's Hill, Mt. Boorambool or Ward's Hill and the Mountain. Mt. Zamia is the name given by some people to the Mountain and by others to Gill's Hill. In order to avoid confusion the term Mt. Zamia will not be used throughout this paper. Mr. McCahon, of Springsure, writes on this point: "After very full enquiries from some of the oldest residents and from several born and still living here I am inclined to think that Mt. Zamia has been given on maps, plans, etc. to the wrong mass. Many are positive that the correct name for what you have called the "Mountain" is Mount Zamia and the hill named Mt. Zamia on the maps is Gill's Hill."

The Pinnacle Range to the north-east and Gap Range to the east were not visited by the author but appear to be

*Verbal communication from Mr. B. Dunstan, Chief Govt. Geologist.





Text-Fig. 25.—Geological Sketch-Section from east to west, from Springsure to Mount Boorambool.

Text-Fig. 26.—Geological Sketch-Section from Mt. Boorambool to Dilly Pinnacle.

Hor. Scale : 1 mile to an inch. *Vert. Scale* : 2,000 feet to an inch accumulations of volcanic rocks. The Opal Ridge and Gill's Hill consist of trachyte and trachytic tuff rising to a height of 1,260 feet above sea level on Gill's Hill, *i.e.*, approximately 200 feet above the railway station level.

Mt. Boorambool further west from the town than Gill's Hill is about 2,000 feet above sea level and has a level top several hundred yards long and in width from 20 to 100 yards. The length of the ridge is along a north and south line. Mt. Boorambool is very steep and this is due to the hard protecting cap of olivine basalt which weathers less readily than the underlying volcanic rocks (*see* Text-Fig 27).

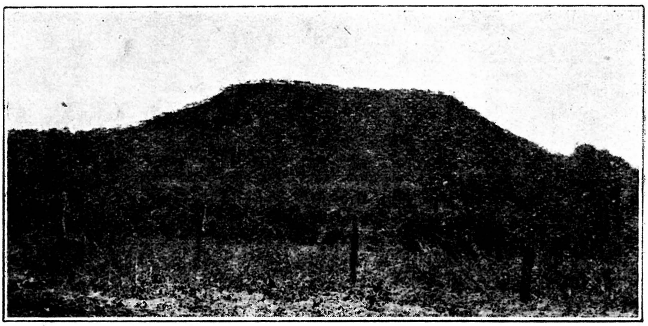
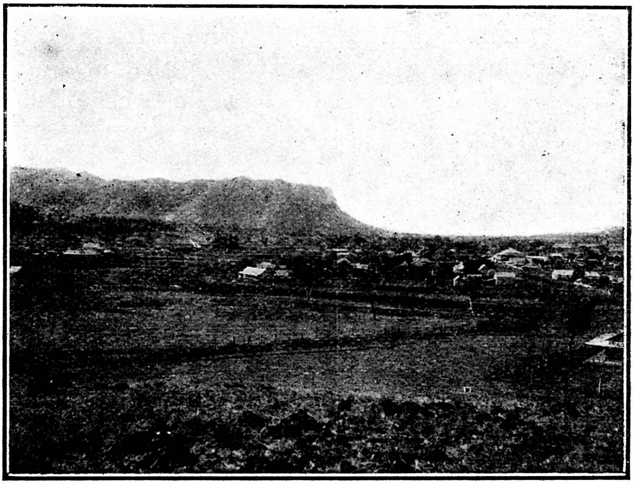


Photo. H. C. R.

Text-Fig. 27.—Mt. Boorambool from the Tambo road near the Opal Patch. The level surface of the basalt capping is well seen.

Further to the west a ridge on a more extensive scale but with a similar mesa-like character occurs. Several isolated mesas with basalt cappings occur to the south and south-west. The question arises as to whether these points were all connected at one time and subsequent denudation has left them as residuals or whether they are the residuals of several flows in different valleys. The latter view is the more probable.

