DEPARTMENT OF MINES
SOUTH AUSTRALIA

A REGIONAL INTERPRETATION OF 1:1 000 000 GRAVITY AND AEROMAGNETIC MAPS OF THE GREAT ARTESIAN BASIN IN SOUTH AUSTRALIA

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ABSTRACT

Geophysical maps at a scale of 1:1 000 000 have been published by the South Australian Department of Mines to assist regional interpretation of the geology of the Great Artesian Basin in South Australia. These consist of a Bouguer gravity map with contours at intervals of 5 milligals and a combined map of contours of total magnetic intensity and interpreted depths to magnetic basement, the latter having a contour interval of 500 m. A topographic base map with elevation contours at 20 m intervals at the same scale is included to enable geographical location of the geophysical patterns.

Interpretation has been made on a regional scale, with the known and speculative geology of a number of features being related to geophysical patterns. The extent and configuration of three Permian infra-basins are outlined on the maps, and the relationship of geology and geophysics discussed under the headings of Cooper, Arckaringa and Pedirka Basins. The Cooper Basin has complex density and magnetic distributions which make interpretation difficult, although more subsurface information from drilling and seismic exploration exists than in the remainder of the map area. The Arckaringa Basin is relatively simple to interpret and is closely outlined on the geophysical maps. The Pedirka Basin is also closely delineated by geophysical patterns, but interpretation is largely speculative due to the lack of subsurface control.

Other features described are the extension onto the map area of the Eastern Officer Basin and the Musgrave Block, the Birdsville Track Ridge which separates the Cooper and Pedirka Basins, and the north-western portion of the Adelaide Geosyncline.

INTRODUCTION

The Great Artesian Basin in South Australia comprises about one fifth of the total basin area and covers about 250 000 km^2. The plans presented herein cover an area bounded by latitudes 26° and 30°S and longitudes 133°30' and 141°E and thereby exclude the Frome Embayment to the south of the eastern part of the

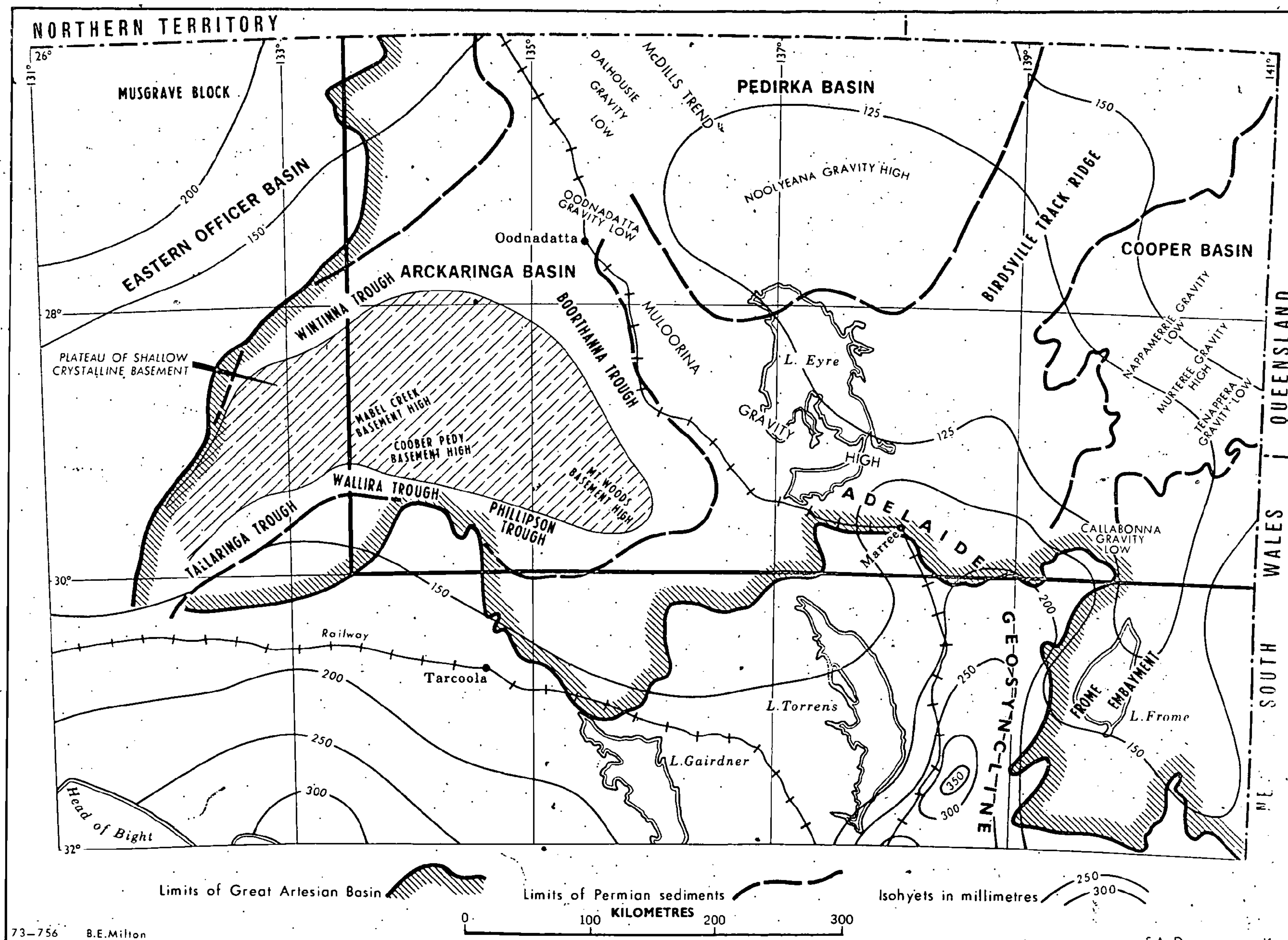

Fig.1 Tectonic and Gravity Features in the Great Artesian Basin in South Australia

region, and a section of the Arckaringa Basin to the south-west. As these features are included within the boundaries of the Great Artesian Basin, their limits are shown on the tectonic feature map (fig. 1).

The existence and approximate limits of the Great Artesian Basin have been known since the latter years of the nineteenth century, but until the mid 1950s, information on which interpretation was based was restricted to surface mapping and lithological logs of mostly shallow water bores. With the development of interest in petroleum exploration since the 1950s, extensive geophysical exploration followed by stratigraphic, petroleum exploration and development drilling has led to a considerable understanding of the geology of some regions of the basin and, by extrapolation, to a more reliable interpretation of geophysical data in the lesser explored areas. Where carried out, drilling and seismic exploration have enabled more certain interpretation of gravity and magnetic information. This has confirmed early interpretation in some regions and necessitated re-interpretation in others.

The Adelaide - Alice Springs railway line traverses the region from south to north, while the main roads, all unsealed, also run generally north-south and consist of the Stuart Highway in the western sector, the Marree - Oodnadatta road west of Lake Eyre, the Birdsville Track east of Lake Eyre, and the Strzelecki Track in the east. The only centres of population of note are the opal mining town of Coober Pedy, Oodnadatta, Marree and the gas treatment plant at Moomba. The town of Birdsville lies just over the border in Queensland in the north-east sector, and the coal mining town of Leigh Creek is located on the railway line about 100 km south of Marree. These features are shown on enclosure 1. The pipeline transporting natural gas from fields of the Cooper Basin traverses the eastern sector in a north-south direction.

Industries within the region are conditioned by its aridity and are mainly mining or pastoral in nature. Mining activities of current economic importance are the production of hydrocarbons from the Cooper Basin and opals from the western areas, centred about Coober Pedy.

PHYSIOGRAPHY, CLIMATE

Surface elevation within the region varies from about 12 m below M.S.L. on Lake Eyre North to 350 m above M.S.L. at Mount Fitton in the North Flinders Ranges on the southern boundary of the area and 410 m at Mount Margaret in the Peake and Denison Ranges. Contours of elevation at 20 m intervals are superimposed on a topographic base map in enclosure I. These contours are based on information of variable reliability, ranging from elevation of South Australian Department of Lands third order bench marks to barometric levels from helicopter gravity surveys. The density of data also varies, averaging about one station to 160 km^2. The contours must therefore be regarded as an approximation of the topographic surface only.

Sandy deserts, gypsiferous clay plains and stony deserts cover much of the basin in South Australia, while the normally dry salt pans of Lakes Eyre, Gregory, Blanche and Callabonna occupy about 5% of the map area.

The region covered by the maps is largely arid, with average rainfall varying from less than 125 mm to 200 mm (fig. 1). However, the annual total is extremely variable and can range from less than 50 mm to more than 500 mm.

Permanent water holes exist on some of the water courses, mainly those forming part of the Lake Eyre drainage basin. Some of these rivers are the Diamantina and Warburton to the north-east of the Lake, the Macumba and Neales to the north-west and west, the Frome to the south-east, and Cooper Creek to the east. The latter has permanent water as far west as Gidgealpa water hole. Surface water is present apart from the water holes for only short periods after heavy rains, when it collects in ephemeral lakes and interdunal clay pans of the sandy deserts. The evaporation rate is extremely high, particularly in summer months, and ranges from 2800 to 3400 mm per annum. The maintenance of surface supplies is consequently very unreliable. By contrast, supplies of underground water are generally abundant and of good quality, particularly when they originate from the main aquifers of the Great Artesian Basin. The main exception applies to the south-west sector, where supplies are highly saline, e.g. the town of Coober Pedy obtains its supply by solar distillation of saline water.

Vegetation is generally sparse with saltbush (Atriplex spp.) and bluebush (Kochia spp.) dominant over large areas where these plants form the main fodder for stock. In the Simpson Desert, porcupine grass or spinifex (Triodia spp.) forms a cover over lower slopes of the dunes, while fairly dense mulga and mallee scrub consisting mainly of species of Acacias and Eucalypts grows in the sand country of the west and south-west. A number of species of trees, frequently Eucalypts, flourish along water courses. Some of these attain considerable size. After occasional heavy rains, a dense cover of ephemeral plants develops over large tracts of country, particularly in sand covered areas and flood flats of water courses.

ORIGIN OF DATA

Two lists of references are appended to the report. Specific references from the text are included in the first, while the second contains reference to published and unpublished papers with interpretation of exploration data in regions which have been the subject of detailed investigations.

Enclosure I. Topographic and Surface Elevation Contour Map

Contours of surface elevation at 20 m intervals have been superimposed on the State topographic base map at a scale of 1:1 000 000. The plan is intended for use with the geophysical enclosures to provide geographical locations for geophysical patterns. Data on which surface elevations are based consist of levels from South Australian Department of Lands bench marks, bore levels, surveyed seismic lines and, where no other information is available, from barometric levels from helicopter gravity surveys. Where the density of information is particularly sparse, as in the Peake and Denison Ranges, topographic features have been used as a guide in determining contour patterns. As stated in the previous section, the contours must be accepted in a general sense only.

Enclosure II. Bouguer Gravity Anomaly Contour Map

The Bouguer gravity anomaly contour map was compiled from (i) helicopter surveys undertaken by Wongela Geophysical Pty. Ltd. for Delhi International Oil Corporation and Santos Ltd.; for the French Petroleum Co. (Aust.) Pty. Ltd.; and for the Bureau of Mineral Resources; (ii) various ground surveys, some on seismic lines, for Delhi International Oil Corporation, particularly in the Cooper Basin; and (iii) helicopter and ground surveys undertaken by the South Australian Department of Mines. The origin of the data is shown in a key diagram in enclosure II. Density values used in calculating the Bouguer anomaly are also shown in this key, together with the year of the survey. Density values assumed are generally adequate for a map at a scale of 1:1 000 000, but more realistic values are required in many areas for production of more detailed maps.

Density of coverage is about one station at 6 to 7 km intervals on a square grid, but a considerable amount of information from values obtained on South Australian Department of Lands bench marks, ground stations located on aerial photographs, and values at surveyed stations, including seismic shot points, has been included for control purposes. Plans at 1:250 000 and a contour interval of 2 milligals were re-contoured at 5 milligal intervals and results reduced to the 1:1 000 000 scale.

The enclosure is referred to in the text as the "gravity map".

