PARTicular attention has been paid to localities where these features appear. The author has established a private geophysical research station, "Hills and Dales" in a ten-acre area covering portions of X33, X34, X41, X42, X43, X44, X49 and X50.

Map Co-ordinates. The district included in this survey is shown in Plate I, and covers an area of some twelve square miles, the Gib itself being towards the centre. In this map each side of a large square (A, B, C, 2A, etc.) represents half a mile, so that the side of a small square represents five chains. In the text a large square is referred to by its letter, as A, 2B, a; a small square by the appropriate letter followed by a numeral, as Al, B3, 2N26. When it is desired to fix a position to the nearest chain, a map-reference such as A1.32, or 2N26.24 is given. The origin of co-ordinates of each small square being its south-western corner, the first reference above is to a position in square Al, three chains east and two chains north of its south-western corner; the second reference is to a point two chains east and four chains north of the south-western corner of square 2N26. The map is orientated to magnetic north.

Topography. The Gib trig, station is at W57.00, the feature forming the Gib rising as much as 800 feet in the general area V, W, 2D, and 2E, above the surrounding country. The area K, L, T, U is occupied by a hill of sandstone rising from Gibber-Gunyah Creek on its east, falling to the main Berrima-Mittagong road (in the extreme north of Plate I), and through J and S to the continuation of that road to the west (not shown). Sunning approximately north-and-south in 2J and 2A up to the east-west road is a basalt-capped ridge which falls to the west off the map, and to the east into 2K and 2L towards Mittagong Creek.

The Gib itself rises, almost perpendicularly in parts, along the line 2E33.00, V63.00, V40.00; thence it rises fairly steeply from a line running north-east from that last point, falls fairly steeply on its north-eastern face into the creek running north in W, and falls more gently towards the east and south-east. The altitudes of certain points (by aneroid) are given on p. 44.

The research covered by this paper originated in an endeavour to assist geologists in an interpretation of the igneous intrusion forming Mt. Gibraltar or "The Gib", situated between Mittagong and Bowral, in the parish of Mittagong, County of Camden, N.S.W. It was not definitely known whether it was a volcanic plug or a subhorizontal intrusion, and the author considered that a magnetic survey, occupying a relatively short time, might indicate the true nature of the mass. It was soon found, however, that the surrounding country included such a complexity of magnetic formations, mostly not apparent from the surface, that a detailed survey of the entire Mittagong-Bowral district would be required before a definite statement could be made; also, that such a survey would be valuable, in that purely local anomalies would fall into place in the general district survey, so that the superposed effects might be observed and noted for comparison and use in other areas.

Whereas simple and uncomplicated anomalies may be considered as problems in mathematics, a consideration of a given region as a whole and of experimental results in other regions forms the only practicable basis for interpretation where there are many unknown quantities affecting the field strengths and gradients.

This district is particularly rich in "negative anomalies", a fact likely to enhance the value of the results to be obtained from a regional survey; consequently
particular attention has been paid to localities where these features appear.

The author has established a private geophysical research station, "Hills and Dales", in a ten-acre area covering portions of X33, X34, X41, X42, X43, X44, X49 and X50.

Map Co-ordinates.

The district included in this survey is shown in Plate I, and covers an area of some twelve square miles, The Gib itself being towards the centre. In this map each side of a large square (A, B, C, 2A, etc.) represents half a mile, so that the side of a small square represents five chains. In the text a large square is referred to by its letter, as A, 2B, α; a small square by the appropriate letter followed by a numeral, as A1, B3, 2N26. When it is desired to fix a position to the nearest chain, a map-reference such as A1.32, or 2N26.24 is given. The origin of co-ordinates of each small square being its south-western corner, the first reference above is to a position in square A1, three chains east and two chains north of its south-western corner; the second reference is to a point two chains east and four chains north of the south-western corner of square 2N26. The map is orientated to magnetic north.

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Three accepted altitudes are those of Mittagong railway station (2,070 ft.), The Gib trig. station (2,830 ft.), and Bowral railway station (2,210 ft.). The general slope of the country is to the north.

The north-to-south roads (King Street and Earl Street) in W and 2E exist only as tracks on the ground; they run into precipices. The same applies to the western portion of Count Street in W. Cliff Street in 2D runs into a precipice at the quarry in 2E33.10 (about its junction with Ellen Street), and has no existence to the east. Though The Gib itself is a tourist feature, the roads to the top from both Bowral and Mittagong are very rough, and at present impassable for cars in wet weather.

The area 2F, 2G, 2H, 2I is high land, falling towards the east from The Gib, and is mostly basalt-capped in the southern halves of those sections.

Plate II will help to make clear the nature of the topography

**GEOLOGY OF THE DISTRICT WITH NOTES ON MAGNETIC INTENSITIES.**

The geology of this district has been studied in part by several writers, the most complete descriptions being those of Jaquet\(^1\) and Taylor and Mawson.\(^2\)

**Syenite.**

The eruptive mass of The Gib itself is of fine-grained syenite (popularly referred to as "Bowral trachyte") probably of Middle Tertiary age.\(^3\) According to Taylor and Mawson this is the denuded plug of an old volcano; those authors consider it improbable that it represents a denuded laccolith, though that is the conclusion drawn from the results given in this present paper. The stone varies in colour, in general darker stone being quarried from the Mittagong end, the stone from the south-eastern quarries being light grey to green-grey. It has been assumed by Taylor and Mawson that the light-coloured (leucocratic) syenite is the marginal rock, whilst the dark (melanocratic)


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with rocks in situ, and can calculate the intensity of magnetisation (taken as a surface polarity of a per sq. cm.) over extensive plane areas; we can collect samples of rock, and determine their magnetic moments, and hence their intensity of magnetisation. These values the author has found in good accord over a wide diversity of conditions. It seems that values of \( I \) are of much greater interest than values of \( \mu \) (permeability) or of \( K \) (susceptibility), usually quoted. Determinations of values of \( K \) for different fields in the laboratory, for comparison with values of \( K \) for specimens in situ, are of definite interest in discussions of the magnetic history of the rocks; but that subject, particularly with regard to permanency of magnetic effects, is still extremely controversial. The applied geophysicist is generally concerned with mapping geological formations, etc., in terms of variations in existing intensities of magnetisation.

