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Western Victoria Detailed Aeromagnetic Survey, 1967

by

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CONTENTS

ILLUSTRATIONS

1968/146

SUMMARY

A detailed aeromagnetic survey was made between September and December 1967 in conjunction with the Geological Survey of Victoria, who is concerned with the exploration of brown coal in western Victoria. Parts of the brown coal deposits are covered with basalt flows and can be mined economically only where the basalt is thin, weathered, or absent. The survey was the second of a series of three surveys carried out between 1966 and 1968 with the purpose of mapping the boundaries of the Tertiary lavas and locating 'windows' within the basalt. The 1:63,360 map areas of Skipton, Lismore, and Rokewood were covered with east-west flight lines a fifth of a mile apart with the aircraft at a constant ground clearance of 400 feet.

In accordance with the findings of the 1966 survey, the data were not contoured, because basalt boundaries were found to be best delineated by zoning the magnetic profiles. Also, owing to the unknown variables associated with the basalt, a purely quantitative interpretation of basalt thickness could not be made. A qualitative method was adopted based on zoning the survey area in terms of the character and amplitude of the magnetic anomalies. The area was divided into three major zones representative of areas of no basalt; areas of thin basalt (30 to 60 feet); and areas of basalt with a probable thickness of 60 to 210 feet.

1. INTRODUCTION

The Geological Survey of Victoria is concerned with exploration for brown coal in western Victoria. Most of the potential brown coal areas in the Western Plains are overlain by basalt, but where this is thin or sufficiently decomposed, it should be possible to mine (open cut) the underlying brown coal economically.

B.M.R. in conjunction with the Geological Survey of Victoria selected three 1:63,360 areas in the Ballarat 1:250,000 map area. These are Skipton, Lismore, and Rokewood and these map areas will be referred to as SKIPTON, LISMORE, and ROKEWOOD in this report. They are situated to the west, south-west, and south of the township of Ballarat, and cover a surface area of 1428 square miles (Plate 1).

The detailed aeromagnetic survey of these areas was carried out between September and December 1967, the objective of which was to define areas where the basalt is either absent, thin, or decomposed. Information from the survey is expected to assist in a programme of exploratory drilling for brown coal.

The Cessna aircraft 180, registration VH-GEO, was used with a proton precession magnetometer MNS-1 mounted in a towed bird. The survey altitude was 400 ft above ground level, with the detector at 370 ft. The flight-lines were orientated east-west and spaced at 1/5th of a mile apart.

2. GEOLOGY

Regional

The area is situated between two major thrust belts, the Staverly Belt to the west and the Heathcote Belt to the east. The Palaeozoic rocks between these two thrust belts have been sharply folded into brachy-anticlinaria and brachy-synclinaria with innumerable high-angle faults and many major thrusts. The structure trends generally to the north-west.

A belt of Mesozoic rocks, trending east-west, rests unconformably on the Palaeozoic, and thereby has a marked contrast with the meridional strike of the older rocks. The Mesozoic rocks of the Otway Ranges extend in an easterly direction, plunging beneath the younger Tertiary deposits south of Geelong, and reappear in the Coleraine and Casterton area in the west. It is therefore likely that Mesozoic sections may occur beneath the Tertiary basalt in the Ballarat 1:250,000 map area. These rocks have been affected by faulting to produce broad east-west structures. This general east-west trend is also visible in the deposition of the Tertiary deposits.

The Tertiary deposits show rapid changes of facies, and the discontinuous outcrops have given rise to several interpretations of the Tertiary sequence. Thomas (1960) has generalised the facies into four types of sediments which are apparently widespread in Victoria:

1. Non-marine: deposition of fluviatile gravels, lacustrine sediments, brown coals, siltstones, and clays.
2. Marine anaerobic environment: deposition of carbonaceous and pyritic sands and clays.
3. Normal marine sedimentation: both calcareous and non-calcareous. (Marine transgression reached a maximum in Balcombian times).
4. Return to non-marine sediments in younger Tertiary times.

The Tertiary sedimentary basin in the Western District plunges westerly and attains a depth greater than 5000 ft.

The Cainozoic was a period of basic vulcanicity with two maxima in the Eocene and Pleistocene, linked by spasmodic flows in the Oligocene and Miocene. The Older Volcanics (Eocene) are concentrated to the east of Melbourne, whereas the Newer Volcanics (Pleistocene) lie entirely to the west of Melbourne and form the Werribee and Western District lava plains and valley flows in the highlands. The Older Volcanics which are more than 1100ft thick, are olivine basalts averaging 45 percent SiO_2, with unsaturated differentiates such as nephelenite, tinguaite, and phenolite. On the other hand the Newer Volcanics, which are up to 500 ft thick, are olivine basalts (tholeitic) averaging 50 percent SiO_2, with saturated alkaline differentiates including alkaline basalt, trachyte, and soda trachyte.

Detailed

The geological information for the survey was obtained from papers by Baragwanath (1953), Coulson (1954), Gill (1964), Hunter (1909), Oliver and Joyce (1964), and Yates (1954). Palaeomagnetic information was obtained from papers by Green and Irving (1958), Irving and Green (1957), and Green (1959).

The Ordovician rocks in the area consist of slate, sandstone, sub-greywacke and mudstone. Their major areal outcrop occurs in ROKEWOOD (Plate 2); minor amounts occur in the northern and eastern parts of SKIPTON (Plate 4), and in the eastern portion of LISMORE (Plate 3). These rocks appear to underlie the whole survey area and the surrounding country. The Ordovician is folded into a series of north-striking synclines and anticlines, and has been intruded by minor dykes, both acidic and basic in composition. Numerous fauls occur, many of which have been infilled by quartz; these quartz reefs were important sources of gold in the Ballarat goldfield area.

Unconformably overlying the Ordovician are sediments of the Cainozoic. Oligocene sediments, which consist of limestone, marl, and silty and sandy clays crop out in the south-east corner of ROKEWOOD.

The Miocene and Pliocene sediments consist of sands, gravels, and clays, which are ofter ferruginous. These sediments mainly overlie the Ordovician in ROKEWOOD and the post-Ordovician granite in LISMORE. Some Pliocene river sediments occur in the old valleys formed by the erosion of Ordovician rocks. It is these sediments that carried rich alluvial gold.

Overlying the Pliocene and Ordovician sediments, and completely infilling the old valley systems, are basalt flows of mainly Pleistocene age. These flows form part of the extensive volcanic period of activity that took place in western Victoria. This activity commenced at the end of the Miocene period and finished with an explosive phase in Recent times. Much of western Victoria was covered with olivine basalt flows and tuff. This sequence (up to a few hundred feet thick) consists of a number of basalt flows, often with distinct differences in composition between individual flows. These flows are interbedded with sediments and pyroclastics. The basalt was derived from numerous volcanoes, which are now apparent throughout western Victoria as low hills 200 to 400 ft high. These are usually lava or scoria cones and domes, and occur as follows: in SKIPTON, extinct volcanoes exist at Black Lake and Mount Widderin; in LISMORE, scoria peaks occur at and near Mount Elephant; in ROKEWOOD, extinct volcanoes exist at Mount Mercer, Mount Lawaluk, and Wallindue Hill. The Newer Volcanics have been mapped as two main units. The lowest member consists of basalt, tuff, and scoria, and crops out over most of the three areas. The upper member consists of basalt and is restricted to SKIPTON and LISMORE. This member overlies the lower member in definite north-easterly trending zones in the above areas.