Enclosure III. Total Magnetic Intensity and Interpreted Depths to Magnetic Basement Contour Map

This map shows contours of total magnetic intensity with contours of interpreted depths to magnetic basement superimposed thereon. Sources of data are shown on a key diagram, together with survey details. Magnetic basement contours are one possible interpretation based on the depth estimates, many of which are widely spaced, and this interpretation should not be regarded as definitive.

The major part of the region was flown and results reduced and interpreted by Aeroservices Corporation for the holders of P.E.L.s 5 and 6, Delhi-

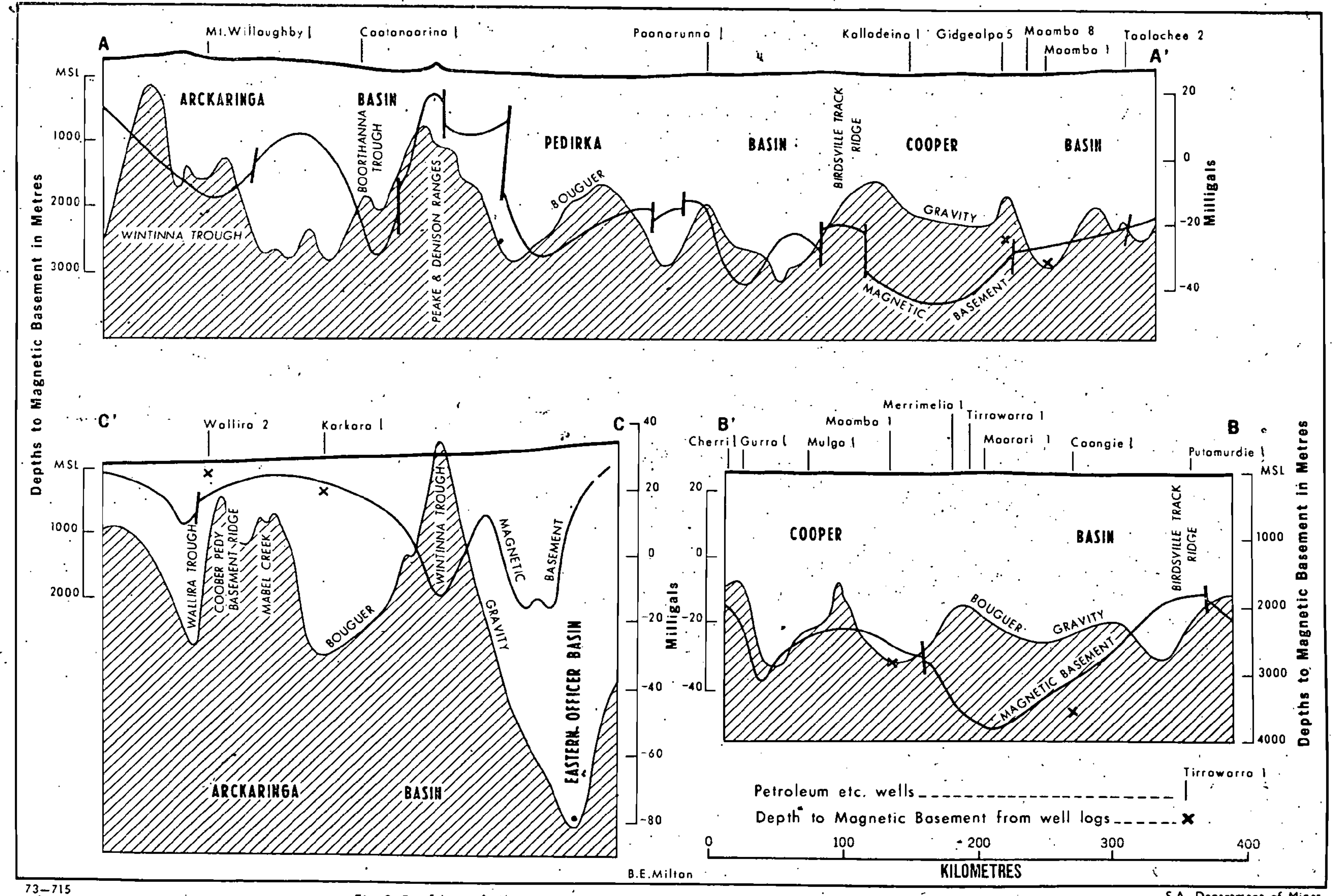

Fig.2 Profiles of Elevation, Bouguer Gravity and Depths to Magnetic Basement
(Location of Sections shown on Topographic Plan, Enclosure 1)

Santos, in 1961 and 1962. The data were re-interpreted in 1963 by Compagnie Generale de Geophysique (Laherre & Drayton, 1965) after some seismic and drilling information had become available, and this interpretation has been used in compiling contours of depth to magnetic basement. Other sectors were flown by the Bureau of Mineral Resources and the data computed and contoured by the South Australian Department of Mines and by Geophysical Resources Development Company for the Department of Mines. A small segment in the west has been taken from a survey flown for Oilmin N.L. by Aeroservices Corporation.

The 1:1 000 000 compilation has been obtained by tracing contours at a suitable interval from published plans, usually at a scale of 1:250 000, and reducing the tracings mechanically. No attempts have been made to integrate pattern values across survey boundaries where flight direction and height are not compatible, on the basis that the value of the plan lies in a qualitative expression of regional trends and that quantitative interpretation can be carried out from basic data or published plans at 1:250 000.

The enclosure is referred to in the text as the "magnetic map".

Figure 2. Elevation and Geophysical Profiles

Profiles of elevation, Bouguer gravity and depths to magnetic basement have been constructed along sections shown on the topographic map. The sections have been drawn to pass through a number of stratigraphic and petroleum exploration wells for control of interpretation. Magnetic horizons, where intersected in these wells, are also shown on the sections.

AA' is an east-west section located in the central part of the map area; BB' and CC' are north-south profiles at the eastern and western extremities respectively.

INTERPRETATION

The Great Artesian Basin is a Jurassic-Cretaceous basin; in South Australia it overlies either gently warped rocks of Devonian to Triassic age or more strongly folded strata of early Palaeozoic and Precambrian age. As a result of geological and geophysical exploration and geological information from water bores, stratigraphic drilling and petroleum exploration and development wells, three Permian infra-basins have been recognised. These have been named the Cooper Basin in the east, extending into south-west Queensland (Kapel, 1972); the Arckaringa Basin in the west and south-west (Wopfner, 1970); and the Pedirka Basin in the north central area, extending into the Northern Territory (Youngs, 1973).

The Permian sediments of the infra-basins either rest directly on Proterozoic or older rocks, e.g. crystalline basement of the Gawler Platform in the central Arckaringa Basin area, or on sediments ranging in age from Cambrian to Devonian of the peri-cratonic Warburton Basin (Wopfner, 1972). Contributions to the gravity pattern over much of the infra-basin area can then be attributed to either the contrast between low density Mesozoic/Permian and high density basement material, or the contrast between low density Mesozoic/Permian, high density Cambro-Devonian, and high density basement. The ratio between specific gravities of lower Palaeozoic sediments and basement material may be greater than or less than unity. Where there are three contrasting densities, in many localities the geological origin of magnetic basement has not yet been identified. In contrast, magnetic basement can generally be correlated with the basement material where Permian sediments rest directly thereon.

Approximate boundaries of the infra-basins are shown on figure 1. These basins can also be identified on both gravity and magnetic maps, although in some places their limits are ill defined on both or either of the maps. In contrast with the situation where the two types of geophysical data are in agreement, there are other features which give rise to gravity anomalies but do not show on the magnetic patterns, such as non-magnetic intrusions which vary the horizontal density distribution.

There are four other major features which can be found on the geophysical maps, viz. the northern part of the Adelaide Geosyncline, the Birdsville Track Ridge, the extreme eastern limits of the Officer Basin, and the eastern end of the Musgrave Block. The first runs in a north-westerly direction through the central part of the map area, the second in a north-easterly direction in the north-east quadrant, and the latter two are in the north-west corner. Some minor features are present outside of the major divisions described above and are listed in a separate section. To enable specific features discussed in the text to be identified, approximate coordinates are given.

Reference is made in the text to three structure contour maps of the south-western Great Artesian Basin published by the South Australian Department of Mines. These are (i) the "C" horizon, which maps the Lower Cretaceous Cadna-owie Formation; (ii) the "P" horizon, the base of the Mesozoic; and (iii) the "Z" horizon, the pre-Permian unconformity. Map details are included in the list of references.

The Cooper Basin

This is an intracratonic Permo-Triassic basin with a total area of approximately 7 x 10^4 km^2, of which 3 x 10^4 km^2 are in South Australia. Its limits are not precisely defined by either gravity or magnetic patterns, but its extent in South Australia and the thick sedimentary section within the basin were first demonstrated by interpretation of the aeromagnetic data (Aeroservices Corp. 1961 & 1962). Major structural features and trends are indicated on the gravity map, and some of these are named on figure 1 (Ingall & Lonsdale, 1964 & 1965).

A consequence of the discovery in the basin of economic accumulations of natural gas and liquid petroleum has been extensive company exploration. This has been mainly seismic investigations followed by the drilling of oil exploration and development wells. Many papers on the geology and geophysics of the basin have resulted and some of these are included in the list of references.

Contours of magnetic basement and Bouguer gravity together with the section profiles AA' and BB' show several structural features which have been proved by seismic exploration and drilling. These are the ridges to the north-west (the Birdsville Track Ridge) and south which control the limits of Permian sedimentation, and the south-west trending anticlinal crests of the Innamincka and Gidgealpa structures ($27^o30'$, 141^o - 28^o, 140^o), which are also outlined on the topographic elevation map. Two closed basinal areas are also delineated by the magnetic basement contours. The first is north of and parallel to the

Nappamerrie gravity low (fig. 1) and the second coincides with the south-western end of the Tenappera gravity low (29°, 140°15').

The south and south-western limits of Permian sediments, as interpreted from recent data, are shown on the "P" horizon map, but there is no definite correlation with these limits on either the gravity or depth to magnetic basement map. However, the gross structural elements which form the generalised boundary of this basin are apparent on the maps. These are the Adelaide Geosyncline to the south-west and, to the north-west, a north-easterly trending gravity high which coincides with a topographic high. The latter is an offshoot of the Muloorina gravity high and is either a gravity expression of the Birdsville Track Ridge or arises from a density contrast within sediments of the lower Palaeozoic Warburton Basin. An east-west gravity high in the south-east corner of the map sheet extending from 139° to the New South Wales border, is an expression of a ridge of lower Palaeozoic sediments. The Frome Embayment, in which no Permian sediments are present, is separated from the Cooper Basin by this ridge.

Immediately to the north of this ridge, the Callabonna gravity low (29° 40', 139°50') is superimposed on the regional negative gradient of the gravity pattern into the Cooper Basin. A decrease in gravity values in the western section of the low corresponds to deepening of the Mesozoic - lower Palaeozoic horizon as shown from seismic data (CFS line - United Geo., 1970), but the pattern over the eastern half does not correspond with the seismic horizon. There is a possibility that Permian sediments are present over the eastern sector and make a contribution to the gravity anomaly, but this would not be great enough to cause the eastern closure of the low. Total magnetic intensity anomalies are fewer and lower in amplitude than in surrounding areas and this, with the elliptical shape of the gravity anomaly, may indicate the presence of a low density, non-magnetic intrusive (Tucker & Brown, 1973). However, there is no evidence on the seismic section, which is not of good quality, of the presence of such a body. To the north and east of the low, there is good agreement between the configuration of interpreted depth to magnetic basement and the gravity pattern, suggesting that structure in the magnetic horizon is reflected in the gravity pattern. Also, within this area, total magnetic intensity data have characteristics which are similar to those in the Denison Block, suggesting that magnetic basement is coincident with crystalline basement.

Interpretation of magnetic data in the main sector of the basin resulted in a maximum computed depth to magnetic basement in excess of 4000 m below M.S.L., but in many areas even the deepest wells do not penetrate any horizon which can be positively identified as magnetic basement. The strongest negative gravity anomaly lies to the south of the major magnetic basement low, indicating different origins for the geophysical patterns. This interpretation may be qualified to some degree, as alternative interpretations of the magnetic data vary the displacement effect considerably.

