THE GEOLOGY OF MITTAGONG.

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[Communicated by Prof. T. W. Edgeworth David, B.A., F.G.S., F.R.S.]

[With Plates XXV., XXVI.]

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Mittagong on the main Southern Line is 77 miles from Sydney by rail, and about 30 miles from the coast. The town is over 2,000 feet above sea-level, and the railway rises gradually to Bowral, passing through the Gib tunnel at the foot of "The Gib." The following paper is the outcome of several visits to Mittagong during the past year, and represents field survey with subsequent laboratory work at the University. The area dealt with consists chiefly in that portion of the country lying between "The Gib" and Mount Jellore, and we have incorporated in our map a large amount of the field work done by J. B. Jaquet, during his survey of the iron ore deposits of the Mittagong district. The whole area, with Mittagong as a centre, comprises about 40 square miles. We propose to divide the paper into the following sections:—

I. Introduction.
II. Sedimentary Formations.
III. Eruptive Rocks.
IV. Petrological Descriptions.
V. Chemico-Mineralogical Classification.
VI. Age.
VII. Summary.

I. Introduction.

The huge eruptive mass of "The Gib"[1] has probably attracted attention from the time of the earliest settlers, and was termed trachyte by the earlier geologists.

Previous Observers :

Rev. W. B. Clarke in his "Sedimentary Formations," mentions occurrence of fossils in the shales.

C. S. Wilkinson, described the coal measures of Mittagong very fully in "Annual Reports Mines Dept. N.S.W., (1879, p. 215; 1882, pp. 141-2; 1890, pp. 206-11.)

J. B. Jaquet, Chapter IV., in his Memoirs on "Iron Ore Deposits of N.S.W.," treats of the Chalybeate Spring Deposits of Mittagong.

R. Etheridge, Junr., in "Invertebrate Fauna of the Trias," mentions Triassic fossils in the local railway cuttings.

E. F. Pittman, in "Mineral Resources of N.S.W.," mentions Iron ore deposits, p. 199 and p. 205; Diamonds p. 395; Mineral Water p. 448; Building stone pp. 444-5.

Mittagong is situated at the north-east extremity of a triangular valley whose apex divides the Mittagong Range at the angle nearest Bowral which is known as the Gap. This valley forms part of the watershed of the Nattai River, which runs northward through deep gorges in the Hawkesbury Sandstone. The Gib extends along the south-east boundary forming a large area of intermediate character. Standing on the Gib and looking north, we see first the Mittagong valley consisting of sandstones and shales which are altered and intruded by numerous dykes of trachytic character. Further northward, beyond a steep escarpment are the anthracite mines where the Newcastle measures outcrop, surrounding what is evidently the eroded boss of a syenite laccolite. Beyond are the steep gorges

[1] The name "Gib" is the popular abbreviated form of the name Gibraltar Rock" given to this mass on the Government maps.

of the Nattai and its tributaries which have cut down through the sandstone to the Permo-Carboniferous measures and exposed sills and laccolites of basalt and dolerite. Eight miles away the sharp cone of Mount Jellore stands out, a mass of trachyte with cones of basic rock near its southern slope. Ridges and cappings of basalt can be seen stretching from Mount Jellore west of the Gib to Berrima, but separated from the point of outlook by an extensive area of elevated sandstone hills. Towards the east another series of basalt flows is encountered, extending towards the Nepean. (See *Plate 25.)*

II. Sedimentary Formations.

1. *Recent*—(*a*) Alluvial deposits.
   (*b*) Chalybeate deposits.
2. *Tertiary*-Ferruginous gravels and shales.
3. *Triassic*—(*a*) Wianamatta Shales.
   (*b*) Hawkesbury Sandstone.
4. *Permo-Carboniferous*—Shales sandstones, and coal measures.

1. *Recent Deposits.*

1. (*a*) The alluvial deposits formed of débris washed down from the hills, occupy swampy flats around "Woodlands," and necessarily

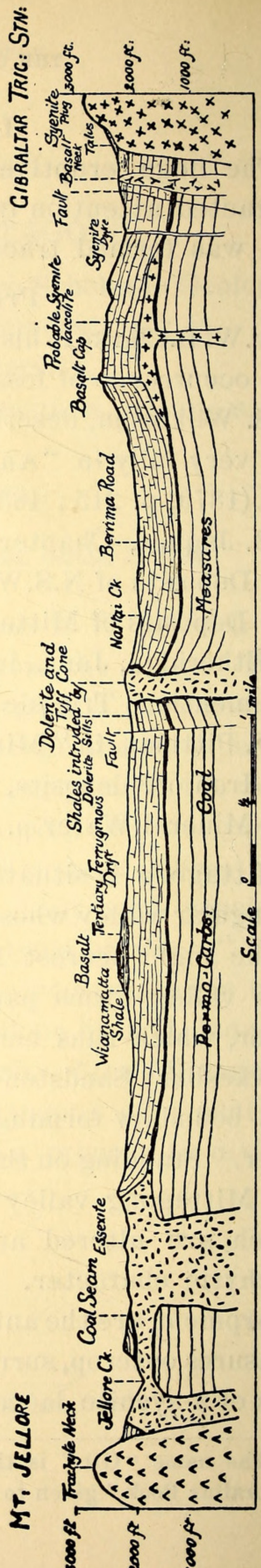

Fig. 1—Section A–G (see Plate 25) through the Mittagong district to "The Gib" to Mount Jellore. (For legend see Plate 25.)

obscure the true character of the country. (*b*) Very little has been said by previous observers as to the origin of the iron ore deposits of the district. They occur in two types. (1) Connected with basalt cappings situated on more or less elevated ground. (2) Deposits from ferruginous springs on low level ground.

We did not examine class (1) in detail as they are of no economic importance. Their mode of origin has already been referred to.

As regards the second class of deposits, they occur usually on the lowest ground in the vicinity; they are irregular shaped shallow masses of no very great magnitude (running up to 150,000 tons). In most cases the deposition can still be seen going on, in one or more small springs occupying crater-shaped depressions on the surface. The best known of these deposits occurs close to the Fitzroy Iron Works and has an area of 5½ acres. Three of these "craters" appear on the surface. From one of these there is a considerable flow of water, another gives a small trickle, the third none at all. The water is used medicinally by the residents and contains besides other mineral substances ·0712 parts per 1000 of bi-carbonate of iron. The deposition of the iron is brought about in the shallow crater-like depressions by exposure to the air, when carbonic acid is evolved and the iron is deposited as a hydrated peroxide. The composition of a sample of this ore analysed in the Department of Mines is as follows :—

Hygroscopic moisture (100° C.)	1·44
Combined water	10·97
Ferric oxide	70·58
Silica	12·42
Phosphorus	·03
Alumina	·76
Lime	·10

Magnesia	·55
Alkali oxides	·48
Sulphur	·039
Titanium	trace
Manganese oxide	2·44
Total... ...	99·80

Most of the above information has been drawn from Mr. J. B. Jaquet's book on the Iron Ore Deposits, which contains a very full description of this ore body, but one point which seems to have escaped previous observation is the presence of a large dyke intersecting the deposit close to the main spring. This dyke is best seen in a small road cutting close to the blast furnace about 200 yards away, where it appears as a white trap about 25 yards wide, and has a narrow parting of talcose rock. The position of the dyke is evidently a fault fissure as seen by a cross section of it (*vide* fig. 2). The dyke narrows down as it passes through the ore body and is lost some distance on the other side.

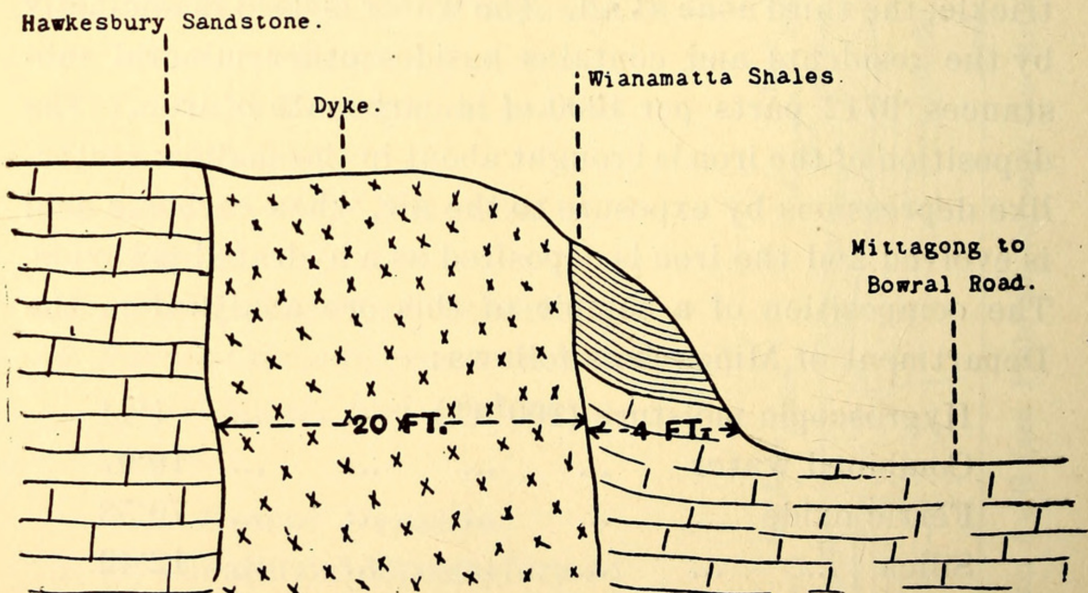

Fig. 2—Sketch of Section of dyke which intersects the iron ore deposit. (The section is taken through the dyke 200 yards to the north-east of the deposit.)

This type of deposit is common from near Picton as far south as Goulburn (*vide* J. B. Jaquet's report). One point to be noticed is that these deposits only occur in the vicinity of Post-Triassic volcanic action. The faulting and cracking of the sedimentary formations due to this action would allow the escape of the chalybeate waters to the surface, and consequent deposition of the ore. As to the source of the iron in the spring water, there are two possible hypotheses—that the iron was dissolved (*a*) out of the sedimentary rocks, (*b*) out of the eruptive rocks.

