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TASMANIA AEROMAGNETIC SURVEY, 1966

by

W.A. FINNEY and E.P. SHELLEY

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ILLUSTRATIONS

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SUMMARY

An airborne magnetic survey was flown over Tasmania and over the adjoining ocean to about 100 miles off the east and west coasts at an altitude of 10,000 ft and a line spacing of 10 nautical miles in order to provide information on deep crustal bodies.

The land area has been divided into zones based on magnetic character, the zones showing good correlation with major geologic and tectonic features.

Estimates of depth to magnetic basement have been calculated for most anomalies in the off-shore area. A contour map based on the most reliable of these values indicates that the magnetic basement is at or near the sea floor over most of the area, although several deep troughs are delineated.

A number of suitable anomalies were subjected to a more detailed analysis to determine the shapes, attitudes, and susceptibilities of the sources.

1. INTRODUCTION

The Bureau of Mineral Resources has considered for several years the possibility of using the airborne magnetometer at high altitudes as a means of providing useful information on deep crustal bodies. Tasmania was chosen as a suitable area in which to examine the usefulness of this type of survey as each traverse would sample the magnetic effects of two land-sea contacts and known major geological structures such as dolerite sheets and large grabens.

By recording the magnetic data at a high altitude, the magnetic effect of a surface or near-surface body is greatly reduced, provided that the dimensions of the body are not great in comparison with its distance from the detector. In this way the magnetic expression of deeper, larger bodies is more clearly seen and a resolution of major magnetic features and the deep magnetic basement is made possible. With these ideas in mind the altitude and line spacing were set at 10,000 ft above sea level and 10 nautical miles respectively. The methods of navigation and position control are described in Appendix B.

Previous regional airborne work covered a large area off the south-eastern coast of Victoria from Gippsland in the east, through the Bass Strait to Encounter Bay and Kangaroo Island in the west. This was flown by Aero Service Ltd, in 1961 for Haematite Explorations Pty Ltd to assess the petroleum prospects in the area (Haematite Explorations Pty Ltd, 1965). The greater part of the area was flown at 2000 ft above sea level. Anomalies encountered were of the order of 250 gammas with maximum values of approximately 500 gammas. Interpretation of the data indicated that the magnetic basement was from 1000 to 12,000 ft below sea level.

The Bureau of Mineral Resources also carried out on-shore and off-shore aeromagnetic surveys of the neighbouring Gippsland Basin in 1951-52 and 1956 (Quilty, 1965).

Detailed aeromagnetic surveys were made by the BMR over three small areas in north-west Tasmania in 1955 and 1956. These were the Savage River, Nelson River, and Hampshire-Blythe River districts. They were flown at a nominal altitude of 500 feet above ground level, and so the results are only of limited value in the interpretation of the high-level data.

Geophysicists from seven universities, the Bureau of Mineral Resources, and several mining and exploration companies co-operated in the Bass Strait Upper Mantle Project (BUMP) during February 1966. The object of the project was to investigate by seismic methods the material of the upper mantle under Bass Strait, to determine the thickness and composition of the Earth's crust in this region, and to add more detailed knowledge of the sedimentary layers at the top of the crust to that already determined by other geophysical methods. The results of this seismic investigation are not yet available.

The high-level aeromagnetic survey described in this Record was made during February and March 1966 over Tasmania and the adjoining area of ocean off the east and west coasts (Plate 1). The survey was made with the co-operation of Professor S.W.Carey and members of the Staff of the Department of Geology, University of Tasmania. In particular, the authors would like to acknowledge the help of Mr B.D. Johnson in carrying out the spectral analysis interpration.

2. GEOLOGY

Because of the nature of the survey, only an analysis of igneous activity and tectonics has been attempted; sedimentary rocks have been to a large extent ignored. This is considered satisfactory because only the rocks of high magnetic susceptibility, usually basic igneous and metamorphic rocks, will greatly affect the magnetic field at an altitude of 10,000 ft above sea level. Also, some of the outcropping igneous rocks are likely to be representative of deep-seated magma, the magnetic effects of which might be detected by measuring the magnetic field at a high level.

The tectonic history of Tasmania since the Precambrian Frenchman Orogeny can be divided into three stages (Spry, 1962):

1. The Geosynclinal Stage extending from late in the Precambrian to the Devonian, characterised by thick sedimentation, but with vulcanism restricted to a comparatively brief but violent phase in the Cambrian.

2. The Orogenic Stage of the middle Palaeozoic when folding was followed by what appear to be the only true plutonic granites in Tasmania.

3. The Epeirogenic Stage when the thin marine sediments of the Permian were followed by the thin terrestrial beds of the Mesozoic and Tertiary; tectonically this stage was characterised by faulting but not folding and large volumes of basic magma were erupted in Jurassic and Tertiary times with very minor intermediate intrusions in the Cretaceous.

During the Precambrian a large stable block (Tyennan Geanticline) was located in the centre of the island and a smaller block (Rocky Cape Geanticline) in the north-west. Several arcuate basins developed between and around these masses during Cambrian and Lower Ordovician times but from the Ordovician to early Devonian the entire island was probably submerged. The structural pattern established in the early Palaeozoic was accentuated during early Tabberabberan deformation but later was partly obscured by superimposed north-west folds, north-east faults, and north-south shear zones (Carey, 1953).

The following brief notes on the tectonics and igneous activity of the geologic periods are mainly derived from "The Geology of Tasmania" (J. Geol. Soc. Aust. 9 (2), 1962). A summary of the relationship of igneous activity to tectonic evolution is presented in Appendix A.

Precambrian. Two associations of igneous and metamorphic rocks have been recognised, but their relationship is difficult to interpret. They are thought to be separated by a phase of metamorphism and tectonic activity, the Frenchman Orogeny (Spry, 1957).

Late Precambrian intrusive activity was extensive and doleritic sills and dykes intrude older and younger Precambrian rocks. The Penguin Movement in the middle or late Proterozoic did not result in widespread folding but either reduced the rate of sedimentation or brought about extensive erosion of the late Proterozoic or Lower Cambrian sediments.

Cambrian. By the Middle Cambrian, the Tyennan Geanticline had risen in the centre of Tasmania. It plunged fairly steeply north near Lorinna but probably reappeared further north near the present coast; its western and northern margins seem to have been sharp and were possibly faulted. To the north-west, the Rocky Cape Geanticline was probably emergent (Solomon, 1962).

It has been suggested (Carey, 1947) that during deposition of the Dundas Group there was a narrow arcuate belt of volcanoes that stood off-shore around the margins of the Tyennan Geanticline, probably related to deep-seated fractures fringing the Tyennan structure.