Gravity patterns forming the Nappamerrie and Tenappera lows and the Murteree high indicate the relative thickness of sediments in each feature to the pre-Permian unconformity. These anomalies dominate the trend pattern for the Cooper Basin in the hydrocarbon province and reflect the major structural elements of the substrata. Some smaller localised anomalies coincide with structures defined by seismic information and drilling e.g. Gidgealpa and Moomba structures. At a scale of 1:1 000 000 and a contour interval of 5 milligals, such small anomalies can only be interpreted with any degree of certainty by reference to less ambiguous structural information from seismic and drilling data. Specific gravity measurements of core material from petroleum exploration wells show that, in general, the major density contrast within the section is between pre-Permian and overlying Permian sediments.

Interpretation of gravity and magnetic data in this basin, even though a considerable amount of drilling and seismic information exists in some areas for control, is not easy due to the complex distribution of densities within and below the sedimentary section, and the existence of several magnetic horizons, most of which have yet to be identified.

The Arckaringa Basin

In contrast to the Cooper Basin, the Arckaringa has been mainly explored by the South Australian Department of Mines; company contribution consists of aeromagnetic coverage, a limited amount of seismic work and two exploration wells in the Boorthanna Trough. Sufficient exploration has been undertaken to interpret the geological history of much of the area and this has been summarised in Wopfner (1970). Because of the relatively small amount of published information on the geophysics of this basin, the section has been written in greater detail than those describing the Cooper and Pedirka Basins.

Most of the boundary of this Permian infra-basin, which is about 10^5 km^2 in area, is well defined by gravity and magnetic patterns. About a third of the basin lies outside the region covered by the enclosures, and the complete basin area is indicated in figure 1, together with names of tectonic features.

Exploration of the basin has revealed a central area of shallow crystalline basement overlain by Permian and Mesozoic sediments, with several elongate troughs of varying depths around the periphery. Gravity patterns within the basin are more varied than in the rest of the area covered by enclosure II and result from the contrast between the central area of shallow sedimentation and the deep peripheral grabens and half grabens.

The central area of shallow crystalline basement

This region is characterised on the gravity map by widely spaced contours with gentle gradients and its limits interpreted from gravity and magnetic data are shown on figure 1. Depth of sedimentary cover ranges from outcrop at Mount Woods and about 30 m on the Coober Pedy and Mabel Creek basement ridges to about 1000 m in the north, with a general increase in depth to the north of about 5 m per km (Milton, 1972 - fig. 3). The area can be clearly seen on the profile of depths to magnetic basement on the north-south section CC' from the Wallira Fault to a point about 120 km north. The gentle undulations of the basement surface have been plotted from seismic refraction data over much of the eastern sector, particularly in the vicinity of the Stuart Highway (Milton, 1973).

Density measurements on cores from Karkaro No. 1, Mount Furner No. 1 and Wallira Nos. 1 and 2 stratigraphic wells in this region result in an average value of 2.07 g/cm^3 from 23 samples of Permian and Mesozoic sediments, and 2.65 from 7 samples of crystalline basement.

Wallira and Phillipson Troughs

A system of narrow, fault bounded grabens showing clearly on both gravity and magnetic basement plans forms a margin to the basin in the south-western region south of the Coober Pedy basement ridge. The coincidence of gravity low and magnetic basement trough over the Wallira feature is strikingly displayed on the section CC'.

The negative gravity anomalies are the result of a density contrast of about .58 g/cm^3 between crystalline basement material and the sediments within the troughs. Some pre-Permian sediments may be present in the deeper parts of these troughs, but if so they would not contribute greatly to gravity patterns because of the small volume of sediments involved.

The magnetic basement pattern in this area arises from crystalline material of the Gawler Platform which was intersected at 820 m below M.S.L. in the Lake Phillipson bore on the northern margin of the Phillipson Trough and at 67 and 166 m respectively in Wallira Nos. 1 and 2 wells. The latter two wells were drilled on the upthrown sides of the south and north bounding faults of the Wallira Trough.

Tallaringa Trough

The Tallaringa Trough lies to the north-west of the Karari Fault (29^{o}26', 133^{o}30') and is delineated by an elongate gravity high and magnetic basement trough, with a maximum depth to magnetic basement interpreted as being about 1250 m. The major part of the sediments filling the basement trough consists of the limestones and dolomites referred to below.

The arcuate trend of the Wallira and Phillipson gravity anomalies appears to continue to the south-west in the Wallira West [redacted] low, the eastern end of which appears on enclosures II and III. Investigations have revealed, however, that the most prominent part of the anomaly arises from two different sources. The south-south-eastern portion has its origin in a lateral increase in basement density to the south: granite was intersected in a seismic shot hole about 1 m below surface at the minimum of the gravity low. To the north-west of the Karari Fault, the major cause of the gravity gradient is a thick sequence of high density carbonate rocks which increase in thickness in that direction. These rocks were discovered in the Wallira West No. 1 stratigraphic well and have been equated with the Observatory Hill Beds of probably Cambrian age (Milton, 1973; Townsend, 1971).

Wintinna Trough

The northern and north-western boundaries of the basin are formed by the Wintinna Trough and its eastern extension. These appear on both gravity and magnetic maps as major features with a magnetic basement trough coinciding with positive gravity anomalies (sections AA' and CC'). Depth to magnetic basement which reaches a maximum in excess of 2000 m on the eastern extension, reflects depth to crystalline basement. Drilling on the eastern extension (Milton & Thornton, 1970) and seismic profiling on both features reveals that the origin of the gravity highs is a dense, high speed dolomite. This is at present undated and cores from the stratigraphic well Mount Willoughby No. 1 have an average density from 6 samples of 2.77 g/cm^3. The dolomite was intersected in this well at 624 m below surface. Seismic and magnetic interpretation shows that the dolomite has a thickness of between 2000 and 2250 m on the eastern extension, while magnetic basement in the main trough is greater than 1500 m below M.S.L. A seismic refraction horizon plotted over the major gravity anomaly at a depth of 180 m below surface at the culmination has a velocity of 5.3 km/s (Hall, 1973) and probably arises from weathered dolomite. This compares with a velocity of 6.5 km/s from unweathered material; published graphs relating velocity and density (Grant & West, 1965) equate a value of 2.76 g/cm^3 with this velocity, which agrees well with the measured value of core material quoted above.

The extent of the Wintinna Trough is indicated on figure 1, and its major axis is parallel to that of the Tallaringa Trough to the south. As indicated above, the geophysical anomalies have similar origins, viz. basement troughs containing carbonate rocks of high density, and appear to delineate in a general sense the northern and southern boundaries of the western Arckaringa Basin.

The gradient forming the northern boundary of the Wintinna gravity high is about 2 milligals/km over a distance of about 60 km dropping into the gigantic gravity low of the Eastern Officer Basin, the eastern limits of which appear on enclosures II and III. A small gravity high, part of which appears on the gravity map ($27^{0}39'$, $133^{0}30'$) and also on the profile CC', and a magnetic basement ridge coincide with the Ammaroodinna Inlier (Krieg, 1972); basement outcrop of this feature lies just to the west of the map boundary. A section over the gravity gradient can be interpreted as due to faulting with a magnitude of 2500 m (Nettleton, 1970), with the fault extending the full length of the Wintinna gravity high. However, seismic information obtained since this interpretation suggests the presence of a fault zone on either side of the Ammaroodinna Inlier, i.e. to the north-west into the Eastern Officer Basin and to the south-east into the Wintinna Trough.

Boorthanna Trough

This feature is defined on both gravity and magnetic plans at the eastern limit of the infra-basin. The gravity pattern is largely determined in the northern part of the trough by the density contrast between (?) Ordovician quartzites and lower density Permian and younger sediments; in the central region between high density dolomites (Milton, 1971) of possible Devonian age and younger sediments; and in the south by the density contrast between metavolcanic and the overlying Permian rocks. Magnetic basement depths, however, are not influenced by the dolomites. The central part of the trough is outlined by contours of depth to magnetic basement, with limits of the dolomites roughly outlined by the 1500 m contour.

Gravity and magnetic patterns in the Wintinna, Tallaringa and Boorthanna Troughs are similar as all are basement troughs containing dolomitic rocks of high density, overlain by low density Permian and Mesozoic sediments.The gravity values are largely dependent on the depth to dense carbonate rocks, while magnetic basement shows the depth to crystalline basement in the Wintinna and Tallaringa and to possibly Proterozoic basement in the Boorthanna Trough.

In the Boorthanna Trough, the picture is further complicated in that two types of dolomite can be distinguished in Weedina No. 1 (Milton, 1971). The shallower, from 626 to 1219 m has an average density of 2.64 g/cm^3 and can be correlated with dolomite intersected in Cootanoorinna No. 1 (density 2.71), while the deeper from 1219 to 1564 m has a density of 2.85. Other density values from these wells are 2.25 for 5 samples of Permian/Mesozoic sediments and 2.69 for a single sample of (?) Ordovician quartzite from the bottom hole core of Weedina.

The limits of the dolomites have been partly determined by seismic exploration while two structures, viz. Cootanoorina (28^o, 135^{o}20') and Warrangarranna (28^{o}30', 135^{o}40'), both of which show on the gravity map, have been drilled, the latter revealing the 938 m of dolomite recorded above. Both structures are outlined as highs on the gravity map, with much of the effect arising from the contrast between Permian/Mesozoic sediments and underlying high density dolomitic material. To the north-west of the Trough, an area of broad gravity lows coincides with a broad magnetic basement ridge, as can be seen on section AA' between Cootanoorina and Mount Willoughby wells. It seems likely that dolomites are absent in this region and that geophysical patterns indicate the thickness of Permian and post-Permian sediments, resting on (?)Ordovician quartzites. To the south, the dolomites wedge out with, apparently, the denser of the Weedina dolomites persisting south of the Coober Pedy - Anna Creek road, i.e. about 60 km further south than the shallower dolomite.

The gravity low south of the Boorthanna Trough anomaly probably originates from contrast between metavolcanic rock, such as that intersected in Boorthanna No. 1, and overlying less dense Permian and Mesozoic fill. To the east, the trough boundary is largely fault controlled, as is evident from the enclosures and section AA'. The Denison Block shows on the same maps as a gravity high, suggesting that the Precambrian inlier has shallow roots, and as a magnetic basement ridge.

The Pedirka Basin

This is the third feature within the map area defined as a Permian infra-basin. It lies beneath the central western part of the Great Artesian Basin and covers an area of about 2 x 10^5 km^2, of which more than half lies in South Australia (Youngs, 1973). Most of the basin limits in South Australia are based on geophysical evidence, much of which is reconnaissance in nature and without subsurface control. The basin description based on gravity and magnetic data must be therefore indefinite and in general only broad features can be described.

Both geophysical maps show a division of the basin in South Australia into two lobes, an eastern and a western, separated by a north-south subsurface ridge. The ridge, "McDills trend", has north-south faulting associated with it. The gravity patterns of the eastern lobe show broad features with fairly gentle gradients and a range of about 20 milligals, similar to areas further east and south-east. This region is bounded in the east by the Birdsville Track Ridge, which can be traced on the magnetic basement plan, but is difficult to define on the gravity patterns (sections AA' and BB').

The southern limit of the eastern feature as interpreted at present is parallel to and north of the north-easterly trending extension of the Adelaide Geo-syncline (Youngs, 1973). Interpretation of all geophysical data, however, suggests that the limit is closer to basement outcrop. A northerly trending gravity ridge, an offshoot of the Mulcoorina gravity high (fig. 1), separates this southern section of the Pedirka Basin from the Cooper Basin. The eastern lobe is further subdivided into two areas with different characteristics by the east-west trending Noolyeana gravity high. The southern section has greater gravity relief than the northern and contains some proven structures, at least in the post-Cambrian section. Poonarunna No. 1 was drilled on such a structure.