The thickness of the basalt in numerous water bore holes was obtained from the Annual Reports, Drilling Reports, and Boring Records of the Victorian Department of Mines, and the positions of these are plotted in groups in Plates 2, 3, and 4. Selected data relevant to the individual groups are tabulated in Appendix 3. The data selected include the number of drill holes within each group; the thickness and depth of the base of the basalt below the surface; the depth of the 'Ordovician' basement; the basement lithology; and any information concerned with the salinity and depth at which the underground water was encountered in the individual groups of boreholes.

Recent alluvium derived from the Ordovician slates and sandstones and the Tertiary basalts occur in the vicinity of the rivers and creeks; Recent soil derived from decomposed basalt overlies the basalt flows.

Palaeomagnetic samples taken by Green and Irving (1958) from the basalt flows throughout western Victoria showed normal and reverse remanent magnetisation in the direction of the Earth's present magnetic field. In this report the basement is defined as the Permo-Carboniferous erosion surface, which is represented in this area by Ordovician sediments and post-Ordovician granite.

3. PREVIOUS GEOPHYSICAL EXPLORATION

In 1966, the Bureau of Mineral Resources carried out an experimental survey in two selected areas situated on the Western Plains of Victoria to test the feasibility of determining the thickness and state of decomposition of the basalt (Dockery, 1967). It was found that the magnetic contour maps over the basalt in both areas was extremely disturbed. The intensity of the magnetic field appeared to vary randomly from point to point over the basalt, and the thickness of the basalt obtained from drill hole data showed that there was no direct relation between the thickness of the basalt and the magnetic field intensity measured above the basalt. However, Dockery suggested that an apparent relation between the thickness of the basalt and the amount of variation of the magnetic field intensity may be seen by measuring the peak-to-peak amplitude of the numerous magnetic anomalies over different thicknesses of basalt. He found that this amplitude was smaller near areas of thin basalt cover.

As a consequence of these findings it was decided that the results of future surveys of this type could best be interpreted by direct inspection of the magnetic profiles. The method of analysis used in the 1967 survey, outlined in Appendix 1 of this Record, is a development of this approach.

4. RESULTS

The method used to interpret the magnetic data is discussed in Appendix 1. The original magnetic zones showed a pronounced east-west trend and the boundaries between individual zones showed a 'herring bone' structure. This was smoothed out in the major zonal presentation. The interpretation in terms of the three major magnetic zones is shown with the geology in Plates 2, 3, and 4. In addition, some intensely magnetic zones are shown to outline probable volcanic necks or cones and there is an intense magnetic trend of Zone 6 in LISMORE and SKIPTON. Probable areas of buried river valleys are also represented. The major magnetic zone A, B, and C are interpretated in relation to drill hole data in Appendix 1.

Zone A is free of superficial basalt, but may be covered by 15 to 60 ft of Tertiary and Quaternary sediments. This zone delineates the Ordovician and Tertiary sediments and the Post-Ordovician granite.

Zone B probably represents areas of thin or weathered basalt cover. The basalt thickness could be of the order of 30 to 60 ft, and this is considered thin with respect to the basalt thickness in Zone C. The depth to basement beneath this zone ranges from 65 to 90 ft. This basement is either Ordovician sediments (slate, sandstone, limestone, hornfels) or the post-Ordivician granite.

Zone C represents areas of basalt with a thickness ranging from 60 to 210 ft. The basement (Ordovician sediments and post-Ordovician granite) depth ranges from 75 to 230 ft. This depth to basement may be an underestimate since the basement tends to increase in depth southwards, and away from the outcrops of basement. The basement contours for the Otway Basin from the Tectonic map of Australia indicates that the basement is nowhere greater than 500 ft below ground level in the survey area.

The major magnetic zones for ROKEWOOD, LISMORE, and SKIPTON will be discussed separately.

ROKEWOOD (Plate 2)

The major magnetic zones distinguish the Ordovician and Tertiary sediments in the northern and eastern portions of the area from the basalt plains in the western and southern portions. Some basalt-filled river valleys are clearly delineated by the magnetic zones in the Ordovician. Within the basalt country, Zone B is situated near known Ordovician outcrops, whereas Zone C is situated over basalt away from the basement outcrops.

Large areas of Zone A are situated in the north of ROKEWOOD; to the north and south of Bamganie, east of Yarrowee River; and to the north of Wallinduc. These zones show good correlation with Ordovician and Tertiary sediments and the post-Ordovician granite, but boundaries of these zones differ from the known geological ones.

The boundary of Zone A situated north of Wallinduc over the granite appears to be displaced northwards. The boundary of the zone situated around the Woady Yaloak River, west of Cape Clear, differs from the known geological boundary as the Ordovician extends through Zone B and penetrates southwards for one mile along the Woady Yaloak River into Zone C.

The main area of Zone A is situated north of Rokewood, between Illabarook Creek and Yarrowee River. It's boundary generally correlates with the geology. West of Rokewood, the zone includes a large area of Quaternary deposits, which probably overlie Ordovician sediments. The western boundary of this zone is bordered by Zone B. On Illabarook Creek, near Illabarook are small indentations of the boundary of Zone A, which could represent small buried valleys. The Zone A situated at Horthorpe Grange Homestead appears to cover a larger area than outlined by the geology.

In the eastern part of ROKEWOOD, there are three areas of Zone A: east of Grenville on Williamsons Creek: east of Yarrowee River, between Woodbourne and Bamganie; and south of the Yarrowee River and Woodbourne Creek junction. These zones outline the Ordovician and Tertiary sediments. The Ordovician tongues, cropping out along the Yarrowee River to the south and west of Bamganie, transgress into Zones B and C. The apparent width of this outcrop is 0.3 mile in the direction of the flight lines and was unresolvable.

The tentative Zone A situated on the Yarrowee River, east of Mount Lawaluk and north of Cargerie Creek was based on isolated areas of zones 1 and 2 separated by zones 4 and 5. The known outcrops of Ordovician, north of this zone was represented by zones 3, 4, and 5 and were included in Zone C.

The areas of Zone B are adjacent to the main outcrops of Ordovician and Tertiary sediments and granite. These areas of Zone B are situated:

1. To the north of Woodbourne and west of Cargerie
2. To the south of Rokewood and stretching westwards to Little Woady Yaloak Creek
3. To the west of Illabarook Creek and east of Pitfield Plains
4. Between Bingleys Swamp and Yarrowee River
5. On Illabarook Creek and to the north of Illabarook
6. To the west of Emu Hill.

The Zone C indicates a progressive thickening of the basalt and a probable deepening of the basement surface away from the basement outcrops. Areas of this zone, which can be considered to represent basement 'depressions', occur both to the east and west of Rokewood. The eastern zone extends from Mount Lawaluk to south of Warrambine Homestead and the western zone extends from Emu Hill to the south of Wilgul. These basement depressions are bordered on the west by the post-Ordovician granite, and on the north and east by Ordovician and Tertiary sedimentary rocks. In the extreme south of ROKEWOOD, these 'depressions' appear to merge and have a probable basalt thickness of from 150 to 200 ft, and the basement is postulated to be between 300 and 400 ft below ground level.