From the Middle to the Upper Cambrian, Tasmania lay within the Tasman Geosynclinal Zone, and the Tasmanian sedimentary basins consisted of elongate, relatively narrow, inter-ridge basins that subsided independently and erratically. The sedimentation was accompanied by considerable volcanic and intrusive igneous activity.

Three groups of igneous rocks have been recognised:

1. Alkaline lavas and pyroclastics ranging from acid to basic, the most common lavas being spilites, keratophyres, rhyolites, and trachytes.

2. Minor intrusive rocks including dolerite, gabbro, syenite, and minor granite.

3. Ultrabasic complexes containing serpentinites and pyroxenites with subsidiary periodotites, dunites, and gabbros.

Ordovician. The Jukesian Movement in the late Cambrian or early Ordovician was marked by horst and grabben type tectonics. The major parts of the old geanticlines formed prominent positive features, the principal sedimentation zone forming a 90° arc around the Tyennan Ridge together with smaller basins around and within the Tyennan and Rocky Cape structures.

The Tyennan Geanticline was rejuvenated late in the Cambrian or early Ordovician during the Jukesian Movement producing a zone of steeply dipping Cambrian rocks along the western side of this geanticline.

Devonian-Carboniferous. Deposition ceased during the Devonian and was not resumed till the late Carboniferous or Permian. The Tabberabberan Orogeny took place between the early Lower Devonian and late Middle Devonian. Structural trends seem arcuate around the Tyennan Geanticline parallel to the margin. The Tyennan Geanticline was involved in all phases of the orogeny yet acted as a stable block that strongly influenced the deformation pattern (Solomon, 1962).

Acid to intermediate plutonic bodies were intruded after the Tabberabberan Orogeny. These intrusions have cross-cutting relationships, sharp margins, and very narrow contact aureoles. The most abundant rock type is a coarse granodiorite or adamellite (Spry, 1962).

Jurassic. Large-scale intrusion of a tholeiitic magma took place during the Middle Jurassic. More than 2000 cubic miles of magma formed a nearly continuous body through the Permian and Triassic sediments over almost all of Tasmania. The dolerite occurs mostly in the form of discordant sheets or sills and occasionally steep-sided dykes. Evidence points to a single short-lived period of intrusion during which the magma quickly moved up into the crust. This favours the view that a thick tholeiitic layer of uniform composition occurs near the base of the crust. The dolerite mostly appears as a single body made up of interconnected sheets about 1500 ft in thickness, which resists erosion and tends to dominate the landscape (Spry, 1962).

At several localities, cone-sheets have been produced. These cones in the basement appear to dip at about 40° but flatten to 25° or less through much of the Permian and to 10° or less in the Triassic, where very extensive true sills occur (Carey, 1958).

Cretaceous. Several stocks of porphyritic syenite and a radial dyke swarm of various alkaline intermediate porphyries occur at Cygnet. Carey (1958) considered that the Jurassic dolerite invaded the Permo-Triassic strata from an orifice approximately coincident with the later Cygnet alkaline syenite. This was taken to mean that the dolerite and syenite might be genetically related and of similar age.

Cainozoic. The Cainozoic era in Tasmania was marked by faulting, comparatively slight sedimentation, and widespread basic vulcanism.

Volcanic rocks crop out over 1600 square miles. Sources of many flows cannot be found but almost 30 volcanic centres have been mapped and several of these are located on Tertiary faults. Most flows are between 30 and 60 ft in thickness and the greatest thickness of volcanics is 1300 ft.

The volcanics are mainly olivine basalt flows, but appreciable deposits of pyroclastics occur near the volcanic centres.

3. MAGNETIC RESULTS AND INTERPRETATION

The magnetic profiles have been reduced from the original charts to a horizontal scale of 1:506,880 (8 miles per inch). The vertical scale of the profiles varies from line to line and within each individual line but is approximately 150 gammas per inch. Plate 1 shows the profiles superimposed on a geological map supplied by the Department of Mines, Tasmania.

The profiles are accurately positioned near the east and west coasts and in most cases two other control points near longitude 147°E have been used. The maximum probable error on land at intermediate locations is $\pm$ 2 miles east-west.

In the off-shore sections of the profiles, the positional control varies considerably from line to line. In lines 8 to 11 and 16 to 19 over the eastern off-shore area and in lines 14 to 19 over the western off-shore area, the maximum probable error is ± 3 miles east-west, occurring approximately 55 miles from the coast. The error at the ends of these lines is ± 1½ miles. On all other lines with the exception of line 7 in the western off-shore area and line 20 in the eastern off-shore area, the maximum probable error is ± 5 miles east-west, occurring 55 miles from the coast and ± 3 miles at the ends of the lines. On lines 7 and 20 mentioned above the error is ± 8 miles at the ends of the lines.

The north-south error in the positioning of the profiles varies considerably. Over land the maximum probable error is ± 1 mile. At sea it is generally within ± 2 miles, but in some places the error increases to ± 6 miles, and in one case it could be as large as 10 miles (see Appendix B).

Plate 2 is a magnetic contour map constructed from the profiles and superimposed on a geological base.

The interpretation of the magnetic data is mainly qualitative over the land, and the area has been zoned on the basis of magnetic character (Plate 3). Interpretation of data in the off-shore area has been confined to determinations of the depths, attitudes, and other parameters of the sources of the anomalies. Estimates of the depth to magnetic basement have been made wherever possible and this basement has been contoured at an interval of 5000 ft (Plate 3). The various methods of obtaining the depth estimates are discussed in Appendix C. Where several estimates have been obtained by different methods in one locality the mean value has been used to control the basement contours in that area.

<u>On-shore area</u>

The land mass of Tasmania has been zoned on the basis of the character of the magnetic profiles. These zones show good correlation with known geology and are described below.

<u>Zone A</u> is located in the north-east corner of Tasmania. The magnetic field is generally uniform with only a few small anomalies up to 50 gammas in amplitude. It corresponds to an area of Devonian granite and Silurian and Devonian non-magnetic sedimentary rocks. The zone extends for some 20 miles off the north-eastern coast and probably extends northwards to Flinders Island, where granitic rocks have been mapped.

<u>Zone B</u> occupies most of the eastern half of the State. It is characterised by high frequency magnetic disturbance with anomalies whose amplitudes are in the range 20 to 200 gammas. Some anomalies could be traced from one line to an adjoining line but generally lineations were very obscure.

The zone corresponds to the area of outcrop of the Jurassic dolerite. No definite anomaly could be attributed to the large cone-sheet at Great Lake although an anomaly of 230 gammas coincides with the volcanic centre near Cygnet.

