DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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MAGNETIC AND GRAVITY INTERPRETATION ON THE STUART SHELF

GEOLOGICAL SURVEY

By

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ABSTRACT

The Stuart Shelf region is a stable platform of Carpentarian and older crystallisation basement which is overlain by flat lying Adelaidean and Cambrian sediments. It extends eastward from the exposed crystalline Gawler Block area to the mobile "Torrens Hinge" zone. The Olympic Dam copper-uranium deposit occurs near the eastern margin of the region in a zone of high magnetic relief which covers much of the ANDAMOOKA 1:250 000 sheet. The deposit was discovered by reconnaissance drilling of coincident gravity and magnetic highs by Western Mining Corporation Ltd. in 1975. The mineralisation occurs beneath approximately 350 m of Adelaidean sediments and therefore is an excellent example of the type of concealed ore body which will become a more frequent exploration target in the next decade.

Regional gravity and magnetic data in the area are widely spaced and variable in quality. Interpretation of the magnetic data indicates that the Olympic Dam deposit occurs in an upfaulted basement block, with fault movement controlled by northeast and northwest trending fractures. Quantitative modelling indicates that the interpreted fault immediately north of the deposit may contribute directly to the magnetic anomaly observed at Olympic Dam. The northwest trend which is prominent in the regional magnetic data is attributed to dolerite dykes which are eroded feeders to the Lower Adelaidean Beda Volcanics. Detailed aeromagnetic data from Billakalina improve the resolution of these anomalies in an area where they are not as evident in the regional data. The northwesterly trend is also evident in the region of more intense magnetic relief which contains the Olympic Dam anomaly.

Interpretation of the depth to pre-Adelaidean basement in the region is complicated by the presence of several stratigraphically separate magnetic sources. Anomalies due to the Adelaidean Beda Volcanics and associated dolerite dykes are imposed on basement and intra-basement sources. These are distinguished on the basis of anomaly form, orientation and interpreted susceptibility values, but clear distinctions cannot always be made. The proposed regional interpretation of depth to basement shows some correlation with gravity features, but density variations within basement are also evident. Gravity interpretation is also complicated by the unknown contribution of the Cambrian Andamooka Limestone.

INTRODUCTION

The Olympic Dam copper-uranium deposit occurs near the eastern margin of the Stuart Shelf region in central South Australia (Figure 1). The deposit occurs in a hematitic-granitic breccia beneath approximately 350 m of flat lying Adelaidean shales, quartzite and Cambrian limestone and was discovered by reconnaissance drilling of coincident gravity and magnetic highs by Western Mining Corporation in 1975. Within the Stuart Shelf, significant copper mineralisation occurs at Mt. Gunson (approximately 120 km south of Olympic Dam), where the Cattle Grid copper deposit is currently being mined by Mt. Gunson Mines Pty. Ltd. In this area, the copper mineralisation occurs within the Adelaidean sedimentary sequence and is situated low on the flank of coincident gravity and magnetic highs.

The announcement of the Olympic Dam discovery generated considerable exploration interest in the Stuart Shelf. Because the nature and depth of the mineralisation precludes the use of geochemical or electrical exploration techniques, subsequent exploration has been restricted to stratigraphic drilling, principally in areas of high gravity and/or magnetic values.

This paper presents an interpretation of the broad scale basement features outlined by the regional geophysical data. In attempting to define the form of the Carpentarian surface in the Shelf region, it is necessary to differentiate between magnetic anomalies from several stratigraphically separate sources. Regional gravity and detailed aeromagnetic data have been used to provide a more complete interpretation of some features.

MAJOR GEOLOGICAL FEATURES

The term "Stuart Shelf" refers to the depositional environment which existed during the Adelaidean Period on the eastern margin of the Gawler Craton (Figure 1). The Stuart Shelf extends eastward from outcropping Carpentarian and older basement to the north-south trending belt of fractures (known as the Torrens Hinge Zone) which marks the western edge of the Adelaide Geosyncline (Johns, 1968). The Adelaidean Shelf sediments were deposited on "a major platform of variable mobility" (Thomson, 1976) and the shelf sequence contains five recorded breaks in sedimentation. Exploration and stratigraphic drilling has indicated that basement faulting was a controlling factor in sedimentary processes. The following description of geological units from the shelf and surrounding regions is based on Thomson, et. al., (1976) and Mason, et. al., (1978). Particular reference is made to possible magnetic sources in each unit.

Archaean - Lower Proterozoic

Rocks of probable Archaean age have been described (Daly et. al., 1978) from the Tarcoola region, immediately west of KINGOONYA (Figure 1) and these include a quartz-magnetite rich, banded iron formation which is strongly magnetic. The Archaean rocks include paragneisses, metamorphosed basic rocks and syn-orogenic

granites, and substantial magnetic relief would be expected over these lithologies. Directly overlying the Archaean 'sequence' are the metasediments of the Lower Proterozoic Hutchison Group. These include the iron formations of the Middleback Range iron ore district and also numerous amphibolite sills which may be magnetic sources. Other units in the Hutchison Group are highly variable in composition and metamorphic grade, and so the regional magnetic expression of the Group is also likely to be variable. Metasediments of this age occur south of the Shelf area in PORT AUGUSTA and YARDEA, near the southwestern corner of KINGOONYA and also to the northwest, in the Mt. Woods inlier. The Proterozoic metasediments are intruded by the Burkitt Granite and its equivalents south of the shelf region.