(*a*) Dealing first with the possibility of its being derived from the sedimentary formations, we should expect to find this type of deposit scattered over the Permo-carboniferous coal basin, and that instead of occurring more abundantly near the periphery, as is the case, such ore deposits would be more extensive towards Sydney the centre of the basin. The iron certainly could not be obtained from the Hawkesbury Sandstones, because of their small iron contents; so that if obtained from the sedimentary formations it would in all probability be derived from the coal measures. Objections to this would be that whilst the coal measures occur over so large an area in the east of New South Wales the iron ore deposits are limited; also that water taken out of the coal seams does not contain nearly so large a percentage of iron.

(*b*) The eruptive Intermediate rocks of the district contain slightly more than 8% of ferric oxide. Mr. Jaquet estimates the amount of iron ore as 150,000 tons containing 70·58% ferric oxide. The decomposed syenite appears as a white trap, and would only contain a trace of iron, so that we may say that 8% of the ferric oxide in the rock is leached out during decomposition. Then we find to produce the iron ore deposit 1,323,300 tons of syenite would be required. Taking the specific gravity as 2·6 this is equivalent to 18,185,230 cubic feet.

Now suppose that the iron ore was derived from the decomposition of the dyke which intersects it, suppose that the decomposition reached as far as the coal seam, and the dyke to have an average width of 10 feet, then the deposit would represent the decomposition of the dyke for a length of over 3,000 feet. Objections to this assumption—that the iron has been leached out of such a length of the dyke and deposited at the one spot are

1. The dyke is only seen to outcrop at the surface for a length of about 2,000 yards.
2. That part of its iron contents went to build up another ore body situated further along the dyke.
3. Iron derived from the decomposition of such a length would not under ordinary circumstances reach the surface at the same point.

Now the point where the iron ore deposit occurs is about the lowest part of the valley between the Gib and the dome shaped hill over the anthracite mines, this can be readily seen on examining the accompanying section.[1]

The sedimentary formation both next the Gib and in the anthracite valley is slightly tilted upwards by the syenite,

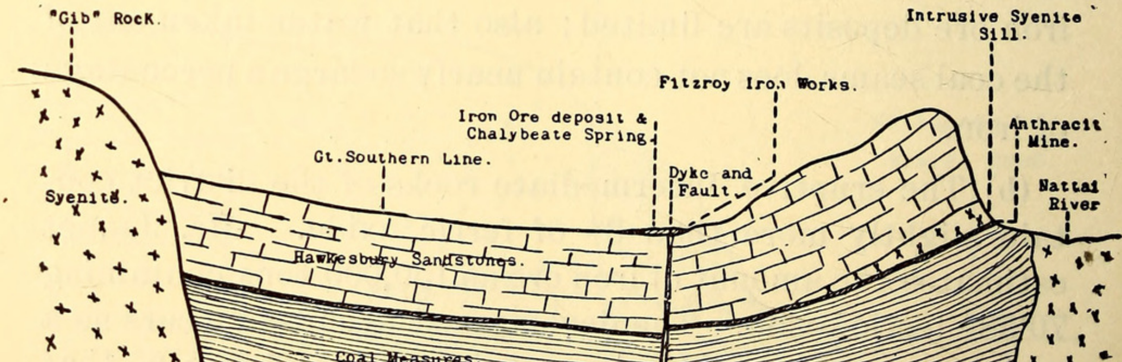

Fig. 3—Section across the Mittagong Valley, showing the probable origin of the chalybeate deposits.

[1] This section is drawn approximately to scale, the data has been drawn largely from Mr. Jaquet's map.

and as the coal seams are porous it is evident that a fair amount of soakage must take place into the coal seams from either side of the valley, which would later on rise up to the surface through any available cracks such as dyke and fault fissures, etc. Moreover as the coal seam is intruded by the eruptive rock in the anthracite valley, and as at least 20 feet of it next the seam is decomposed into a white trap, it is only natural to suppose that all the iron from it has been dissolved out by the water circulating along the seam, this iron augmenting the supply if not furnishing almost the whole of that rising to the surface in the waters of chalybeate springs. Summary of arguments in favour of its origin from the eruptive rocks :—

1. In most of the decomposed dykes of the district a narrow parting of limonite occurs between the dyke rock and the sedimentary rock.
2. That these springs are always found in the vicinity of eruptive rock.
3. What has become of the iron leached out of the trap in the anthracite valley ? It could not have run directly into the Nattai, as the dip of the strata is inwards.
4. The iron ore contains all and only the constituents of the eruptive rock, even to Titanium, which is usually uncommon in sedimentary formations.
5. It could not be derived from the sedimentary formations for reasons already given under that head.

2. *Tertiary Deposits.*

The drifts and gravels occur almost invariably wherever the basalt caps have protected them from denudation. They consist of rounded fragments of quartz and basalt cemented together by ferruginous material so as to form a conglomerate, which usually occurs as rounded blocks around the edges of the overlying basalt. The contained basalt indicates that the drift was partially derived from lavas earlier than the basalt capping. The iron cement was either leached out from the later covering of basalt or, as at the time of deposition these gravels occupied the river beds, it may have been derived from contemporaneous chalybeate springs.

3. *Triassic Deposits.*

(*a*) The Wianamatta shales extend over a considerable area of the district, and largely occupy trough faults and areas of depression, as in the Mittagong valley. The thickest beds in our district occur at the north entrance of the Gib tunnel where they are 80 feet thick. Inspection showed they had been preserved by a capping of basalt, which has since been denuded away with the exception of loose boulders on Hynde's Farm.

(*b*) The Hawkesbury Sandstone occurs as beds 600 feet thick. Much has been turned into quartzite of varying degrees of hardness through alteration by "the Gib" and other centres of eruption. To this latter cause also must be ascribed the occurrence, in a glassy quartzite in a cutting on the Joadja tram line near Currockbilly, of bright glistening particles of graphite about 1 cubic millimetre in size.

4. *Permo-Carboniferous Deposits.*

These have already been described very fully by W. S. Wilkinson, as noted previously. Three well defined areas occur at Mittagong:

(*a*) Anthracite valley at head of the Nattai River.

(*b*) At the end of Mittagong Coal Co's tramway on Nattai River, four miles below (*a*).

(*c*) Extensive series of shales near Powell's Creek and Jellore Creek.

With respect to the first outcrop Mr. J. B. Jaquet says: "These beds are exposed to the north of Mittagong, where the strata have been forced up by igneous intrusion and the Nattai has cut through the overlying Hawkesbury Sandstones."

The second area is reached by way of the old tramway which leaves the Berrima road on the right about four miles to the north-east, passing over high trestle bridges and through a tunnel excavated in the Hawkesbury series. In many of the cuttings towards the end fine specimens of decomposed dykes can be seen. From the end of the line a very steep inclined tramway brought the coal up several hundred feet from the adit just above the river. A very fine section of the Newcastle series and overlying triassic rocks can be seen in the cliff face above the adit.

The main point of interest in the third area is the occurrence of an impure graphite representing the coal seam highly altered by the intrusion of eruptive rocks.

III. Eruptive Rocks.

The district is very rich in eruptive rocks of the following types :—

1. Alkali-felspar, Intermediate series.
   - a. *Syenite*
   - b. *Trachyte.*
   - c. *Intermediate Tuffs and Breccias.*
   - d. *Trachytic dykes.*
2. Basic rocks including Picrites.
   - a. *Dolerites.*
   - b. *Essexites.*
   - c. *Basalt.*
   - d. *Basic Tuffs and Breccias.*
   - e. *Basic dykes.*
   - f. *Ultrabasic series of Jellore.*

1.—*a. Syenites.*—The most important area of this class is of course the huge dome of the Gib. Its summit stands

2,830 feet above sea level, rising about 1,000 feet above the surrounding country. It consists of a syenite allied to Bostonite (Harker, p. 117) consisting chiefly of orthoclase