Points of eruption of scoria peaks. All the isolated hills, with an average elevation of 200 ft above the basalt plain, were located in areas of Zone 6 and these are shown in Plate 2. Mount Mercer and its associated peak Mount Lawaluk, and the hill situated at Larundel Homestead are points of eruption. Hardies Hill, Wallinduc Hill, and Emu Hill are probably scoria peaks with a basic plug at depth.

Deep leads. Higher order magnetic zones (Zone C) located in or near the main Ordovician outcrops, and separating smaller areas of Zone A from the main one, may represent basalt-filled river valleys in the Permo-Carboniferous erosion surface. These probable basalt-filled river valleys are situated:

1. Near the intersection of the Yarrowee River and Woodbourne Creek, to the south of Bamganie
2. At the intersection of Yarrowee River and Cargerie Creek to the west of Woodbourne
3. To the west of Yarrowee River between Hardies Hill and Grenville and trending in a north-south direction. This basalt flow probably filled the original Yarrowee River and the recent one is a displaced drainage system. This is the position of a portion of the auriferrous Duninyong-Ballarat Lead
4. To the west of Horthorpe Grange Homestead and extends north-south along the present position of Spring Creek.
5. On Illabarook Creek, north and south of Cape Clear. The Woady Yaloak River, west of Cape Clear, has been displaced by basalt flows that have filled the 'old Woady Yaloak River' (now Illabarook Creek). This is the position of the auriferous Pitfield-Symthesdale Lead
6. On Illabarook Creek, south of Illabarook and west of Rokewood Junction; it is indicative of a basalt-filled river valley.

All of these basalt-filled river valleys have a potential relationship to the Victorian deep buried leads, which have auriferous alluvial deposits in them. Two such leads have been mentioned.

LISMORE (Plate 3)

The areal extent of the magnetic Zones A and B in the south-eastern portion of LISMORE includes most of the known granite outcrops. Some higher-order magnetic zones situated in this area may outline basalt-filled river valleys. The basalt area to the west and south-east of Zones A and B corresponds to Zone C.

A series of isolated areas of Zone A separated by narrow areas of Zone B are situated in the region between Derrinallum in the west and Mount Kinross in the east.

Although granite outcrops are generally included within Zones A and B between Lismore and Mount Kinross, there are three exceptions, in which the granite extends into a magnetic Zone C.

These are situated to the east of Moira Homestead: on Naringhil Creek to the north of Mount Kinross; and south-east of Mount Kinross. The apparent width of the first two granite outcrops is 0.2 mile, which is less than the minimum detectable area. But the latter consists of 0.8 mile of granite in the flight-line direction. This may be a positional error of the zonal boundary, produced by the system of grouping of the original zones or a compositional change in the granite.

No known granite outcrops occur in the Zone A situated to the east of Derrinallum and around Gnarkeet. From drill hole data (see Appendix 3, Lismore 2, 3, and 5), it was found that the granite basement was at 130 to 225 ft below ground level. This indicates that the basement must decrease in depth towards the magnetic Zone A, but there is no information concerning the granite at Gnarkeet. It is likely, however, that here the granite is near the surface.

Zones B are situated along the north-western and south-eastern sides of Zone A. The granite basement under Zone B is shallow and ranges from 60 to 90 ft below ground surface.

Zone C occurs over the rest of LISMORE and is indicative of an increase of basalt thickness and a probable deepening of the basement. This present Zone C combines both basalt types (Vp and Vv) as one unit, but it may be possible to outline the extent of the two basalt types using the original group distribution of Zones 3, 4, 5, and 6 with respect to a particular background zonal level.

Probable volcanic necks and cones are outlined by Zone 6, and are situated at Banangil Hill, Mount Vite Vite,and Mount Elephant. Mount Vite Vite is a point of eruption, and Mount Elephant is a scoria peak. Mount Elephant's magnetic anomaly had two resolved peaks, each with an amplitude of 1000 gammas, which probably relate to the walls of the crater or two intrusions.

Water borehole data around Mount Elephant (see Appendix 3, Lismore 1, 2, and 3) indicates that the basalt thicknesses and basement depths range from 100 to 175 ft and 200 to 225 ft respectively.

The dominant magnetic Zone 6, which has a north-easterly trend, is located south of Mount Emu Creek and passes through Mount Elephant Homestead and Stonehenge Homestead in the south-west. This zone occurs in the stoney rises area (basalt Vv) and along the boundary between the two basalt types Vv and Vp; it could represent either a local magnetic contrast between two basalt formations, or a dyke, or a fissure intrusion.

Magnetic Zones B and C which occur within the grantic area are assumed to represent areas of isolated basaltic material or basalt flows filling old river valleys in the granite. These proposed basalt-filled river valleys are situated:

1. To the north of Mount Kinross
2. To the north-east of Mount Bute on Gnarkeet Chain of Ponds
3. To the west of the Mount Bute road and north of Moira Homestead on the creek
4. Between Gnarkeet Chain of Ponds and the junction of Pitfield Road with the Hamilton Highway
5. To the north and south of the road between Derrinallum and Lismore, west of Hazlewood Homestead.

SKIPTON (Plate 4)

The magnetic Zone A correlates with outcrops of Ordovician sediments along the northern boundary of SKIPTON, and correlates with outcrops of granite and Ordovician sediments on the eastern side of the area. The basalt plains are dominated by Zone C.

In the northern part of SKIPTON, Zones A and B coincide with known outcrops of Ordovician sediments. These zones are situated at Mount Weejort; four miles north-east of Mount Weejort; and to the north-west of Lake Goldsmith at Buln Gherin Homestead. The boundaries of the Zones A enclose the Ordovician sediments, except in a small area south-east of Buln Gherin Homestead and east of Mount Weejort. The displacement of the latter is of the order of 0.8 mile westwards. The Zones B in this region indicate areas of thin and/or weathered basalt resting on a shallow basement.

On the eastern side of SKIPTON, Zones A and B occur as a series of isolated areas, which stretch from Mena Park in the north, southwards through Mount Emu and Pittong. The Zones A and B situated south-east of Mount Emu Creek correspond to the outcrops of Ordovician sediments and post-Ordovician granite. The isolated granite outcrop situated 1.5 miles south-east of Skipton, and the one situated 2 miles north-east of Monmot Hill, are outcrops 0.4 and 0.6 mile in diameter. These bodies were not resolved magnetically because the outcrops were smaller than the detectable size of a body, which is 1 mile in diameter. The granite outcrop at Mount Emu is well outlined by a Zone A, but it's northern extension is only 0.2 mile wide. This was not resolved as it penetrates into Zone C.

The Zone A situated north-west of Mena Park is located in an area of Quaternary sediments and appears to be displaced 1 mile south of a granite outcrop. This granite, considered as a circle 1.25 miles in diameter, should have been resolved as a Zone A, but was only partially resolved by a Zone B. The original magnetic trace showed an anomaly with an amplitude between 50 to 100 gammas, and no short-period magnetic anomalies were present. This probably indicates a compositional change within the granite.

The Zones B situated near Pittong occur over the granite, which suggests that the granite has a variable composition, and explains why the granite north-west of Mena Park was only partially resolved by a Zone B.

The Zone B which extends to the south-west of Mena Park is a probable area of thin and/or weathered basalt with the granite mass at a shallow depth.

The northern extension of Zone 6, referred to in LISMORE is also present to the west of Mount Widderin.