Carpentarian

Crystalline rocks of the Hutchison Group are unconformably overlain by acid volcanoclastic sediments of the Moonabie Formation and conglomerates and clastic sediments of the Corunna Conglomerate in the south and the Tarcoola Beds in the west. Apart from the initial sedimentary phase, the Carpentarian period was dominated by major extrusions of the Gawler Range Volcanics. The volcanic sequence is up to 2 000 m thick and consists mainly of dacites and rhyodacites. Minor basaltic flows occur in the lower part of this sequence and have a slight magnetic response. Numerous intrusions of Hiltaba Granite marked the final consolidation of the Gawler Craton at the end of the Carpentarian. Plutons of this age occur around the southern and western margins of the shelf region and also in the Mt. Woods area. Copper mineralisation is associated with this plutonic phase in the Moonta-Wallaroo area to the south of Port Augusta.

(?)Pre-Adelaidean Transitional Cover

Trachytic, amygdaloidal basalts of the Roopena Volcanics unconformably overlie the Moonabie Formation at Roopena homestead, in PORT AUGUSTA. This volcanic unit was initially considered to occur at the base of the Adelaidean (Thomson et. al., 1976) but recent exploration drilling (Mason et. al., 1978) has indicated that the Roopena Volcanics and the overlying Pandurra Formation occur beneath the newly defined Beda Volcanic unit, which is now considered to be the basal Adelaidean horizon. The Pandurra Formation is a feldspathic sandstone and conglomerate unit which was deposited in deltaic or fluviatile environments controlled by basement fault movements. For the purposes of this discussion the Pandurra Formation will be considered as an Adelaidean sedimentary unit.

Adelaidean

The lower Adelaidean sequence on the Stuart Shelf is described by Mason et. al., (1978), who define the new basal-Adelaidean Beda Volcanic unit. The volcanics are described as "spilitic, clinopyroxene basalts" which intertongue with the conglomeratic Backy Point Beds. Dolerite dykes which intrude the Pandurra Formation are petrologically similar to upper flows in the volcanics and are considered to be eroded volcanic feeders. The dykes are associated with prominent northwest-trending magnetic anomalies (Figure 1) and this suggests that the Beda Volcanics are also a possible magnetic source.

The overlying Adelaidean sequence consists predominantly of clastic, shallow water sedimentary units which are often separated by major hiatuses. The Adelaidean units are overlain again unconformably, by the Cambrian Andamooka Limestone.

Magnetic Sources - Summary

A schematic geological section for the southern Stuart Shelf (Figure 1) indicates the complexity of magnetic sources which may exist beneath the sedimentary cover units. As indicated in the section (Figure 2), block faulting within the basement is a controlling factor in sedimentation and this further complicates magnetic interpretation. The Pandurra Formation and overlying Adelaidean units may directly overlie a number of distinctly different magnetic basement lithologies in the Shelf region. The main magnetic sources in the region are the iron formations of Archaean and Lower Proterozoic age. These formations may be overlain by a substantial thickness of Gawler Range Volcanics and/or associated volcanoclastic sediments which are expected to be essentially nonmagnetic. Interpretation of depth to the pre-Pandurra surface from magnetic data alone is therefore inconclusive, particularly in areas where anomalies due to the Beda Volcanics or dolerite dykes are imposed on relief due to basement sources.

REGIONAL MAGNETIC CHARACTERISTICS

Aeromagnetic data in the Stuart Shelf region have been obtained on east-west flight lines at spacings of 1.6 km on ANDAMOOKA, TORRENS and PORT AUGUSTA, 3.2 km on KINGOONYA, CURDIMURKA and southern BILLAKALINA and 8.0 km on northern BILLAKALINA. Within areas of outcropping basement, magnetic relief is characteristic of the basement lithologies outlined above. In both the Archaean areas around Tarcoola and the areas of Hutchison Group metasediments south of the Shelf, the magnetic field is dominated by large amplitude, linear anomalies associated with banded iron formations in each area. Similar

relief is observed over Hutchison Group equivalents in the Mt. Woods inlier (Figure 1). The variable magnetic response of the Hutchison Group metasediments is evident in detailed data from the Charleston area, southwest of Port Augusta, which was interpreted by Roberts (1978).

Anomalies in excess of 1000 nT are observed over the margins of the Burkitt Granite in PORT AUGUSTA, but plutons of the younger Hiltaba Granite are evident as areas of low magnetic relief. The large area of outcropping Gawler Range Volcanics shows relatively minor magnetic relief except for anomalies of 200 to 300 nT observed over outcrops of basaltic flows. Some relief is also observed over magnetic obsidians within the volcanic pile.

Magnetic Relief within the Shelf region

The Olympic Dam deposit occurs in a fairly distinct province of moderate magnetic relief which is separated from outcropping basement to the southwest by a zone of low relief (Figure 1). Within the latter area, northwest-trending, low amplitude anomalies due to the dolerite dykes which intrude Pandurra Formation are the most prominent magnetic feature. The Olympic Dam magnetic province covers most of ANDAMOOKA and is characterised by a generally high level of magnetic relief, a lack of continuity of magnetic features and the presence of large amplitude, equidimensional anomalies. Three major linear trends are evident in the magnetic data and the lateral extent of the Olympic Dam magnetic province appears to be largely controlled by linear features which are interpreted as basement faults. The most obvious trend is oriented northwesterly, parallel to the Norwest Fault. The trend is particularly apparent in the zone between the Olympic

Dam province and outcropping basement where anomalies due to intruded dolerite continue for hundreds of kilometres in a northwesterly direction. Dislocations of this orientation have been interpreted within the Olympic Dam province, but are not as evident as elsewhere because of the generally higher level of magnetic relief. The interpreted fractures (faults?) within the Olympic Dam province do not appear to have been intruded along their strike in a similar manner to the western features but this may also be obscured by the more magnetic nature of the rocks within this area.