The approximate area occupied by the syenite outcrop is enclosed within crosses (xxx) on Plate I. To the north, west and south the actual boundary is masked by syenitic talus-material, but to the east it is quite distinct, as there is no abrupt change of level.

Triassic Shales and Sandstones.

To the south and west the syenite of The Gib intrudes Wianamatta shales; to the north and east, Hawkesbury sandstone. The shales have their greatest known local thickness of about 80 feet near the northern end of the railway tunnel (V50). According to Taylor and Mawson, the sandstone is 600 feet thick. Both these series of strata may be regarded as the main non-magnetic rocks of the district, the intensity of magnetisation being negligible in all specimens examined. Exceptions to this are in places where the soil appears of a definite red colour, possibly due to some small local occurrence of superficially decomposed igneous rock (see p. 56).

Basalt.

Probably the whole of this district has been covered by one or more extensive flows of late Tertiary basalt. This rock is found abundantly in the south-east of the area surveyed, overlying both sandstone and shale, with a line of contact through 2F, 2G, 2H and 21; also to the south-west through 2A and 2K. Another, though smaller, area

Intensity of Magnetisation of the Syenite.

Tests for susceptibility showed a wide variation, undoubtedly due to the difficulty of obtaining small specimens that were not weathered. Tests of small blocks recently quarried gave the same discrepancies, it being apparent that the edge material is far from uniform so far as intensity of magnetisation is concerned, even for specimens within a few yards of one another; but it must be remembered that all specimens available were either marginal rock, or from exposed rock surfaces up on The Gib itself where the degree of leaching is unknown. In many cases the stone quarried is taken from very large blocks separated from the main body by decomposed rock.

It is apparent, however, from readings taken on the mass itself, that in places the field is uniform over large areas of the flat, exposed rock-surface, so that either the mean value of intensity of magnetisation thus presented is uniform, or the intensity of magnetisation is fairly uniform away from the peripheral zone of leached and fallen material. (This does not apply to a length of about ten chains along an east-west line through The Gib trig. station itself; see p. 51.)

Specimens, picked for apparent freshness, gave values for intensity of magnetisation (\( I \)) ranging from \( 10^{-3} \) to \( 10^{-2} \) c.g.s. units. An average value for \( I \) for freshly quarried specimens was \( 3 \times 10^{-3} \) c.g.s. units; this may be taken as the value in the magnetic field, the vertical component of which is 0.6 gauss. If we assume that the intensity of magnetisation is that due to the specimens being magnetised in a field of that order (the magnetic dip is 65° S.), the susceptibility may be taken as being of the order \( 5000 \times 10^{-6} \) c.g.s. units. Since the rock-content so varies from zone to zone that the applied geophysicist is generally working on mean values, and since the history of the magnetisation of the rock is quite unknown, it is very doubtful if laboratory determinations of the susceptibility of specimens gives results which can be applied to the interpretation of magnetic surveys. We are presented
with rocks in situ, and can calculate the intensity of magnetisation (taken as a surface polarity of $\sigma$ per sq. cm.) over extensive plane areas; we can collect samples of rock, and determine their magnetic moments, and hence their intensity of magnetisation. These values the author has found in good accord over a wide diversity of conditions. It seems that values of $I$ are of much greater interest than values of $\mu$ (permeability) or of $K$ (susceptibility), usually quoted. Determinations of values of $K$ for different fields in the laboratory, for comparison with values of $K$ for specimens in situ, are of definite interest in discussions of the magnetic history of the rocks; but that subject, particularly with regard to permanency of magnetic effects, is still extremely controversial. The applied geophysicist is generally concerned with mapping geological formations, etc., in terms of variations in existing intensities of magnetisation of the materials in position in the earth's crust.

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occurs in W and X, overlying sandstones; this portion is dealt with in greater detail on p. 49.

Small basalt caps are found in K10 and vicinity, and in M34 (this latter is thin and leached). Two little knolls protected by thin basalt caps stand up in 2F5 and 2F51.

All the basalt which could be collected for examination was considerably weathered. Small specimens, broken out of the central portions of larger boulders, gave values for I of the order $3 \times 10^{-3}$ c.g.s. units. This is high compared with values found for larger boulders removed to Base and examined under the magnetometer; they displayed definite polarity, north-seeking polarity being associated with the upper surfaces as found in situ. These boulders were surrounded by and separated from their neighbours by decayed basalt, and probably have never moved from their original positions. Browne (loc. cit.) considers that the basalt is of later date than the syenite, which had been laid bare by erosion prior to the effusion of the basalt.

Volcanic Necks.

A volcanic breccia-neck lies in V58; this has been cut through by the railway tunnel, so that the highest value found above it ($1,874\gamma$) represents the effect after subtracting a mass of material removed during the excavation of the tunnel. No good specimens of this material were found to test for intensity of magnetisation. A tuff-neck of some interest occurs in 2C and 2D; it is described in detail on p. 57.

Minor Features.

The above represent the major rock-features of the area; smaller occurrences of trachyte, dolerite, limonite, etc., will be dealt with under the appropriate section of the magnetic summary.

According to Jaquet (loc. cit.) layers of Tertiary material, "sandstones and shales for the most part highly ferruginous, with bands of concretionary iron ore" underlie the basalt flows. This material crops out on the lower slopes of the geophysical research area, "Hills and Dales"; it is non-magnetic, so that its presence is not of interest in this survey. It is of interest to note in passing that specimens of limonite collected from the vicinity of a chalybeate spring at E40 acted as nearly non-magnetic material (see p. 58). Taylor and Mawson say of these 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."