The Mountain which rises to 2,000 feet above sea level is a mass of trachyte resting on basaltic agglomerate and basalt. Its sides are very precipitous and it is a matter of considerable difficulty to ascend the mass. The height of the Mountain above the surrounding country is about 1,000 feet and the upper 600 feet are of trachyte. The top of the Mountain, which occupies several hundred acres has a very uneven surface and great gorges up to 300 feet in depth have been carved out of the solid trachyte, the streams in them falling over on to the lower surrounding country by waterfalls several hundred feet high. The southern and eastern sides of the Mountain are precipitous and so the mass stands out in bold relief (*see* Text-Fig. 28).



Text-Fig. 28.—View looking north across the Springsure Township over the lower basaltic rocks to the Mountain, which is composed of trachyte. The steep sides of the Mountain are well seen.

(*Block lent by Government Tourist Bureau.*)

The Virgin Rock is the name given to one of the more prominent peaks on the eastern edge of the Mountain.

PALÆOZOIC SEDIMENTS.

These form the basal rocks of the area and have been intruded by the volcanic rocks. They consist of sandstones, gravels and shales where met with seven or eight miles to the south-west of Springsure, near the homestead on Rainworth Station. In the immediate neighbourhood of Springsure they do not outcrop at all as the basal rock showing in the vicinity of the town is the basaltic agglomerate which underlies the trachytic rock.

Dr. Jack* recorded the occurrence, between Dilly Station and Crystal Creek, of a blue limestone containing

*Ann. Progress Report, Q'ld. Geol. Surv., 1894, p. 9.

numerous fossils, including a large *Aviculopecten, Productus subquadratus, Stenopora ovata, Protoretcpora* and encrinite stems. This outcrop is about seven to eight miles north from Springsure township and a few miles less from the alkaline trachytic rocks. The occurrence of this limestone in the sedimentary series of rocks intersected by the volcanic rocks is noteworthy in connection with the origin of alkaline rocks as postulated by Daly and others.

Dr. Jack recorded another patch of limestone with similar remains three miles west of the patch above mentioned, and he speaks of the limestone as belonging to the Gympie division of the Permo-Carboniferous rocks. Mr.

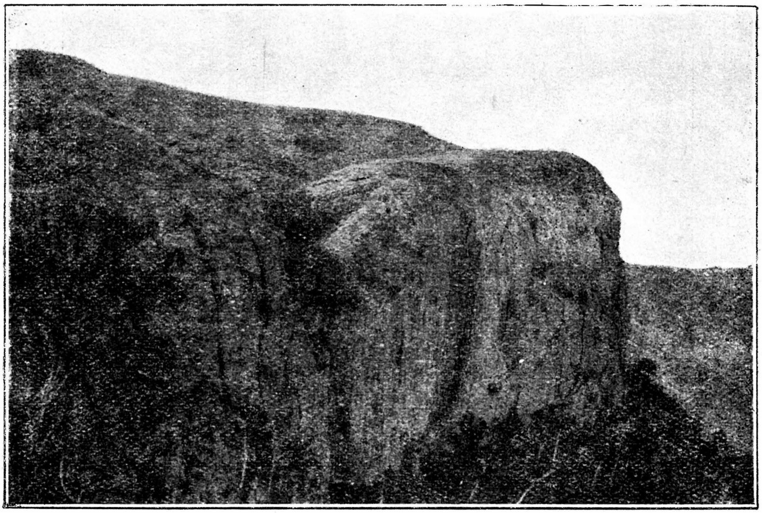


Photo H. C. R.

Text-Fig. 29.—View of the eastern edge of the Mountain from the Virgin Rock. The precipitous nature of the cliff face is well seen.

B. Dunstan, the Chief Government Geologist, regards these rocks as belonging to the Lower Bowen Series.

PETROGRAPHY OF THE VOLCANIC ROCKS.

The volcanic rocks which have a total thickness of about 1,000 feet are naturally developed into three divisions.

Lower Volcanic Rocks.