<u>Zone C</u> is a large north-south elongated zone in the west and south-west parts of the island. It is magnetically flat with anomalies not exceeding 20 gammas. It corresponds to the area of Precambrian rocks and some Ordovician and Devonian sediments.

<u>Zones D and E</u>. Zone D is elongated north-north-west and lies approximately midway between Queenstown and Hobart. Zone E trends north-north-east from Queenstown for about 50 miles and then swings east towards Deloraine.

These two zones are characterised by anomalies of about 150 gammas in amplitude which have pronounced trends. Calculations of depths to the sources of the anomalies indicate that the sources lie between 2000 and 6000 ft below ground level. Both zones coincide with areas mapped as Cambrian, Ordovician, Silurian, and Devonian sedimentary rocks, but the amplitude and width of the anomalies suggest much deeper sources with moderately high susceptibility contrasts such as basic to ultrabasic igneous rocks. A narrow area of Cambrian ultrabasics has been mapped in the south of Zone D.

<u>Zone F</u>. This zone lies to the west and north of Zone E and extends as far east as Bridport. It contains anomalies with amplitudes in the range 50 to 500 gammas, the average being about 200 gammas. The trends of the anomalies are not definite although a number can be traced from one line to an adjoining line. The zone corresponds to an area of predominantly Cambrian, Silurian, and Devonian sedimentary rocks with ultrabasic intrusives and Tertiary basalts.

Depth calculations on a number of the anomalies up to 150 gammas amplitude put their sources at or just below ground level and these are thought to be basic and ultrabasic intrusive bodies. The anomalies of high amplitude are probably due to very ultrabasic masses lying between 8000 and 15,000 ft below ground level.

<u>Zone G</u> occupies the north-west corner of the State and a narrow strip along the west coast towards Queenstown. It is characterised by a relatively uniform magnetic field with anomaly amplitudes less than 30 gammas. It corresponds to an area of Precambrian rocks with some lower Palaeozoic sediments and granite.

<u>Zone H</u> lies along the western coast of Tasmania south from Queenstown. It contains anomalies with strong lineations ranging up to 250 gammas amplitude. It lies to the west of the main Precambrian block and corresponds to an area containing mainly Cambrian sedimentary and igneous rocks. The amplitude and width of the anomalies in this zone suggest that their sources are ultrabasic masses at or within 2000 ft of ground level. Banks (1962) has stated that ultrabasic intrusions appear to be concentrated near the contact between the Precambrian and Cambrian rocks along the margins of structural 'highs'.

A magnetic 'low' extending for about 40 miles over Oyster Bay is probably due to the non-magnetic material of the Oyster Bay Graben (<u>J. Geol. Soc. Aust.</u> 9 (2) Fig. 39) contrasting with the dolerite to the west and the postulated more basic rock to the east.

The magnetic 'low' expected from the Macquarie Harbour Graben (loc. cit.) is completely masked by anomalies due to postulated basic intrusive sources in zone H. The Midlands and Derwent Grabens (loc. cit.) do not appear as magnetic 'lows'; this is probably due to the magnetic effects of the underlying dolerite and intrusions within the sediments.

Western off-shore area

Magnetic anomalies detected off the western coast have relatively low amplitudes and only three are greater than 250 gammas. The mean amplitude is approximately 100 gammas.

The magnetic field in the southern part of the area is much less disturbed than in the north; anomalies tend to have lower amplitude and longer wavelength. Anomaly widths are of the order of 8 to 10 miles with a few up to about 20 miles. This suggests that the anomaly sources also have widths of this order. Profiles 19 and 20 show what appears to be a broad anomaly about 50 miles wide, but the greater detail of the original chart indicates that these are made up of at least three anomalies and are not due to a single homogeneous source.

Anomalies on lines 3, 4, and 5 are similar in character to some in the northern part of zone F and it is suggested that a region similar to zone F exists on the western side of the Precambrian block and that the anomalies are possibly due to basic intrusives within Cambrian sediments. The anomalies near the coast on lines 6 and 7 are probably due to basic bodies at a depth of 6000 to 8000 ft below sea level. Anomaly 1 (Plates 1 and 3) has been analysed quantitatively by several methods and calculations indicate a source with a susceptibility of the order of 1.6×10^{-3} c.g.s. This suggests a source of basic character.

The sources of some magnetic anomalies with an east-west extent of up to 10 miles do not appear to have very large north-south extent because they are detected clearly on one line only, their magnetic expression on neighbouring lines being very small. One example is Anomaly 2 on line 9 (Plates 1 and 3). The source in this case deviates considerably from the model used in the depth determination but, as the cross-sectional dimensions of the source are much greater than the depth from the detector, the deviation is not considered to be too serious. A possible source of this anomaly is a body with large vertical extent and very steep dip such as a volcanic plug or neck. The top surface of the source is approximately 16,300 ft below sea level.

The magnetic basement contour map of the western off-shore area indicates that the basement rises in several places to near the sea floor. No very deep features were delineated and the deepest trough about 70 miles west of Macquarie Harbour is 10,000 to 12,000 ft below the sea floor. A deep depression is indicated just west of Nelson Bay, the basement rising quite steeply north of this to less than 3000 ft below the sea floor.

Eastern off-shore area

The magnetic contour map (Plate 2) shows clearly that magnetic anomalies detected over this area are greater in amplitude than those in the western off-shore area. The most significant feature is the large amplitude anomaly detected 60 miles off the coast with a north-south extent of 80 miles between latitude 41°30'S and 42°50'S. South of latitude 42°50'S the amplitude falls off rapidly, indicating a sharp cut-off or perhaps a displacement to the east beyond longitude 150°20'E.

A 12-mile eastward displacement of the peak of the main anomaly occurs at latitude 42°15'S. A similar displacement at latitude 42°55'S could account for the cut-off of the main peak. North of latitude 41°20'S the trend of the anomaly swings from north to N30°W and the source appears to deepen. Alternatively the broad anomaly north of 41°20'S (Plate 1) might be due to an entirely different source.

The source of the large feature must have considerable depth extent in order to produce an anomaly of approximately 500 gammas in amplitude at the detector, which is at least 20,000 ft above the source. Anomaly 3 on line 10 (Plates 1 and 3) typifies this feature and a quantitative analysis indicates that the source, if assumed prismatic with a horizonatl upper surface, is 13,000 ft below sea level. This would place the upper surface of the source at the sea floor in this region. The susceptibility contrast, assuming the body to be homogeneous, is 3.25×10^{-3} c.g.s. The body is approximately 44,500 ft in width and dips to the west at 60°. A possible source of this feature is a large basic block such as extensive thick lava flows or a line of volcanic centres. A submarine volcano, Mount Woolnough, is known to exist at the edge of the continental shelf off the eastern coast of New South Wales. The volcanic centres postulated here would be much further from the coast, approximately at the bottom of the continental slope.