The Poonarunna structural high can be seen on the profile section AA' and was also defined seismically. It appears on the "C" and "Z" seismic reflectors and on an intermediate horizon. This intermediate horizon, by analogy with known stratigraphy of the Cooper Basin, was interpreted as a Permian coal horizon which pinched out on the flanks of the structure. No Permian was intersected in the well, casting doubts on the Cooper Basin analogy, but the poor quality of seismic data in the region of the well leaves other structures in the area possible targets with respect to Permian sediments.

About 20 km west of the Poonarunna structure, a gravity trough trends north-north-east for 80 km until it intersects the Noolyeana gravity high, and seismic lines which cross it identify structural highs in each horizon. This situation in which gravity lows are associated with seismic highs contrasts with that over the Poonarunna structure where gravity and seismic highs coincide.

Features of the northern sector are low gravity relief with no major trends indicated by contour patterns and only a few closed anomalies. The magnetic basement map shows patterns similar to those of the gravity, viz. less relief in the northern than the southern sector. However, there is no well defined ridge in magnetic basement corresponding to the Noolyeana gravity high.

The western lobe is outlined by a major magnetic basement low, with interpreted depths greater than 4000 m, and a complex of gravity lows. A connection between the western Pedirka Basin and the Eastern Officer Basin is suggested by the gravity patterns, but this is not supported very strongly by the magnetic interpretation. However, the general correspondence between gravity patterns and magnetic basement configuration is good. An examination of geological evidence from petroleum exploration wells and seismic surveys (Drayton, 1967) suggests that changes in thickness between the base of the Permian or Mesozoic sediments and magnetic basement also contribute largely to the regional gravity pattern. On the other hand, local gravity lows within the region are due to a thick but confined sequence of low density Devonian sediments, of which 600 m with an average specific gravity of 2 g/cm^3 were intersected in Witcherrie No. 1.

The Oodnadatta gravity low (27^{o}25', 135^{o}45') is located in the southern sector of the western lobe. It is contained within the area of the magnetic basement low where depths are about 2500 m below M.S.L., but does not appear on the magnetic map as a separate feature. The character of magnetic anomalies is substantially the same over the entire lobe, suggesting that the magnetic horizon is unchanged even though two separate features appear on the gravity pattern. A density contrast of .5 g/cm^3 between magnetic basement and overlying sediments combined with the configuration of magnetic basement is sufficient to cause the gravity anomaly. Information from drilling in the northern sector suggests that the gravity anomaly may arise from a contrast between sediments with a density of about 2.2 g/cm^3 and possibly crystalline basement of 2.7 g/cm^3, with no necessity to invoke the presence of low density Devonian sediments.

Eastern Officer Basin and Musgrave Block

The extreme eastern extension of the lower Palaeozoic Officer Basin can be seen on both gravity and magnetic contours in the north-west of the map area and is very well defined on the northern end of section CC'. The northern boundary of this basin and the western boundary of the Pedirka Basin in South Australia abut onto the Musgrave Block, the eastern extension of which also shows on the two geophysical maps.

As most of these features lie outside the region of the Great Artesian Basin, they will not be discussed further in this paper.

The Birdsville Track Ridge

The north-western and western margins of the Cooper Basin are defined by a regional structural high, the Birdsville Track Ridge, which appears on the "C", "P" and "Z" maps. The absence of Permian sediments over this structure has been revealed by the petroleum exploration wells Putamurdie No. 1, Pandieburra No. 1 and Kalladeina No. 1. However, the feature is not defined with any great degree of precision on the gravity and magnetic basement contour maps (refer also sections AA' and BB'). Magnetic basement contours show a south-south-westerly trending ridge which is well defined at the northern margin of the map, but progressively loses definition to the south, and is not present to the north-west of Kalladeina No. 1. Bouguer gravity values are generally low in the region of the magnetic basement ridge with a few closed low amplitude anomalies trending east-west which have no obvious relationship to the magnetic feature.

The southern section of the Rdige, by contrast, shows as a south-south-westerly trending gravity high, which intersects the Muloorina gravity high in the south. Kalladeina No. 1 was drilled on the eastern flank of this gravity feature, which could be due to density variations within the lower Palaeozoic Warburton Basin sediments or could have the same origin as the Muloorina high (refer next section).

The Adelaide Geosyncline

A west-north-west trending gravity feature, the Muloorina gravity high ($28^{o}45'$, 137^{o} to 30^{o}, $139^{o}15'$), can be related to surface geology in several places. Where it crosses the southern margin of the map sheet, the high coincides with either outcropping Sturtian and Marinoan units of the Adelaide System or crystalline basement of the Mount Painter Block. The gravity anomaly has the same trend direction as outcropping Adelaidean sediments and may indicate their presence in the subsurface to the north-west of outcrop. The north-western limit of the gravity feature corresponds to outcropping crystalline basement of the Denison Block. The origin of the central part of the anomaly is not known and cannot be diagnosed from the gravity or magnetic data.

Interpreted depths to magnetic basement in the area of the gravity high show no definite ridge structure. This is to be expected where the gravity anomaly is caused by non-magnetic, high density upper units of the Adelaide System.

A gravity low parallel to and south-west of the high, near the southern margin of the map sheet, corresponds to outcrops of Torrensian and Willouran units of the Lower Adelaide System. Its south-west margin corresponds to the Norwest Fault shown on enclosure III (Tucker & Brown, 1973), on the south-west side of which depth to magnetic basement is greater than 5000 m. The fault is recognised geologically and is shown on enclosure III as being downthrown on the south-western side, but gravity data indicate the north-east side to be downthrown. Possible explanations of this anomalous situation are that the gravity pattern is due to either a large thickness of high density Adelaidean sediments on the south-west side of the fault, or to pre-Adelaidean basement densities being greatly reduced across the fault in a north-east direction.

To the north-west of the Muloorina high, the amplitude of both gravity and magnetic intensity anomalies increases, while depth to magnetic basement decreases in the area of outcropping crystalline basement in the Denison Block. These factors, and especially the magnetic patterns, suggest that magnetic basement is coincident with crystalline basement.

In the region where the gravity expression of the southern Birdsville Track Ridge intersects the Muloorina high, there is little correlation between the configuration of magnetic basement and gravity patterns. If the gravity anomalies are due to upper Adelaide System rocks as suggested above, then the magnetic horizon is either a magnetic unit below the Adelaide System rocks, or crystalline basement.

Minor Geophysical Anomalies

A gravity high in the south-west corner of the map south of the Phillipson and Wallira Troughs has its origin in shallow crystalline basement. The anomaly lies outside of the Great Artesian Basin.

The southern part of coincident gravity and magnetic basement highs appears at about 139^{0} on the Queensland border. The complete Bouguer anomaly is circular in shape, and a density contrast of .23 g/cm^3 between magnetic basement and overlying material is sufficient to give rise to the feature. The character of magnetic intensity anomalies with the shape of magnetic basement and gravity highs, suggests the presence of a high density, low magnetic susceptibility intrusive body. If this is the case, the overlying sediments would have an average density indicating that much of the section is likely to be lower Palaeozoic in age.

B.E. Milton

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G.K. MORONY G.K. Morony
GEOPHYSICIST per BEM.

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Structure Contour Plans of South-Western Great Artesian Basin

"C" horizon compiled by Stadter, M.H. & Townsend, I.J., Dept. Mines plan No. 73-53

"P" horizon compiled by Thornton, R.C.N. & Youngs, B.C., Dept. Mines plan No.73-54

"Z" horizon compiled by Morony, G.K. & Ramakrishna, B.N., Dept. Mines plan No.73-55

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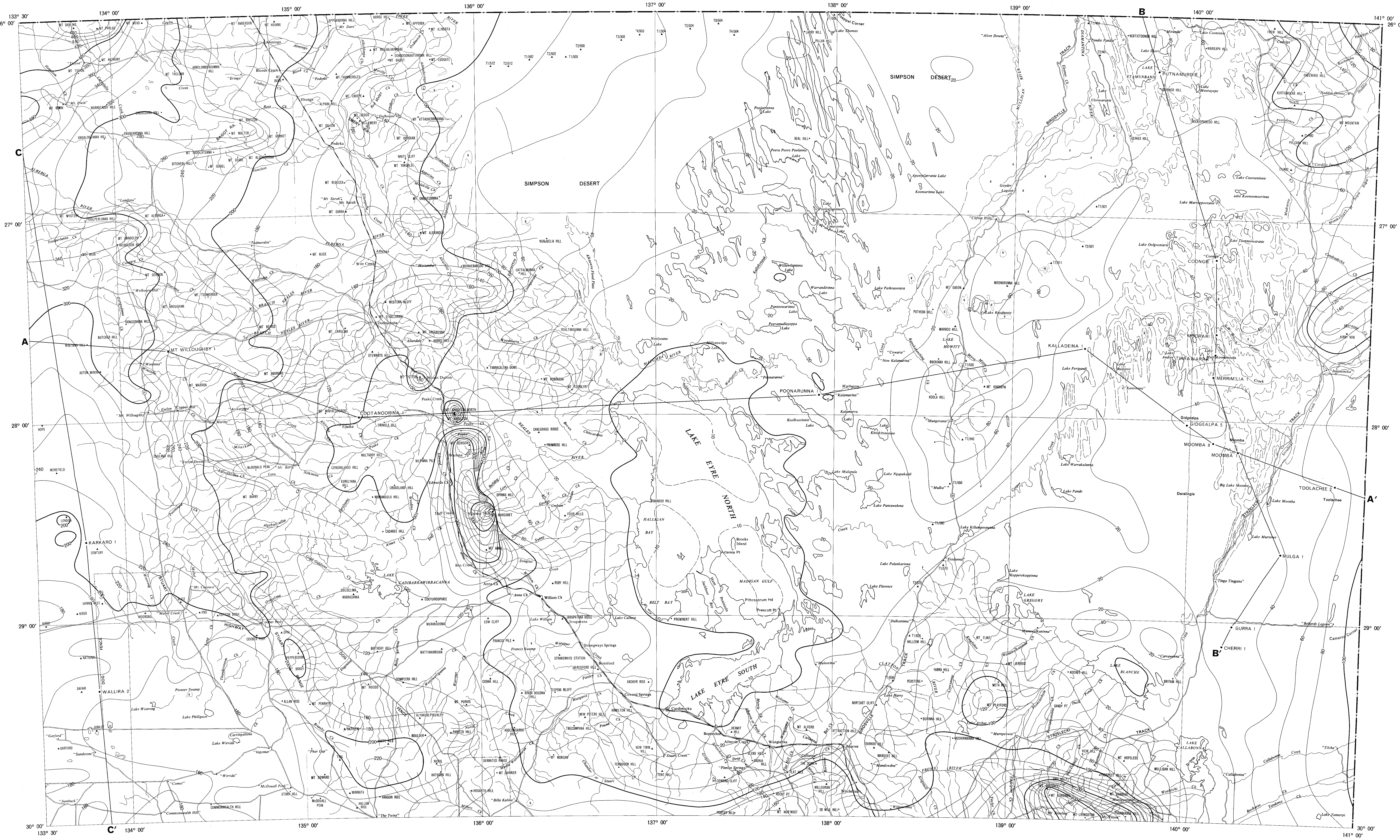
GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES, ADELAIDE

GREAT ARTESIAN BASIN IN SOUTH AUSTRALIA

TOPOGRAPHIC MAP



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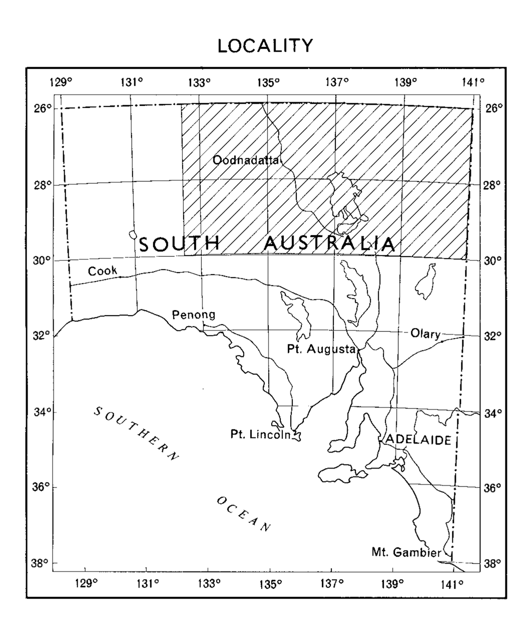


Elevation Data compiled by Seismic Geophysics Section,
Petroleum Exploration Division.