These consist of basaltic agglomerate and basaltic flows which extend from a height of about 1,050 feet above sea level to a maximum height of 1,400 feet on Mount Boorambool, and a minimum height of 1,160 feet on Gill's Hill, before they are succeeded by the trachyte tuffs and trachytic flows which, in their turn, have been succeeded by a series of basaltic flows. This basal agglomeratic material is very well developed in the southern portion of the town where it is shown in the streamcourse under the road-bridge. The agglomerate is made up of fragments of scoria which range in size from that of a walnut to that of a large apple. The fragmental material is bright in appearance and shows a marked contrast in colour to the grey-blue lava with which it is associated. Chalcedony is very abundant all through the weathered flows and scoria, and the junction line between the lava and agglomerate is the most favourable spot for its development.

Evidently from the presence of agglomerate here, there must have been a centre of explosive activity in the immediate vicinity. Similar agglomerate is met with on the southern slope of the Mountain which is a huge trachytic mass situated north-east of the town.

Scattered about on the weathered surface of the lower basaltic rocks are abundant pieces of chalcedony which at one time occupied the vesicles, etc. in these rocks. Many of these fragments show opaline characters and occasionally closely approach precious opal.

The flows exhibit a marked platy character and this is due mainly to movement of flow during the consolidation period as microscopic investigation shows the augite well drawn out and with the lath-shaped plagioclase crystals all through it.

Specimen 278*, from a well sunk in the yard of Scott's Hotel, Springsure, is a dense fine-grained, greenish-black plagioclase basalt. It has a density of 2.822 which is high and, no doubt, largely due to the great amount of augite and iron ores which the rock contains. Occasional amygdules of chalcedony occur.

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*This number and others subsequent refer to the numbers in the collection in the University of Queensland.

A microscopic examination (*see* Plate xii, Fig. 6) shows the rock to be holocrystalline and to be made up of lath-shaped plagioclase crystals set in allotriomorphic, drawn-out crystals of deeply violet-tinted augite. Granules and rods of the iron ores (magnetite and ilmenite) occur very abundantly throughout the section. The felspar crystals have an average length of about 0.5 mm. while the drawn-out augite crystals which are optically continuous but much dissected by the plagioclase crystals, range up to 1.0 mm. in length and 0.5 mm. in width. The chemical analysis of the rock shows the high percentage of 4.04 for titania which corresponds with the deep violet tint of the augite. Patches of a dark-green chloritic product occur occasionally through the section and this material is probably derived from the augite. The plagioclase obviously ceased crystallising before the augite, and the allotriomorphic drawn-out crystals of the latter with idiomorphic plagioclase crystals sticking through them indicate movement in the flow after the plagioclase had crystallised and before the augite has ceased crystallising.

The plagioclase could not be determined optically. There is a marked absence of olivine in this rock which is in strong contrast with the olivine-rich basalt of the flows forming the uppermost series of volcanic rocks in the area.

A chemical analysis carried out by Mr. G. R. Patten, of the Agricultural Chemist's Laboratory, Brisbane, is shown on Table I. A comparison of the analysis with that of the olivine basalt from Mt. Boorambool shows how closely allied the two rocks are chemically; this is still further emphasised by comparing the norms.

Specimen 279, from the Opal Ridge about three-quarters of a mile south-west of Springsure, is a very finely scoriaceous, glassy basalt. It forms the uppermost portion of the lowest division of volcanic rocks and immediately underlies a trachytic tuff which in its turn is succeeded by trachytic pitchstone and trachyte. The material is somewhat agglomeratic and in colour it is a dark bluish-grey. The material has been met with at the bottom of the shaft which was sunk on the opal patch through the trachyte and trachyte tuff. It outcrops over the lower portions of the ridge, having been exposed by the weathering of the covering material.

The microscopic section (*see* Plate xii, Fig. 4) shows the rock to be a finely scoriaceous black glass through which there are minute microlites of felspar. The cavities are lined with very fine rounded granules which have a refractive index lower than Canada balsam and are probably tridymite.

Middle Volcanic Rocks.

These consist of trachytic tuffs and flows.