The elongated appearance of this source would suggest a horst-type of structure or wedge of mantle material thrust up to the sea floor. A third possibility is that this feature reflects a continuation to the south of a large south-trending geanticlinal structure, the Mitta Mitta Geanticline, which is known in eastern Victoria. This structure is known to have ultrabasic intrusives along its margins. This suggestion requires extrapolation over very long distances with no supporting geophysical evidence in the intermediate area in Bass Strait and hence must be treated as highly speculative.

The large amplitude anomaly is very similar in width and amplitude to one detected near the edge of the continental shelf off the eastern coast of North America (Watkins & Geddes, 1965). Seismic results showed that the anomaly peak was over or on the shoreward flank of a basement ridge. It was suggested that the basement ridge is formed by a buried quiescent island arc and that the anomaly is caused by intrusive and extrusive rocks associated with the earlier development of the arc. This hypothesis is not inconsistent with the first structure proposed to account for the large anomaly off the east coast of Tasmania.

The magnetic basement contour map in this area (Plate 3) indicates a number of depressions and 'highs' resulting in a doming effect. The exact areal extent of these domes is difficult to determine owing to insufficient depth estimates, but the general pattern is indicated. The deepest part of the basement, more than 20,000 ft below the sea floor, occurs in the south, with a fairly rapid rise to the north-west where the basement rises to near the sea floor.

The magnetic basement in the area of the major magnetic feature about 70 miles off-shore varies in depth by as much as 10,000 ft, but over a large region it is very close to the sea floor. Further north the basement deepens generally, but isolated 'highs' have been interpreted as shown in Plate 3.

Near both the western and eastern coasts of Tasmania, the magnetic basement is at sea level. Proceeding seawards off the west coast the basement deepens fairly regularly in contrast with the eastern side where large irregulatirites in basement gradient are interpreted in several places. For example, an extensive basement depression occurs about 10 miles east of Seymour, whereas east of Oyster Bay the basement reaches similar depths about 50 to 60 miles off-shore.

<u>Magnetic profiles along BUMP traverses</u>

During the two flights between Melbourne and Hobart, magnetic data were recorded along two traverses which approximated the eastern and western seismic traverses of the Bass Strait Upper Mantle Project (Plate 4). The eastern traverse was flown from just west of Wonthaggi to Warrego Rock at an altitude of 7500 ft above sea level and from Warrego Rock to Oatlands at 10,000 ft. The western traverse was flown from south-east of Great Lake to a point 25 miles north-east of King Island at an altitude of 10,000 ft above sea level. A regional magnetic gradient of 6.1 gammas per mile in a direction S23^{o}W has been removed from the data shown in Plate 4, which also shows determinations of the maximum depths to magnetic sources.

The eastern traverse is relatively undisturbed, with the exception of two anomalies west of Wilsons Promontory. These two anomalies (of 300 and 150 gammas amplitude) have their sources at less than 1000 ft below sea level and are probably due to basic rocks (cf. Haematite Explorations Pty Ltd, 1965, p. 20). The aeromagnetic survey by Haematite Explorations Pty Ltd shows that in the area of the eastern traverse the magnetic basement is shallow. Their results as recorded at 2000 ft above sea level, show very low magnetic relief in the northern part of the traverse, whereas in the area of the southern leg of the traverse anomalies up to 300 gammas in amplitude were observed. However, these are narrow anomalies and are probably due to shallow bodies of limited depth extent. The attenuation of these anomalies is such that at an altitude of 10,000 ft they are not recorded.

The depths calculated from the western traverses systematically differ by plus 2000 to 3000 ft from those obtained by Haematite Explorations Pty Ltd in their interpretation of the Bass Strait survey. The difference is probably due to the fact that the former values are uncorrected for strike. The depth of 23,000 ft calculated for the anomaly 12 miles north-west of Burnie agrees favourably with the concept of a deepening trough as shown in Plate 3. This anomaly is probably from a much deeper magnetic horizon than the other anomalies along the traverse. The short wavelength anomalies at the southern end of the western traverses are due to the Jurassic dolerites.

Spectral analysis

As the data were available in digital form, it was possible to perform a spectral analysis of the data with the aid of a digital computer. The development of a suitable programme and the subsequent analysis of the results was carried out by B. D. Johnson, a research student in the Department of Geology, University of Tasmania.

The spectral analysis was applied to line 8, which is an east-west profile just south of Launceston and which extends approximately 70 miles off-shore on both sides of Tasmania. The treatment of the data consisted essentially of performing a Fourier analysis and plotting the logarithm of the sum of the squares of the Fourier coefficients against the wave number on semi-log graph paper (see Plate 5). By making assumptions regarding the existence at certain horizons of sources producing all frequencies one can obtain from the gradients of various parts of the graphs estimates of the depths to these horizons. Details of the analytical procedure are given in Appendix D.

The results of the analysis indicate a horizontal variation in the magnetic structure of the crust. Plate 6 is a representation of the magnetic structure deduced from the results obtained by analysing line 8. The depths to the magnetic horizons is in part agreement with those obtained by other methods discussed earlier. However, in general the depth estimates tend to be much greater than those obtained by calculations from profiles and, in particular, the deepest estimates have not been resolved by working from the original analogue charts.

A point of interest is that the magnetic basement in the off-shore areas has been determined as a single continuous surface by the application of the methods of Peters (1949), Gay (1963), and Moo (1965), whereas the spectral analysis has apparently delineated several distinct magnetic horizons. It is possible that both sets of results are partly true. It is very difficult to interpret more than one magnetic horizon by methods based on the analogue charts unless there are two or more distinct groups of depth estimates in any area. A large number of estimates is required to establish the true existence of two or more groups of different orders of value. The paucity of depth estimates in the off-shore areas, combined with the large horizontal distances between them, has led to an interpretation showing a single magnetic basement surface only (Plate 3), which might not be the actual case. In the spectral analysis the mathematical treatment requires resolution of the graphs in Plate 4 into sections of linear gradient. This is open to serious errors of judgement, but if successfully achieved, two or more horizons can be delineated.