Map preparation by Cartographic Division,
Department of Mines, S.A.

Compiled under the direction of G. F. Whitten
acting Government Geologist, acting Director of Mines.

Issued under the authority of the Honourable
D. A. Dunstan, M.P., Minister of Development and Mines.

Published 1972

SCALE 1:1,000,000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 KILOMETRES

MILES 10 0 10 20 30 40 50 60 70 80 90 100 MILES

H. J. WALL, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE

Sections on which profiles of depths to magnetic basement and Bouguer gravity with depths to geological horizons from selected wells plotted are shown AA′, BB′ and CC′

Topographic map extracted from State Base Map at 1:1,000,000

Contours of elevation based on: S.A. Department of Lands bench marks along main roads; petroleum, stratigraphic and water bore levels; seismic shot point elevations; and barometric levels mostly from helicopter gravity surveys. Data density on which contours are based is about one station to 16,000 ha. Contours are to be accepted as representative of general levels only.

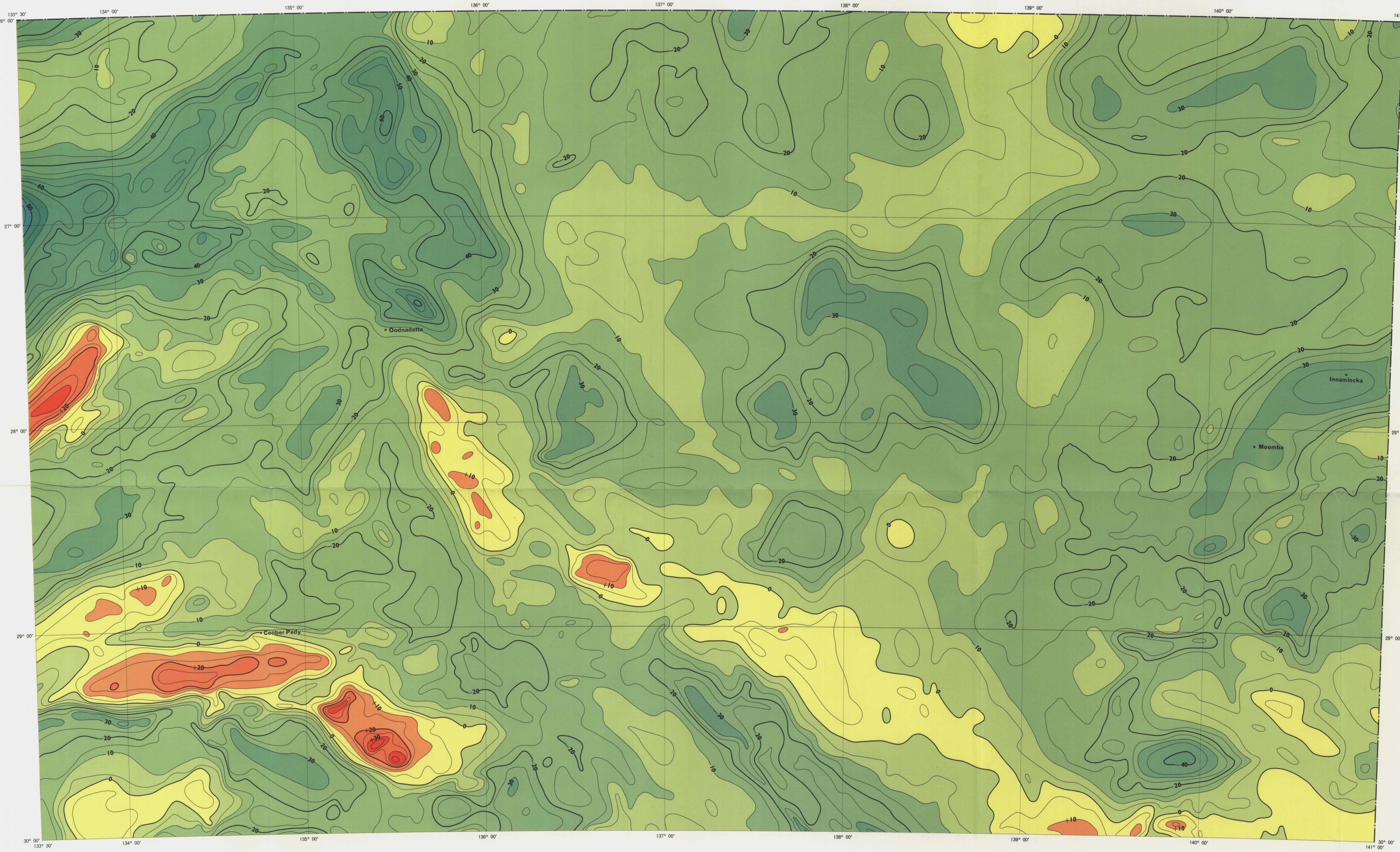
REFERENCE

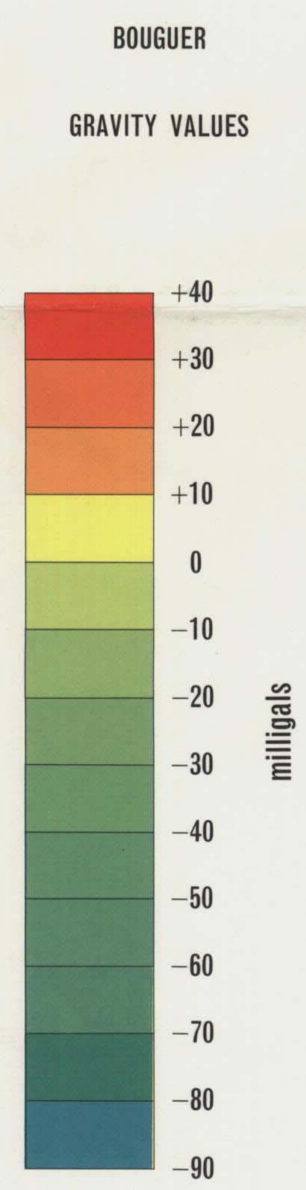
Road
National Route Number 87
Railway
Town
Head Station
First Order Triangulation Station
River or Creek
Lake or Lagoon
Swamp
Area of Inundation
Contour (elevation in metres – represents general level only) 200
Section Line A A′
Location of Petroleum and Stratigraphic Wells

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES, ADELAIDE

GREAT ARTESIAN BASIN IN SOUTH AUSTRALIA

BOUGUER GRAVITY ANOMALY MAP





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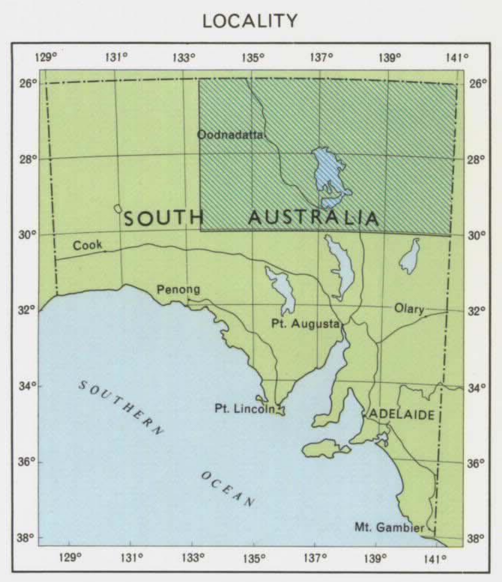

Compiled by R. J. Coppin, J. McG. Hall and B. E. Milton of the Seismic Geophysics Section.

Map preparation by Cartographic Division, Department of Mines, S.A.

Compiled under the direction of L. W. Parkin, Government Geologist, Director of Mines.

Issued under the authority of the Honourable D. A. Dunstan, M.P., Minister of Development and Mines

Published 1971

SCALE 1:1,000,000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 KILOMETRES

MILES 10 0 10 20 30 40 50 60 70 80 90 100 MILES

H. J. WALL, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE

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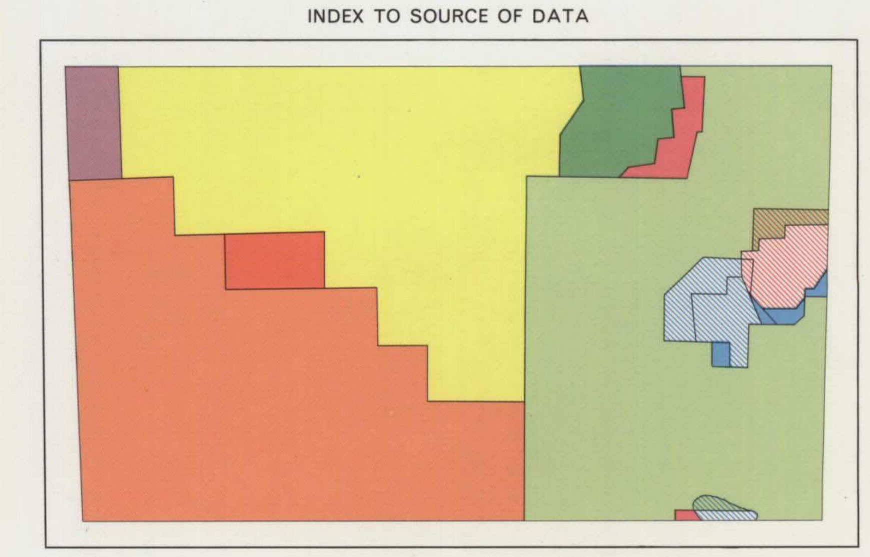