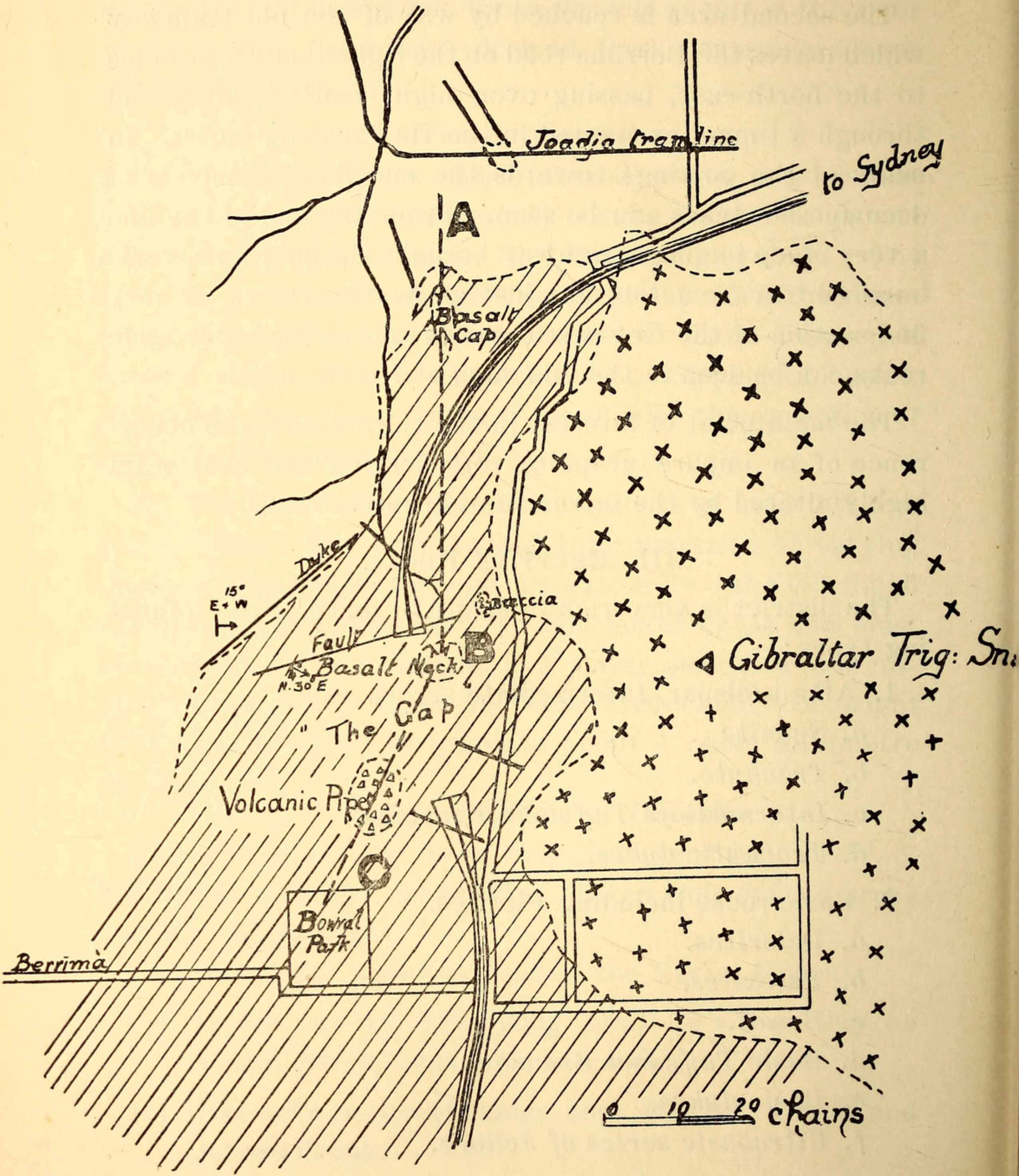

Fig. 4—Map of the district to the west of the Gib ; showing volcanic necks and dykes. (For legend see Plate 25.)

felspar. It covers an area of 450 acres, and is surrounded by tilted sandstones on the northern side, while the east slope is overlaid by later basalts. The stone is largely used for building purposes and is obtained from seven quarries on the steep southern and western faces. Of these the most eastern (Loveridge's) is the largest. The rock is of very uniform character though the stone from Saunder's Quarry nearer Mittagong is of darker hue than that further east. Probably the lighter colour of the latter is part due to its proximity to the Hawkesbury Sandstone. It is remarkably free from fissures and cross cracks, and so it is possible to obtain huge blocks for architectural purposes. Narrow segregation veins of beautiful sanidine (glassy orthoclase), mingled with large hornblendes and ægerine crystals, traverse the syenite. Small irregular grains of fluorspar are fairly common in Loveridge's quarry, while sparkling little quartz geodes can be found in western quarries. Small black fragments and stains of carbonaceous material are present. These are supposed to be due to the condensation of bituminous matter carried up by volcanic rock, in a gaseous state, from the underlying coal measures.

The Gib represents the denuded plug of an old volcano. It is improbable that it represents a denuded laccolite, since only a very few hundred feet of shales, judging from surrounding strata, could have remained undisturbed to check the immense volcanic energy of so large a mass of molten magma.—(See Section IV. No. 1.) Again although any ejectamenta which may be present on the eastern slope have been covered by basalt, and much have undoubtedly been removed by denudation, yet what appears to be an ejected breccia occurs at the foot of the western slope. There is also a true trachytic lava which probably welled up from a parasitic cone, but this is described more fully later on. (See 1. c. *infra*).

Another large area of syenite occurs in the Nattai Valley near the anthracite mines, concerning which Jaquet writes: "This great mass has forced the strata upward and formed a dome, while at the same time sheets have run along the bedding planes of the coal measures. One of these sills, which has a thickness of over 100 feet has followed the roof of the coal seam upon the south side of the valley, and is in actual contact with the coal. The coal is, however, comparatively unaltered." The syenite sill has decomposed into a trap closely approaching kaolin and has been mined by local residents.

1.—*b. Trachytes.*—A small quarry for local purposes, chiefly roadmending, has been opened in a hill about one and three-quarter miles from Mittagong, along the Berrima road. The rock is a trachyte, and some fine examples of columnar structure were to be seen, but have probably since been broken up. The columns are composed of bluish rock with a somewhat spotty appearance, and readily crack off in large flakes.

Mount Jellore.—This striking cone rises abruptly out of the Triassic sandstones. The south face has slopes of 60° and rises sharply up from Jellore Creek. A steep ridge runs towards the west composed of quartzites, etc., which are intruded by trachyte dykes, especially near the Peak. From the Trignometrical Station (height 2,734 feet above sea level) a magnificent view northward over the Wollondilly River can be obtained. The top consists of a fine grained greenish rock which is jointed so that the slabs dip away from the centre. The lava composing the cone appears to have differentiated largely during the process of solidification. The summit is composed of a trachyte consisting of felspars more or less kaolinised, and irregular bunches of blue hornblende, giving a mottled appearance to the hand specimen. About 200 feet from the summit the track crosses a large outcrop of rock, which is gray on the weathered surface, but when broken into discloses a dark blue colour like that of the basalts. This rock breaks readily into flakes with a conchoidal fracture, the non-basic character of the rock is shown by the fact that the flakes are translucent on thin edges. This outcrop was of large extent, but the boundaries were either hidden by talus slopes, or formed cliffs which rendered mapping almost impossible. This dark trachyte contains a large proportion of ægerine (soda augite) in its composition.

A similar association of trachytes of like composition occurs in the Glass House Mountains, Queensland. Indeed several sections made by Mr. H. I. Jensen from rocks brought by him from that locality show minute microscopical resemblance. The blue hornblende mentioned above also occurs in the trachytes of the Warrumbungle Mountains near Mudgee. This similarity in structure in the trachytes extending along the western slope of the present Dividing Range is of much interest and will doubtless repay investigation. (See Section IV. Nos. 2 and 3).

1.—c. *Intermediate Tuffs and Breccias.*—The tuffs are in all cases much decomposed and in many instances merge into breccias.

(1) Tuff cone, half mile west of the Gib.
(2) Tuff bed, one and a half miles on Berrima road.
(3) Tuff, west slope of Jellore.
(4) Tuff, three miles east-north-east of the Gib.

(1) This volcanic cone rises sharply from lower levels round Bowral, just to the west of the southern end of the tunnel. The top is fairly flat and oval in shape, being approximately 100 yards long by 30 yards wide. The cone is composite in character, the eastern slope consisting of decomposed syenitic breccia and vesicular lavas in which the steam holes have been filled with calcite. Towards

the south the rock becomes darker and harder and has been mistaken for a basic breccia. In sections, however, it is seen to be composed largely of fragments of trachyte. The south-west end has been quarried for light colored rock of a tuffaceous character. On the north-west slope more vesicular lava (much decomposed) occurs. (See Section IV. No. 4.)

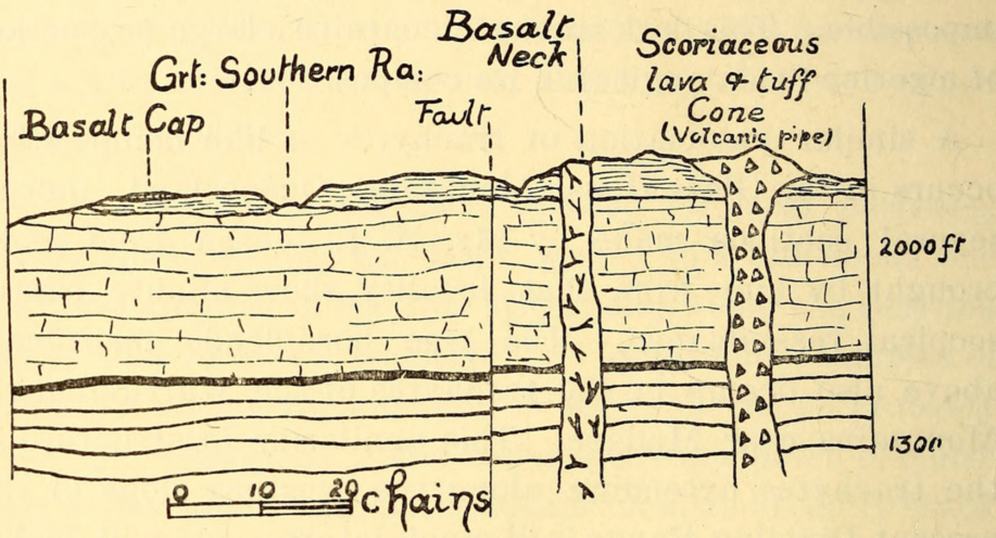

Fig. 5.—Section A B C (see fig. 4) showing small volcanic necks to the west of the Gib.

This cone probably does not represent the remains of the crater of the Gib, but is the result of material which has welled up from a laccolite some hundreds of feet below. The large area of sandstone to the north of this cone has been upheaved to a considerable extent as shown by the dip of the strata. It is worthy of note that the fragments included in the tuff resemble (when sectioned) the rock quarried from a small hill about one and half miles away on the northern slope of this same elevated sandstone area. This would tend to show the existence of a mass of eruptive material below the sandstone, in form of a laccolite, extending from the quarry on the north to the tuff cone on the south.

(2) Berrima Road.—This is a fairly extensive bed extending about 100 yards along the road and 50 yards back on the northern side. It is not so decomposed as many of the tuffs. Fragments of shale and sandstone are enclosed. This bed was probably formed at the time of eruption of the neighbouring mass of trachyte mentioned previously.

(3), (4) These tuffs are very much decomposed and are of little use for stratigraphical purposes.

1.—*d. Trachyte dykes.*—The whole district round the Gib, but especially for a few miles to the north, is permeated with dykes. Over fifty have been mapped by us. As before mentioned, these dykes have to a great extent determined the contour of the country. Although the dyke itself is almost invariably decomposed to a soft trap of light colour, yet the intruded rocks have been very much hardened, the sandstone into quartzites and shales into chert. Hence the hard quartzites resisting erosion have in many cases formed the crests of ridges. We found it to be the rule that almost every small hill owes its existence to the presence of dykes or other volcanic action.