The second group of major trends are parallel to the interpreted fault which forms the southern margin of the Mt. Woods area of shallow basement. Several major magnetic features within the Olympic Dam province are also truncated by interpreted faults with a similar northeasterly orientation. The most prominent of these features lies immediately north of the Olympic Dam anomaly and is discussed in some greater detail below.

The third magnetic trend is oriented north-south and is well developed in the south-eastern portion of the shelf region. The main feature lies immediately east of the magnetic highs at Mt. Gunson and coincides with the western margin of a zone of low magnetic relief on TORRENS and southern ANDAMOOKA. These features are interpreted as continuations of the faulting mapped on PORT AUGUSTA and may be responsible for the observed gravity and magnetic highs at Mt. Gunson.

Billakalina detailed aeromagnetic survey

The three major trends are evident to varying degrees in the area flown for Samedan of Australia near Billakalina homestead (Figure 3). The survey was flown on east-west lines 500 m apart at an altitude of 100 m MTC. Small amplitude anomalies

due to dykes are clearly resolved and are obviously imposed on deeper-seated basement features. These latter anomalies are truncated by northeasterly trending faults, which do not displace the dyke anomalies. North-south faulting is also indicated in the magnetic data and this is supported by evidence from BILLAKALINA (Ambrose and Flint - in prep.) where Mesozoic and younger sedimentation patterns indicate that north-south faulting occurs within the area.

A gravity survey was conducted over the southeastern corner of the magnetic survey area and, under a joint venture agreement, Kennecott Explorations (Australia) extended the gravity coverage over the southwestern corner and drilled three diamond drill-holes (Figure 3) to test gravity and magnetic anomalies. Results of this programme are discussed in detail by Warne (1979). The Miller's Creek and Price's Bore drill-holes were sited to test gravity highs which were considered as possible expressions of dense, hematitic breccias. The drill holes failed to penetrate the Pandurra Formation and the gravity anomalies are attributed to variations in the Andamooka Limestone. The Playford hole was sited to test an isolated magnetic high which was interpreted as a small basic intrusive. The hole entered Pandurra Formation at approximately the depth interpreted for the magnetic source, suggesting that the anomaly may be due to a small intrusive source associated with the Beda Volcanic event. The source was not intersected by drilling, however, possibly because of displacement of the magnetic anomaly due to remanent magnetisation.

The northwest-trending Anomaly 'D', on the eastern edge of the survey area, is qualitatively different to other dyke anomalies in the survey area. The anomaly is considerably larger

in magnitude (150 nT) than a 'normal' dyke anomaly (50 nT) and it lacks the continuity of other features with this orientation. The trend which passes through Anomaly 'D' continues to the southeast through the Olympic Dam anomaly and aligns with a break in magnetic character within the Olympic Dam magnetic province (Figure 1).

INTERPRETATION OF DEPTH TO MAGNETIC SOURCES

If interpretation of magnetic data is to be successful in outlining the form of the pre-Adelaidean surface within the shelf region, anomalies from source rocks at or near this surface must be resolved from those due to dolerite dykes or volcanics which may occur above the surface, and also from Archaean or Lower Proterozoic sequences which may occur beneath non-magnetic Carpentarian volcanics and sediments. In the latter case, the distinction for an individual anomaly cannot be made on the basis of the magnetic data alone, but must rely on regional gravity data, surrounding magnetic features and interpreted regional structure. Anomalies due to the Beda Volcanics are distinguished on the basis of interpreted susceptibility value and form of the anomaly while anomalies due to dolerite dykes are generally recognised from their northwesterly attitude and magnitude (Anderson, 1978).

Interpretation of the Olympic Dam magnetic anomaly

The Olympic Dam magnetic anomaly is a local high on the south side of a regional linear magnetic gradient which is oriented in a northeasterly direction. This major gradient is indicative of faulting within a crystalline, magnetic basement and the lateral extent of the linear portion of the gradient implies a relatively deep source for the anomaly. However,

drilling results from Olympic Dam, which are reported in SADME Mineral Industry Quarterly No. 7 (August, 1977), indicate that mineralised hematitic and granitic breccias which are thought to be pre-Adelaidean in age occur beneath only 350 m of Adelaidean and younger sediments. This is much shallower than the interpreted depth to magnetic material and illustrates the need for differentiating anomalies from sources within crystalline 'basement'. Regional magnetic and gravity profiles for a northwest-trending section through Olympic Dam and across the major magnetic gradient are shown in Figure 4. The interpreted magnetic 'horizon' shown provides an approximate fit for the regional magnetic field and is interpreted as the envelope for highly magnetic iron formations of either Archaean or Lower Proterozoic age. The residual anomalies A, B and C are much shallower-source features and all are interpreted as being due to material within 500 m of the ground surface. These values correlate with the pre-Adelaidean surface at 350 m depth at Olympic Dam and the source rocks are interpreted as Hutchinson Group metasediments or early Carpentarian basalts. The regional Bouguer gravity profile is inferred from widely spaced data points and shows little correlation with the interpreted magnetic horizon. This implies that the material overlying the major magnetic source is variable in density and susceptibility and probably includes both Hutchison Group equivalents and Early Carpentarian sediments. Similar relationships between magnetic source depths, gravity values and basement lithologies are observed in areas of outcropping basement on PORT AUGUSTA.