French Petroleum Co. (Aust.) Pty Ltd 1963 Density 1·9

Delhi Australian Petroleum Ltd 1964 Density 1·9

Delhi Australian Petroleum Ltd 1965 Density 1·9

Delhi Australian Petroleum Ltd 1963 Density 1·9

Delhi Australian Petroleum Ltd 1964 Density 1·9

S.A. Department of Mines 1967 Density 1·9

Bureau of Mineral Resources 1970 Density 2·2

S.A. Department of Mines 1968-69 Density 1·9

Detailed surveys various companies

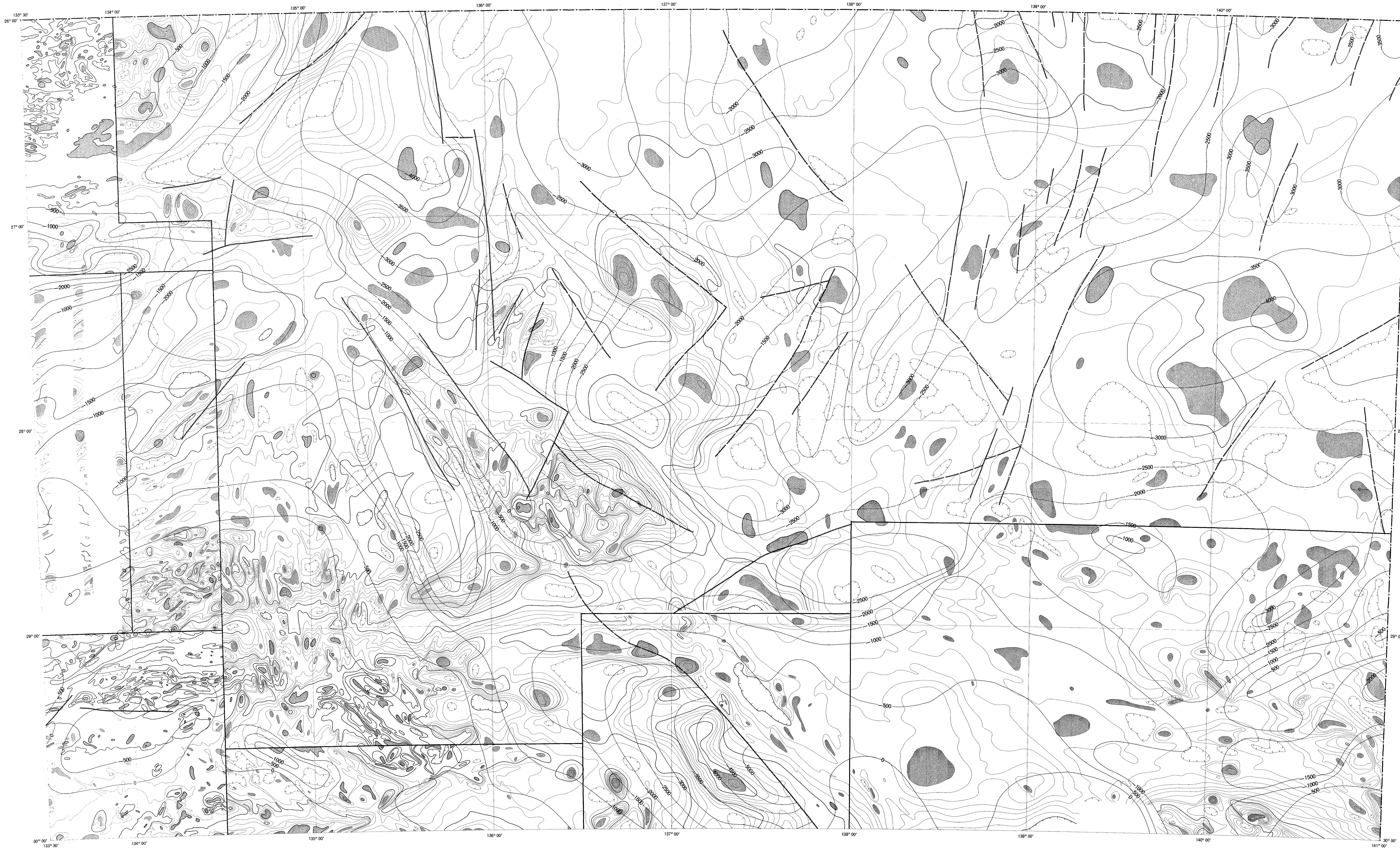
Extrapolated

Density value in g/cm³ used to compute Bouguer value.

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES, ADELAIDE

GREAT ARTESIAN BASIN IN SOUTH AUSTRALIA

CONTOURS OF MAGNETIC INTENSITY AND INTERPRETED DEPTHS TO MAGNETIC BASEMENT



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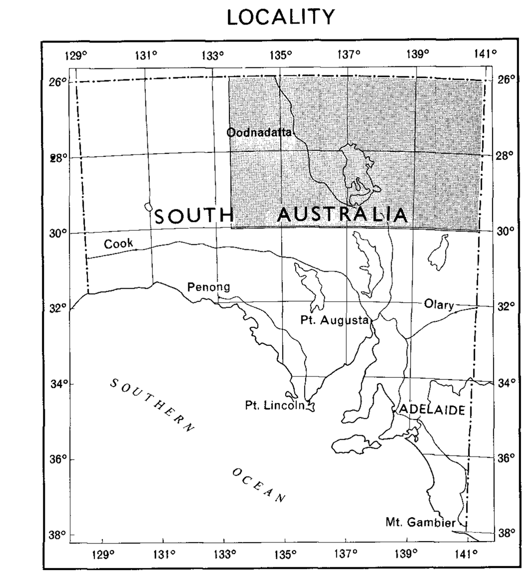


LEGEND

Fault
Inferred Fault
Magnetic High
Magnetic Low
Contour of Total Magnetic Intensity
Contour of Interpreted Depth to Magnetic Basement

Values for contours of magnetic intensity omitted as various surveys are not related to a common datum.

CONTOUR INTERVAL 500 METRES
(RELATIVE TO MEAN SEA LEVEL)

SCALE 1:1,000,000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 KILOMETRES

MILES 10 0 10 20 30 40 50 60 70 80 90 100 MILES

H. J. WALL, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE

Contours of Magnetic Intensity compiled by R. J. Coppin and J. M. Hall; Magnetic Basement by B. E. Milton.
(Seismic Geophysics Section, Petroleum Exploration Division)

Map preparation by Cartographic Division, Department of Mines, S.A.

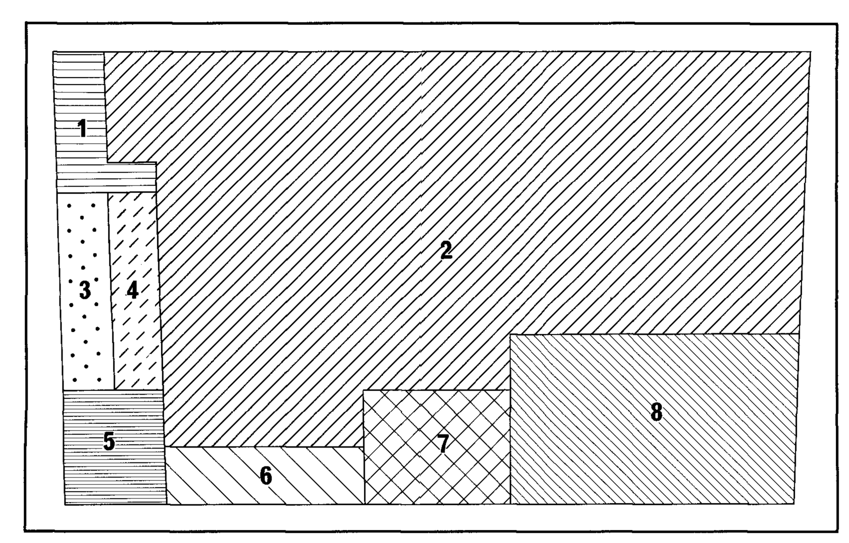
Compiled under the direction of G. F. Whitten acting Government Geologist, acting Director of Mines.

Issued under the authority of the Honourable D. A. Dunstan, M.P., Minister of Development and Mines.

Published 1972

AREA	FLOWN FOR	DATE	FLYING HEIGHT (FEET)	SPACING (MILES)	INTERPRETED BY
1	S.A. Dept. of Mines	1967	500 above ground level	1 mile N.S.	
2	Delhi Australian Petroleum Ltd.	1961-62	1500 above sea level	5 miles E.W.	Campagnie Generale de Geophysique
3	Exoil N.L.	1964-65	2000 & 2500 above sea level	Three at 1 mile N.S. Groups at 10 miles	Geophysical Associates Pty Ltd
4	S.A. Dept. of Mines	1968	1500 above sea level	2 miles N.S.	S.A. Dept. of Mines
5	S.A. Dept. of Mines	1958	500 above ground level	1 mile N.S.	Bureau of Mineral Resources
6	S.A. Dept. of Mines	1966	500 above ground level	2 miles E.W.	Bureau of Mineral Resources
7	S.A. Dept. of Mines	1966	1500 above sea level	2 miles E.W.	Bureau of Mineral Resources
8	S.A. Dept. of Mines	1963	1500 above sea level	2 miles E.W.	After Bureau of Mineral Resources

INDEX TO SOURCE OF DATA



Instruction Manual

MAGNETIC SUSCEPTIBILITY

SYSTEM (MODEL 3101)

(Bison Instruments)

Instr. Manual

Magnetic Susceptibility System

Model 3101 (Bison Instruments)

INSTRUCTION MANUAL

BISON INSTRUMENTS
MAGNETIC SUSCEPTIBILITY SYSTEM
MODEL 3101

BISON INSTRUMENTS
3401-48TH AVENUE NORTH
MINNEAPOLIS, MINNESOTA 55429, USA
CABLE: GEOPRO/TEL. (612) 588-9471

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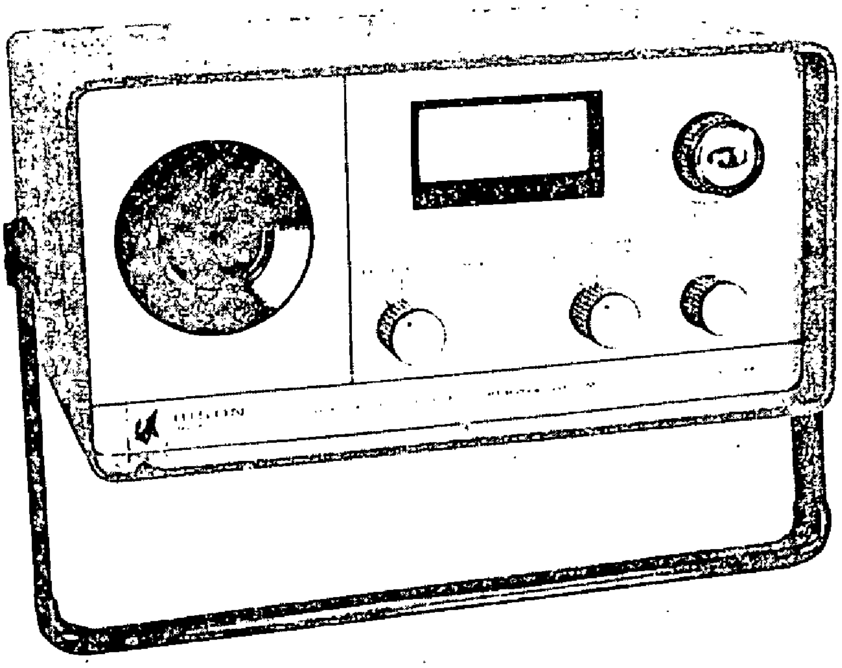

MODEL 3200 – Auto-phase balance High Sensitivity Magnetic Susceptibility System for very low Susceptibility Samples. Selectable Direct Reading or Recorder Output.

I
INTRODUCTION

The Bison Magnetic Susceptibility Meter is based upon a fundamental design originally described by Mooney (1952), but a substantial number of improvements and modifications have been made. These result in greater accuracy, precision, reliability, and convenience of operation.

The Susceptibility Meter serves to measure the magnetic susceptibility of rocks and other materials in the range 0.00001 to 0.1 cgs units. This range includes virtually all naturally occurring materials. Even higher values can be measured using simple dilution techniques described in Section V.

An important feature of the Susceptibility Meter is that measurements are made in a magnetic field whose intensity is approximately equal to that of the earth's magnetic field. Magnetic susceptibility for ferrimagnetic materials depends strongly upon field strength, hence measurements made at higher intensities would have little relevance for the interpretation of magnetic surveys.

Another feature of the Susceptibility Meter is that the measurements obtained are independent of the remanent magnetization and (except for very highly conducting materials) of the conductivity of the sample. The former is particularly important because most magnetizable materials exhibit both induced (i.e., susceptibility) and remanent magnetization. These two phenomena can be completely separated using the Bison Magnetic Susceptibility Meter. The measurement of remanent magnetization requires a different type of instrument.

II
MAGNETIC SUSCEPTIBILITY AND ITS APPLICATION

When a magnetizable substance is placed in a magnetic field of intensity H, it takes on an intensity of magnetization J. The ratio of these two quantities is called k, the magnetic susceptibility per unit volume:

$$k = J/H.$$

Magnetic susceptibility is related to the more familiar quantity magnetic permeability, μ, as

$$k = \mu - 1\text{, MKS units, or}$$

$$k = (\mu - 1)4\pi\text{, CGS units.}$$

Thus k is a dimensionless quantity, but the numerical values will differ by a factor of 4π in the two systems. The general practice of using CGS units will be followed here.

The magnetic properties of rocks and earth materials depend largely upon the presence of small amounts of certain ferrimagnetic minerals. These are principally iron-titanium oxides, of which magnetite (Fe_3O_4) is the most important because of its common occurrence and high values of magnetic susceptibility. For most rocks, the magnetic susceptibility is proportional to the volume percent of magnetite. Numerical data to illustrate this point are presented in Figure 1, which is reproduced from *Handbook of Physical Constants* (Lindsley, *et al.*, 1966).