The areas of subsidence are in many cases bounded by long dykes which have evidently intruded the planes of weakness. One example of this class occurs running north and south along the slope of the sandstone hill to the west of the Gib. Here the junction between the later Wianamatta Shales and much more elevated Hawkesbury Sandstone is marked by a decomposed dyke. The dykes are usually three or four feet wide and can sometimes be traced for half a mile.

2.—*a. Dolerites.*—One of the finest specimens of dolerite in the State occurs on part of a small hill now occupied by a private garden, about three-quarters of a mile east-north-east of Mittagong Station. It is found in form of large subangular boulders which are extremely hard. The surface is slightly weathered but inside the rock is quite undecomposed. It breaks with a ring like phonolite, and pieces fly away to great distances. The dolerite appears to have intruded an isolated patch of syenite (much decomposed). The actual line of junction is completely hidden by the clays etc., resulting from the latter. The rock makes a beautiful micro slide, a description of which will be found in the petrological section (No. 5).

In the Nattai River at the foot of the incline leading to the Mittagong Coal Co's. adit, is a large mass of dolerite which probably represents a laccolite. Numerous sills have spread out horizontally between the Permo-Carboniferous Shales. The latter are converted into a black chert somewhat resembling rhyolite macroscopically. The bed of the river from the adit downwards appears to be cut out of this dolerite. The latter varies in texture and passes into a basalt zone about 20 feet thick at its junction with the coal measures, due to its rapid cooling. Several bluffs, some 40 feet high, some with prismatic structure, are cut through by the river a little lower down. On the east bank, 200 yards down from the adit, there are some broad dykes of lighter colour, consisting mainly of felspar and magnetite.

"Currockbilly," three miles along Joadja Tram Line.—This prominent hill consists of intermediate rock on the east, which is much decomposed, but the lower western portion is formed of dolerite and decomposed tuffs. A large broad dyke appearing as red soil runs about one mile east from this centre and a good section (already described) is shown in cutting on Mittagong Coal Co's line. Sills of dolerite, two feet thick, in the shaley bed (Wianamatta) of Kells Creek, south of Currockbilly, probably originated in the above boss. Much of the low lying country in this locality is covered with dolerite which may represent a sill exposed by denudation.

2.—*b*. *Essexites*.—This rock is a variety of dolerite containing some orthoclase, a varying amount of biotite, with ilmenite and analcime, as well as the ordinary constituents of dolerite, *i.e.* plagioclase and augite. The majority of the basic rocks of Jellore have somewhat similar composition, though biotite is rare. It will be seen that the chemical composition agrees fairly closely with Brogger's essexite from Gran. Chant's farm, Jellore, is situated between two hills of essexite, though here the rock is mostly decomposed into a brownish soil. It is surrounded on the north and west by tilted quartzites which have a crater-like appearance, as they stand a little above the level of the soft essexite. This oval neck of essexite is probably the parent of the sills of similar rock which appear quite uniformly underneath the Permo-Carboniferous shales in the neighbourhood. The rock occurs almost undecomposed in Jellore Creek just above Chant's smaller selection at the foot of Mount Jellore. (See Section IV., No. 6.)

2.—*c*. *Basalts*.—Basalt occurs as dykes, necks and cappings. The two former have already been described. The basalt cappings form a very noticeable feature round Mittagong. They are usually easily identified from the fact that they have almost all been cleared by the settlers. They weather into a rich red soil very suitable for agriculture, and hence all such areas have been occupied for many years. The basalt usually occurs as angular boulders about the size of a football. These have a brownish weathered surface, often pitted with small holes, but are very hard within. This structure is due to jointing which lends itself to disintegration and is probably present many feet below the surface. Another example of this jointing occurs in the deep quarry at Dundas. The long ridges of basalt are

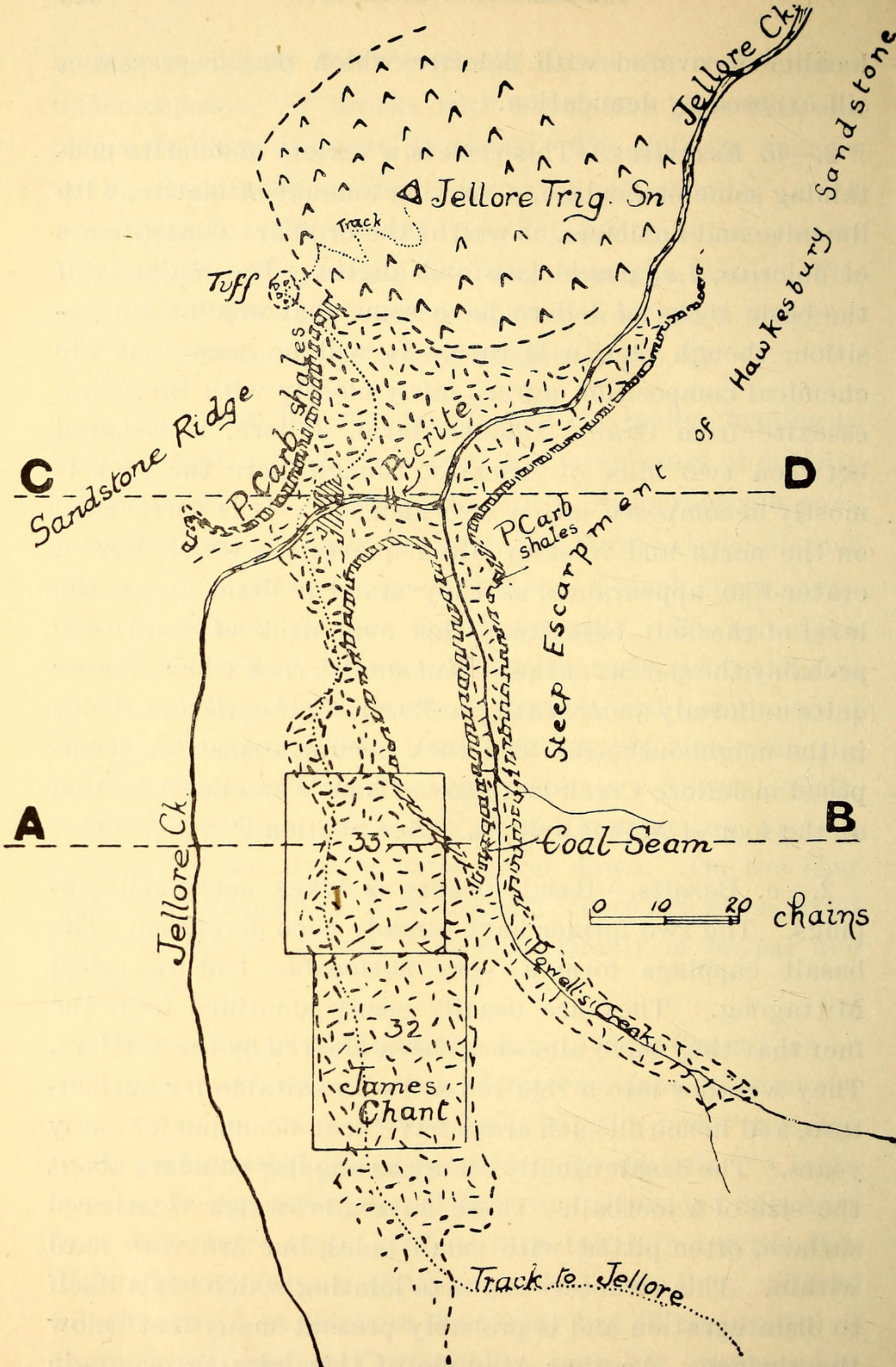

Fig. 6.—Map of the district south of Mount Jellore; showing relations of the essexite and trachyte to the older Sedimentary formations. (For legend see Plate 25.)

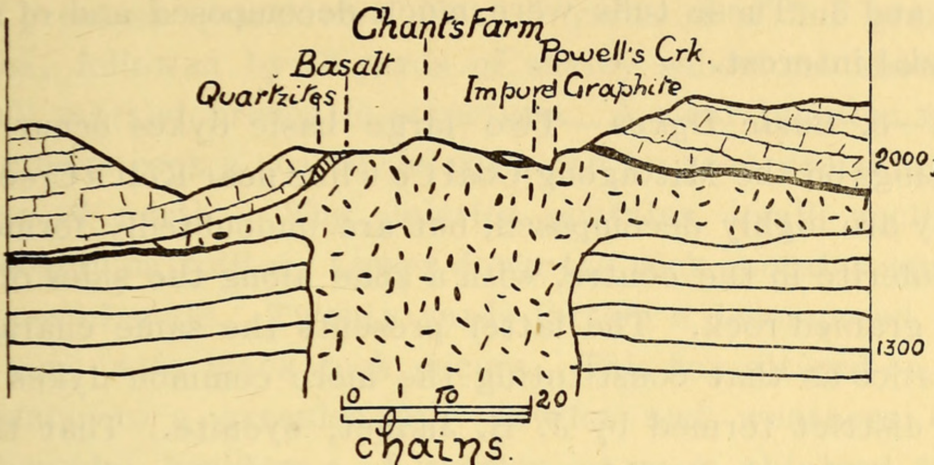

Fig. 7.—Section A B (see fig. 6).

due in many cases to their filling old river valleys. Ensuing denudation has caused these ancient depressions to stand up as ridges. The very varied texture of the basalts obtained from localities near Mittagong is well shown by the sections. (See Section IV., Nos. 8 and 9.)

2.—*d. Basic Tuffs and Breccias.*—

1. Shaft over Gib Tunnel, (north end).
2. Tuff on Currockbilly.
3. Tuff near Frasers Hill.

1. This example of basic breccia occurs in the spoil heap excavated from the shaft used in building the Gib Tunnel. A large quantity of Wianamatta shale has also been tipped here. The breccia is composed of fragments of shale, micaceous sandstone and older basalt enclosed in a dark matrix of basalt. It also contains large lumps of what appear to be orthoclase. These fragments have evidently been torn from the sides of the fissure through which the basalt welled. Close alongside and a little nearer the road is a basalt knob, which probably marks the centre of the boss. The former is a fine specimen of basic breccia not being at all decomposed. We were informed that this basic neck gave much trouble in excavating the tunnel.