Trachytic Tuff. This occurs at the base of the series and is several feet thick. It is made up for the most part of trachytic material but in the lower parts it contains abundant fragments of the underlying scoriaceous basalt. These particles are usually about the size of filberts. The best development of tuff occurs along the Tambo road and on the sides of the ridges in the neighbourhood of the opal patch. Its extension in a south-westerly direction could be traced for some distance, also in a northerly irection around the flanks of Gill's Hill. On the southern slope of the Mountain, at the base of the steep cliffs of trachtye, a trachytic agglomerate was met with at one point. It is much weathered and occurs on top of the basic representatives of the lower division of volcanic rocks. Certain bands in the tuff contain abundant rounded grains of sand.

Trachyte. This occurs outcropping on the surface of the Opal Ridge, Gill's Hill and the Mountain, while on the flanks of Mt. Boorambool it is found outcropping between the lower basaltic and upper basaltic series. It is a very fine-grained, pink rock, showing a very definite fluxion structure. It rests on top of the tuff and in some cases, as on the upper ridge, near Gill's Hill, it has cooled so quickly as to form pitchstone. The pitchstone, in some cases, occurs as a dense black glass and bears a marked resemblance to the Mount Lindsay pitchstone* ; it differs, however, in being almost entirely free from felspar phenocrysts. In other cases it shows a very good fluxion banding and some blocks of this have been brought to the surface

*Richards H. C., Proc. Roy. Soc. Q'ld., xxvii (2), 1916, p. 138.

from the shaft sunk in the opal patch. This material bears a remarkable similarity to the pitchstone on the Springbrook Plateau*, near MacPherson's Range, in south-east Queensland, and occurs in a similar manner as a glassy selvage at the base of the flow of trachyte. On Gill's Hill and Mt. Boorambool, the trachyte flows are about 100 feet thick while on the Mountain the accumulated thicknesses are at least 600 feet.

On the Opal Ridge the trachyte is rather more weathered than elsewhere and is spherulitic for the most part. Sections of the more compact material show this very clearly. The material, however, has been altered into kaolin and chalcedony which occurs abundantly through it.

The precious opal was found in this weathered trachytic material and, as noted by Jackson†, its occurrence in this respect differs from that of the opal deposits in south-western Queensland, north-western New South Wales and Central Australia, which occur in the Cretaceous sedimentary rock. Jackson speaks of opal occurring in a similar manner to this deposit near Rocky Bridge Creek in New South Wales, while the writer has seen a specimen of precious opal obtained from the O'Connell Town quarry in the Brisbane Tuff.

The main mass of trachyte on the Mountain is rather uniform in character and while the prevailing colour is pink, in places it is a greyish-white. As great gorges, in places 300 feet deep, have been carved through the trachyte and as it is almost devoid of soil an excellent opportunity of examining the material is afforded. The rock is very platy as a result of the fluxion structure and thin flakes of the material when knocked together give forth a pronounced metallic clinking sound. The stone well merits the term "Clinkstone," and it is very interesting to find that it is really a phonolite in the strict petrological sense.

Specimen 277, obtained from the Virgin Rock on the Mountain, is representative of the main mass. It is a very fine-grained pink rock with occasional phenocrysts of anorthoclase which range up to 1mm. in length. Under the

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*Richards, H. C., Proc. Roy. Soc. Q'ld., xxvii (2), 1916, p. 137.

†Jackson, C. F. V., Geol. Surv. Q'ld., Pub. 177, 1902, p. 33.

microscope (*see* Plate xii, figs. 1, 2) the section shows a holocrystalline texture although the groundmass is very fine. Phenocrysts of anorthoclase, sanidine and nosean occur. The sanidine crystals range up to 0.5 mm. in length and are idiomorphic, whereas those of anorthoclase are allotriomorphic and up to 1 mm. long, while the nosean crystals are allotriomorphic to hypidiomorphic and the rounded granules range up to 0.25 mm. in diameter. The fluxion structure can be seen in a general way in the section in the ground mass which is composed of felspar, nosean, very fine light-brown augite granules and magnetite. The nosean is rather abundant and the granules are transparent and isotropic with rough cracks through them. The refractive index is much lower than that of Canada balsam. When altered, the granules become reddish brown and this brown staining can be seen developing along the cracks. The nosean was determined by etching with strong hydrochloric acid for 30 minutes and then staining the gelatinous silica produced thereby with fuchsine. Some of the granules showed a weak double refraction but the dust like inclusions, so generally characteristic of nosean, were absent.