Interpretation of Depth to the pre-Adelaidean surface

The interpreted depths to the pre-Adelaidean surface (Figure 5) are dependent upon distinctions between anomalies from the stratigraphic sources outlined above. In some instances, particularly for situations such as Olympic Dam where the magnetic source depth is considerably greater than interpreted depths for surrounding areas, the distinction is a subjective choice based on interpreted regional structure. The regional interpreted depths in Figure 5 consequently outline only broad areas where there is evidence for relatively shallow crystalline basement. The interpretation cannot confidently accomodate areas where non-magnetic Carpentarian units overlie older magnetic units, particularly in areas such as southeastern TORRENS and northern PORT AUGUSTA where northwest-trending dyke anomalies are prevalent. The presence of dyke anomalies makes interpretation of basement features difficult on most of TORRENS and it is not possible to interpret the significance of the north-south oriented faulting through this region from depth values. When considered in conjunction with the gravity data (Figure 6), however, it appears that significant vertical movement of basement blocks may have occurred along these interpreted features in the Mt. Gunson area, in a similar manner to the movement illustrated in Figure 2 for areas south of the Stuart Shelf.

Northeast-trending faults are also indicated in the gravity and magnetic data for the Mt. Gunson region but similarly these are not indicated in the interpreted depth values. North of Mt. Gunson, within the Olympic Dam magnetic province, faulting with this orientation is more evident in the geophysical data and is also apparent in the interpreted depth values. The

Olympic Dam province is interpreted as a regional area of shallow Lower Proterozoic metasediments which is locally faulted and overlain by non-magnetic, dense Carpentarian sediments and possibly volcanics. A major structural break, parallel to the Norwest Fault, bounds this shallow basement area on the northeastern margin and is interpreted as the limit of the Stuart Shelf environment, with the sedimentary sequences thickening rapidly north of this break. The lateral extent of the shallow basement area in the northwesterly direction is controlled by the northeast trending faults but the regional structure apparently continues through the northwestern corner of ANDAMOOKA and into the Mt. Woods area (Figure 5).

The interpreted extent of shallow basement around the margin of outcropping Gawler Range Volcanics on the Gawler Platform is based on a relatively small number of interpreted values in an area where interference from dyke anomalies is common. The interpreted values and the low level of magnetic relief in this area suggest that the Gawler Range Volcanics underlie the shelf sediments and dip gently to the north and east.

Magnetic coverage of the Mt. Woods area is very widely spaced and the magnetic character of the region poorly resolved. Consequently, no attempt was made to define structures within the shallow basement area and the main intention was to outline the extent of shallow basement. The extension of the area in a southeasterly lobe around Billakalina homestead supports the interpretation of a regional basement high along the northeastern margin of the Stuart Shelf.

In the areas other than those indicated as shallow basement, there is no evidence for magnetic material, other than dykes and Beda Volcanics, being withn 750 m of the ground surface.

In the PORT AUGUSTA and southern TORRENS portion of the region, relief due to basement sources is very slight and little information can be interpreted from magnetic data.

Comparison with gravity data

Regional gravity data (Figure 6) further illustrate the complexity of basement relationships in the Stuart Shelf. Gravity highs are observed over areas of outcropping Hutchison Group metasediments and also over most of the area of outcropping Gawler Range Volcanics. An isolated high also occurs over outcropping Tarcoola Beds in southwestern KINGOONYA. Available density measurements, however, indicate that neither the volcanics nor Tarcoola Beds are likely to be excessively dense and this suggests that the gravity response is due to shallow Hutchison Group metasediments in each area. This contrasts with the observed gravity data in the shelf area, where the major gravity high occurs in an area of rapidly deepening basement immediately northeast of the interpreted area of shallow basement on ANDAMOOKA. A similar situation occurs on PORT AUGUSTA, where a substantial gravity high is observed over Moonabie Formation outcrop which is faulted against Hutchison Group metasediments. Sedimentary evidence from the Corunna Conglomerate (Lemon, 1972) indicates that the Hutchison Group was exposed and weathered during deposition of the early Carpentarian sediments and this gravity high in the shelf area could be due to a large thickness of dense sediments which were derived from the interpreted area of uplifted Hutchison Group. This would explain the near coincidence of the edge of high gravity values with the edge of interpreted shallow basement.

The gravity highs in the Mt. Gunson area coincide with magnetic highs but it is not possible to resolve basement structure in this area from interpreted depths. Hence, the gravity highs could be related to shallower Hutchison Group metasediments or density variations within basement.

The Olympic Dam gravity anomaly is a local high in an area of intermediate gravity values which correlates reasonably well with the area of interpreted shallow basement. Elsewhere in the shelf area, areas of interpreted deep basement on KINGOONYA coincide with regional gravity lows, apart from isolated highs in the northern portion of the sheet area. These latter features may be attributed to near surface features, such as the variations in Andamooka Limestone thickness proposed in the Billakalina area, or deep-seated density variations in the basement.

CONCLUSIONS

Interpretation of gravity and magnetic data on the Stuart Shelf can not be conclusive because of the complexity of magnetic sources and the variations of density within pre-Adelaiden basement. The major magnetic sources in the region are Archaean and Lower Proterozoic metasediments but these units may be overlain by non-magnetic members of the Lower Proterozoic Hutchison Group of Carpentarian sediments and volcanics. Gravity highs are generally observed over areas of shallow Lower Proterozoic metasediments but highs are also observed over the Carpentarian Moonabie Formation. Within the Stuart Shelf the major area of gravity highs does not correlate with interpreted shallow magnetic basement and may be due to dense, non-magnetic sediments.