**The Magnetic Survey.**

**Instruments, Corrections, Bases.**

Observations were made of the variations in the vertical component of the earth's field. The apparatus used was a vertical field balance of the Adolf Schmidt type, constructed by the Askania-Werke Coy. The instrument is No. 88057, and the sensitivity on its present adjustment (checked regularly during the survey) is 40γ per division. The temperature correction is 8.5γ per centigrade degree.

The Main Base for the area was established at 2D61.24, a point on the shales (which there dip gently west) being pegged and spit-locked. Readings over several square yards in this vicinity, and with varying reasonable heights of magnets above ground level, were practically identical, varying by less than 4γ. This spot is referred to as Base Luxembourg in all records, from the private hotel "Luxembourg" conveniently situated up the slope on the opposite side of Clarke Street. Sub-bases were established as required, and were locked in with Base Luxembourg by repeated check readings. Much of the work was carried out under very difficult conditions; many traverses had to be repeated on the western face of The Gib, as it was feared that unavoidable slight shocks to the instrument during work on the steep, and in parts nearly precipitous, slopes might have caused an error. Readings, and check readings on later occasions, agreed very well, and it is considered that the important readings out to the west and east of the outcrop of The Gib syenite are correct to within 5γ.

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The apparatus used and its method of employment are described in many books and articles. Reference may be made to Edge and Laby: "Geophysical Prospecting", Camb. Univ. Press, 1931.
Where big magnetic anomalies occur the readings are more accurate than the determined positions; the relative magnetic values, on which are based the closed curves, are correct to within 5γ.

The temperature correction was checked regularly, the observed variation from the mean value taken (8·5γ per centigrade degree) being less than 0·5γ per centigrade degree over twenty centigrade degree changes. Precautions were taken to protect the instrument from direct sunlight, and as far as possible from rapid changes of temperature.

To allow for variations in the vertical field due to diurnal changes or atmospheric magnetic disturbances, reference was continuously made to the sub-base concerned, at which generally at least four sets of readings a day were taken. On sections of the work where the variation from station to station was small, the sub-base was locked in with Base Luxembourg at the beginning and end of each traverse.

The interlocking of intersecting traverses was in all cases within 5γ of the previous reading, or of the interpolated reading, except over zones of big differential variation.

The observations have been corrected to allow for the normal northward gradient of 8γ per mile over the area.

**Interpretation of Observations.**

**The Main Anomaly.**

Base Luxembourg is recorded arbitrarily as 600γ, and is on shale, just off the talus from The Gib, on ground sloping gently to the west; its altitude is 2,280 feet.

Values over a large area to the north in Section E, in the vicinity of the Berrima-Mittagong Road, are uniform at 535γ. This is the lowest uniform value over a large area, which is thus considered to be that under which the magnetic rocks are at greatest depth; so that 535γ may be taken as the value over "non-magnetic" areas of the district.

According to Jaquet a bore sunk in 1887 in a position about F9.22 passed through 650 feet of sandstone to the coal-seams immediately underlying and conformable with the Hawkesbury sandstones. He reports the upper formation as being "coarse-grained sandstones and occasional narrow bands of shale". The sandstones there are either horizontal or dipping at a low angle. Jaquet adds: "The coal-measures would seem to have a thickness
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of about 650 feet, having regard to observations which we
made lower down the valley, where the Upper Marine
formation can be seen cropping up from underneath
them". The small magnetic fluctuations over this area
are due to igneous intrusions which are known to have
penetrated the coal-measures as sills and dykes. The
country here is flat.

To the east of the area (see Plate I) values fall below
600γ in Section x (on shale) and continue to drop further
east; actually readings have been taken far to the east,
the value decreasing to 553γ at the station three and
one-eighth miles on a magnetic bearing 71° E. of N. from
The Gib trig. station. (This station is at the position shown
on parish maps as the junction of the old Bong Bong Road
and the old Main Southern Road.) Even out here there is
evidence of volcanic activity; for example, volcanic breccia
is exposed in the grounds of the Marist Brothers, in a
position about 20 chains east of the 553γ-station first
mentioned. A chalybeate spring is found some 50 chains
further east again. Readings were taken up the old
Southern Road (running generally north-east, and approxi-
mately along the same 71° line from The Gib trig. station)
for a further mile. They fluctuated very slightly (under
10γ) as far as the last station, where the reading was
528γ; half a mile further on (now a total distance of
four and a half miles on 62° from the trig. station) another
chalybeate spring exists. It would, however, require a
detailed survey of this far-eastern area to correlate minor
fluctuations with the main features dealt with in this
paper. To avoid extending the map unnecessarily these
eastern stations are not shown.

Isodynamic lines are drawn on Plate I at intervals of
100γ; the 600γ-lines are of greatest interest, because the
spaces between 600γ-lines associated with different systems
of closed curves represent zones of greatest depth of
magnetic rock, and the areas where boundaries possibly
exist at depth between different types of igneous forma-
tions. The 600γ-curve in x, Q, P, O, N, etc. (which would
presumably be closed if the basalt cover were stripped off
in the south-east portion in 2l, 2H, 2P) indicates the
configuration of the magnetic body associated with The
Gib itself; and since values are dropping slowly to the
east, the material causing this magnetic disturbance
presumably continues still to drop deeper, or to become
gradually thinner, for at least a further three miles.
The creek running north in W has cut its way through the syenite; the sandstone begins within 50 yards of that creek on its right bank. In the vicinity of the junction of Whinstone Road and Duke Street (2E5) there is no abrupt change in surface slope, but, to judge from the isodynamic lines, the syenite passes below the sandstone, falling fairly steeply in 2E5 and 2E6; beyond that it continues to fall gradually to the east. Sandstone encountered in a shaft in W62 dips at about 45°.