The alteration into brown limonite and a kaolin-like aggregation is, according to Iddings*, one of the characteristic weatherings of nosean and this, together with the very low lime content of the rock, inclines one to nosean rather than hauyne. The analysis of this rock, as shown on Table I, shows the very alkaline character, with 10.61 per cent. of alkalies and less than one per cent. of lime. Although the silica percentage is 67.32 the rock is regarded as a phonolite. The specific gravity is 2.519.

Specimen 283, is from the Opal Ridge and is also characteristic of the material on Gill's Hill and on Mt. Boorambool. The material is somewhat weathered and veins of chalcedony along the fluxion lines and through the cracks are prevalent. The rock is very fine-grained and in colour is pinkish-brown. It is reported that this is the type of material in which the precious opal was found. Under the microscope the texture is hypohyaline and the

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*Rock Minerals, 1911 Edtn, p. 257.

whole rock is microspherulitic with very well defined perlitic cracks through it (*see* Plate xii, fig. 3). There were no traces of nosean crystals in this section. The specimen was obtained from near the base of the flow and is evidently a more glassy form of the phonolite.

At Dilly, which is about five miles north of Springsure, there is a pinnacle standing about 700 or 800 feet above the surrounding basaltic country. The writer did not investigate it but from the railway line it appears to be similar material to the phonolite on the Mountain and local inhabitants state that it is of a similar nature.

Dr. Jack* refers to a series of centres of eruptions or "necks" standing about 300 to 600 feet above the level of the old telegraph road between Springsure and Minerva Creek. He mentions Mt. Zamia, the Pigeon House, Saint Peter and Little Saint Peter. He regards these necks as composed of trachyte for the most part but some of them, *e.g.* Red Hill, are partly filled up with a coarse angular agglomerate in which basaltic fragments are mixed up with the trachyte. Unfortunately, owing to limited time, the author was unable to visit these points.

Upper Volcanic Series.

This consists of basaltic flows and just near Springsure they are best developed on Mt. Boorambool. The flows are horizontally disposed and there is a total thickness of about 600 feet. The thickness of individual flows ranges from six to ten feet.

Mt. Boorambool has a very well defined "table-top" appearance and to the west and south, similarly-shaped, flat-topped mesas may be seen.

The weathering of the upper series of basaltic rocks has resulted in several of these mesas being left where the rocks have been more resistant ; the sharp breaking across and comparatively steep sides of the ridges gives the table-top effect.

At Mount Boorambool there are several layers of rock especially rich in hyalite which occurs in large masses. Some of the flows are particularly rich in fayalite which on ex-

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*Annual Prog. Report, 1894, p. 9.

posure to weather alters to ferric oxide and silica* and this is probably the source of the hyalite so commonly developed in the flows in vughs, cracks, etc. A rough columnar structure is developed in the flows at the north end of Mt. Boorambool.

Specimen 280, from the top flow of Mt. Boorambool is typical of the series and in the hand specimen it is a fine-grained, grey, scoriaceous rock. It has a density of 2.747. Under the microscope (*see* Plate xii, fig. 5) the section is seen to be that of a fayalite basalt made up of plagioclase, fayalite, augite and the iron ores, set in a partly-glassy groundmass. The rock shows a rough fluxion structure. The plagioclase is a basic andesine corresponding to Ab_{55} An_{45} and ranges in length up to 0.6 mm. The augite is strongly violet-tinted and is titaniferous, and is much disconnected by the interlacing felspar laths. The drawn-out augite crystals occur up to 1 mm. in length. The fayalite occurs in rounded grains and averages 0.25 mm. in diameter. Limonite occurs as a secondary product from the alteration of the fayalite while serpentine does not occur at all.