The points of eruption situated at Mount Widderin, Monmot Hill, Black Lake, and the hills situated 2.5 miles north-east of Monmot Hill, are represented by areas of magnetic Zone 6. The hills, Mount Weejort and Mount Emu, are areas of Zone A, and represent outcrops of post-Ordovician granite.

5. CONCLUSIONS

The position of the magnetic zones showed a good agreement with the geological mapping of the Geological Survey of Victoria. In particular, Zone A delineated known areas of Ordovician and Tertiary sediments and the post-Ordovician granite. Zone B delineated possible areas of thin and/or weathered basalt cover and areas of shallow basement. Zone C was situated in the basalt plains and is thought to represent regions of thick fresh basalt cover and a deeper basement than Zone B.

The magnetic Zone A correlated with large areas of known basement. It was observed that the sediments were more clearly delineated than the granite, probably because the sediments are more uniformly non-magnetic than the granite. This is as expected, because the granite masses may have internal compositional changes and/or multiple intrusions. It was observed that the granite occurs in areas of Zones A and B, whereas the sediments are restricted to Zone A.

Most of the basement outcrops larger than one mile in diameter were distinctly resolved by Zones A and B. The isolated granite outcrops in LISMORE, which can be considered as circles of 0.4 and 0.6 mile in diameter were not resolved. This is in agreement with the smallest detectable size of one mile in diameter (Dockery, 1967). It was also observed that basement outcrops that trend north-south along river valleys, with an apparent width of 0.2 to 0.3 mile, were not resolved.

The magnetic zonal boundaries are in some places displaced from the known geological boundaries by up to 0.8 mile in the east-west direction and 0.4 to 1 mile in the north-south direction. The accuracy of positioning the zonal boundary was considered as the cummulative error of plotting and transferring the edge of the original zone.

This ranged from 330 to 370 ft for a ground speed of 90 to 100 knots (i.e. 0.06 mile). These zones were later grouped, smoothed, and regrouped into larger simplified units (major zones). This smoothing could have introduced an error of up to 0.5 mile for a 1-mile herringbone pattern. Dockery stated that a boundary positional error of 0.5 mile was likely between two distinctly different magnetic units, and this positional error would be greater for two similar magnetic units. These errors could explain the east-west displacement of the zonal boundaries with respect to the geology and perhaps the error in the north-south direction.

Zone B occurs in close proximity to Zone A, and tends to surround the granite in LISMORE and SKIPTON. This indicates that the granite in both areas coversa larger extent than depicted by the geology.

From the distribution of Zones A,B, and C, and the available drill hole data, it is thought that the basement depths and the Newer Basalt thickness increase away from the areas of basement outcrops. In the southern part of ROKEWOOD, the basement depth is approximately 300 to 400 ft below ground level, and the basalt thickness in this area ranges from 180 to 200 ft. The basement depth is revealed by the Cressy No. 1 drill hole, which is situated 4 to 5 miles south of ROKEWOOD. Here, no Newer Basalt was encountered, but 115 ft of the Older Basalt was intersected at 486 ft below ground level and the basement was intersected at 600 ft.

In LISMORE and SKIPTON, Zone C gives a general indication of a thickening of the basalt and a deepening of the basement away from the basement outcrops. In the north-eastern corner of SKIPTON, the basalt thickness ranges sporadically from 90 to 370 ft. This probably reflects irregularities in the Ordovician erosion surface at the time of basalt extrusion. Near Mount Elephant (LISMORE), the basalt thickness is more regular, and ranges from 100 to 175 ft. Further to the south, at Koort-Koort-Nong No. 2 drill-hole, the basalt thickness is 144 ft. This indicates that the basalt thickness is sporadic near Ordovician outcrops and tends to become more uniform in thickness southwards.

The basement depths in the north of SKIPTON are sporadic and range from 160 to 380 ft below ground, and become more regular (220 ft) at Mount Elephant. Basement was at 1033 ft in Koort-Koort-Nong No. 2 drill hole. This indicates a basement deepening in the northern part of LISMORE and in the southern part of SKIPTON, with the granite mass forming a local ridge as the basement deepens southwards towards the Otway Basin.

The magnetic zones were used in ROKEWOOD and LISMORE to delineate areas of basalt-filled river valleys on the Ordovician sediments and post-Ordovician granite. These are shown in Plates 2,3, and 4. Two of these basalt-filled river valleys are known auriferous deep leads (Pitfield-Smythsdale and Duninyong-Ballarat Leads). The others may be worthy of examination with respect to auriferous deposits.

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APPENDIX 1

INTERPRETATION METHODS

The interpretation is based on the ideas outlined by Dockery (1967).

Because of all the unknown variables associated with the basalt and the resulting complexity of the total magnetic field, a purely quantitative method for estimating basalt thickness could not be used. A list of the unknown variables connected with the basalt is listed below:

(1) Variable number of flows

(2) Variable thickness and distribution of flows. The thickness is not constant in any one flow, either across or along its length.

(3) Variable composition in any one flow, both laterally and vertically.

(4) Remanent magnetisation is variable in magnitude and direction throughout the basalts flows. There are six known periods of reversed magnetisation within the last 4 million years.

A more qualitative method, based on a zoning of the survey area in terms of the character and amplitude of the magnetic anomalies, was adopted. The magnetometer charts were smoothed and zoned initially on anomaly amplitude, without taking account of any linearity in the data. Six zones were adopted, viz.

Zone	Amplitude (gammas)
1	0-10
2	10-20
3	20-50
4	50-100
5	100-200
6	greater than 200

The zone boundaries were transferred to the plotted flight lines on the control photography to an accuracy of ±300 ft.

A study of the disposition of these six zones indicated that they could be further reduced to three groups, or major zones, designated A, B, and C in this Record. Major zone A is predominantly zone 1 with scattered areas zoned as 2 and 3, whereas major zone B is predominantly zones 2 and 3 with relatively minor areas zoned as 1 and 4. Major zone C includes the most magnetically disturbed areas initially zoned 4, 5, and 6, although small areas of zones 1, 2, and 3 are included.

Table 1 displays a possible interpretation of zones A, B, and C when related to the available drilling data.

Zone A shows a close correlation with the known geology. The boundary of this zone is marked by Zones B and C. It is suggested that Zone C represents areas of relatively thick basalt and Zone B represents areas of thin and/or weathered basalt.