The whole of the eastern and north-eastern sandstones have been tilted by the intrusion, the effect being noticeable on strata in X2, 2G29 and as far out as Z26. The intrusion falls, or thins, beyond the 600γ-line, gradually to the north and to H and G, and much more gradually, as has already been noted, to the east. In the north-east matters are complicated by the proximity of an intrusive mass of dolerite in H, which is surrounded by trachytic or syenitic material. A house has been built on the higher portion of the outcrop, so that it cannot be surveyed completely. A reading on rock, northern slope, gave 532γ; five chains further south from this up slope, 861γ; five chains further south, nearer crest, 1,209γ; on the far side of the house ("Drumeevin"), highest ground, about eight chains on, back to 517γ.

The ground to the south-east of the area is high (2G, 2H, 2I); unfortunately it is covered by basalt, and this cannot be mathematically "skinned" from the surface without carrying the survey over a very much bigger area to the south and south-east, on to lower ground; it is considered that this would involve undue expenditure of time.

Immediately to the north of The Gib trig. station, and along the western side of The Gib, the ground falls precipitously into zones of negative anomalies; these negative anomalies lie on the lower slopes on talus, and are probably associated with big inverted and jumbled masses of magnetised material in juxtaposition to the cliffs of magnetised material in situ. The isodynamic lines are crowded together on the steep slopes. The syenite has a steeply plunging contact with the shales to the west and

5 Actual altitudes in this area are: The Gib trig. station, 2,830 feet; 2E2.22, 2,765 feet; 2E3.20, 2,730 feet; 2F4.41, 2,695 feet; W55.24, 2,615 feet; 2F10.02, 2,615 feet; 2F3.14, 2,515 feet; 2F52.12, 2,565 feet (the hill drops fairly steeply down the road to Merrigang Street beyond this point); X36.20, 2,405 feet; X38.02, 2,290 feet Mittagong railway station, 2,070 feet.
with the sandstones to the immediate north; indications are that it falls fairly steeply to the south also, but readings could be taken for a short distance only, owing to the proximity of the town of Bowral.

The negative anomalies are discussed in more detail below.

Whilst the country has not been contoured, a large number of altitudes have been taken. Attention should be drawn, in this connection, to two points as examples: W55.24 and 2F10.02 are places separated from one another by the dropping hill crest running west to east between them, but are at the same altitude; they are both also just within the 800γ-curve.

In general, decreasing values are associated with decreasing altitudes; exceptions are in creeks and valleys. It should here be noted that the bulge in the 800γ- and 700γ-curves (towards the north-west) in the north-eastern portion of W is in a deep depression between the basalt-capped ridge in the east of W and the main mass of the syenite to the west; the main creek and its three chief branches occupy this depression. Values rise from 800γ to 941γ in the descent of 280 feet (aneroid) from W55.24 to the creek junction at W14.10, a horizontal distance of some 20 chains; in a continuation of the traverse down the creek to the north, along the edge of the syenite (probably talus), a descent of 160 feet is accompanied by a drop in values from 941γ to 503γ in 16 chains; in a further 11 chains to the final station (six chains off the railway line) there is a fall of 15 feet only, with a rise to 567γ, an expected value for that position.

Figure 1 is an isodynamic graph from F64.00 to 2064.00, the readings on the basalt which caps portion of 2F and 2O being neglected. This section from north to south across the country to the east of The Gib is seen to give values rising from 590γ to 780γ in about a mile, and falling to 590γ again in another mile. There seems no reason to doubt that this magnetic anomaly is due to the same igneous intrusion that is exposed about a mile to the west as The Gib itself.

The Anomalies on the Western and Southern Side of the Gib.

The irregular shape of the area bounded by the 600γ-contour will be noticed on the map. The author believes that it is in accord with corresponding irregularities of shape in the intrusive mass. A valley eroded through
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The sandstone runs from 2E into 20. The tongue of (presumably) syenite running from 2E into 2N has caused the tilting of the shales exposed at 2N20.33. The eastern edge of the main syenite mass in Section 2E has risen to a much greater height through the surrounding material than has the still concealed rock further east; Taylor and Mawson postulated that the magma had actually been erupted at the surface, though, as it is a microsyenite, and for other reasons, Browne believes that it remained covered by Triassic deposits through which it did not break, and that this covering, in part, has subsequently been denuded. Whichever happened, the magnetic readings suggest that the syenite welled up to a greater height and extends down to greater depths in the area bounded by the more congested isodynamics.

Nature of the Gib Intrusion.

The igneous mass appears to be somewhat like a partially buried lion lying on its side, portion of the syenite head being now uncovered and the body, still covered, sloping back therefrom some three or more miles to the east. It has forepaws (buried) protruding down through 2E into 2N and down through 2F into 20 and 2N; whether hind paws exist we do not know.

A consideration of all the facts set forth above leaves little room for doubt that, if minor irregularities be neglected, The Gib intrusion is essentially of the nature of an asymmetrical laccolith having its greatest thickness, and probably an elongated feeding-channel, to its west, thinning rapidly to north and south, and having its greatest extension to the east.

The Major Anomaly to the West.

To the west of The Gib, after the steep fall to the 600-year curve and the zone occupied by negative anomalies, there is an area with values generally around 550y, and in small localised zones below 500y. Then begins another magnetic feature, with a 600-year line running approximately north and south in M, V, 2D, and 2M; this line swings back to the north-west through L and B. The 700-year line is nearly a mile further west, with a small area rising to 900y immediately behind this, in S. An investigation of this locality led to the discovery of an outcrop of quartz-dolerite in the vicinity of S24, S32, and S40, not yet recorded by geologists. Just south of this point is the...
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To the west of The Gib, after the steep fall to the 600γ-curve and the zone occupied by negative anomalies, there is an area with values generally around 550γ, and in small localised zones below 500γ. Then begins another magnetic feature, with a 600γ-line running approximately north-and-south in M, V, 2D, and 2M; this line swings back to the north-west through L and B. The 700γ-line is nearly a mile further west, with a small area rising to 900γ immediately behind this, in S. An investigation of this locality led to the discovery of an outcrop of quartz-dolerite in the vicinity of S24, S32, and S40, not yet recorded by geologists. Just south of this point is the
peak of a positive anomaly, a closed curve with an observed enclosed maximum of 928γ; no rock outcrop is seen there, but the soil is a very bright red where rabbits have excavated it from beneath the darker surface soil and humus.