4. CONCLUSIONS AND RECOMMENDATIONS

Tasmania has been divided into eight zones on the basis of magnetic character. These zones show a strong correlation with surface geology. Ultrabasic bodies extending for about 50 miles have been inferred to account for large anomalies detected in zone F. No large magnetic anomalies have been found underlying the extensive dolerite sheets in the east and south-east except at Cygnet where a possible dolerite feeder of great depth extent has been detected. A series of magnetic traverses over Great Lake in central Tasmania did not reveal a similar large source thought to exist in that area.

The western off-shore area is, in general, magnetically flat and magnetic basement is close to the sea floor over most of the area, although several troughs have been delineated. In the north-west the basement is very shallow and possibly reflects Cambrian sedimentation similar to that east of the Precambrian block in north-west Tasmania.

The eastern off-shore area has greater magnetic relief with a very pronounced anomaly extending 80 miles north-south approximately 60 miles off the coast. The magnetic basement is generally close to the sea floor but deep troughs descending to over 15,000 ft below the sea floor occur in several places.

Magnetic anomalies of wavelengths greater than 20 miles were not apparent on the profiles. This suggests that deep magnetic sources that would produce anomalies of this wavelength or greater, either do not exist, or, which is more likely, that large amplitude, small wavelength, anomalies are superimposed on the long wavelength anomalies making it impossible to separate the latter satisfactorily. Most of the interference due to the short wavelength anomalies has been reduced by surveying at high level, but sufficient remains to obscure the desired data.

One method of overcoming this problem would be to represent the magnetic data as a Fourier expansion and effectively smooth the data by extracting the higher frequency terms and reconstructing a residual contour map. To do this accurately it is necessary to obtain the original data on digital tapes free of errors and also to have accurate positional control at all times. In addition, an accurate knowledge of the geomagnetic field is necessary for interpretation by computing techniques.

The significant parameters of many anomalies were not clearly delineated by the use of a line spacing of approximately 10 nautical miles. A spacing of 2 to 3 miles would appear to be necessary for a complete delineation of the strike direction and areal extent of individual anomalies. Closer line spacing would require greater lateral control of flight lines, and this could be achieved by navigational aids such as D.M.E. or Doppler. These aids would be necessary for detailed surveying over the sea because dead-reckoning and the use of a drift-sight are not sufficiently accurate.

The survey altitude is chosen so as to obtain the best signal-to-noise ratio without attenuating the signal too much. The geological noise depends on the types of sources one expects to encounter. The methods available for the analysis of results are also an important factor. Interpretation methods based on the analogue charts require anomalies to be free from 'contamination', that is, the anomalies should be smooth with only one point of inflexion on each flank. This condition is more likely to be achieved at higher altitudes, where the noise from shallow sources of limited extent is very small, although the effects of shallow sources of great depth extent could still obscure the desired data from deeper horizons. If digital computing techniques are available for analysing the results then the signal-to-noise ratio becomes less important, as the data can then be analysed in terms of wavelength rather than amplitude. The altitude in this case could be reduced because this would increase the signal amplitudes and improve the accuracy of calculations of depth to the deeper magnetic horizons.

A point to be noted here is that if visual and photographic methods are used for recovery of the flight path then the error in final positioning tends to increase with altitude, and this becomes an important factor in detailed surveying.

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APPENDIX A

RELATIONSHIP OF IGNEOUS ACTIVITY TO TECTONIC EVOLUTION

(after Spry, 1962)

Age	Rock types	Geographic environment	Tectonic environment
Older Precambrian	Dolerites (now amphibolites)	Marine	Miogeosynclinal (?) (minor intrusions)
Younger Precambrian	Dolerites (Cooee) Basalts (Bernafai Volcanics)	Marine	Miogeosynclinal deposition with possible slight volcanism
Cambrian	Extrusive sodic, potassic, and sodipotassic lavas, and pyroclastics. Intrusive serpentinites	Marine	Eugeosynclinal (submarine and island arc deposition) Tyennan Orogeny
Devonian-Carboniferous	Major plutonic 'granite' intrusions	Marine	Miogeosynclinal deposition (no volcanics) followed by major orogeny. Granite after folding.
Permian	Meta-bentonite possibly of volcanic origin (slight importance)	Marine	Somewhat unstable continental shelf
Triassic	Tuffaceous (?) sandstone (slight importance)	Lacustrine	Somewhat unstable
Jurassic	Tholeiitic dolerite in extensive sheets	Lacustrine	Somewhat unstable
Cretaceous	Minor syenite-porphyry	Terrestrial	Stable
Cainozoic	Olivine basalts with some alkaline types	Chiefly Terrestrial	Epeirogenically affected craton

APPENDIX B

METHOD OF NAVIGATION AND POSITIONAL CONTROL

Positional control of the survey data varies considerably depending on the locality. This variation results from errors in navigation. No radio aids were available and only drift-sight readings were used to correct deviations from the desired flight path. By employing the services of a professional navigator the errors were reduced considerably. Further improvement occurred as the pilots and navigator obtained a 'feel' for the problem and more knowledge of the local wind vector, giving rise to reasonable results at the end of the survey.

For on-shore flights, aerial photomosaics and topographic maps were used for navigation. The procedure adopted as the best method in maintaining the desired flight path for off-shore flights is detailed below.

(a) A calculation of wind speed and direction was made by observing aircraft drift on three different headings. This is referred to as the multi-drift wind (M.D.W.)

(b) The predetermined flight path was commenced at least 20 miles inland from the coast and the drift continually monitored and checked against the drift expected from the M.D.W. value.

(c) At the coast the drift and ground speed were computed when possible, and, based on these calculations, the flight time to the end of the line was calculated.

(d) Over the sea, drift readings were taken by sighting on waves this being possible only when there is a surface wind of at least 15-20 knots. In addition if the sunlight was too bright, glare from the water made reliable readings difficult to obtain.

Smoke floats were used as markers on the sea with variable success. These could only be used when visibility was good. It was found that greater success resulted from using the smoke floats in pairs as, often, some did not burn. This was probably due to shattering on impact as they were only designed to be used from an altitude of 2000 ft or less. Attempts to measure the angle of the smoke trail were not successful.

(e) At the end of the line a 90° turn was made and after proceeding north or south for 10 nautical miles (estimated on flight time) a second 90° turn was made towards the coast. Prior to, and after, each turn, drift values were obtained and wind speed and direction calculated.

(f) An estimated time of arrival at the coast was calculated from the data in (c), (d), and (e) and this was checked against the actual time of arrival at the coast. The procedure as outlined in (d) was repeated on the return flight.

An east-west line of best fit between two plotted control points was used as the position of the flight line. The ends of each line were calculated from the results obtained in (a) to (f).

This method of navigation and flight path recovery is subject to considerable error arising from the magnitude of wind speed variations and visibility. Table 1 is a resume of the estimated errors in each line.