The correlation shown in Figure 1 does not permit the prediction of magnetic susceptibility on the basis of rock type, because the volume percent of magnetite in any given rock type can vary between wide limits. Magnetite is an accessory mineral in most rocks, hence it does not enter significantly into the classification scheme for rocks. Certain trends do exist; for example, mafic rocks normally exhibit higher susceptibilities than do silicic rocks. This is illustrated by the data in Table I, also reproduced from the *Handbook of Physical Constants.*

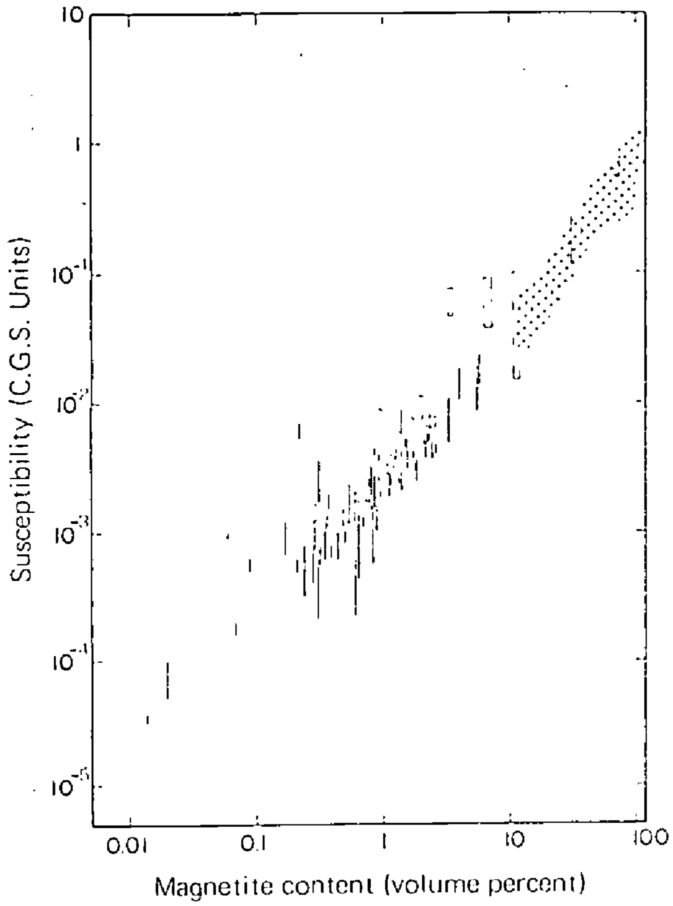

FIGURE 1: Relationship between magnetic susceptibility and magnetite content for a variety of rocks and ores. (From Lindsley, et al., 1966, p. 548).

Table I: Range of Magnetic Susceptibility in Major Rock Types

Rock type	Number of samples	Percentage of samples with susceptibility: Less than 10^{-4}	Between 10^{-4} and 10^{-3}	Between 10^{-3} and 4×10^{-3}	Greater than 4×10^{-3}
Mafic effusive rocks	97	5	29	47	19
Mafic plutonic rocks	53	24	27	28	21
Granites and allied rocks	74	60	23	16	1
Gneisses, schists, slates	45	71	22	7	0
Sedimentary rocks	48	73	19	4	4

The principal application for the Bison Magnetic Susceptibility Meter is in connection with ground and airborne magnetic surveys. Essential data for planning and interpreting these surveys consist in magnetic susceptibilities for the rock types which may be encountered. Given this information, the expected magnetic anomalies can be predicted, appropriate field procedures and equipment can be selected, and the observed anomalies can be interpreted.

Another important application lies in the correlation between magnetic susceptibility and the magnetite content of iron ores. The data shown in Figure 1 suggest that susceptibility measurements can be used to estimate magnetite and iron content in iron ores. The effectiveness of this correlation is greatly improved by calibration measurements in the particular ore district or even the particular iron formation under investigation. Examples of work of this sort may be found in papers by Jahren (1963), Shandley and Bacon (1966), and Webb (1966).

OPERATION

A. Description of Panel Controls

The panel controls are shown in Figure 2. Their function is as follows:

1. SPECIMEN SAMPLER. The panel mounted specimen sampler is used primarily for very short cores, pieces, crushed or powdered samples. The specimen under measurement is inserted into the opening. Rock fragments or powdered materials should be contained in a glass or plastic vial to avoid contaminating the sample holder.
2. NULL GALVANOMETER readings are obtained by bringing the needle to its center position.
3. THE FUNCTION SWITCH allows you to set the various sides of the bridge; left for BALANCE, and right for either READ or ZERO. This switch includes an automatic on and off function, thus eliminating any possibility that the instrument will be left on inadvertently when not in use.
4. MULTIPLIER SWITCH. Correct readings may be obtained in either position, but the x1 position is recommended for susceptibilities of less than 10,000 x 10 $^{-6}$ cgs unit and the x10 position for susceptibilities between 10,000 x 10 $^{-6}$ and 100,000 x 10 $^{-6}$ cgs units. The position of the MULTIPLIER switch may be changed freely without the need for re-nulling the system.
5. BALANCE (POTENTIOMETER) CONTROL. When the function switch is in the BALANCE position, the BALANCE control is turned in the direction which would lift the needle up to the center Null position.
6. ZERO (POTENTIOMETER) CONTROL. This control is used only during the initial balancing sequence where the system is balanced with nothing in the specimen ZERO sampler. When the function switch is in the ZERO position, the ZERO control is turned in the direction which would lift the needle up to the center Null position.
7. READ CONTROL. The final reading is obtained from this dial. The scale reads from 0 to 10,000 with the final

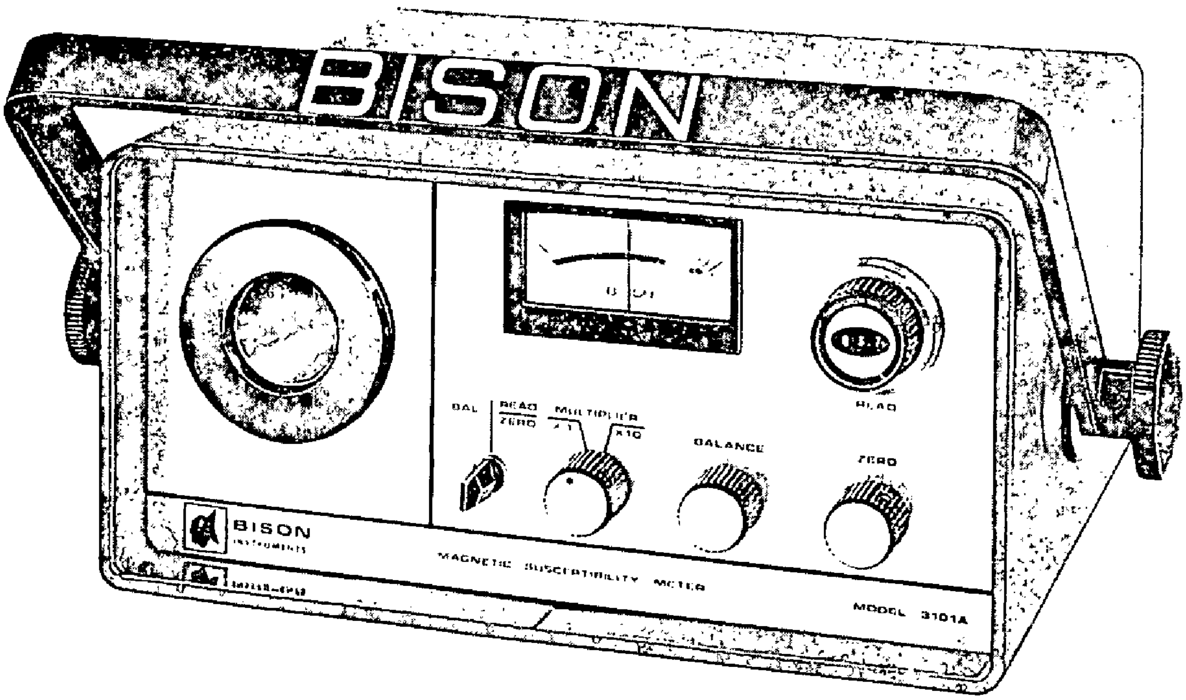

FIGURE 2: Magnetic Susceptibility Meter.

digit being read from the scale along the right hand side of the dial.

8. COIL SELECTOR SWITCH. Located on the back panel of the instrument. It must be in the INTERNAL COIL position when using the front panel specimen sampler and in the EXTERNAL COIL position when using any of the optional remote specimen samplers (In-situ or pass-through specimen samplers).

B. Operating Instructions. Operating is carried out in two steps. The first step consists of a Null adjustment, with the specimen sampler empty. The sample is then inserted into the specimen sampler and final adjustments made (Air Balance). The reading on the dial is directly converted into magnetic susceptibility. See Section V following.

To Air Balance:

The initial step is to Null balance the instrument without a sample in the specimen sampler, or as is the case with the In-situ coil, without the possibility of magnetic material affecting this initial Null balance.

1. Set READ dial to 0000.
2. Set the MULTIPLIER switch to the x1 position.
3. With the specimen sampler empty, hold the function switch in the right or ZERO/READ position and rotate the ZERO control until the Null meter is returned to the center position.
4. Hold the function switch in the left or BALANCE position and rotate BALANCE control to again bring the Null meter to the center position.
5. Repeat steps 3 and 4 to assure yourself that both center adjustments are satisfied.

To Read:

BE CAREFUL NOT TO ALTER THE SETTING OF THE ZERO CONTROL DURING ANY OF THE FOLLOWING STEPS.

1. Set the MULTIPLIER switch to the anticipated range.
2. Insert the sample into the specimen sampler.
3. Hold the function switch in the READ/ZERO position and rotate the READ control to bring the Null meter to center.
4. Hold the function switch in the BALANCE position and rotate the BALANCE control to again bring the Null meter to center.
5. Repeat steps 4 and 5 in turn until both adjustments are satisfactorily at a center balance.
6. Take the readings from the READ dial. A typical reading might be 5,704 with the last digit obtained from the dial along the right hand side of the dial.
7. Apparent susceptibility equals the READ dial x the factor selected on the MULTIPLIER switch x 10^{-6} and is expressed in cgs units. Additional correction factors that may be required are described in the next section.

C. Battery Test and Maintenance. The only maintenance which should ever be required is battery replacement. The current requirement is so low (c. 15 milliamps) that usage life equal to shelf life can be anticipated with the self-contained mercury cells. It is recommended, however, that fresh cells be replaced annually.

The Bison Model 3101 Meter uses two Mallory TR-234R (5.4 volt) (or equivalent) mercury cells. These can be obtained from local suppliers or Bison Instruments, Inc.

To replace the batteries, the rear panel (four screws) is removed. Caution should be exercised to insure that correct battery polarity is observed. In replacing the back panel, tighten the four screws. A snug fit is sufficient.

IV
PREPARATION OF SAMPLES FOR PANEL SPECIMEN SAMPLER

Measurements may be made on samples in a great variety of forms. These include cylindrical drill cores of various diameters, chips or fragments, or powdered material. (It should be noted that very fine powder may give erroneous susceptibility values; the value will decrease with decreasing particle size.)

The diameter of the panel specimen sampler (1, in Figure 2) is 1-1/2 inches (38mm) hence the sample diameter can be no greater than this value. Any smaller diameter of sample or of sample container may be used. A simple correction for sample diameter will be described in the next section. The sample container should be centered within the specimen holder so far as possible.

The length of the sample must be at least 2 inches so that the sample will extend slightly above the top of the specimen holder. Any length greater than this is acceptable, although the measured magnetic susceptibility will apply only to that portion within the specimen holder. If the available volume of sample is limited, then the diameter of the sample container should be decreased (by using a small diameter test tube, for example) in order to produce the required minimum length.

Approximate measurements can be made on still smaller samples, although accuracy will be reduced. The technique here is to place the sample as close as possible to the geometrical center of the specimen holder opening. In addition to the usual correction for diameter (see next section), a correction for short length must be made: the measured susceptibility must be multiplied by the ratio (depth of the sample holder)/(length of the specimen).

An alternative procedure with very small samples is to calibrate the instrument with a sample of the same shape and volume whose susceptibility is known. Normal measurements are made for a larger volume of the calibration material in order to determine its true susceptibility, and a reading is then obtained with the small sample of this calibration material.

Cylindrical drill cores can be inserted directly into the specimen holder. The bottom of the drill core should be flat or nearly so, if possible. Samples in the form of chips, fragments, or powder should be contained in glass or plastic vials. Such material should never be poured directly into the specimen holder, for this might contaminate the holder. (For lengthy cores or cores of varying diameter see Section VI.)