Chemical Characters of the Volcanic Rocks.

The chemical analysis of the phonolite shows a very high percentage of alkalies with the soda and potash in approximately equal amounts. The lime content is very low as is also the magnesia. Sulphuric trioxide occurs to a slight extent and occurs probably in the nosean. In the norm the alkaline character of the rock is very well indicated as orthoclase and albite together total over 75 per cent. of the rock while anorthite totals less than 2 per cent.

The chemical analyses of the two basalts are very close to one another, the most marked difference being in the lime content. A comparison with the average composition of the basalts of the world shows they are nearly normal in their compositions, except in the titania content which is very high indeed in both cases. Both rocks are rich in augite which, from its violet colour, appears titaniferous, but, in addition, a considerable portion of the iron ore must be ilmenite.

*Iddings. Rock Minerals, 1911 Edtn., p. 381.

TABLE I.—*Chemical Analyses of Volcanic Rocks and their Norms.*

A. Phonolite. Virgin Rock, The Mountain, Springsure.
B. Basalt. Scott's Well, Springsure.
C. Fayalite Basalt. Mount Boorambool, Springsure.
D. Average composition of Basalts of World*.

	A.	B.	C.	D
SiO_2	67.32	46.41	47.20	48.78
Al_2O_3	15.10	16.61	15.25	15.85
Fe_2O_3	2.70	3.85	4.61	5.37
FeO	1.57	8.69	8.43	6.34
MgO	0.41	5.41	5.72	6.03
CaO	0.70	6.24	8.14	8.91
Na_2O	5.32	3.41	3.45	3.18
K_2O	5.29	1.36	1.57	1.63
H_2O+	0.35	0.50	1.54	{ 1.76
H_2O-	0.55	2.86	0.50	
TiO_2	0.32	4.04	3.25	1.39
P_2O_5	0.08	0.62	0.55	0.47
MnO	tr	0.14	0.16	0.29
SO_3	0.07	0.03	0.07	
Total	99.78	100.17	100.44	100.00
Spec. Grav.	2.519	2.822	2.747	

NORMS.

	A.	B.	C.	D.
Quartz	14.94	—	—	
Orthoclase	31.14	8.34	9.45	
Albite	44.54	28.82	28.82	
Anorthite	1.95	25.85	21.68	
Diopside	0.65	1.11	12.30	
Hypersthene	0.70	14.59	4.42	
Olivine	—	3.53	7.55	
Magnetite	3.94	5.57	6.73	
Ilmenite	0.61	7.60	6.23	
Pyrites	0.06	—	0.06	
Apatite	0.34	1.34	1.34	
Water	0.90	3.36	2.04	
Total	99.77	100.11	100.62	
Classification	I.4.1.3. *Liparose*	II.5.3.4. *Andose*	III (II).5.3.4. *Camptonose*	

*Daly. Igneous Rocks and their Origin, p. 27.

There is a marked difference in the *modes* of the two rocks although they are so close chemically and that is with respect to the mineral fayalite. The basalt from Scott's Well does not contain any fayalite or olivine as seen in the microsection, while the Mt. Boorambool basalt is very rich indeed in the mineral.

RELATIONSHIPS AND ORIGIN OF THE VOLCANIC ROCKS.

The close association in this field of normal sub-alkaline or calcic basalts and alkaline trachyte rocks causes one to speculate as to the cause of the variation. The phonolitic magma has been extruded after calcic basaltic magma was effused and in its turn it was followed by a succession of outpourings of basaltic flows.

The analyses of typical samples of both the upper and lower series of basaltic flows show them to be very similar and to be closely comparable with the average composition of the basalts of the world.