The Olympic Dam magnetic anomaly is interpreted as a local high on a linear, northeast-trending anomaly associated with faulting of highly magnetic material within pre-Adelaidean basement. The magnetic material is interpreted as Archaean or Lower Proterozoic banded iron formation which is overlain by non-magnetic Carpentarian sediments and Lower Proterozoic meta-sediments of varying magnetic susceptibility. The local magnetic feature at Olympic Dam may be related to intrusive activity along a northwest-trending fracture which extends into the "Billakalina" aeromagnetic survey area.

Regional structure of the pre-Adelaidean basement surface within the Stuart Shelf is largely controlled by basement faulting with three major orientations apparent in the magnetic data. North-south faults on PORT AUGUSTA are interpreted to continue through the Mt. Gunson area onto ANDAMOOKA and a basement ridge may exist between these faults. North of Mt. Gunson, an area of shallow magnetic basement, probably Hutchison Group equivalents, is defined by interpreted depth values. This area is delineated by northeast and northwest-trending faults and is apparent as a regional northwest-trending structure, continuing into the Mt. Woods area.

ACKNOWLEDGEMENTS

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C. G. Anderson.

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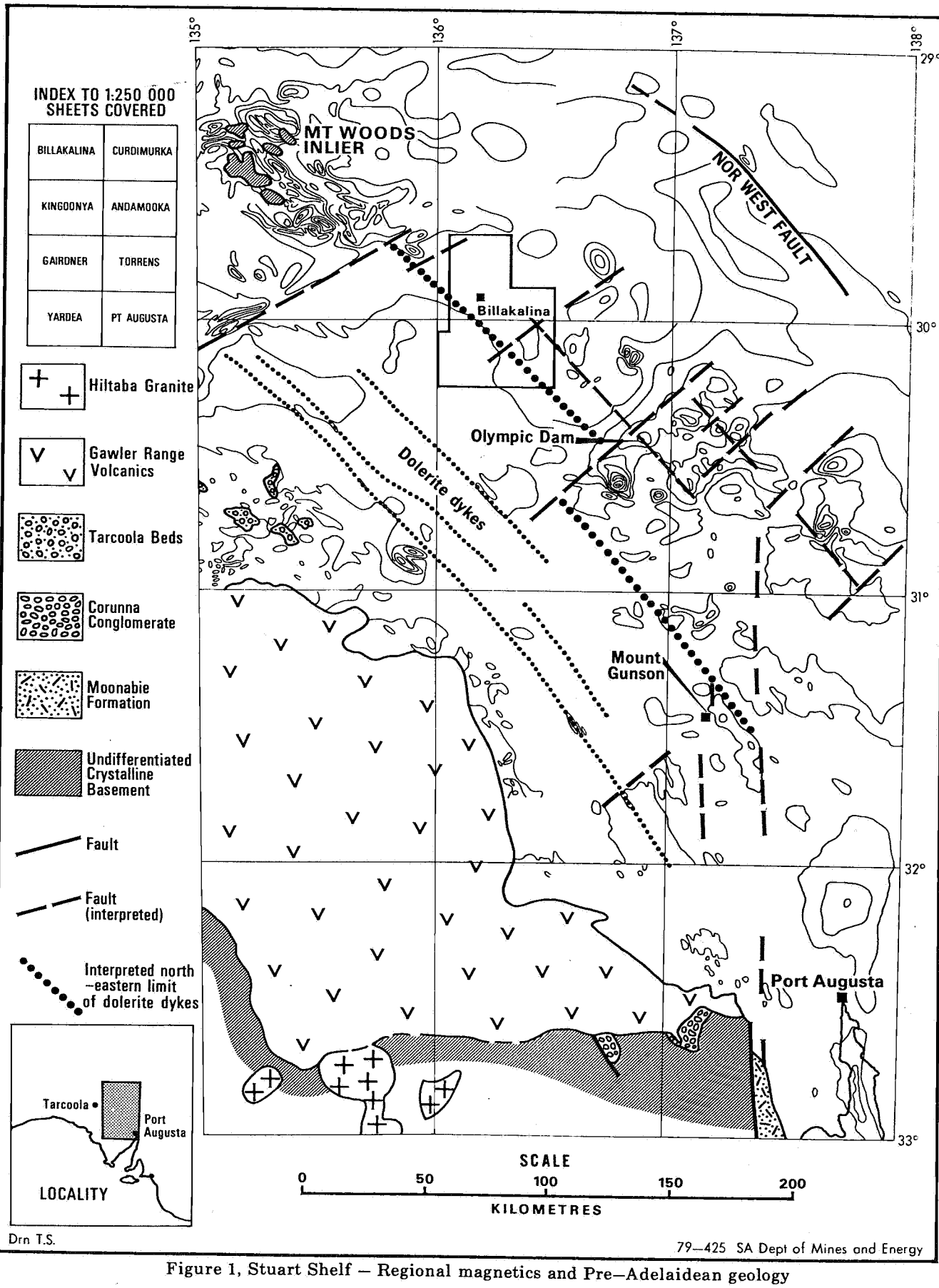