TABLE 1

Maximum probable errors in flight-line position

Line	Probable error (miles)					
	Off-shore western area		On land		Off-shore eastern area	
	E-W	N-S	E-W	N-S	E-W	N-S
3	3	3	¼	1		
4	3	1½	1	2	2	2
5	3	1½	1½	2	2	2
6	6	8	2	2	9	2
7	9	8	1½	2	9	3
8	6	2	1½	2	6	2
9	6	5 6	1½	2	3	3
10	2½	2½	1¼	2	3	2
11	2½	5	1	2	6	1
12	6	3	1	2	1½	3
13	6	5	1½	2	1½	5
14	5	2½	1½	2	5	5
15	5	5	1½	2	5	3
16	2	1	1	2	2	2
17	2	2	1	2	2	2
18	2	1	¾	2	2	2
19	2	2	½	2	2	2
20	2	2	½	2	8	2

APPENDIX C

METHODS OF DEPTH DETERMINATION

Depth determinations were made by the half-maximum-slope method of Peters (1949), the elaboration of this method by Moo (1965), and the method of 'curve-fitting' developed by Gay (1963).

The horizontal distances between points of half-maximum-slope vary between 1.2 times the depth for a thin sheet to 2.0 times the depth for the edge of a semi-infinite block. In most cases a factor of 1.6 was used, this being applicable to a body whose width is equal to about twice its depth. The method devised by Moo produces a more reliable factor than 1.6 but requires an anomaly which is relatively free of interference from neighbouring anomalies. Two other depth estimates are possible from the analysis and in several cases the average result has been quoted.

In general, comparisons between adjacent profiles did not enable adjustments to be made for depth determinations influenced by oblique intersections of magnetic contours with flight lines. The correction is a simple multiplication by the sine of the angle of intersection: hence, uncorrected depths, which occur frequently off the coast, are maximum estimates.

Systematic errors are introduced by the application of standard factors for depth determinations in areas where they are not appropriate. Anomaly interpretation by 'curve-fitting' methods (Gay, 1963) produce more reliable depth estimates providing the anomalies have simple forms. This method of depth determination was used wherever possible to establish control depths and further to provide anomaly analysis for local adjustment of half-maximum-slope factors.

APPENDIX D

SPECTRAL ANALYSIS PROCEDURE

The digital tape was first processed to search for errors, which were then eliminated or allowed for in the later programme. Sequencing errors were the most common, these arising from the digitiser in the aircraft, and were eliminated by interpolation between valid readings. An acceptance test was also applied to the data whereby each data point was tested to determine whether it lay within the range calculated from the two previous values. A minimum range was inserted to prevent equal adjacent values from giving a rejection of valid readings.

It was necessary to represent a complete magnetic traverse by less than 4000 readings, as this was the limit of the computer store. Line 8 and the BUMP traverse contained nearly 10,000 data points and were reduced by averaging successive groups of five readings.

The total field readings were converted to variations from a straight line determined by the averages of the first ten and final ten field values of each traverse. A spectral analysis of the remaining data was carried out using a modification of a standard programme. Line 8 was also analysed by dividing it into four sections, the two outer sections consisting of data obtained over the sea, and the two inner sections over the land. Three further sections of the same length, overlapping the original sections, were used to show the correspondence between each of the four original sections. The locations of these sections are shown on the locality diagram in Plate 5.

The analyses showed considerable variation in relative amplitudes, and more consistent results were obtained after removing a best fitting line by a least squares technique. The latter results are shown in Plate 5. Plate 6 is a representative cross-section of Tasmania along line 8 showing the magnetic horizons determined from calculations based on gradients on the graphs in Plate 4, using the method of Dean (1958). Graphs of sections 2 and 6 have not been used in the depth calculations. These sections show a very irregular spectrum compared with the spectra obtained in the other sections.

APPENDIX E

OPERATIONAL DETAILS

Staff

Party leader	: W.A. Finney	
Geophysicist	: E.P. Shelley	
Senior radio technician	: P.B. Turner	
Geophysical assistants	: D. Park	
	C.I. Parkinson	
Pilots	: Capt. M. Stewart)	
	F/O D. Spiers)	
Navigators	: F/O J. Colebourne)	T.A.A.
	F/O K. Radke)	
Aircraft maintenance engineer	: K. Phillips)	

Equipment

Aircraft	: DC3 VH-MIN
Magnetometers	: MFS-5 saturable core fluxgate, tail-boom installation coupled to "Speedomax" and digital recorders. MFD-3 saturable core fluxgate, ground installation for storm warning coupled to Esterline-Angus recorder.
Air position indicator	: Track recorded by DeVar recorder
Camera	: Vinten 35-mm single frame.

Survey Specifications

Altitude	: 10,000 ft above sea level
Line spacing	: 10 minutes of latitude
Line orientation	: East-west
Navigation control	: Aerial photo-mosaics and topographic maps over land; drift-sight readings over the sea
Record sensitivites	: MFS-5, 50 gammas/inch
	MFD-3, 20 gammas/inch

Survey Timetable

Party arrival Hobart	:	29th January and 1st February
Survey flying commenced	:	5th February
Survey flying completed	:	27th March
Party departure Hobart	:	28th March, 1st and 4th April