The several outpourings seem to have followed one another at frequent intervals as there is no evidence of any period of time having elapsed between successive outpourings. The lower series of basalts were extruded in the immediate vicinity of Springsure, as evidenced by the agglomeratic character of much of this series; also the middle series was effused from a focus in the same vicinity, as shown by the occurrence of trachytic tuffs and agglomerate and by the character of the main mass of the trachytic rock.

There is no evidence as to whether the upper series was effused from the same centre of activity or not. The fact that the flows on the disconnected mesas "line up" rather suggests a different centre of effusion as the upper series is of greater thickness and on a far more extensive scale of development than the lower and middle series.

There are, however, many points of resemblance between the lithological and chemical characters of the two basaltic series and a somewhat common origin may be assumed for them.

The phonolitic material is interbedded between these two series of basic calcic rocks and the interesting question of accounting for this association arises.

The basaltic rocks both above and below may represent outpourings of a comparatively undifferentiated primary basaltic magma and on chemical evidence this view is supported. Gravitative differentiation may have gone on to some extent as the lower series is olivine free, while the upper series is rich in olivine (fayalite). This arrangement is the reverse of that cited by Daly*, as found by Lewis and Du Toit in certain areas in New Jersey and East Griqualand respectively. If the magma had been affected by the olivine crystals separating out and owing to their higher gravity settling at the bottom the material in the upper part of the magma if extruded first would tend to be olivine free, while the material at the bottom of the reservoir and extruded last would be olivine rich. How has the phonolitic material resulted? Has it been formed from the basic calcic magma by fractional gravitative differentiation as advocated by Bowen, by the absorption of foreign material as advocated by Daly, by the action of gases or mineralisers as advocated by Smyth, or by any other means? In answering this, a consideration of the nature of the intruded terrane is of importance. The underlying rocks are sandstones, shales and limestones as far as can be ascertained. These sediments† outcrop just to the north of the area covered by the volcanic rocks.

The intruded terrane almost certainly contains limestone, and the solution of this material to a small extent would be regarded by Daly as sufficient to result in the production of the phonolitic material from the calcic basaltic magma.

The writer, in dealing with the origin of the volcanic rocks of south-eastern Queensland, regarded them as being differentiates of a single original magma and owing to the almost entire absence of any known limestone in the intruded rocks rejected the sediment-syntectic hypothesis of Daly.

Daly‡ in the "Genesis of Alkaline Rocks" points out that he does not regard limestone as necessarily a partner in a syntectic from which trachytes, etc. are differentiates,

*Daly, R. A., Igneous Rocks and their Origin, p. 316.

†Ann. Prog. Rept., Q'ld. Geol. Survey. 1894, Pub. 103, p. 9.

‡Jour. Geol., xxvi, 1918, p. 108.

and he has "indicated the grounds for regarding shales and other sub-siliceous, hydrous sediments as more influential in the generation of trachytic and syenitic magmas generally." On these grounds of course the alkaline rocks in south-eastern Queensland and in the Springsure area may be accounted for, but it is difficult to explain why the outpourings from the same eruptive centre should be at one time calcic and at another time alkalic when the same series of sediments are being intruded. A further matter to account for is the reason for the middle series only of volcanic rocks being alkaline.

All through the south-eastern Queensland area the alkaline rocks are restricted to the middle series of the three-fold development of volcanic effusions and the same holds good in this area.

Even if Daly's origin of the phonolitic material be accepted, it is difficult to account for the regular mode of occurrence in south-eastern Queensland and at Springsure, of the material in between the two developments of calcic basic to sub-basic volcanic rocks.

It is perhaps easier to reconcile such a regular occurrence with a gravitative differentiation scheme as postulated by Bowen, or even with some modification of Harker's hypothesis of crustal dislocation by radial movements. With respect to Harker's hypothesis the writer has not any evidence at all as to crustal movements or otherwise in this particular area.

Age of Volcanic Rocks.

With respect to the age of the volcanic rocks there is no stratigraphical evidence except that they are later than the Upper Bowen Series (Permo-Carboniferous). On lithological and chemical grounds, however, there seems to be no reason for regarding them other than part of the Cainozoic development of volcanic effusions so abundantly developed in eastern Australia.