Figure 1, Stuart Shelf – Regional magnetics and Pre–Adelaidean geology

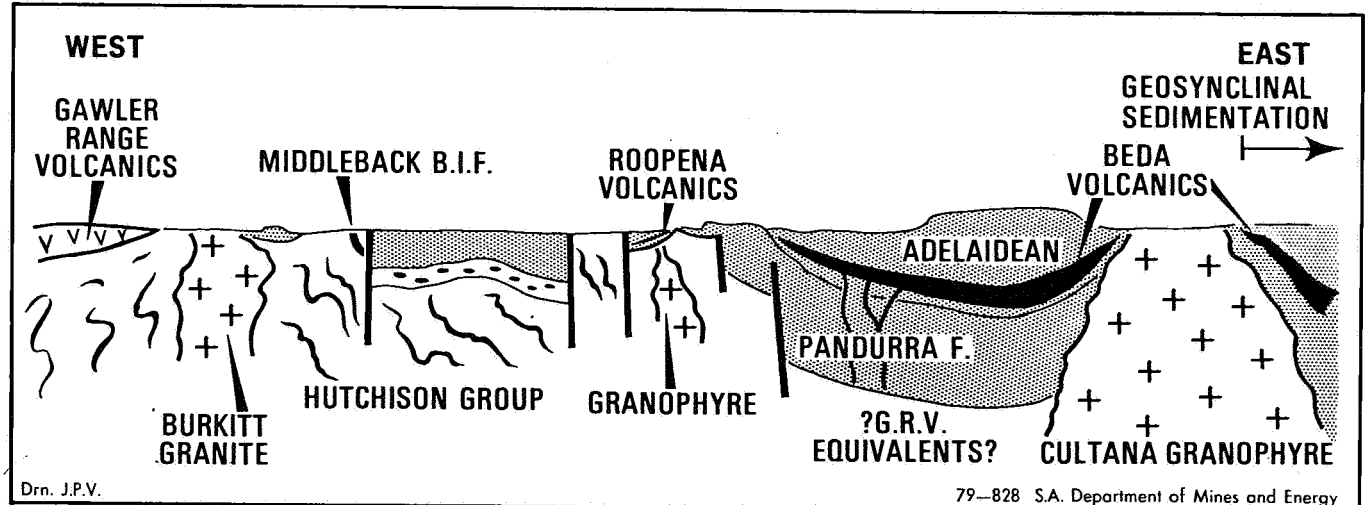

Figure 2, Schematic section for S—E Stuart Shelf