To judge from the magnetic features, this anomaly to the west should be referred to a different geological feature from The Gib itself. Sandstone in A and C respectively has dips of 25° and 30°, and the dip directions at these points and in K33 and T64 indicate that the strata have been tilted from the direction of the quartz-dolerite in S. The general conclusion to be drawn from the tilting of the strata is that this western anomaly is due to magnetic disturbances associated with the outcrop of dolerite referred to above. There can be no doubt, however, that the whole of the area is underlain by an assortment of intrusive igneous rocks of varying magnetic content and at varying depth, forming superimposed minor anomalies which would require detailed survey; an instance of such (exposed in this case) is the isolated patch of trachyte in C, breaking through a small patch of shale. The whole district abounds in such minor problems, which should present small difficulty in observation and interpretation when the survey of the whole area is considered.

Some few readings were taken well to the north-west, and to the west of this western anomaly, along the Berrima Road where it runs south-west again off the map. A reading at the sharp road-turn one mile ten chains on a magnetic bearing N. 19° W. from the basalt at K10.00 was 564γ. Southwards down the road, and thus at an approximately constant distance from that same reference position, readings ranged rapidly up to 670γ in the first half mile, and up to 674γ by the end of the next half mile. The 700γ-contour would be crossed about 15 chains on, the reading at the junction of this road with the road out from Bowral (one mile 15 chains about W. 20° S. from the basalt at K10.00) being 760γ. From these few readings out to the far west the general positions of the 600γ- and 700γ-curves, continued, can be visualised.

**Special Anomalies.**

*Basalt Flows.*—Reference has already been made to the basalt flows; remnants of these, probably of considerable thickness in places, appear on the high ground, the only exception being the cap in M34. A reading of 1,326γ was recorded on solid basalt in 2K57, in the vicinity of
Mt. Oxley; the highest value on the knoll (rock) in the grounds of "Hopewood" (2A40) was 884γ; the basalt-covered ridge slopes down from the first position (highest altitude) to the second, which is near the northern limit of this basalt; readings just north, off the basalt, are about 750γ.

A reading of 1,158γ was made on the small cap in K10 (not necessarily the highest value there).

The small cap in M34 is leached, and no reading taken in the vicinity showed an increase of as much as 10γ above the adjacent sandstone values.

The outcrop of basalt to the south-east of The Gib was not examined, traverses ceasing as soon as the basalt boundary was crossed; crossing the boundary resulted in increases in the vertical component by amounts varying from 200γ to 400γ in a few chains; surface indications were the red soil, strewn with small basalt boulders.

A considerable number of readings were taken on and about the basalt knoll in 2F51, in a search for a high reading, but this feature persisted in being a negative anomaly, all readings being far below that of the surrounding sandstone; a value as low as 60γ was obtained. There is the surrounding sandstone, the values on which are 660γ to 680γ; on this is perched the small basalt cap, which forms a definite knoll some three chains by two; it is an outlier from the larger basalt sheet, from which it is well isolated; and it is a negative anomaly. This is not merely a reversal effect at an edge. In spite of arguments advanced by other writers that structures must be magnetised in the direction of the existing field and that "reverse" effects due to invasion of magnetised masses, for instance, cannot persist, here definitely is a reversed polarity. The author would suggest that it may be a reversal due to strong local currents, the basalt (possibly then a cap standing up above the surrounding ground) having been struck by lightning. A similar explanation is suggested below for other negative anomalies. In this isolated feature the lower surface of the basalt would be of positive polarity; possibly a positive anomaly originally existed in its immediate vicinity.

The Basalt in W and X.—The remaining basalt in Sections W and X is difficult to map by surface indications, as much of the area that appears to be basalt, to judge by red soil and stones, is wash from higher areas. As it is possible in the general scheme to "strip off" the basalt

D—June 5, 1935.
flow by calculation, this has been the subject of a more detailed survey, to be shown later. Solid rock in situ runs along the ridge in an east-west direction in 2E7 and 2E8, and in 2F1 and 2F2. Thence it runs towards the north, ending in a cap in X9 and X17, which has resulted in the preservation of a ridge falling steeply into X1 and X2 ("Green Hills").

Notes on Water Supply, etc.—Readings indicate that there is still some unleached basalt in situ in W32, W40, and W48. There are isolated patches of basalt in the vicinity, and considerable thicknesses of clay underlie the basalt and crop out around its margins, as marked on the map. The geophysical research station ("Hills and Dales") is situated at X41.23, and many excavations have been made in the vicinity to check the observations. The layer of sandy soil and basalt wash between the more impermeable basalt and the clays forms a temporary reservoir for water flowing from higher up the hill, so that water seeps out continuously from springs just north of Whinstone Road in W47 and W48. A number of pits dug in X41 to a depth of three feet disclose springs in wet weather, and during periods of heavy rain the water-level rises, and water pours out freely over the eastern side of this basalt barrier. The author has had a large dam dug in the impervious clay (found, as expected, about two feet below the surface) in X34, on the eastern slope of the anomaly; this is filled by water pouring down the watershed and by seepage.

On the higher levels south of Whinstone Road, in W62, W63 and W55, there are two clay layers, the water being trapped and flowing north and east between them. A shaft sunk in W62 ("Perry's") down about 66 feet passes through: (i) 28 feet of clay and rotten basalt; (ii) eight feet of very soft sandstone, white to yellow, iron-stained in bands, and dipping at about 45° away from the trig. station; (iii) 30 feet of white clay; (iv) what is possibly an igneous rock, leached, and fairly rotten. The sandstone was moist, and could readily be cut with a knife. It is apparently Triassic, so that no basalt can be expected underneath it.