TABLE 1

Zone	Number of drill hole groups in zone	Maximum range of basalt thickness (feet)	Probable range of basalt thickness (feet)	Maximum range of basement depth (feet)	Probable range of basement depth (feet)	Possible interpretation
A	2	Zero	Zero	0 to 90	15 to 60	Tertiary sediments overlying Ord. sediments and Post-Ord. granite
B	16	0 to 65	30 to 60	10 to 130	65 to 90	Thin and/or weathered basalt
C	24	30 to 370	60 to 210	60 to 390	75 to 230	Relatively thick basalt

APPENDIX 2

OPERATIONAL DETAILS

Staff

BMR	R.A. Gerdes	: Party Leader
	W.R.D. Buckley	: Drafting Officer
	R. Curtis-Nuthall	: Act.Senior Technician (Radio)
	B.M. Tregellas	: Geophysical Assistant
TAA	Flight Officer G.E. Brown	: Pilot

Equipment

Aircraft	: Cessna 180, VH-GEO
Magnetometers	: MNS-1 with CTPI power/cycling unit (prototype) proton precession magnetometer with towed bird detector, output to two Moseley Autograph recorders
	: MNZ-1 proton precession magnetometer, base station moniter, output to Esterline-Angus recorder
Radio altimeter	: AN/APN-1 (aid to altitude control - no record taken
Camera	: Modified Vinten, 35-mm, single-frame with wide-angle (fish eye) lens (186° field of view)

Survey specifications

Altitude	: Aircraft nominally at 400 ft above ground level with detector at 370 ft above ground level.
Line spacing	: Nominally 1/5th mile
Line orientation	: East-west

Recorder sensitivities	1. Moseley recorders: 100 and 1000 gammas f.s.d. 2. Estaline-Angus recorder: 100 gammas f.s.d.
Magnetometer cycle time	: MNS-1(P) 0.85 seconds MNZ-1 30 seconds

Operations

Survey party arrived Ballarat, Victoria	1st September
Flying commenced	4th September
Flying concluded	5th December
Survey party departed for Canberra	7th December

Removal of diurnal variation

A baseline was chosen for its ease of reflying and for its low magnetic relief. This baseline check of the diurnal variation was recircled for every survey flight. A linear variation of the magnetic field was assumed between the times when the baselines were flown. For the whole survey the range of the diurnal variation was $\pm$ 20 gammas, with respect to the baseline.

Appendix 3

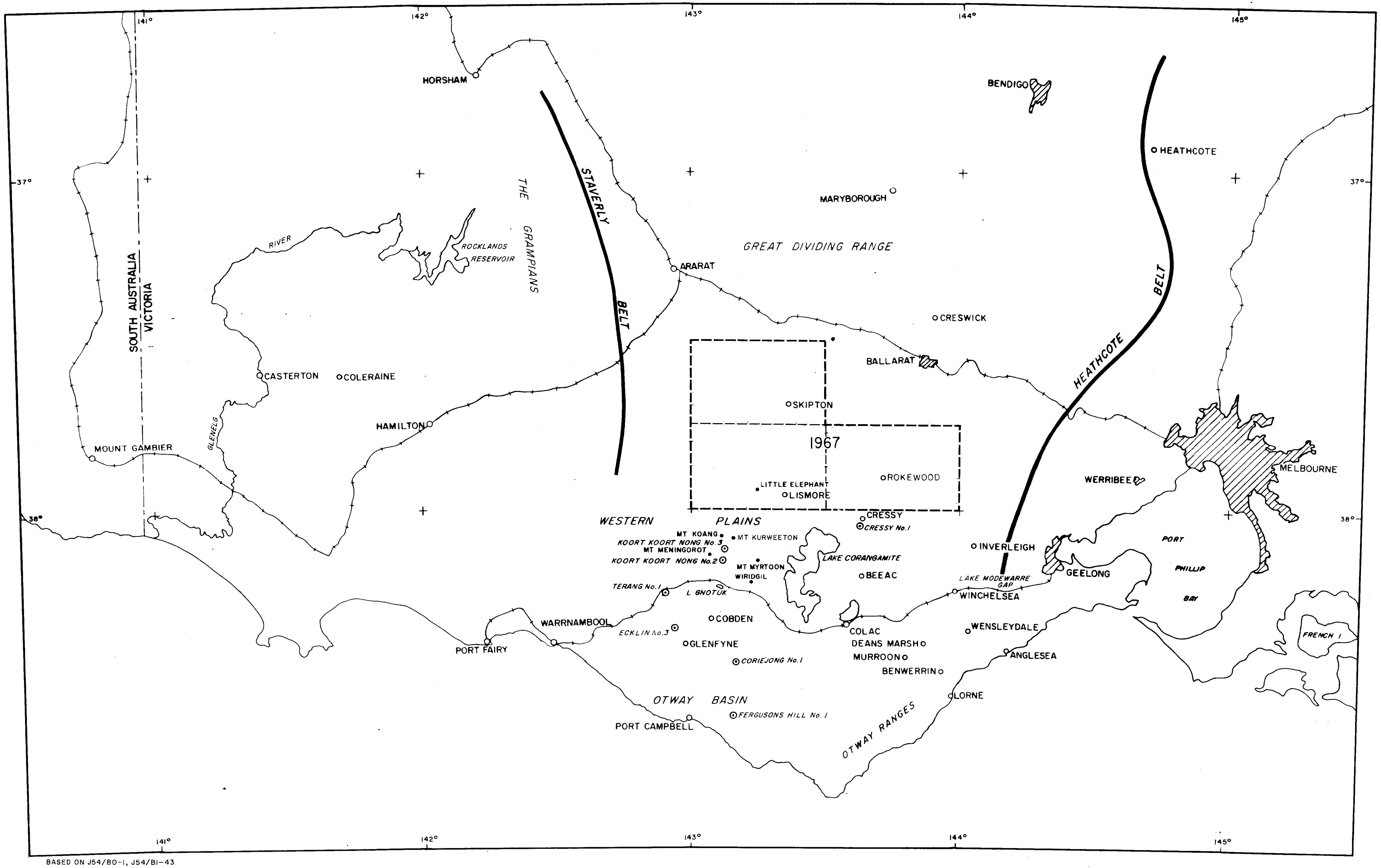
Selected Water Bore Data relevant to ROKEWOOD, LISMORE and SKIPTON 1:63,360 map areas