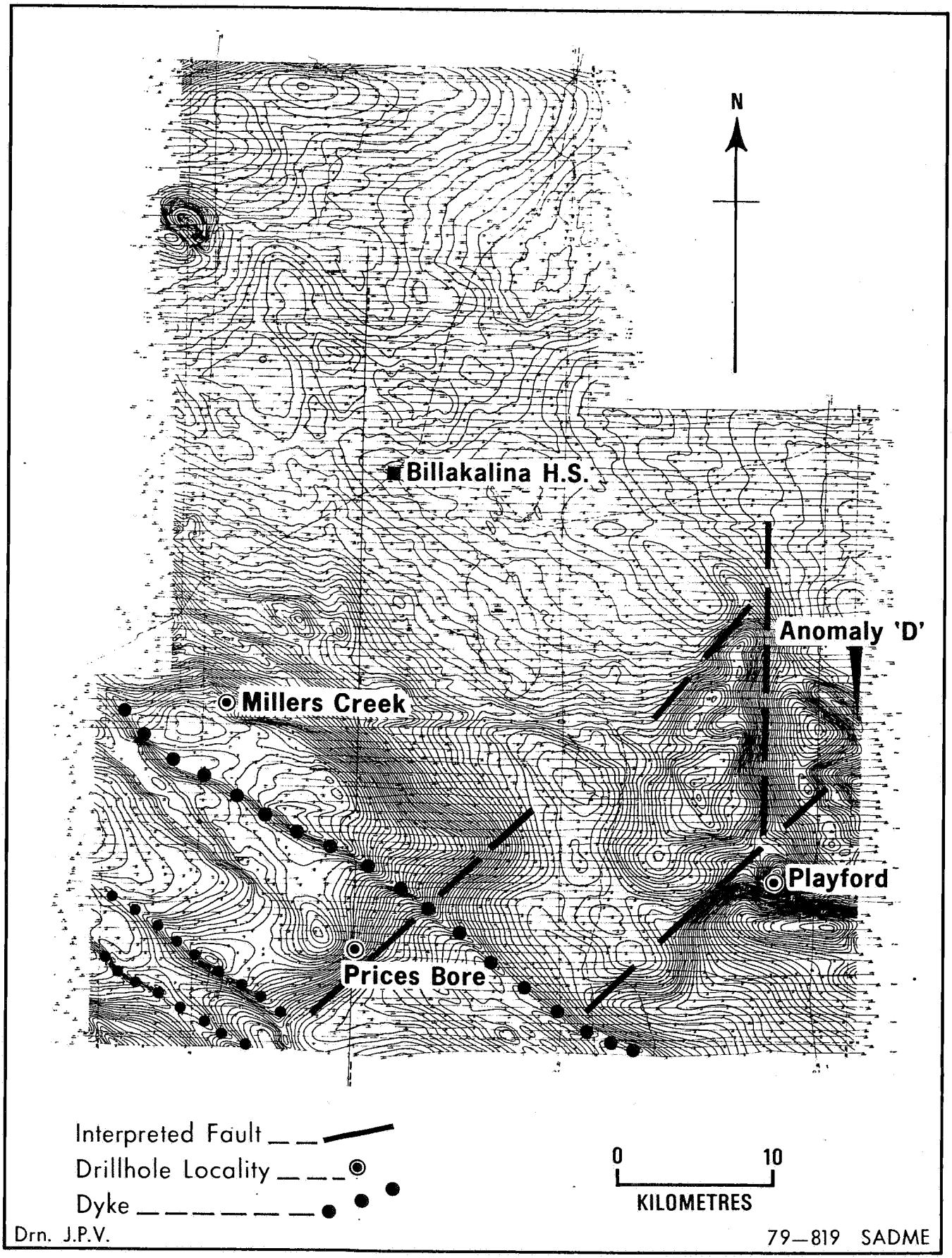

Figure 3, "Billakalina", detailed aeromagnetics

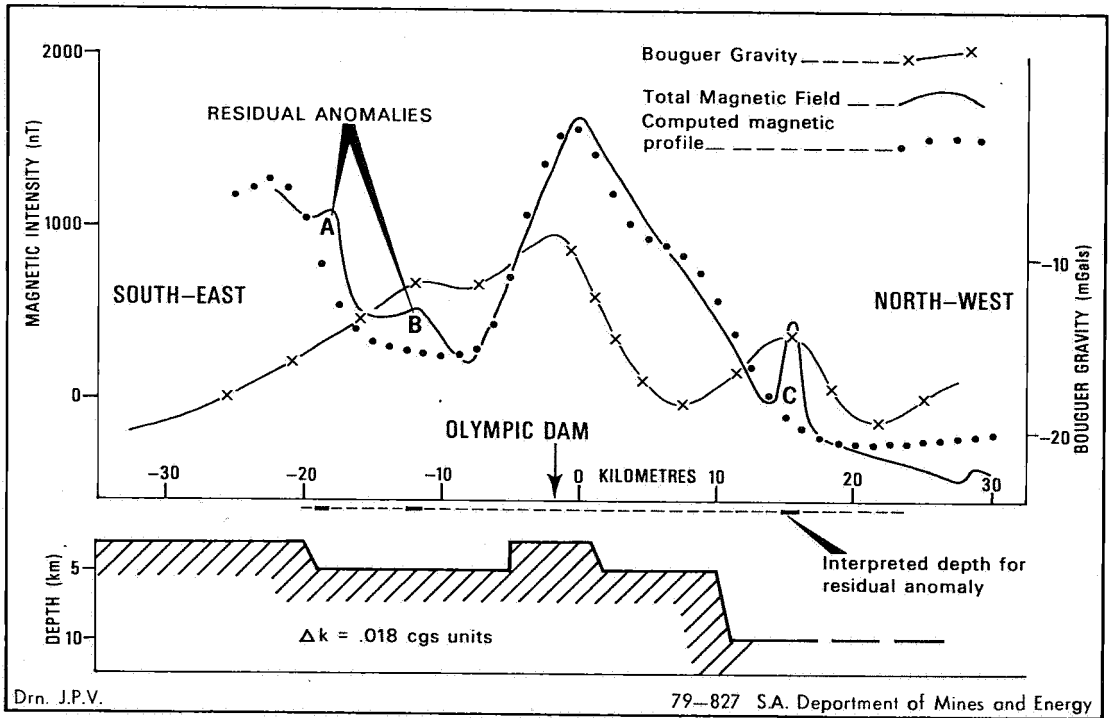

Figure 4, Olympic Dam geophysical sections and interpretation