PLATE I

Based on K55/B0-4
Based on K55/BI-27

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics K55/BI-28

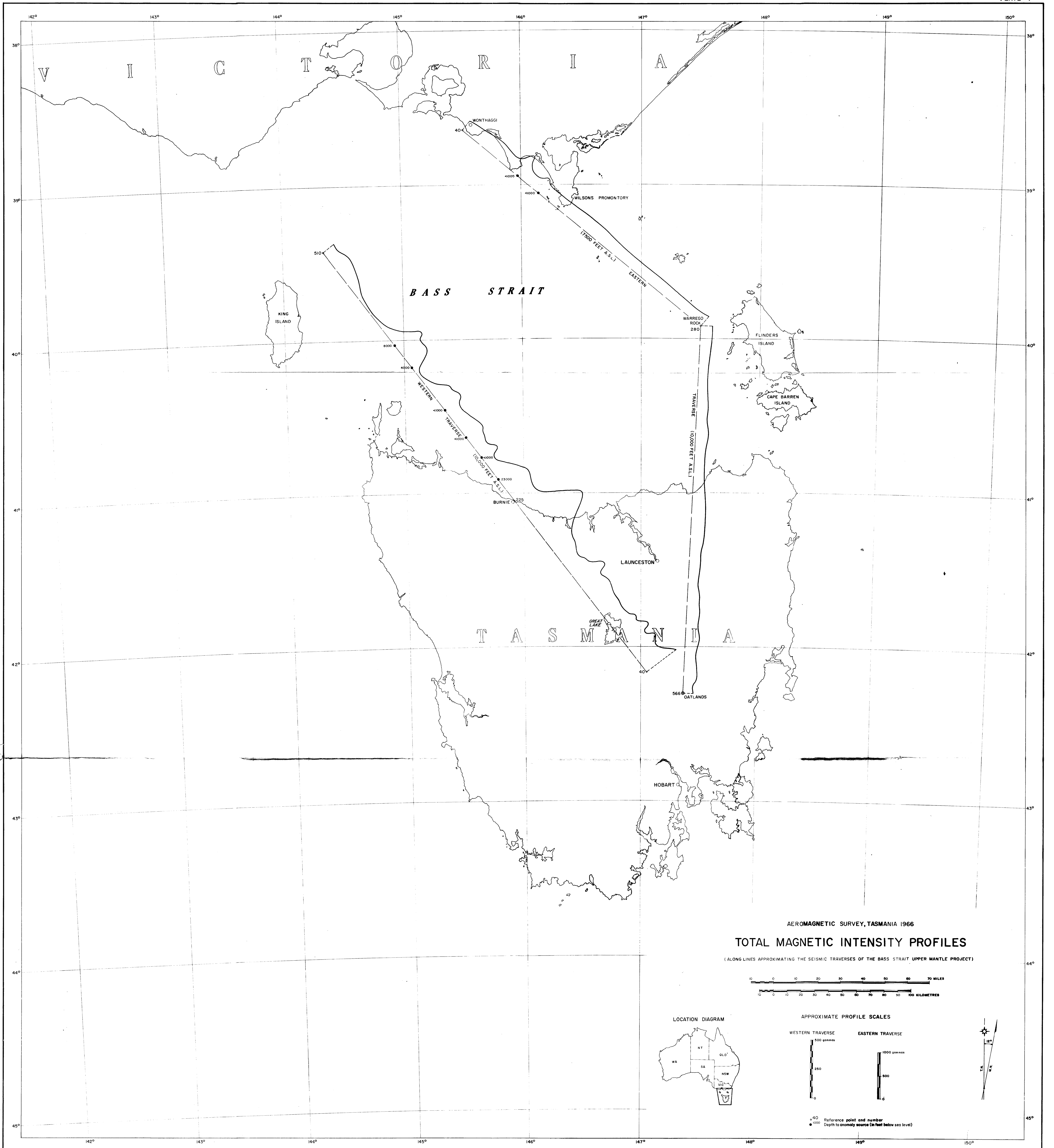
To Accompany Record No 1967/19


PLATE 2
AEROMAGNETIC SURVEY, TASMANIA, 1966
TOTAL MAGNETIC INTENSITY CONTOURS
AND
GEOLOGY
CONTOUR INTERVAL 50 GAMMAS
TOPOGRAPHICAL LEGEND
River or Creek
Highway or Road
Railway
Named place
GEOPHYSICAL LEGEND
Magnetic contour
Magnetic "low"
MILES
KILOMETRES
GEOLOGICAL REFERENCE
RECENT
TERTIARY Marine
TERTIARY Non-marine
TRIASSIC
PERMIAN
DEVONIAN AND SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN Unmetamorphosed
PRECAMBRIAN Metamorphosed
PRECAMBRIAN Undifferentiated
TERTIARY Basalt
JURASSIC Syenite
JURASSIC Dolerite
DEVONIAN Granite
CAMBRIAN Ultrabasics
CAMBRIAN Granite
IGNEOUS
RELIABILITY DIAGRAM
1 inch to 1 mile Map Sheets.
Regional Surveys.
Photo Interpretation.
Information sketchy.
SMITHTON
BURNIE
WARATAH
ZEEHAN
QUEENSTOWN
LAUNCESTON
SCOTTSDALE
BRIDPORT
ST HELENS
SWANSEA
OYSTER BAY
OATLANDS
HOBART
HUONVILLE
143°00'
144°00'
145°00'
146°00'
147°00'
148°00'
149°00'
150°00'
41°00'
42°00'
43°00'
Geological base map after Geological Map of Tasmania compiled by Tasmanian Mines Department
Based on K55/BO-4
Based on K55/BI-29
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics K55/BI-30
To Accompany Record No 1967/19