2 and 3. These tuffs were much decomposed and of no special interest.

2.—*e. Basic Dykes.*—Two large basic dykes occur in cuttings on the Mittagong Coal Co's line near Kell's Creek. They are highly decomposed, but are undoubtedly formed of dolerite in the centre, with a zone along the sides of a fine grained rock. The latter presents the same characteristics as that constituting the more common dykes of the district termed by J. B. Jaquet, syenite. That the more acid rock should separate out first in a rock magma is quite contrary to the commonly accepted law. Hence it seems possible that many of the decomposed dykes of the district are basic and not intermediate. This view is also strengthened by the fact that in other parts of the district where sections of the dolerite can be obtained (as at Mittagong Coal Co's adit) the dolerite is always fringed by a narrow belt of basalt. The above dykes are similar in structure and of sufficient interest to warrant a description of one of them. The second one occurs in a cutting about one-third of a mile past Kell's Creek. The sides are bounded by quartzites exhibiting slickensides and interpenetrated by smaller dykes. Bands of limonite and chalcedony occur near the edges. Its direction is 10° East of North, and width about two chains. It is undefined to the south but extends some distance to the north. The dolerite has weathered into spheres with concentric crusts.

2.—*f. Picrites.*—In the channel of Jellore Creek, about half a mile above its junction with Powell's Creek occurs the following series of dolerites and picrites. About one-third of a mile below the clearing (on the path from Chant's Farm to Mount Jellore) the creek cuts through a dyke of coarse-grained dolerite weathering spheroidally but containing undecomposed pieces in the interior. This is 30 yards wide and carries a little pyrites. Then come 15 yards of greenish quartzites. Next 5 yards of a fine grained rock, followed by 70 yards of shaley sandstone showing well marked prismatic structure. A clear junction with the next rock a coarse dolerite, can be seen, trending 60° east of north. The dolerite contains small zeolites, probably natrolite. Lower down the rock contains square pieces of shale. Twenty yards further a decomposed cliff of very basic black rock occurs. This has altered on the surface to a greenish-grey powder and weathers into spheroidal boulders. A section of rock obtained from centre of a boulder shows it to be a picrite containing much magnetite and pyrites. On the southern bank is a high bluff (75 feet) of rock with granitic texture but which turns out to be a kaolinised dolerite. (See Section IV., No. 9.)

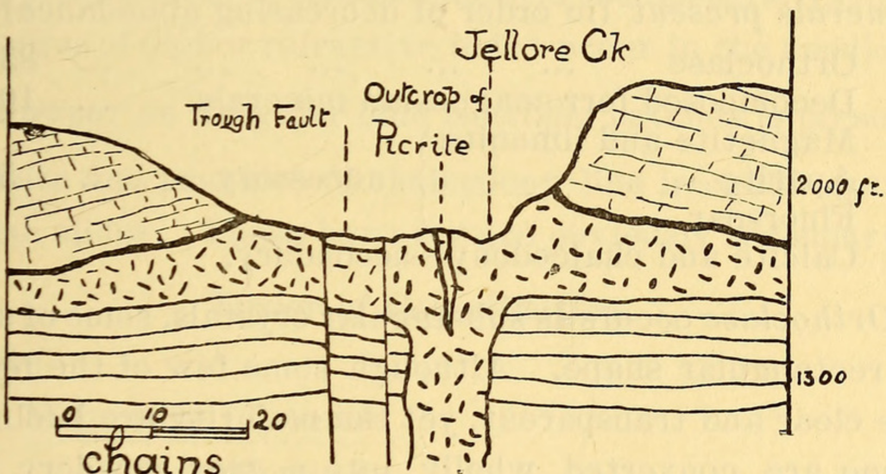

Fig. 8.—Section C D (see fig. 6).

IV. Petrological Descriptions.[1]

This section is accompanied by microphotographs of four of the most interesting rocks of the district, see *Plate 26*. The chief type of each group of rocks will be described petrographically in some detail first, and any points of interest in other similar rocks then noted. The percentages of constituent minerals given are, in the case of the finer

[1] A list of the Rock Sections described herewith will be found at the end of this Section IV.

grained rocks, only approximate. Under the head "Order of Consolidation," small tables are given showing approximately the relative age and duration of the mineral consolidation. Ordinates may be taken to represent starting points, while abscissæ indicate periods during which crystallisation went on.

No. 1. *Locality* Loveridge's Quarry, Bowral.
(See *Plate 26*, fig. 1.)

Texture—Hypidiomorphic granular.

Fabric—No base is present. The rock is composed almost wholly of a mass of orthoclase with some grains of ilmenite and a fair amount of indefinite dark coloured decomposition products.

Minerals present (in order of decreasing abundance)—

Orthoclase	... ...	85%
Decomposed ferromagnesian minerals	...	10%
Magnetite and ilmenite, Apatite, Fluorspar	accessory ...	5%
Calcite and chalcedony—secondary.		

Orthoclase occurs as sub-angular crystals, some of square or rectangular shape. Although some few of the felspars are clear and transparent, yet the majority are kaolinised. Some are converted wholly into a grey powdery mass, while others show included parallel rows of brownish coloured matter. The latter arrangement is due to the fact that cleavage planes offer the easiest point of decomposition. Many of the prisms show clear borders while the remainder of the crystal is more or less kaolinised. Twinning is fairly common, after the Carlsbad law.

In some sections irregular patches of secondary *iron oxide* occur. They have a somewhat fibrous structure and are perhaps due to decomposition of hornblende or other ferromagnesian mineral.

Magnetite is present in small black opaque grains, sometimes it is aggregated into a long narrow row of grains. It is also included in both clear and kaolinised felspars and is often surrounded by a border of brownish matter, due to the colouring of the kaolin by iron. The magnetite is best examined by reflected light which also shows up the kaolin well.

Grains of *ilmenite* are common, and are invariably partly altered into leucoxene. Small grains of the latter are scattered through the section, and in reflected light, stand out a purer white than the kaolin.

Among accessory minerals *apatite* is very abundant as small needle-shaped prisms and hexagonal basal sections. These prisms occur in small bunches in the felspars. Central enclosures of higher refractive index occur in the needles.

Fluorspar as irregular blue isotropic patches is present.

Calcite and granules of chalcedony line irregular spaces in some slides. These however are obviously secondary.

Order of Consolidation.

Apatite

Magnetite Ilmenite

Hornblende ?

Orthoclase

Fluorspar
Calcite
Chalcedony

Name.—The rock is a SYENITE allied to bostonite. The latter (*vide* Harker, p. 117) is a rock consisting essentially of felspar, the ferromagnesian silicates being typically absent. According to the new classification based on chemical analysis the rock is named *boxolanose.*

No. 2. *Locality* Mount Jellore, 200 yards from top on west side.

Texture—Pilotaxitic.

Fabric—Hypautomorphic-granular. Rock consists of a groundmass of small felspars and small fibrous aggregates of green soda-augite (aegirine). Larger felspars of lath shaped habit are scattered irregularly through the mass, together with aegirines which are as a rule somewhat smaller than the former.

Minerals present (approximate area)—

Felspar (orthoclase and sanidine)	90%
Aegirine	10%
Magnetite, Arfvedsonite } (accessory).	

Felspar—The larger crystals are usually broken and angular. Many are singly twinned and comparatively long and narrow. These are of variety sanidine. The small felspars of the groundmass are of granular habit with ill-defined edges.

Aegirine—In long ragged laths of green-brown colour.

Arfvedsonite—A slate-brown mineral visible with high power in the groundmass in some quantity, is referable to this variety of hornblende.

Magnetite in small grains is present.

Order of Consolidation.

Aegirine	
Felspar	magnetite
	aegirine and arfvedsonite
	felspar

Name.—The rock is evidently a trachyte. From comparative abundance of aegirine it may be termed AEGIRINE TRACHYTE. It may be mentioned that this rock was stained, after acting on section by hydrochloric acid, in order to test for nepheline. No definite result was obtained, the small amount of mineral which absorbed the stain being very probably a decomposition product.

No. 3. *Locality* Top of Mount Jellore.
(See *Plate 26*, fig. 2.)

Texture—Hypautomorphic granular. No base is present, but rock consists of a mixture of somewhat rounded grains of orthoclase mingled with larger but less abundant quartz. In some parts of the slide the interstices are filled with a strongly pleochroic hornblende.

Minerals present (approximate area)—

Felspar (few small phenocrysts)	85%
Quartz	10%
Hornblende	5%

Felspar is all somewhat kaolinised. The majority have the form of short laths and a few are singly twinned. No plagioclase is distinguishable.

Quartz is subordinate in shape, of clear undecomposed grains.

Hornblende has the form of irregular masses with a somewhat poikilitic structure. It occurs in bunches surrounding felspars throughout the section. The colour in ordinary light is bluish-green. It shows intense pleochroism changing from olive-green to myrtle green, and seems to be most closely akin to arfvedsonite. (See *Plate 26*, fig. 2 and Analysis I.)

Order of Consolidation.

Felspar
Quartz
Arfvedsonite

Name.—This rock is on the borderline between trachytes and syenites, and contains too much quartz to be a typical trachyte. It seems to be similar to the quartz-syenite of

Bear Paw Mountain (Montana) described by W. Weed and L. Pirsson, (Am. Jour. Sc., May 1896) but is of finer texture. Perhaps ARFVEDSONITE QUARTZ TRACHYTE is a suitable name.

Other trachytes of the district.—A hard bluish trachyte can be obtained from a quarry on the east side of the Berrima road, about one and a half miles from Mittagong. The felspars are decomposed somewhat and of two generations. Large corroded augites are sparsely scattered through the mass.

No. 4. *Locality* Southern End of Cone near Gib. Tunnel.