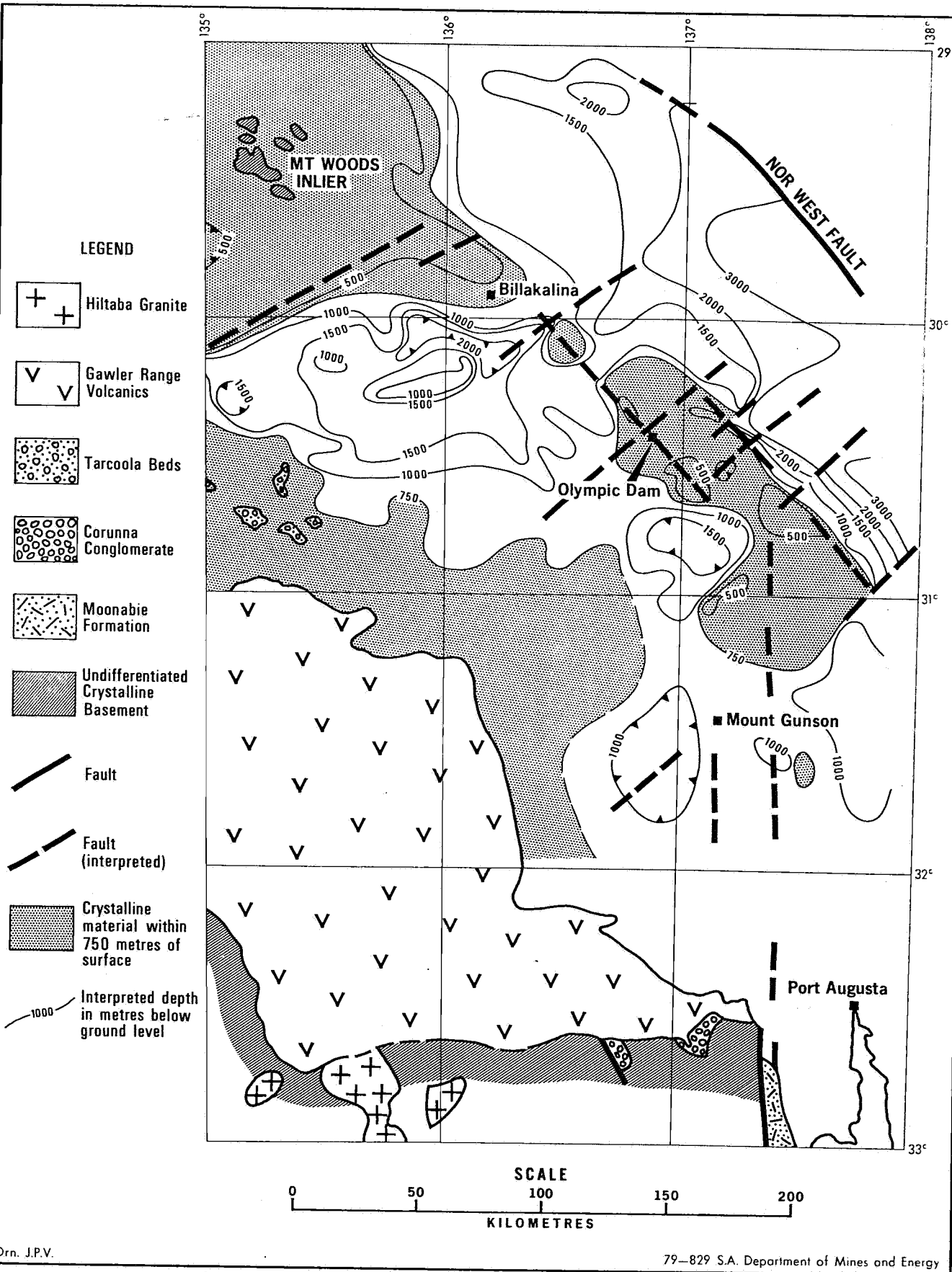

Figure 5, Interpreted depth to Pre—Pandurra Formation surface

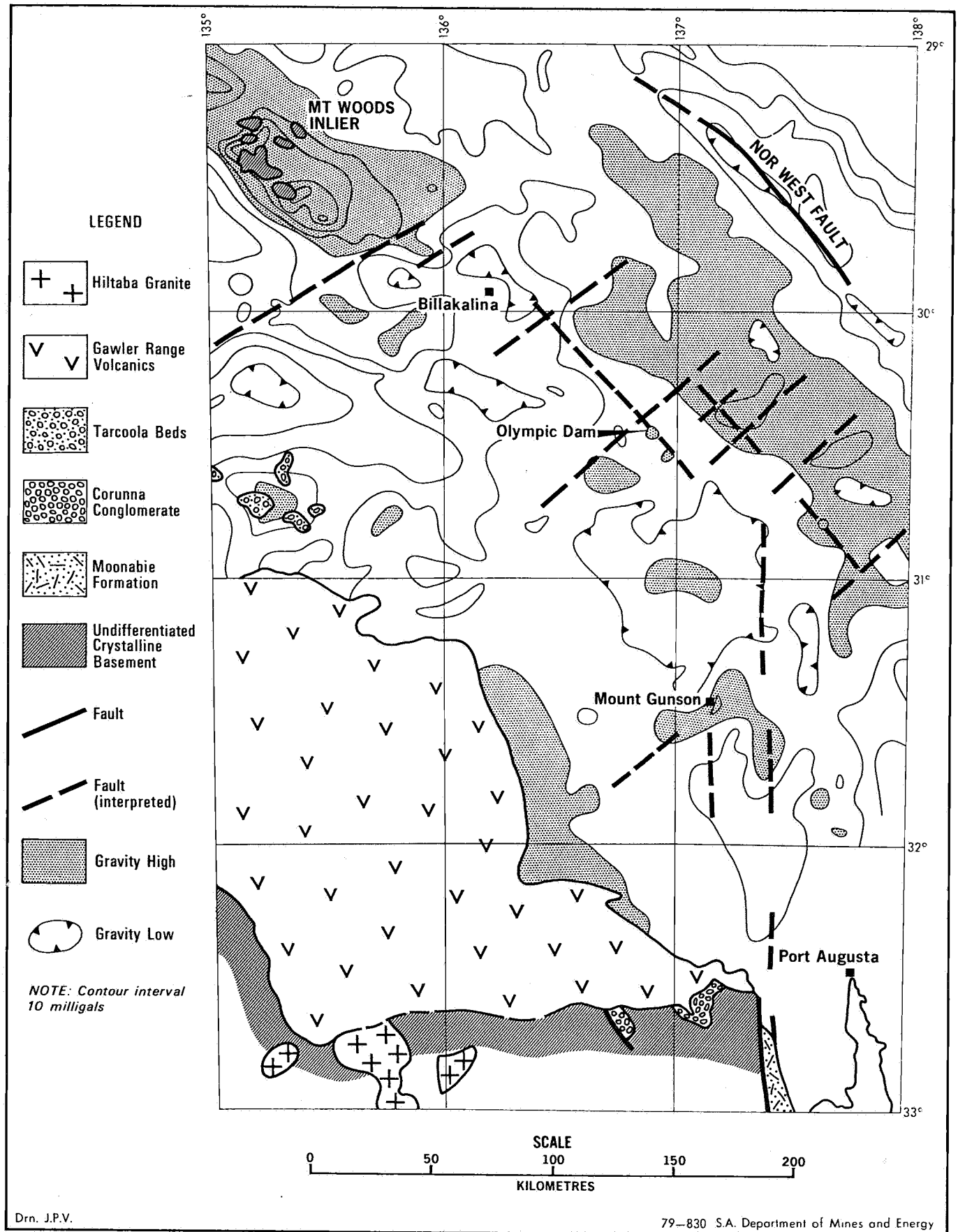

Figure 6, Regional Bouguer Gravity features