Appendix 3

Number of Group of Drill Holes	1:63,360 Map Area	Bore Hole Group Location: Parish	Bore Hole Group Location: Grid Reference	Number of Bore Holes in Group	Thickness Range of Basalt (feet)	Depth Range to Basalt Base (feet)	Basement Depth (feet)	Basement Lithology	Total Depth Range of Bore Hole Group (ft)	Depth to Water (feet)	Remarks
1	Rokewood	Corindhad	803230	9	18 to 50	65 to 84	93 to 95	Slate and sandstone	96 to 104	40	
2		Corindhad	809230	4	Zero	–	63 to 79	Slate and sandstone	66 to 85	52	
3		Corindhad	818235	4	19 to 48	22 to 53	47 to 68	Slate and sandstone	50 to 70	Nil	
4		Corindhad	803237	3	Zero	–	43 to 85	Slate and sandstone	47 to 89	25	
5		Commeralghip	697253	5	126 to 142	138 to 150	148 to 167	Slate and sandstone	151 to 170	92 to 135	Brackish water in one hole only.
6		Commeralghip	687272	10	122	124	110 to 169	Slate	115 to 172	54 to 120	Brackish water in all holes.
7		Lawaluk	999258	7	80 to 127	79 to 130	86 to 130	Slate and sandstone	90 to 140	Nil	
8		Commeralghip	747277	6	0 to 52	20 to 57	6 to 104	Slate and sandstone	10 to 108	Nil	
9		Commeralghip	678293	4	32 to 44	70	85	Slate	90	21	
10		Commeralghip	710296	12	45 to 85	50 to 90	52 to 130	Slate	60 to 132	Nil	
11		Commeralghip	734292	1	Zero	–	15	Slate	20	Nil	
12		Commeralghip	719307	16	1 to 68	10 to 70	6 to 90	Slate	10 to 92	20 to 60	Alkaline water
13		Commeralghip	724306	13	17 to 61	36 to 66	40 to 90	Slate and sandstone	43 to 96	20 to 50	Brackish water
14		Commeralghip	690310	3	144 to 195	149 to 198	152 to 222	Slate and sandstone	174 to 256	Nil	
15		Wallinduc	646321	12	95 to 160	110 to 170	145 to 185	Slate	119 to 221	Nil	
16		Commeralghip	725320	5	62	75	100	Unknown	105	Nil	
17		Commer/Derell/Mindai	732325	74	14 to 66	32 to 92	72 to 106	Slate	10 to 120	51	
18		Mindai	703328	4	146 to 186	159 to 200	177 to 226	Slate	180 to 228	160	Alkaline water
19		Mindai	701341	3	100	100	110	Slate	115	Nil	
20		Mindai	692341	8	35 to 44	43 to 55	60 to 82	Slate and sandstone	60 to 87	Nil	
21		Cargerie	063344	4	50	55 to 65	90	Slate and sandstone	93 to 104	38	
22		Cargerie	060357	7	55 to 64	64 to 70	114 to 155	Slate	130 to 160	45	
23		Cargerie	055364	1	34	42	84	Slate	87	30	
24		Mindai	706378	11	55 to 78	85 to 107	89 to 109	Slate	90 to 112	50 and 90	Brackish water
25		Mannibadar	640376	4	30 to 50	35 to 65	76 to 94	Unknown	100	–	
26		Mannibadar	630378	4	70	35 to 82	105	Unknown	62 to 114	–	
27		Charkesdale	703403	2	157	130 to 190	130 to 190	Slate	139 to 200	34	
28		Charkesdale	755405	5	Zero	–	90	Slate and sandstone	94	Nil	Tertiary sediments resting on Ordovician sediments
29		Charkesdale	708410	7	75	102	180	Slate	180	–	
30		Charkesdale	722418	5	36 to 63	60 to 75	80	Slate	86	35	
31		Charkesdale	719423	5	94 to 120	100 to 153	100 to 160	Slate	110 to 170	60	Outside area (not shown on map)
32		Charkesdale	713428	5	60 to 100	66 to 113	100 to 120	Slate	70 to 130	–	
1	Lismore	Geelengla	103161	1	106	107	Unknown	–	107	Nil	
2		Geelengla	116158	1	172	206	220 225	Limestone Hornfels	240	–	Water seepage at 82 to 86 feet & porous basalt 165ft
3		Geelengla	125157	1	174	196	200 202	Limestone Hornfels	222	Nil	
4		Geelengla	127180	1	47	53	Unknown	–	83	53	
5		Geelengla	133181	1	72	72	130	Granite	150	Nil	
6		Geelengla	137182	1	43	43	Unknown	–	100	Nil	
1	Skipton	Yangerahwill	Topographic map at 1:63,360 not available	3	156 to 191	163 to 199	163 to 207	Sandstone	179 to 217	Nil	
2		Yangerahwill		3	88 to 219	204 to 237	210 to 283	Sandstone and slate	225 to 295	75	
3		Yangerahwill		5	225 to 369	245 to 382	250 to 385	Sandstone and slate	260 to 400	117	Brackish in one hole
4		Yangerahwill		4	152 to 210	170 to 228	172 to 234	Sandstone and schist	220 to 240	Nil	
5		Lillirie		5	0 to 14	0 & 50 to 69	100 to 190	Granite	105 to 194	Nil	Granite covered by granitic drift and clay. Thickness 26 to 53ft.

DETAILED AEROMAGNETIC SURVEY,
WESTERN VICTORIA,
1967

LOCALITY MAP



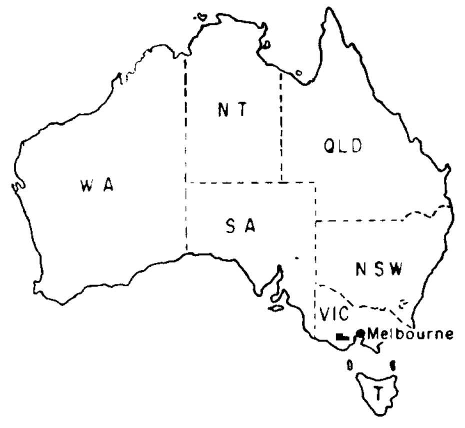
BASED ON J54/B0-1, J54/B1-43

SCALE

MILES 10 0 10 20 30 40 MILES

KILOMETRES 10 0 10 20 30 40 50 60 KILOMETRES

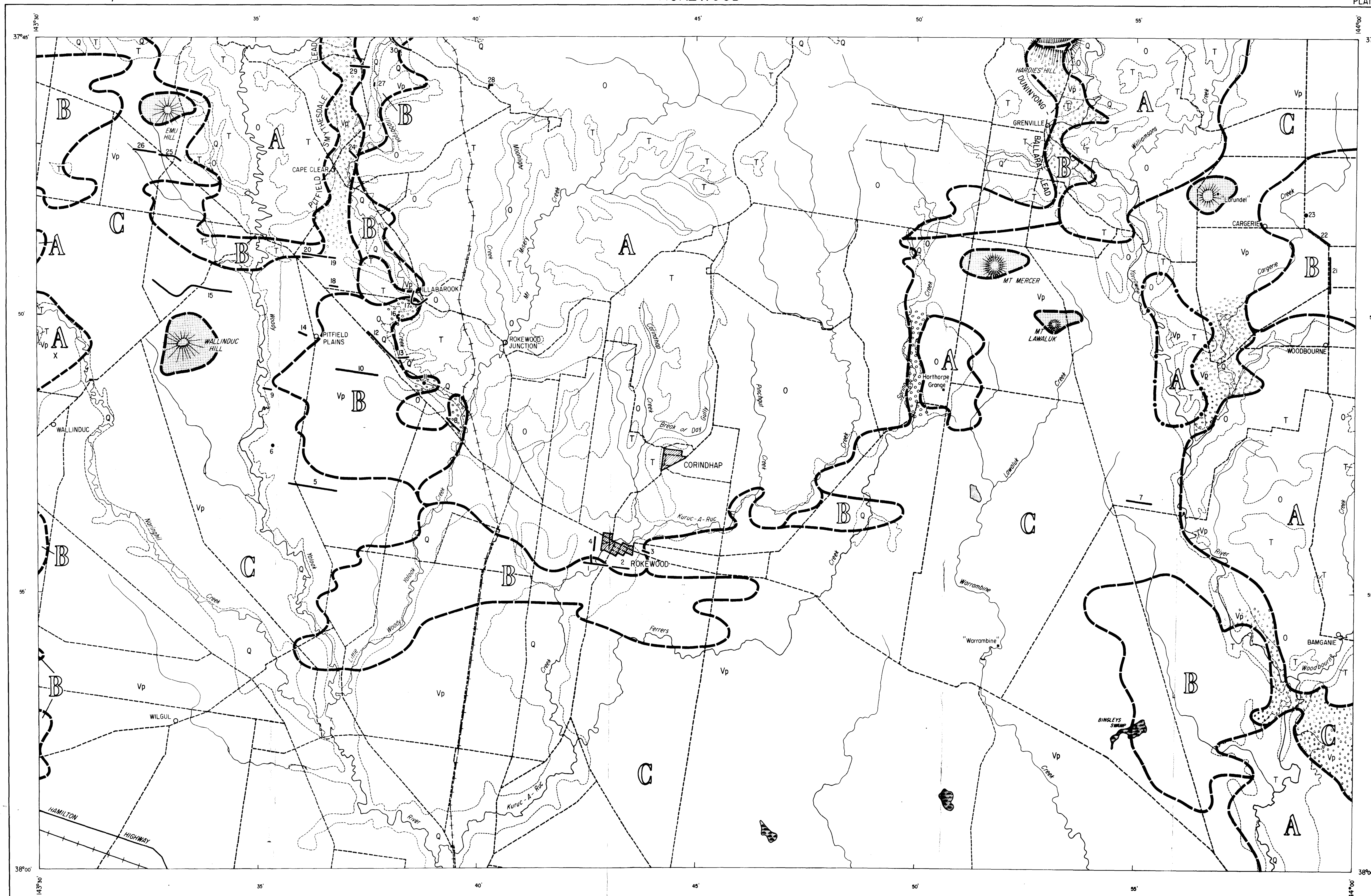
LOCALITY DIAGRAM



LEGEND

- Highway
- River or creek
- Railway
- Lake or reservoir
- Drill hole, named for reference
- Mountain or hill
- Built-up area
- Anticlinal thrust belt
- Town
- Boundary of survey area