A shaft sunk many years ago at X44.11 (for diamonds, not found) passed for 100 feet, so the author is informed, through sands and sandstone.
The Anomaly on the Summit of The Gib.

The readings along and near the line east from the trig. station seem to be inexplicably erratic. The area is a large, flattish surface of broken rock gently sloping towards the east; there is nothing from surface indications to suggest that such irregularities should exist as are shown in Figure 2.

The magnetic gradients are quite what are expected to the west of this, and also beyond a point some eight chains to the east; but readings along that eight chains range from 3,596γ just clear of the trig. cairn to the west, through fluctuating high positive values down suddenly to 658γ at 25 yards to the east; some 30 yards of these relatively low values lead to another peak of 3,261γ, and so on, as may be seen from the figure. The biggest change is from +4,559γ to −991γ, a variation of 5,550γ, in a distance of five yards; ten yards further on the value has dropped to −1,128γ, after which it rises steadily for 25 yards to a reasonably expected value for that position, 1,156γ. Further fluctuations occur for the next two chains, after which no such erratic readings are found.

This all occurs across exposed rock surface.

Four hypotheses are presented: (i) There might be a very localised concentration of magnetite close to the surface at positions of maximum intensity, the corresponding negative anomalies being corollary effects. This is quite improbable, and is rejected; there is no apparent change in the surface of leached syenite, which must be weathered (to judge by rocks broken on the area) to a depth of several feet. The effects are very sharply defined, and it is not reasonable to suppose that just at the summit of an intrusion and nowhere else there should be a sharp division into small zones very rich and others very poor in magnetic material. Nowhere is there any sign of mineral banding in the rock. In the circumstances it is not thought that the effect might have been due to differential cooling, giving local concentrations of magnetite, as suggested by Heiland in his article on abnormal polarisation. The area is nearly plane, the effect is very local, and the distances involved between positive and negative anomalies are very small. It does not seem reasonable to suggest differential cooling here. (ii) The effect may be due to

6 Zeitschrift für Geophysik, Jahrb. 6, Heft 4-7 (Ad. Schmidt-Festschrift).
A DETAILED REGIONAL MAGNETIC SURVEY. 53

mechanical stresses; but when the magnitude of the anomalies and the sharpness of the changes are considered, the formation of "poles" due to mechanical stresses produced either during or after crystallisation does not seem a tenable hypothesis, (iii) The rock might have been fissured, and leached to a considerable depth by water passing down the fissures, whilst leaching occurred only to a very small depth in the rock mass on either side of the fissures; but there are no surface indications of such fissures (the rock is bare, though broken) and the anomalies are again considered too large and too sharply defined to be in accord with this hypothesis, (iv) The effect may be due to lightning; this is the hypothesis that commends itself. The area is exposed rock surface, at the highest altitude in the district. Abnormally big positive and correspondingly big negative anomalies in the immediate vicinity are to be expected, if the magnetic material has been traversed by big currents. The Gib is reported to be struck by lightning frequently, and the author has personal experience of thunderstorms on top, and has seen the effect of lightning striking the earth on two occasions during the two years of these observations—once on the syenite surface, and once on a tree growing on soil on the eastern slope in X49. Unfortunately, the author was several hundred yards away, and could not find the exact spot where the lightning appeared to strike the rock. It seemed to pour on to the surface and run out in all directions; no effects of the lightning could later be found, except that leached surface rocks were cracked and scattered round. This occurred before the anomaly had been observed, so little attention was paid to the matter, the place of striking not even being sought until six months later; it is hoped that some more observations may be made here. Heiland considers the lightning hypothesis also in the article referred to above, and a similar case is examined by Levings.7

In view of the greater uniformity of magnetisation over lower and less exposed surfaces, and the sharpness of the variation here considered, it seems far more reasonable to account for the effect by magnetisation through such abnormal means as lightning, than by simple induction.

mechanical stresses; but when the magnitude of the anomalies and the sharpness of the changes are considered, the formation of "poles" due to mechanical stresses produced either during or after crystallisation does not seem a tenable hypothesis. (iii) The rock might have been fissured, and leached to a considerable depth by water passing down the fissures, whilst leaching occurred only to a very small depth in the rock mass on either side of the fissures; but there are no surface indications of such fissures (the rock is bare, though broken) and the anomalies are again considered too large and too sharply defined to be in accord with this hypothesis. (iv) The effect may be due to lightning; this is the hypothesis that commends itself. The area is exposed rock surface, at the highest altitude in the district. Abnormally big positive and correspondingly big negative anomalies in the immediate vicinity are to be expected, if the magnetic material has been traversed by big currents. The Gib is reported to be struck by lightning frequently, and the author has had personal experience of thunderstorms on top, and has seen the effect of lightning striking the earth on two occasions during the two years of these observations—one on the syenite surface, and once on a tree growing on soil on the eastern slope in X49. Unfortunately, the author was several hundred yards away, and could not find the exact spot where the lightning appeared to strike the rock. It seemed to pour on to the surface and run out in all directions; no effects of the lightning could later be found, except that leached surface rocks were cracked and scattered round. This occurred before the anomaly had been observed, so little attention was paid to the matter, the place of striking not even being sought until six months later; it is hoped that some more observations may be made here. Heiland considers the lightning hypothesis also in the article referred to above, and a similar case is examined by Levings.

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due to the earth’s field, with or without subsequent “folding in” and inversion of earlier cooled portions.⁸

The Anomalies in 2N.