V
CALIBRATION FACTOR AND CORRECTIONS

Each Bison Magnetic Susceptibility Bridge is individually calibrated at the factory so that it reads directly in units of magnetic susceptibility. For example, suppose that the READ Control reads 1765 and the Multiplier Switch is set at the position, x10. The apparent susceptibility of the specimen is then 17,650 x 10^{-6} c.g.s.

Two corrections may be required in order to convert apparent susceptibility to true susceptibility. These are corrections for:

1. Sample diameter, if it differs from the standard value of 1 inch (25.4mm).
2. Air spaces in the sample, if it consists of fragments or powder.

1. Sample diameter.
   The calibration factor is based upon a standard sample diameter of 1 inch (25.4mm). For samples with any other diameter, the preliminary susceptibility value must be multiplied by the square of the ratio of standard sample diameter to true sample diameter, that is by the ratio

$$\left(\frac{1 \text{ Inch}}{\text{Sample Diameter, Inches}}\right)^2$$

OR

$$\left(\frac{25.4\text{mm}}{\text{Sample Diameter, mm}}\right)^2$$

2. Air spaces in the sample.
   The calibration factor is based upon a solid sample. If the actual sample consists of fragments or powder, then part of the sample volume will consist of air space. The readings must therefore be multiplied by the ratio

$$\frac{(\text{true density of the sample})}{(\text{apparent density of the sample})}$$

   This ratio can be obtained simply by weighing. An easier method consists in placing a 100 cc mark on the container and filling the container with sample above this mark. After completing the susceptibility measurement, the container is filled with a measured volume of water, V, sufficient to reach the 100 cc mark. The above ratio is then computed as

$$\frac{100}{100 - V}.$$

For approximate calculations, a factor of 2.0 is often adequate without actually measuring the ratio of true density to apparent density.

To illustrate the preceding calculations, suppose that the apparent susceptibility reading of 17,650 x 10^{-6} c.g.s. had been obtained using a test tube of inside diameter 1¼ inches, such that the ratio,

$$\frac{\text{true density}}{\text{apparent density}} = 1.85.$$

Then we calculate:

$$\begin{aligned} \text{true susceptibility} &= (17{,}650 \times 10^{-6}) \left(\frac{1''}{1\frac{1}{4}''}\right) (1.85) \\ &= 20{,}900 \times 10^{-6} \text{ c.g.s.} \end{aligned}$$

For highly magnetic samples, it is sometimes convenient to keep the Susceptibility Meter reading at a lower value by using a small diameter sample container, for example a glass tube with inside diameter of 1/2" or 3/4". Another technique which may be useful is dilution of the sample with some non-magnetic material such as quartz sand. An additional multiplying factor is then required:

$$\left(\frac{\text{density of sample}}{\text{density of mixture}}\right) \left(\frac{\text{mass of the mixture}}{\text{mass of the sample}}\right)$$

VI
ACCESSORIES

A. Continuous-Core Specimen Samplers

A continuous-core specimen sampler is shown in Figure 3. The continuous-core sampler in Figure 3 sits in a non-metallic support which allows the core to be held while measurements are made. The core is passed through the sampler and the operator makes his measurements at whatever locations are desired, or continuously.

The following external access samplers are available:

3110-5 Continuous Core Sample Coil (Open-ended, 2 inch–5.1 cm diameter) for core sizes BX and BQ or smaller.

3110-6 Continuous Core Sample Coil (Open-ended, 2.5 inch–6.35 cm diameter) for core sizes NX and HQ or smaller.

3120 In-Situ Sample Coil (Flat coil, 6 inch–15.25 cm diameter)

The open end "Continuous Core" samplers for pass-through sampling of long cores allows an intensive examination of a 1 inch (2.5 cm) band anywhere along an unlimited length of rock core.

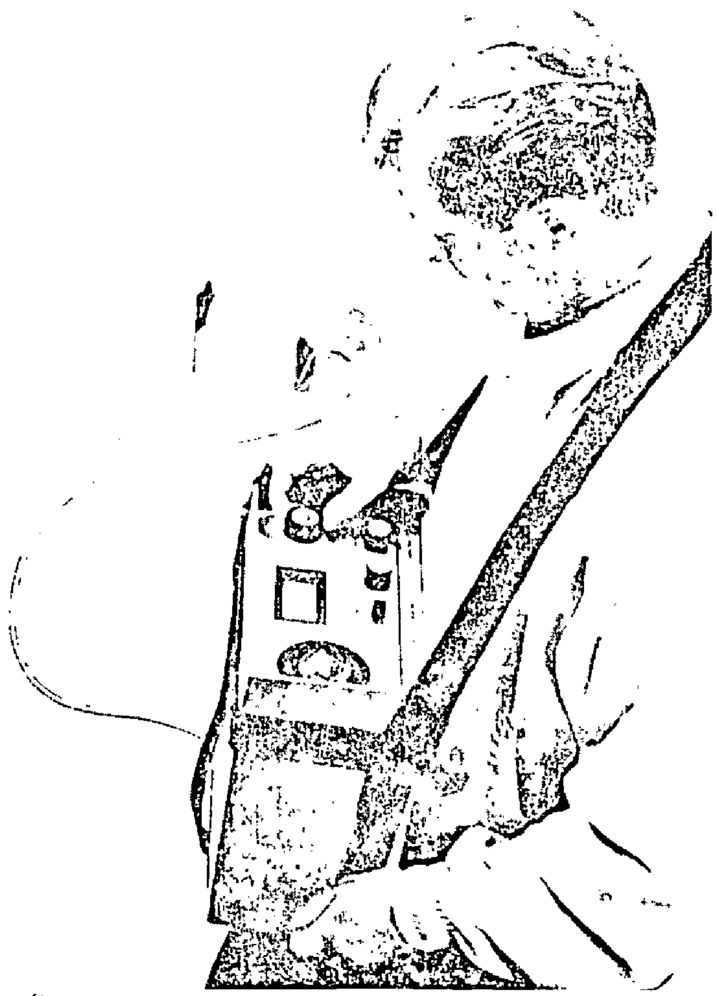

FIGURE 3: Continuous-Core Specimen Sampler

Fast scanning is extremely simple. After initial balance of the 3101A with the Continuous Core sample coil in place on the core, the core is passed rapidly through the sampler until an anomalous condition is indicated by an offset of the dial pointer. Measurement of the anomaly is made as desired. A similar technique can be employed for the In-Situ sampler and this attachment can also be adapted to monitoring conveyor belt transport of magnetic ores.

The purpose of these accessories is to permit susceptibility measurements anywhere along the entire length of extended drill cores. This would not be possible using the internal sample holder (1, in Figure 2) because of the limited length of the sample opening. The Continuous-Core Sampler also accepts larger core diameters and provides greater flexibility in placement of the sample holder.

Connections for the external samplers are made by means of a receptacle together with a Selector switch on the rear of the Bison Magnetic Susceptibility Bridge.

The Specimen samplers should be placed several inches away from metal and magnetic materials, and should not be moved during the course of a measurement. It should also be placed no closer than 3 feet (1 meter) from the Susceptibility Meter. Care should be taken to center the core as closely as possible within the circular opening. If it should prove necessary to mechanically support the core in any fashion, the supporting material should be non-metallic.

The measurement procedure is identical with that described in Section III.B. A preliminary zero-setting is carried out with the core absent from the sample holder. The core is then inserted and the measurement taken. If several measurements are required along the length of the core, they may be taken without any necessity for repeating the zero-setting.

The measured susceptibility refers to a sample length of approximately 1 inch (25mm) at the center of the sample holder. Calibration corrections, if required, are the same as described in Section V, with the exception that a separate calibration factor for the external Specimen Holder must also be multiplied times the susceptibility reading. Reference sample diameter is 1 inch (25mm), just as for the internal coil.

B. In Situ Coil for Measurements on Rock Outcrops

The In Situ Coil is shown in Figure 4:

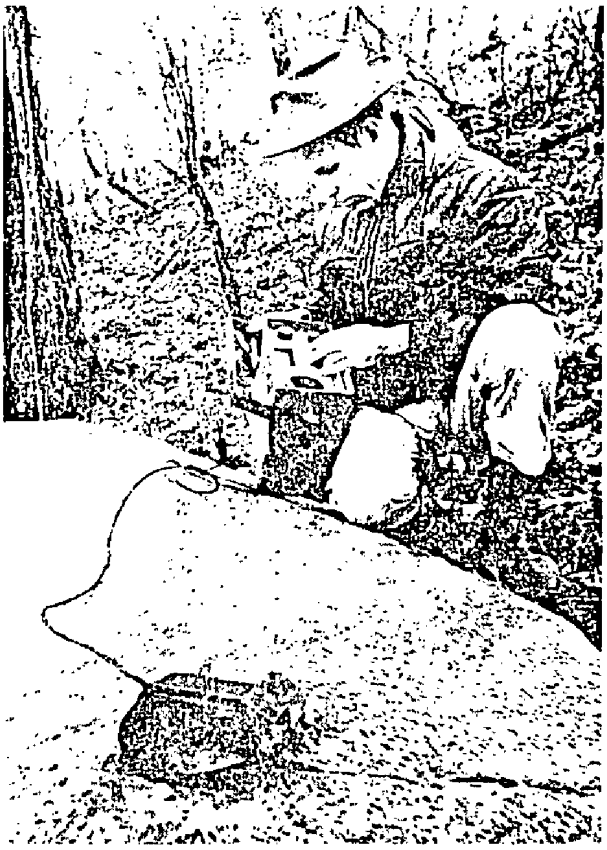

FIGURE 4: Bison 3120 In Situ Coil

The purpose of this accessory is to permit susceptibility measurements on flat surfaces of magnetic materials such as rock outcrops, soil, etc. The measurement is carried out without disturbing the sample material.

The In Situ Coil is supplied as a plug-in accessory. Connections are made by means of a receptacle together with a selector switch on the rear of the Bison Magnetic Susceptibility Bridge.

The sample material should provide a reasonably flat surface for measurement, with horizontal dimensions equal to at least 2-3 times the coil diameter and with sample thickness equal to at least 1 coil diameter. Errors will be introduced by surface irregularities, or by a weathered surface layer, or by insufficient volume of material.

The measurement procedure follows that described in Section III.B. The preliminary zero-setting is carried out with the In Situ Coil held away from the sample material by a distance of at least 2 coil diameters. The Coil is then laid on the surface and the measurement taken. When setting the zero conditions and when taking readings, the coil should be kept as far from the Susceptibility Meter as practical. If several measurements are required at various locations, they may be taken without any necessity for repeating the zero-setting.

The measured susceptibility refers to a volume of material directly beneath the In Situ Coil, of diameter roughly equal to that of the coil and of depth into the rock approximately equal to one-half the coil diameter. These figures are order of magnitude only, since the exact volume of measurement is not precisely definable.

No corrections are required with the In Situ Coil for either sample diameter or sample density, as were needed for the Internal Specimen Sampler and the Pass-Through Samplers.

Two other corrections are required, however:

1. The measured susceptibility must be multiplied by the following calibration factors:

Model 3110-5 Coil system	1.20
Model 3110-6	1.75
Model 3120	1.00

2. If the In Situ Sampler fails for any reason to lie directly in contact with the sample material, then a correction must be made for the spacing. This situation may arise if the sample material has a coating of weathered material, or if the surface is irregular (the average spacing must then be estimated), or if other reasons make it desirable to operate the Sampler away from the surface (when monitoring a conveyor belt, for example). To apply the correction, measure the average spacing S between the rock surface and the bottom surface of the In Situ Coil form and multiply the measured susceptibility by a factor M, as follows:

Sampler offset from rock surface		Multiply measured susceptibility by
Inches	Centimeters	
0	0	1.000
0.1	0.254	1.047
0.2	0.508	1.114
0.5	1.27	1.432
1.0	2.54	2.385
2.0	5.08	6.464
3.0	7.62	14.893
5.0	12.70	52.419

(Before using the above table, the measured offset S must be increased by .08 inches (.2 cm) to take account of the added thickness of the insulating material used on all Bison In Situ coils).

VII
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