J54/B1-41



BASED ON J54/B0-20, J54/B0-23, J54/BI-27

GEOLOGICAL LEGEND

SEDIMENTARY ROCKS

QUATERNARY	Q	
TERTIARY	T	
ORDOVICIAN	O	*Slate, sandstone, sub-greywacke, mudstone.*

IGNEOUS ROCKS

TERTIARY	NEWER VOLCANICS Vp	*Basalt, tuff, scoria.*
POST-ORDOVICIAN (Palaeozoic)	X	*Granite, granodiorite.*

Geological boundary

6 *Position of single drill hole numbered for reference*

10 *Position of group of drill holes numbered for reference.*

NOTES

GEOLOGY AFTER 1:250,000 SCALE GEOLOGICAL SHEET, BALLARAT, NO. S J54-8, PROVISIONAL EDITION, 1965, MINES DEPARTMENT, VICTORIA.

INDEX TO ADJOINING SHEETS

SKIPTON	BALLARAT	BALLAN
LISMORE	ROKEWOOD	MEREDITH
CORANGAMITE	BEEAC	GEELONG

GEOPHYSICAL INTERPRETATION AND GEOLOGY

MILES 1 0 1 2 3 4 5 6 MILES

KILOMETRES 1 0 1 2 3 4 5 6 7 8 9 KILOMETRES

GEOPHYSICAL LEGEND

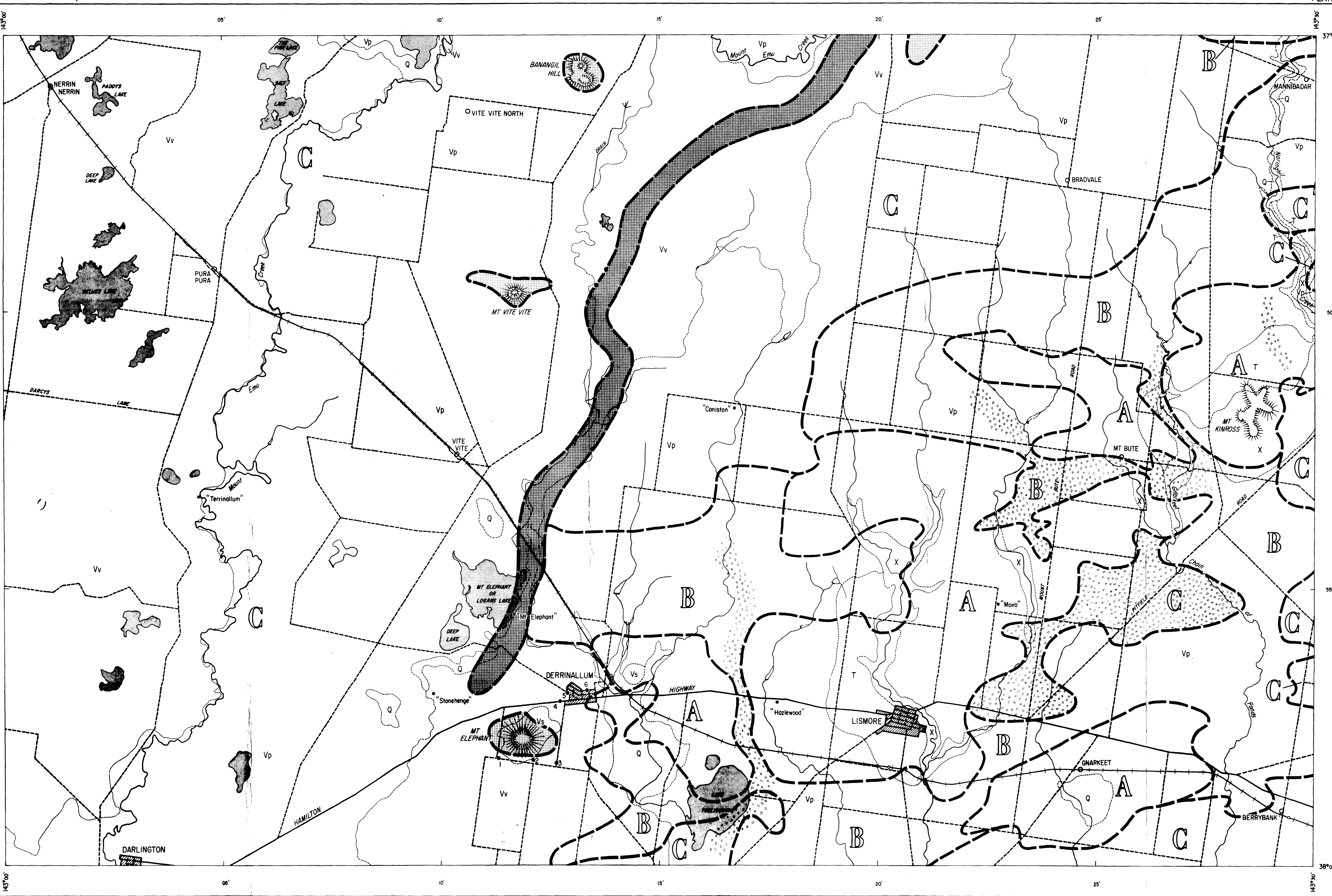
- *Zone boundary, definite*
- *Zone boundary, tentative*
- A — *Magnetic zone; free from superficial basalt.*
- B — *Magnetic zone; probably covered by thin and/or weathered basalt.*
- C — *Magnetic zone; probable areas of thick fresh basalt.*
- *Probable volcanic neck or cone*
- *Buried river valley*

TOPOGRAPHICAL LEGEND

- *Highway*
- *Road or track*
- *Railway*
- *Abandoned railway*
- *River or creek*
- *Dam*
- *Lagoon*
- *Swamp*
- *Mountain or hill*
- *Town*
- *Named place*
- *Homestead*

J54/BI-30

To Accompany Record No. 1968/146



BASED ON J54/B0-21, J54/B0-24, J54/B1-28

GEOLOGICAL LEGEND

SEDIMENTARY ROCKS

QUATERNARY	Q	
TERTIARY	T	

IGNEOUS ROCKS

QUATERNARY	NEWER VOLCANICS	Vs	*Basalt scoria.*
		Vv	*Basalt - stony rises, valley flows in part.*
TERTIARY		Vp	*Basalt, tuff, scoria.*
POST-ORDOVICIAN (Palaeozoic)		X	*Granite, granodiorite.*

Geological boundary

3 *Position of single drill hole numbered for reference*

NOTES

GEOLOGY AFTER 1:250,000 SCALE GEOLOGICAL SHEET, BALLARAT, NO. S J54-8 PROVISIONAL EDITION, 1965, MINES DEPARTMENT, VICTORIA.