There is an interesting negative anomaly shown on the map with its centre (86γ) in area 2N5. Associated with this is a positive anomaly (maximum reading 1,171γ) in 2N23 and vicinity, which is illustrated in Figure 3; isodynamics in that figure are drawn at 200γ intervals. Unfortunately, it has not been possible to complete the

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⁸ It is of interest to note here that although the magnetometer (with one auxiliary magnet only in one case, and complete in its box in the other case) has twice been within 300 to 400 yards of a lightning discharge to earth, the sensitivity has not been changed, and the auxiliary magnets have merely increased slightly in magnetic moment at an unchanged rate, as seems to be their habit.
survey of this anomaly, as houses occur to the immediate south and west; but it is ringed to the north and east with low values, the lowest observed (at about 2N23.44) being \(-412\gamma\). These anomalies are placed well down the southern slope of The Gib; they are not associated with any apparent surface abnormalities, the slope continuing to fall to the south, but not steeply. The position is such as to warrant its rejection as a "terrain anomaly" due to steeply rising cliffs, etc. The positive anomaly might well be due to a plug of magnetic material which has welled up close to the surface in 2N23; it may have broken through, though now weathered or covered by material fallen from the high land to the north. It is interesting to compare the tuff-neck (dealt with later, Figure 4) with this. The negative anomaly with its centre in 2N5 is, then, a "relative low", an area covered with non-magnetic material, or rather with magnetic material which, magnetised in the first instance by induction in the earth's field, subsequently fell in disorderly fashion to form the present hill slope, and is now surrounded by positively magnetised bodies.

The Anomalies at the Quarry (2E33) and on the Near Western Side of the Gib.

At the junction of Cliff Street and Ellen Street the syenite has been quarried, leaving a practically vertical wall of rock. Readings on the steep slope immediately down to the west from the quarry pit are all negative, giving the lowest values recorded for the area (excluding The Gib crest-line shown in Figure 2). Values decrease from \(-274\gamma\) to \(-608\gamma\) as the steep slope is climbed. The original form of the isodynamics in this vicinity has undoubtedly been considerably altered by the removal of great masses of the magnetic material from 2E33 and the north of 2E41; it is an exaggerated case of "terrain" effects which account for abnormally low values immediately below the cliffs on the western face of The Gib.

The other relatively negative anomalies along the western side of the syenite intrusion are in accord with observations in other districts. There exists here a trough-like depression or valley between the igneous masses, which is cut through shale intersected in places by narrow dykes and by small volcanic necks. The negative anomalies cover relatively big areas on the lower slopes of The Gib, the magnetic contours here being widely separated. The
surface valley (through which run the railway and the Mittagong Road) passes over isodynamic "flats".

Red Soil Anomalies.

At the junction of Soma Avenue and Cliff Street (2D39.00 and vicinity), just off the eastern boundary of the exposed shale, there is a patch of red soil, showing out clearly against the surrounding grey of the syenite soil. This patch is some four chains in diameter; unfortunately the presence of cottages in the vicinity prevents a more detailed survey, but a weak local anomaly is associated with it, with a maximum of 882γ and a minimum of 377γ, observed. The natural value for that zone is about 550γ. The anomaly is possibly associated with a neck.

There is a similar anomaly in 2L25, where the ground is definitely magnetic. Handfuls of the wet soil picked at random and moulded into balls had an intensity of magnetisation of approximately $2 \times 10^{-3}$ c.g.s. units. The area of red soil here covers several acres, extending into 2K; but the magnetic anomaly itself is associated with a very small zone of less than two chains diameter, the maximum value being 883γ and the minimum 685γ, where the expected uniform reading would have been slightly over 700γ. The surrounding surface is Wianamatta shale; it is possible that the magnetic material marks the site of a volcanic neck, or of portion of a sill.

It is probable that the adjacent positive and negative anomalies in S and T are not associated with the quartz-dolerite to the north, but are in the same category as the other "red soil" anomalies. Further, considering the large number of such isolated eruptions, the author merely suggests the association of the major western anomaly with the exposed quartz-dolerite, which is apparently portion of a flattish laccolith.

A small anomaly occurs in V36 and V44, extending over an area about 10 chains across. The maximum value observed here is 818γ, and the minimum 323γ, the high zone being of some hundred square yards only (within an apple orchard) and being surrounded by low readings. This is associated with a spring, constantly running; another spring exists on slightly higher ground across the road in V37; apparently soakage is directed here by the underground contours of The Gib itself.* There is

*The road shown on Plate I is the old, or lower road.
no evidence here of a neck. It is too far from the precipices of The Gib to make a large fallen, slanting, inverted, magnetised mass a rational explanation, though much stone fallen and rolled from The Gib lies about. There is material in the immediate vicinity which appears to be volcanic breccia. The road here crosses a ridge.

Tuff Neck, Vicinity of 2C32 and 2D25.

The isodynamics in the vicinity of the tuff-neck in the general area 2C32 and 2D25 are illustrated in Figure 4.

The lines shown are the 600γ-line of the main map, and the 500γ, 1,000γ, 1,500γ and 2,000γ-lines of this anomaly. The neck forms a little hill, the top of which is fairly flat and about 100 feet above the ground level to the south; the general slope of the country from which it emerges is to the north.

The neck is composite; on the eastern slope the material is (Taylor and Mawson, loc. cit.) “decomposed syenitic breccia and vesicular lavas in which the steam-holes have been filled with calcite”. The rock on the south is darker,
and is "composed largely of fragments of trachyte". The south-west end is "a light-coloured rock of a tuffaceous character", whilst on the north-west slope "more vesicular lava (much decomposed) occurs". Jaquet gives a section of this neck, in which the eastern slope is shown as consisting of trachytic lava, whilst the bulk of the hill is of volcanic breccia.

The zone in Figure 4 has two strong positive centres, one at the north-east end (2,332γ), and one at the southern end (2,191γ). There is also a little knoll on its top at 2D25.03 approximately, where occurs another magnetic peak, of 1,927γ.