A close parallel can be drawn with the volcanic rocks in south-eastern Queensland in sequence, on physiographic grounds, and in lithological, mineralogical and chemical characters. As these volcanic rocks are almost certainly of Cainozoic age, a similar age might with confidence be assigned to the volcanic rocks of the Springsure district.

PLATE XII.

Figures 1-6 magnified 22 diameters.

1. *Phonolite* from Virgin Rock, the Mountain, Springsure. The granule of nosean in the centre of the field and crystals of anorthoclase are seen set in a groundmass of felspar and nosean.

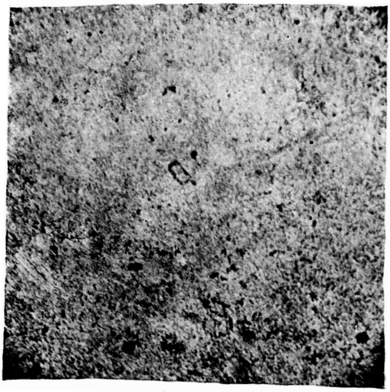
2. Same section as above but under crossed nicols. The isotropic character of the nosean is well shown.

3. *Trachyte* from Opal Ridge, under crossed nicols. It shows perlitic cracks in one portion and the edge of a large spherulite in the other portion.

4. *Glassy Basalt* from Opal Ridge, under crossed nicols. The scoriaceous character is well shown, also the glassy nature of the base. The tridymite lining the cavities is not observable in the microsection.

5. *Fayalite Basalt* from upper flow, Mt. Boorambool. Composed of plagioclase, fayalite, augite and iron ores. The rounded granules with the dark borders are fayalite crystals.

6. *Basalt* from Scott's Well, Springsure, composed of plagioclase, augite and the iron ores.



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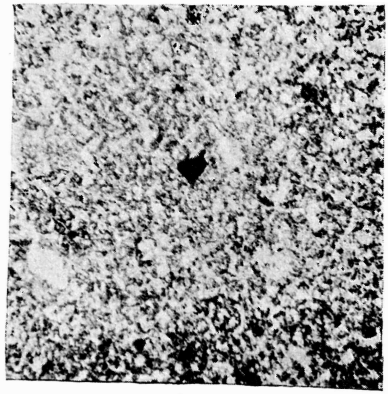

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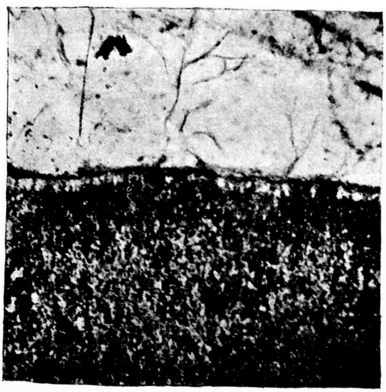

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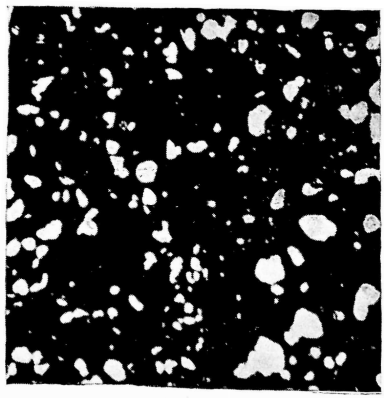

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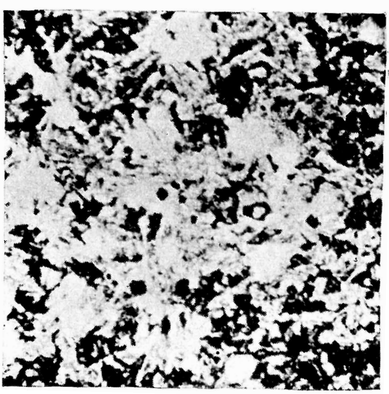

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