INDEX TO ADJOINING SHEETS

WILLAURA	SKIPTON	BALLARAT
CHATSWORTH	LISMORE	ROKEWOOD
MORTLAKE	CORANGAMITE	BEEAC

GEOPHYSICAL INTERPRETATION AND GEOLOGY

MILES 1 0 1 2 3 4 5 6 MILES

KILOMETRES 1 0 1 2 3 4 5 6 7 8 9 KILOMETRES

GEOPHYSICAL LEGEND

Zone boundary, definite

Zone boundary, tentative

A *Magnetic zone; free from superficial basalt.*

B *Magnetic zone; probably covered by thin and /or weathered basalt.*

C *Magnetic zone; probable areas of thick fresh basalt.*

Probable volcanic neck or cone.

Buried river valley.

Trend of magnetic zone 6

TOPOGRAPHICAL LEGEND

Highway

Road or track

Railway and station

River or creek

Dam

Lake

Mountain or hill

Town

Named place

Homestead

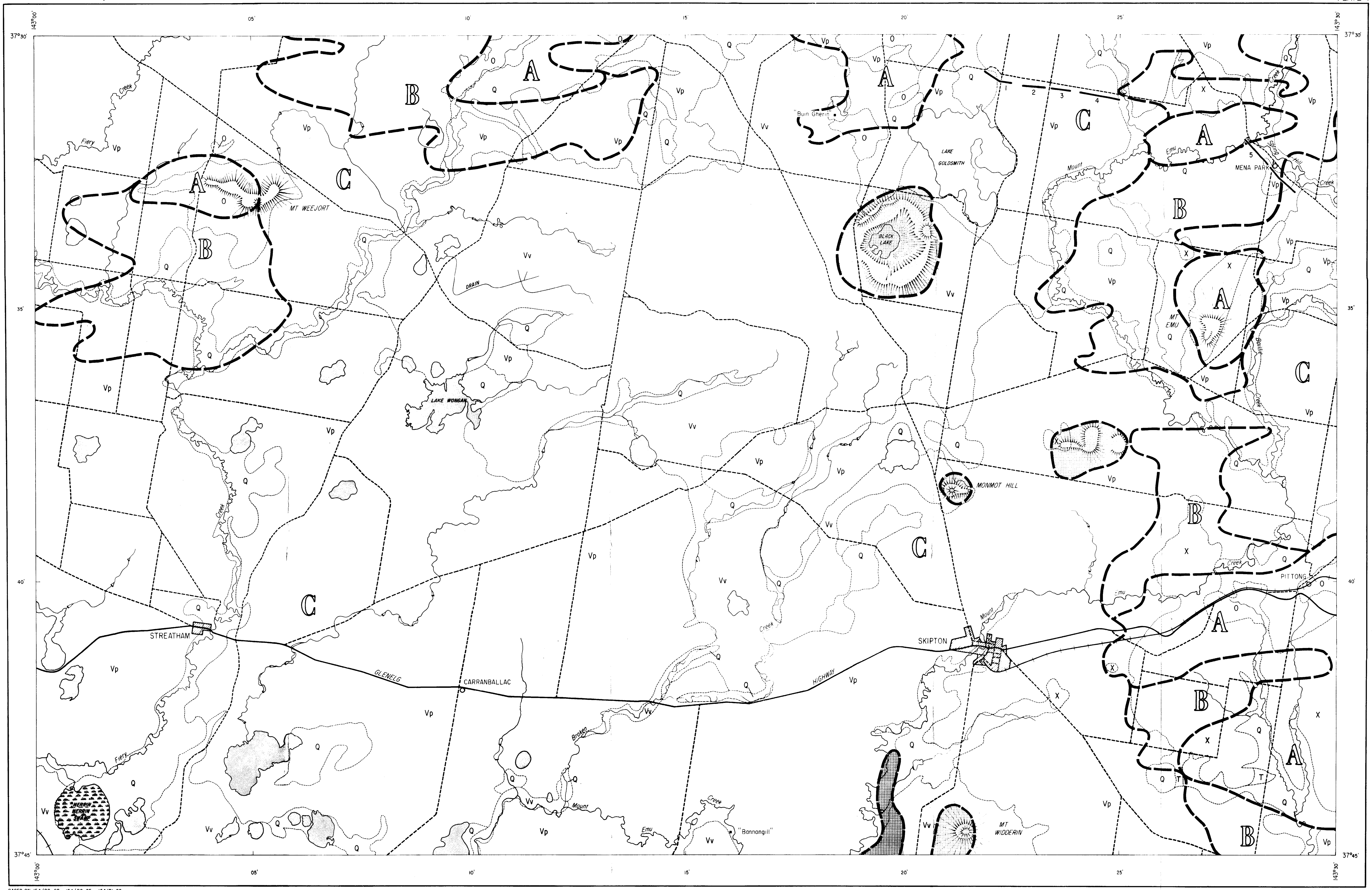
J54/B1-31

To Accompany Record No. 1968/146

AUSTRALIA 1:63,360

SKIPTON

PLATE 4



BASED ON J54/BO-22, J54/BO-25, J54/BI-29

GEOLOGICAL LEGEND

SEDIMENTARY ROCKS

QUATERNARY — Q

TERTIARY — T

ORDOVICIAN — O — *Slate, sandstone, sub-greywacke, mudstone.*

IGNEOUS ROCKS

NEWER VOLCANICS:

QUATERNARY — Vv — *Basalt - stony rises, valley flows in part.*

TERTIARY — Vp — *Basalt, tuff, scoria.*

POST-ORDOVICIAN (Palaeozoic) — X — *Granite, granodiorite.*

Geological boundary

3 — *Position of group of drill holes numbered for reference.*

NOTES

GEOLOGY AFTER 1:250,000 SCALE GEOLOGICAL SHEET, BALLARAT, NO. S J54-8 PROVISIONAL EDITION, 1965, MINES DEPARTMENT, VICTORIA.

INDEX TO ADJOINING SHEETS

ARARAT	BEAUFORT	CRESWICK
WILLAURA	SKIPTON	BALLARAT
CHATSWORTH	LISMORE	ROKEWOOD

GEOPHYSICAL INTERPRETATION

AND

GEOLOGY

MILES 1 0 1 2 3 4 5 6 MILES

KILOMETRES 1 0 1 2 3 4 5 6 7 8 9 KILOMETRES

GEOPHYSICAL LEGEND

Zone boundary, definite

A — *Magnetic zone; free from superficial basalt.*

B — *Magnetic zone; probably covered by thin and/or weathered basalt.*

C — *Magnetic zone; probable areas of thick fresh basalt*

Probable volcanic neck or cone

Trend of magnetic zone 6

TOPOGRAPHICAL LEGEND

Highway

Road or track

Railway and station

River or creek

Dam

Lake

Swamp

Mountain or hill

Town

Named place

Homestead

J54/BI-32

To Accompany Record No. 1968/146