A dyke of trachyte is exposed by the railway cutting just to the west of the neck (at 2D26.40), and runs towards it.

The neck as a whole is a positive anomaly, with three peaks. There is a re-entrant low on the eastern slope, practically the whole of the eastern face being occupied by a negative anomaly, the lowest recorded value being 113γ; there is also a small negative anomaly to the immediate south. There is no need to seek for further explanation here than lies in the diversity of materials, and the unequal leaching, in different parts, of the magnetite-bearing trachyte.

Attention has already been directed to the similarity between the isodynamics here and those of Figure 3.

Dykes.

The district abounds in dykes, mainly trachytic, running in all directions for considerable distances.

They have in general been avoided during this survey so far as detailed observations are concerned, as they are very local in their magnetic effects, and can easily be picked out against the surrounding magnetic values.

Limonite.

The chalybeate spring (Lady Fitzroy's Spring) in E40 and E48 comes up through the limonite masses it has produced. The limonite itself is very feebly magnetic, a large lump close to the magnetometer being required to produce an observable movement. A reading taken on top of the rock, twenty yards west of the spring, gave a value of 736γ, some 150γ higher than a "non-feature" value for that position; the reading is slightly affected by the proximity of a small iron hut. A reading on
EXPLANATION OF PLATES.

PLATE I.

Map of the Mittagong-Bowral district, showing the isodynamic lines of the vertical components of magnetic intensity, superposed on a general outline of geological areas. An explanation of the grid system is given on page 36.

PLATE II.

Fig. 1.—The Gib, and the country to the east, north, and west of it, taken from a position on the hill slope in the sector to the immediate north of G, off the map. Reference points are indicated by arrows. The high land in 2G, 2H and 2I can also be seen, and part of the sandstone hill west of The Gib.

Fig. 2.—The Gib from a position about E57, looking south.

Fig. 3.—The Gib from a position in C, looking south-east. The elevated sandstones to the east of The Gib are also seen, the valley in N and W being in shadow. This figure also shows the precipitous nature of the eastern face of The Gib, better seen in the next figure.

Fig. 4.—The cliff face on the north-eastern portion of The Gib. It is taken from V37, looking east.

Fig. 5.—The volcanic neck in 2C and 2D, photographed from 2D35.

Fig. 6.—Mainly the area in the western half of X, being the elevated ground on "Green Hills" protected by the basalt cap, described on page 49. The geophysical research station is also seen. The view is from X50.00, looking north-north-west.

Fig. 7.—From X42, looking east across the lower land in Y, Z and x, and including portion of the basalt-capped high land in 2H and 2I.
limonite on the northern slope of the small mound was 292\(^\gamma\), so that variations of over 400\(^\gamma\) total are associated with the phenomenon, of which no detailed survey was made.

**GENERAL CONCLUSIONS AND SUMMARY.**

1. The isodynamics having been mapped over a wide area, this can be extended as required over the surrounding fields of geological interest. Moreover, local anomalies within the area can readily be examined against the background of the general district anomalies.

As an instance of the possible economic value of the regional magnetic survey, it should be practicable to select areas under which the coal-seams have probably not been ruined by igneous intrusions.

2. The whole district is underlain by igneous intrusions, which are probably more than 2,000 feet below the surface in parts. There are two main disturbances:

(a) that due to The Gib itself, an asymmetrical laccolith which:

(i) falls steeply for over a thousand feet under the surface on its western side,

(ii) falls steeply at first and then gradually back for several miles on the eastern side, and

(iii) falls less steeply on the north and south, though of a total extent of slightly over a mile in that direction;

(b) that due to an intrusion to the west, of which the quartz-dolerite exposed on the boundary of T and S probably forms a part.

3. Even where the magnetic rock lies at greatest depth, the overlying strata have been intruded by dykes, sills, and volcanic necks, which in many cases are not apparent from surface geological indications; some of the visible necks have ejected volcanic breccia and others may have been outlets for the lava flows over the district.

4. The whole district seems to have been covered by one or more lava flows subsequent to the main intrusions; most of the lava has now been eroded, being represented in places by caps (in some parts, just off this area, up to 400 feet in thickness). It is possible to allow for the magnetic effects due to this; it may mask local anomalies.
MAP SHOWING LINES OF EQUAL MAGNETIC VERTICAL INTENSITIES MITTAGONG-BOURRAL DISTRICTS

[Map details not transcribed into text]
In the heart shakes or cracks of the wood of Podocarpus spicatus (Maori name — matai) a resinous but often crystalline substance occurs which has been isolated and characterised by Easterfield and Bee (Trans. N.Z. Inst., 1910, 43, 54; J.C.S., 1910. 97, 1028). The pure substance, to which the name of matairesinol was given, has a m.p. of 119° and was shown to have the molecular formula of the six oxygen atoms two were shown to be present as hydroxyl groups by the formation of a monoacetyl derivative, m.p. 110°, and a dibenzoyl derivative, m.p. 133°. A Zeisel determination indicated two methoxyl groups. The remaining two oxygen atoms were present in a lactone ring which underwent fission on solution in dilute sodium hydroxide from which the free hydroxy acid, matairesinolic acid, C19H22O7, was precipitated by acidification with dilute acetic acid. A disulphonic acid derivative was also prepared. From their investigations matairesinol possessed the partial formula:

\[ C_{16}H_{13}(O\_0O)(OH)_{2}(O\_CH_{3})_{2} \]

and was assumed to be of the phenanthrene type. With Professor Easterfield's kind permission we have continued the investigation of this resin, and we are now able to present a full formula.

Further analyses of matairesinol supported by analyses of derivatives have shown it to possess the formula C20H22O6. It is thus isomeric with pinoresinol which

* One of the authors (D.A.P.) is indebted to a Duffus Lubecki Scholarship, which has enabled him to take part in the investigation.

f Professor Easterfield, in a private communication, intimated that Mr. McClelland had found the original molecular formula to be incorrect.

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