Light brown glassy matrix containing subangular grains of quartz, and fragments of trachyte. The latter consists of small felspar laths showing flow structure. Magnetite is present chiefly in the trachyte fragments but also in the matrix. Patches of secondary calcite are fairly abundant. None of the rocks of the neighbourhood resemble the included trachyte very closely, except the trachyte exposed in the quarry on the Berrima Road, about two miles from Mittagong, which also contains grains of magnetite.

Name.—The rock is evidently a tuff, composed largely of fragments of trachyte, and may therefore be termed a TRACHYTE TUFF.

No. 5. *Locality* $\frac{3}{4}$ miles E.N.E. of Mittagong Station, in private ground.

Texture—Pilotaxitic. Large plagioclase phenocrysts.

Fabric—Hypidiomorphic groundmass of felspar, augite and magnetite, which are confusedly mixed together. The felspar appears to be last formed, since in several instances it has developed round the other two minerals.

Minerals present (approximate areas)—

Felspar	80%
Augite	12%

Magnetite 7%
Apatite
Analcime

Felspars are of two orders. The large phenocrysts are of square or oblong section all showing polysynthetic twinning, some after albite and pericline laws, others albite and carlsbad type. Many crystals contain small patches of kaolin and other indefinite decomposition products. The felspars of the groundmass occur in laths, and are most usually multiple twin forms. By Becke's method their R.I. is higher than Canada balsam, and hence they are basic plagioclase.

Augite is mainly in form of large rounded grains, some however showing a well defined octagonal crystal form. Colour is a sage-brown with very feeble pleochroism. The crystals are undecomposed but show characteristic cracks; inclusions of magnetite are not uncommon.

Magnetite as small black crystals of square or triangular shape. It is also disseminated through portions of the slide in form of dust-like particles and clustered into small aggregates.

Apatite is very abundant in form of colourless prisms and hexagonal cross sections. The crystals are rather larger than usual in dolerites.

Irregular patches of clear colourless isotropic material of fairly large size with low R. index are probably *analcime.*

Order of Consolidation.

Felspar (Phenocrysts)	
	magnetite, apatite
	augite
	felspar

Name.—The rock is a DOLERITE very much like that figured in Harker's Petrology (fig. 42).

Other dolerites of the district.—Fine specimens for rock section purposes can be obtained from the Nattai River cliffs, just north of the incline terminating the Mittagong Coal Co's. tramline. Microscopically the sections are seen to contain plagioclase, augite and magnetite, with accessory calcite and apatite. The various rocks are characterised by special texture or constituents. Thus in B. 23, under high power, beautiful little hexagons of a brown mineral can be seen. These are most probably micaceous hematite. Many of the dolerite masses have what appear to be less basic dykes (aplitic veins ?) running through them, B. 22 is of this type, consisting mainly of plagioclase. The dolerites from Jellore Creek approach picrite in composition. Augite and magnetite get more plentiful, while much serpentine is present. Pyrites often occurs as grains and prisms (E. 45). Chlorite showing pitted structure is common in some slides from this locality.

No. 6. *Locality* Jellore Creek at foot of Mount Jellore.
(*Plate 26*, fig. 3.)

Texture—Hypidiomorphic granular.

Fabric—No base is present. The rock consists of an intimate mass of augite, felspar and ilmenite.

Minerals present (% by weight. Rosiwal's method)—

Augite	30
Felspar	44·5
Ilmenite...	20

Apatite—accessory

Serpentine, Calcite, Analcime } secondary

The chief characteristic is the prevalence of *ilmenite* in long narrow ragged crystals representing sections of the usual tabular habit. The long axes are very approximately parallel, indicating perhaps some flow while the magma was consolidating. The mineral is opaque with metallic lustre—by incident light of an iron-black tint. Almost all sections show partial decomposition into white opaque granular leucoxene. The latter occurs along cleavage cracks and is very well shown in one or two basal sections. Many ilmenite crystals contain parallel-sided apertures.

Augite occurs in irregular masses, which have filled in the spaces left by the felspar and ilmenite—though a few augites have a fairly regular hexagonal shape. It is sensibly ophitic, in many cases extinguishing simultaneously over comparatively large areas. The colour by transmitted light is pinkish-brown. None of the crystals are twinned. The augites are traversed by cracks along which incipient decomposition is taking place. Inclusions of *apatite* ilmenite and felspar are to be seen, due as stated above, to the later solidification of the augite.

The *felspars* occur in prisms, usually short and wide. Very few are polysynthetically twinned, the crystals being mainly untwinned or singly twinned. This fact and also the low refractive index (lower than Canada balsam in many crystals) points to a preponderance of monoclinic felspar. The felspars are decomposed into kaolin and replaced by brown chloritic material especially round the edges of the prisms. Many crystals include an isotropic glassy material of refractive index less than that of the felspars. This mineral is probably *analcime* which not infrequently occurs in such a manner.

The serpentine, together with the calcite and chalcedony present in the rock, may represent decomposed augite. The beautiful radiating tufts of *serpentine* show black crosses of aggregate polarisation.

The *calcite* can be distinguished by its pale neutral tints under crossed nicolls, and by the rhombohedral cleavage.

Order of Consolidation.

Apatite
Ilmenite
Felspar
Augite | Calcite, serpentine, kaolin, chlorite, leucoxene–(secondary)

Name.—The rock is allied to essexite. The latter is a variety of dolerite originally found near New York, which according to Rosenbusch is composed as follows :—

Labradorite or andesite. Orthoclase. Brown augite, with some biotite and hornblende. Olivine or its decomposition products. Apatite. Titaniferous iron. Analcime (in interstices of felspar).

Hence we see the resemblance is very strong. It may be called an ILMENITE ESSEXITE.

Essexites resembling the above may be found between Chant's Farm and Mount Jellore. The small cone just to the north of Chant's Farm affords a fine micro-section of decomposed essexite. The felspars are mainly replaced by chloritic material, but large apatites and beautiful leucoxenes, the latter after titaniferous magnetite, make the slide well worthy of manufacture.

No. 7. *Locality* 1 mile south of Mittagong Station.

Texture—Porphyritic, with large olivine phenocrysts.

Fabric—Hypautomorphic prismatic. Base consists of small laths of plagioclase mingled with grains of augite and magnetite, the whole enclosed in a dark brown glass.

Mineral present (approximate area)—

Glass	40%
Olivine	30%
Felspar	15%
Augite ... } Magnetite }	15%

Olivine occurs in comparatively large masses, usually of irregularly circular shape, but prisms and hexagonal cross sections are fairly numerous. The olivine has not undergone serpentinisation, and is therefore clear and colourless with well defined edges. The remaining minerals are much smaller and of the ordinary types occurring in basalts.

Order of Consolidation.

Olivine
felspar
magnetite
augite
glass

Name.—From the abundance and size of the olivine crystals the rock may be termed an OLIVINE BASALT.

No. 8. *Locality* McGuire's Creek, 7 miles east of Mittagong.

Texture—Hypocrystalline with large phenocrysts.

Fabric—Dense dark base consisting apparently of small grains of magnetite in a glassy paste. Small ragged laths of plagioclase and irregular masses of magnetite together with some olivine are scattered through the base. Large phenocrysts of felspar and olivine are noteworthy. The flow of the small felspars round these large crystals is well shown.

Minerals present (in order of decreasing abundance)—

Magnetite	80%
Felspar (of two orders)	10%
Olivine (of two orders)	3%

Plagioclase.—The small felspars are of usual lath shape and show twinning carlsbad and albite law, probably of variety labradorite. The phenocrysts are in some cases idiomorphic, while in others the edges are rounded and corroded. They are as a rule broader in proportion than the small felspars. The albite law of twinning is followed.

Olivine.—One large crystal is of a curious annular shape, evidently due to corrosion, showing a portion of the dark ground mass included within the crystal.

Order of Consolidation.

Olivine	
Felspar	
	magnetite
	olivine
	felspar

Name.—Rock belongs to basalt family. The abundance of magnetite both in the base and in layer masses would seem to justify the name MAGNETITE BASALT.[1]

Basalts occur in great variety around Mittagong. In addition to those described above, mention may be made of the following:—

A basalt from the top of the sandstone hill one and a half miles north west of the Gib. A shaft has been sunk through this basalt, presumably to prospect for ironstone. In thin sections the basalt is characterised by large clear augites and felspars, olivine is abundant. The augites have a peculiar smoky colour.

A basalt from a small knob close to the Vice Regal residence at Sutton Forest, some miles south of Mittagong may be mentioned here. The small granular augites in thin sections are seen to be enclosed in a large mass of felspar showing poikilitic structure. This is rather rare in felspars.

Basalts presenting ordinary features can be obtained from Jellore Creek, Nattai River near the coal adits, Woodlands Estate, and the knob over the north end of the Gib Railway Tunnel.

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[1] N.B.—The above somewhat remarkable basalt lies outside the area of our map and was found during a walk to the abandoned diamond fields on the Nepean River.

No. 9. *Locality*, Jellore Creek, at foot of Mount Jellore, near Mittagong.

Texture—Hypautomorphic granular.

Fabric—No base is present. The rock is composed of comparatively large crystals of augite, together with masses of magnetite, serpentine and smaller crystals of plagioclase.

Minerals present (% by weight, by Rosiwal's method)—

Serpentine	38·0
Augite	24·5
Magnetite	13·0
Plagioclase	24·5
Pyrites, Biotite } accessory	

Serpentine has usual fibrous appearance due to decomposition of olivine. It is present both of rich green colour and as colourless fibrous tufts.

Augite.—Large idiomorphic crystals showing strong cleavage.

Magnetite is very massive in this slide and appears to have formed round the serpentine and felspars. Several of the latter are enclosed bodily.

Pyrites of yellow metallic colour by reflected light accompanies the magnetite.

Biotite occurs sparsely as small fibrous squares with strong pleochroism.

Order of Consolidation.

Serpentine (Olivine)

Augite

Plagioclase

magnetite

pyrites

Name.—Rock evidently belongs to ultrabasic group. Since some felspar is present it belongs to the picrites. From the size and abundance of the augite crystals it may be termed AUGITE PICRITE.