PLATE 3

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics K55/B1-32

To Accompany Record No 1967/19



(BASED ON K55/B0-2)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

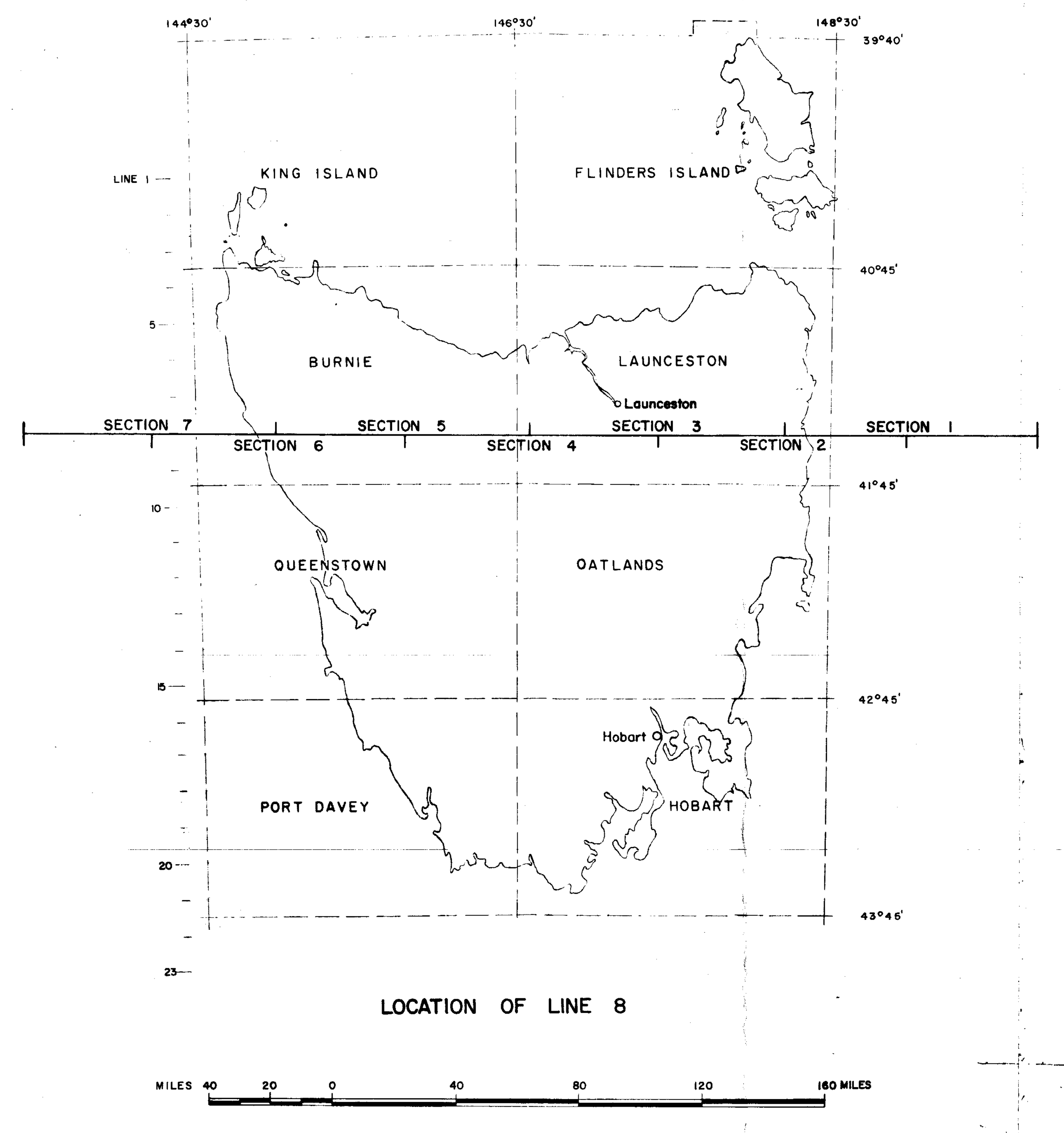
K55/B1-33

TO ACCOMPANY RECORD No 1967/19

AEROMAGNETIC SURVEY, TASMANIA, 1966

SPECTRAL ANALYSIS OF LINE 8

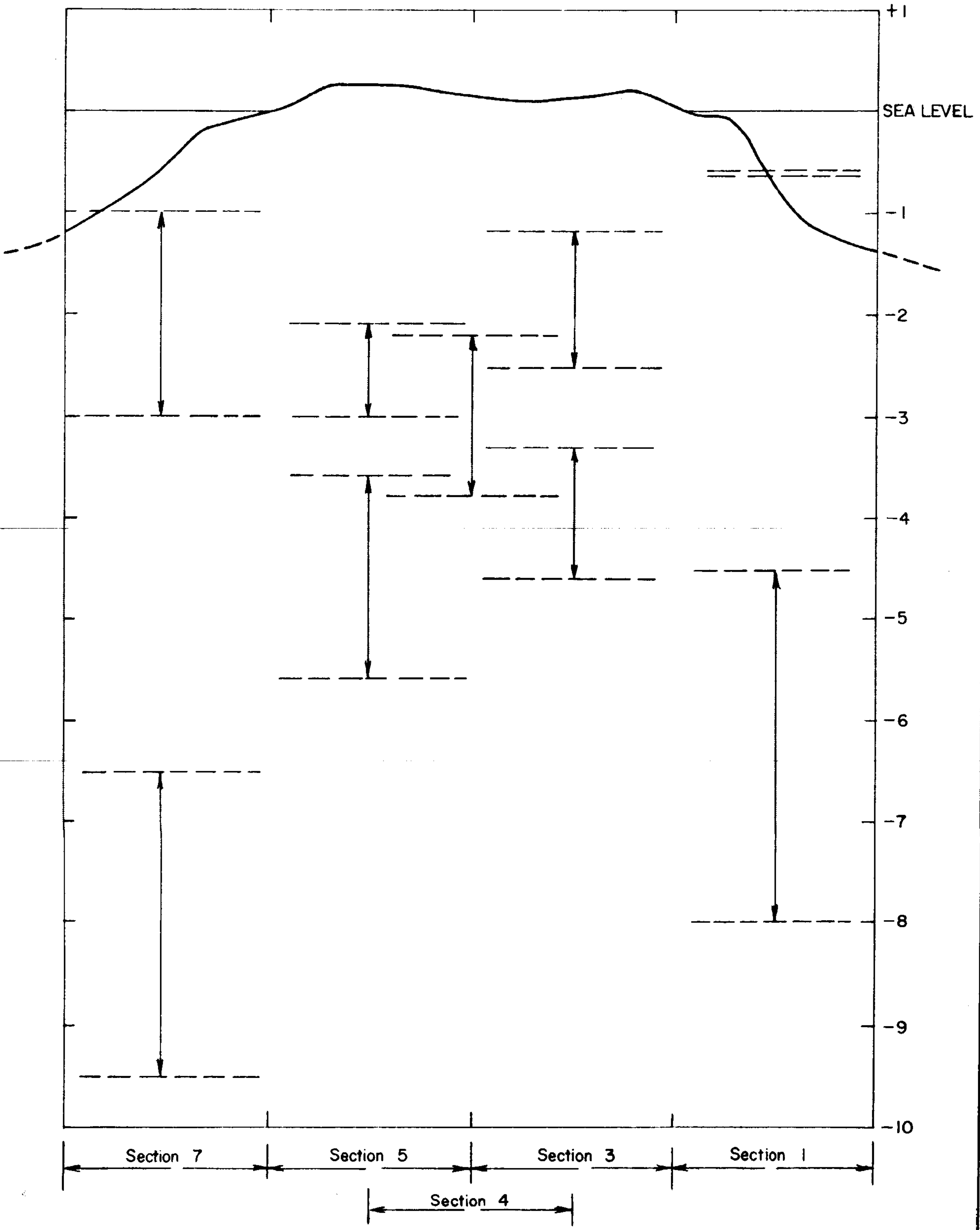
PLOT OF THE LOGARITHM OF THE SUM OF THE SQUARES OF THE FOURIER COEFFICIENTS AGAINST WAVE NUMBER. FUNDAMENTAL WAVE LENGTH FOR EACH SECTION IS ABOUT 83 MILES



LOCATION OF LINE 8

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics
TO ACCOMPANY RECORD No. 1967/19
K55/B1-26

PLATE 6



TRAVERSE LENGTH : 333 MILES
VERTICAL SCALE : UNITS OF 10,000 FEET

AEROMAGNETIC SURVEY, TASMANIA, 1966

THE MAGNETIC HORIZONS IN THE CRUST OF TASMANIA AS INTERPRETED FROM SPECTRAL ANALYSIS OF LINE 8

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

K55/B1-25

TO ACCOMPANY RECORD No. 1967/19