A brief description of the four microphotographs (*Plate 26*) is appended :—

Figure 1—Syenite from "the Gib." (The darker variety from Saunder's Quarry). This photograph shows the wavy appearance of the felspars due to kaolinisation. The opaque masses are chiefly ilmenite and magnetite, while the dark powdery material results from decomposition of the original ferro-magnesian mineral (probably hornblende).

Figure 2—Quartz trachyte forming summit of Mount Jellore. The dark material is the hornblende allied to arfvedsonite. The transparent masses are quartz. The remainder is chiefly felspar.

Figure 3—Essexite from Jellore Creek, showing long opaque ragged ilmenites, broad felspar laths and irregular darker masses of augite.

Figure 4—Augite picrite from Jellore Creek. Augite is characterised by the strong cleavage. The serpentine shows as dark cloudy masses. Felspar constitutes the colourless material. An exceptionally large mass of magnetite occupies one side of the photograph.

Reference list of rock sections described :—1. Syenite, Bowral; 2. Aegirine trachyte, Mount Jellore; 3. Arfvedsonite quartz trachyte, Mount Jellore; 4. Trachyte tuff, near the west slope of the Gib; 5. Dolerite, Mittagong; 6. Ilmenite essexite, Jellore Creek; 7. Olivine basalt, Mittagong; 8. Magnetite basalt, McGuire's Creek; 9. Augite picrite, Jellore.

A stereogram of the Mittagong District will be found at the end of this paper.

V. Chemico-Mineralogical Classification.

As the authors place great value on a new system of rock classification recently propounded by U.S.A. petrographers,[1] it is proposed to adopt their methods in classify-

TABLE OF ANALYSES.

	I.	II.	III.	IV.	V.	VI.
S_1O_2	66·68	55·86	55·16	46·22	43·31	39·91
Al_2O_3	14·63	15·25	16·67	9·33	16·68	13·67
Fe_2O_3	2·18	4·92	2·36	5·85	2·31	6·55
FeO	2·31	6·07	7·31	7·39	9·00	8·98
MgO	·30	·20	·56	3·08	10·56	11·96
CaO	1·88	2·13	2·30	10·80	7·95	6·18
Na_2O	6·12	2·34	5·65	3·21	2·94	1·28
K_2O	4·02	9·28	6·97	1·80	·97	·66
H_2O (100° C.)	·38	·70	·85	·94	·88	3·66
H_2O (+100° C.)	·83	·50	·88	2·30	1·72	3·74
CO_2	·05	1·80	1·50	4·46	·03	·40
TiO_2	·20	·65	·60	3·70	2·20	1·75
ZrO_2	trace	...	...	...	...	...
P_2O_5	·28	·16	·38	·80	·65	·61
SO_3	trace	trace	·25	·32	·05	trace
Cl	·03	minute trace	faint trace	·03	·02	·02
Fl	...	·05	·15	...	...	...
*S (soluble)	·05	·09	·02	·10	trace	·20
Cr_2O_8	nil	nil	nil	·02	·11	·21
NiCoO	...	...	...	...	trace	trace
MnO	·49	·42	·47	·32	·43	·18
BaO	nil	trace	trace	·24	trace	nil
SrO	nil	nil	nil	trace	nil	nil
Li_2O	trace	trace	trace	nil	nil	nil
V_2O_5	nil	nil	nil	·02	trace	trace
	100·43	100·42	100·08	100·41	99·81	99·96
	·02	·03	·07	·05		·10
Total	100·41	100·39	100·01	100·36	99·81	99·86
Sp. Gr......	2·618	2·706	2·675	2·801	2·995	2·891

Legend.

I. Trachyte from the trigonometrical station on top of Mount Jellore.
II. Melanocratic Gib syenite from Loveridge's Quarry.
III. Leucocratic Gib syenite from Saunder's Quarry.
IV. Essexite from Jellore Creek near the junction with Powell's Creek.
V. Basalt from the capping on "Woodlands."
VI. Picrite from Jellore Creek, half mile up from junction with Powell's Creek.

[1] Cross, Iddings, Pirrson—Washington. "Quantitative classification of igneous rocks."

* This represents both sulphides and soluble sulphates; and as pyrites can be distinguished in most of the specimens, this sulphur has been calculated as sulphide.

ing the rocks of the Mittagong district. To this end analyses have been made of the more typical igneous rocks, and magmatic names assigned. The blue hornblende mentioned as occurring in the Gib syenite and in the trachyte of Mount Jellore has been carefully examined, and found to be allied most nearly to arfvedsonite. It is practically a silicate of iron and the alkalies, and it is noteworthy that it contains ·75% of titanic oxide and ·6% lithium oxide. The "norms" are set forth below, for comparison with the actual mineral composition noted under Section IV.

I. *Jellore Trachyte.*—This specimen was taken from the very top of Mount Jellore close to the trigonometrical station. It has a slight greenish appearance in the hand specimen due to decomposition of the hornblende.

Composition of the "norm":—

Quartz ...	12·42	Ilmenite ...	·46
Orthoclase ...	23·91	Pyrite	·10
Albite	51·35	Apatite ...	·67
Anorthite ...	·56	Water	1·21
Diopside ...	6·23		
Hypersthene ...	·26		100·42
Magnetite ...	3·25		

The chief difference between the norm and the mode here is that instead of diopside the rock contains aegirine and arfvedsonite.

Classification.—Class I., Order 4, Rang 2, Subrang 3.

Magmatic name.—Toscanose.

II. *Melanocratic Gib Syenite.*—This specimen probably represents the more central portion of the Gib rock syenite, and is distinguished from the light variety by having a higher silica percentage, and containing a considerable amount of magnetite which is absent in the latter.

Composition of the "norm":—

Orthoclase ...	55·04	Pyrite	·10
Albite	20·44	Apatite ...	·34
Anorthite ...	3·06	Fluorite ...	·07
Diopside ...	5·51	Carbon dioxide	1·80
Hypersthene ...	3·40	Water	1·20
Olivine ...	1·33		
Magnetite ...	7·19		100·70
Ilmenite ...	1·22		

In order to obtain the "mode" a rearrangement of the diopside, hypersthene, and olivine molecules to form aegirine and arfvedsonite would be required.

Classification.—Class II., Order 5, Rang 2, Subrang 2.

Magmatic name.—Ciminose.

III. *Leucocratic Gib Syenite.*—This rock represents the marginal portions of the Gib rock syenite. The specimen was obtained from Saunders' Quarry, which is about 100 yards from the junction with the sedimentary rocks, where the sandstone has been converted into a glassy quartzite.

Composition of the "norm":—

Orthoclase ...	40·03	Apatite ...	1·34
Albite	25·15	Fluorite ...	·23
Noselite ...	2·13	Carbon dioxide	1·50
Nephelite ...	5·40	Water	1·73
Acmite ...	6·47		
Diopside ...	6·17		99·84
Olivine ...	8·47		
Ilmenite ...	1·22		

The presence of a small percentage of nephelite and noselite indicated by the norm, is not confirmed by microscopical investigation and so together with the diopside and olivine would have to be molecularly rearranged to the production of aegirine and arfvedsonite in the mode.

Classification.—Class II., Order 6, Rang 2, Subrang 3.

Magmatic name.—Borolanose.

IV. *Essexite.*—The specimen was obtained at Jellore Creek near the foot of Mount Jellore from the upper portion of the intrusive dolerite sheet. The rock showed abundant large plates of ilmenite, and although macroscopically apparently fresh, was evidently partly decomposed from the large percentage of calcite which appeared in the microscope section.

Composition of the " norm ":—

Quartz ...	11·94	Chromite ...	·22
Orthoclase ...	10·56	Pyrite	·10
Albite	20·96	Apatite ...	2·02
Anorthite ...	6·67	Calcite ...	10·20
Nephelite ...	3·84	Vanadic oxide	·18
Diopside ...	10·63	Water	3·24
Hypersthene ...	6·35		
Magnetite ...	6·96		100·86
Ilmenite ...	6·99		

In this case the norm is very different to the mode; the quartz, nephelite, diopside, and hypersthene of the former representing augite and biotite of the rock.

Classification.—Owing to the advanced state of decomposition it is not possible to classify this rock correctly.

V. *Basalt.*—This basalt obtained from the capping on " Woodlands " was analysed as being typical of the numerous flows of the district. The specific gravities of a number of these basalts showed this particular specimen to be very slightly heavier than the average.

Composition of the " norm":—

Orthoclase ...	6·12	Ilmenite ...	4·26
Albite	15·72	Apatite ...	1·34
Anorthite ...	29·19	Water	2·60
Nephelite ...	5·11		
Diopside ...	7·91		100·26
Olivine ...	24·76		
Magnetite ...	3·25		

The minerals orthoclase, nephelite, and diopside appearing in the norm are absent in the rock. In order to form the mode they would have to be molecularly re-arranged to the production of pyroxene.

Classification.—Class III., Order 5, Rang 4, Subrang 3.

Magmatic name.—Auvergnose.

VI. *Picrite.*—This rock was obtained from Jellore Creek at the spot indicated on the map. The specific gravities of a number of fragments of the rock taken from this outcrop show that the specimen analysed is not so basic as some of the other specimens, but is of fair average composition. The rock was in an advanced state of serpentinisation which accounts for the large amount of combined water.

Composition of the "norm":—

Orthoclase ...	3·34%	Pyrite	·36%
Albite	11·00	Apatite ...	1·34
Anorthite ...	27·52	Chromite ...	·24
Hypersthene ...	26·58	Carbon dioxide	·40
Olivine ...	7·86	Water	7·40
Magnetite ...	9·51		
Corundum ...	·71		99·60%
Ilmenite ...	3·34		

The norm differs from the mode in the rearrangement of its orthoclase, and hypersthene molecules to form augite and olivine of the rock.

Classification.—Class III., Order 5, Rang 4, Subrang 3.

Magmatic name.—Auvergnose.

VI. Age.

It is unfortunate that in the eastern portion of New South Wales, there are no well developed sedimentary deposits of later date than the Trias. The area occupied by the Bue Mountains would appear to have been a land surface since that period. Hence it is a matter of extreme difficulty to fix the age of many eruptive rocks in this division of the State further than to classify them as Post Triassic. We cannot depend therefore on palæontological data, but must rely on uncertain evidence, such as the amount of erosion, petrological resemblance, and tectonic position. It is preferable to deal with the subject under two heads—(*a*) Relative age (*b*) Absolute age.

(*a*) The syenites and trachytes representing the more acid rocks of the district intrude the permo-carboniferous and triassic sedimentary deposits, tilting them up at considerable angles. The dolerite sills of the Nattai River and Jellore Creek intrude the coal measures and send off large dykes which intersect the Triassic sedimentary rocks. A fault occurs in Jellore Creek which seems to be connected with the effusion of the trachytes of Mount Jellore; the dolerites here intrude the coal measures only on one side of the fault which seems to be conclusive evidence that these rocks were intruded at a date subsequent to the faulting of the sedimentary formations ; this faulting being supposed to be due to the intrusion of the intermediate igneous rocks. Another minor point of evidence is that the field occurrence of the basic rock makes them parasitical on the masses of the Gib and Mount Jellore.

The connection between the basalts and dolerites is more obscure, but there is strong evidence to prove that the basalt flows are subsequent to the dolerite intrusions.

The basalts are in the form of approximately horizontal flows, and are found overlying gravel beds in some cases containing pebbles of an older basalt ; in turn these gravel beds overlie the eroded surface of tilted Wianamatta shales. The flows being approximately horizontal is proof that very little earth movement has taken place since the time of their formation, and their mode of occurrence in cappings on the tilted shales proves them to be the production of later volcanic activity than that causing this tilting. Thus an interesting sequence can be traced in these rocks, the more acid forming the earliest intrusions, the basic rocks following afterwards.

(*b*) Under the preceding subdivision the earlier igneous rocks are shewn to be Post Triassic. The basalt flows which represent the latest members of the series were described as overlying pebble drift beds, the age of which although not very exactly determined, has been shown to be later than early Tertiary, by leaf remains found in a similar bed at Wingello. These basalts are homotaxial with the pliocene basaltic flows extensively developed at Gulgong, and other parts of New South Wales.

The syenites and trachytes of this district bear an intimate relationship to similar rocks of the Glass House Mountains in Queensland, the Warrumbungle Mountains in New South Wales, and the soda series of Mount Macedon in Victoria, and as there is good evidence[1] to show that these allied rocks are Cretaceous or Cretaceo-Eocene. It is probable that the Mittagong intermediate rocks which are known to be Post Triassic are of the same age, viz., late Cretaceous or early Eocene.

VII. Summary.

A regular sequence of igneous rocks beginning in Cretaceous times and extending till late Tertiary has taken place in the Mittagong district. The intrusion and effusion of the molten magmas was accompanied by faulting and fissuring of the sedimentary beds, leading to the production of bosses, lavas, sills and dykes. The trachytes of this district, like those already mentioned homotaxial with them, are remarkable for their high percentage of alkalies, and

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[1] T. W. E. David, B.A., F.R.S., "Note on the occurrence of diatomaceous earth at the Warrumbungle Mountains New South Wales." Proc. Linn. Soc. N.S.W., June 1896.

in containing a blue hornblende allied to arfvedsonite. The main point of distinction being that the Mittagong variety is more even grained and compact.

There has been much speculation by geologists of this State as to the relations of the igneous magmas, and their positions in the Permo-Carboniferous coal basin of eastern New South Wales. Much work[1] has already been done in this connection, chiefly by the Geological Survey Department, and it is hoped that this paper will form one more link in the chain of evidence needed, before evidence is no longer supposititious, and theories become facts.

The igneous rocks of the Mittagong district form only one example of volcanic activity subsequent to the deposition of the sedimentary rocks in this coal basin. Many more have already been described, chiefly constituting extensive flows of basalt and associated dykes met with over a large portion of the area.

Attention has already been drawn to the fact that the more acid rocks seem to lie nearer the periphery, basic rocks occupying the central portions. How far this is true can only be ascertained by analyses of a large number of rocks, but in the case of the area dealt with in this paper, this seems to be true, as its intermediate rocks hold a position relatively near the shores of this old lake basin.

A bulletin[2] of the Geological Survey Department recently published dealing with the geology of the Cambewarra Ranges, is of immense importance as affording most valuable evidence of volcanic activity contemporaneous with the sedimentation in the Permo-Carbonaceous coal basin already referred to. Here it is shown that flows of trachyte and associated tuffs constitute a thickness of about 1,000

[1] Records of Geological Survey of N.S.W., Vol. vii., part ii., 1902, p. 93; part iii., 1902, p. 226; part iii., 1903, p. 236.

[2] Ibid., pp. 103 - 140.

feet between the top of the upper marine and the bottom of the Newcastle Bulli coal measures; this outburst was followed in regular sequence by basaltic flows above the coal measures.

Much more data is at hand to prove that volcanic activity was contemporaneous with sedimentation over this subsidence area, as for example the Kiama volcanic series, the chocolate and purple shales of the Narrabeen series etc. Further evidence which has perhaps hitherto been overlooked is the occurrence of foreign pebbles of igneous rocks in the old denuded volcanic pipes of which that at Pennant Hills and at "the basin" on the Nepean are examples. Differentiation in the lower portions of the neck and subsequent tearing off and floating up of the fragments cannot be ascribed as the origin of all these varieties[1] of included fragments. A good example is that of a large fragment, over one inch in length of orthoclase found in the basalt over the Bowral railway tunnel.[2] It would appear then, that the sediments in this area of subsidence form an immense thickness of rock, which like a mighty tomb has buried within it, tier upon tier, the ruins of once active volcanoes, but whose only memory now is an occasional thin bed of lava or a belt of purple shales hardly recognisable as being of volcanic origin.

In conclusion we desire to thank Mr. E. C. Larkin of Fitzroy Iron Works for his hospitality during our numerous visits, and Mr. G. Saunders for aid in field work on the last visit, and to express our gratitude to Professor David and Mr. H. Jevons B.Sc., for help on every occasion where help was necessary.

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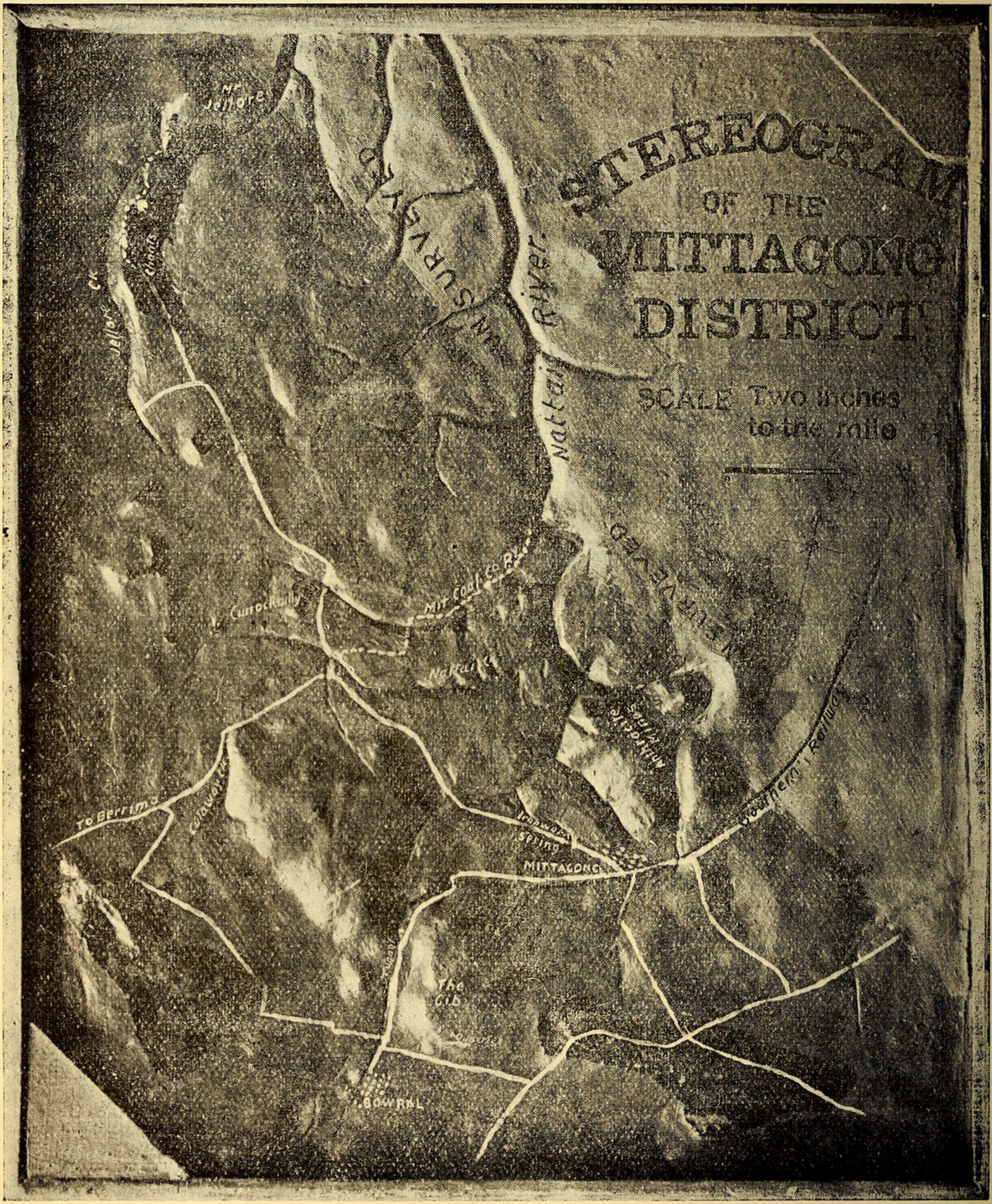
[1] Some of these are more acid than the enclosing lava.

[2] Vide antea page (325).


STEREOGRAM
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