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INFERENCES CONCERNING THE DISTRIBUTION AND COMPOSITION OF PRE-CARBONIFEROUS ROCKS IN SOUTHEASTERN TASMANIA

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(with seven text-figures)

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Interpretation of gravity and magnetic data in southeastern Tasmania indicates that blanketing post-Carboniferous rocks generally lie unconformably on late Precambrian rocks. Supporting evidence is provided by clasts of basement within overlying pyroclastics and till, and three boreholes.

Near Hobart, west of the Huon River and south of Bruny Island, deep troughs were filled with (?) Cambrian sequences with a significant volcanic component. Some ultramafics are present along the western margins. Relatively thin wedges of Ordovician-Devonian rocks are also implied, especially west of the Huon River. All rock-units are comparable with those exposed in western Tasmania.

The boundary between eastern and western Tasmania terranes occurs near Sorell and granitoids are dominant east of it. Jurassic dolerite feeder locations have been controlled by basement structure, and doming at Cygnet is related to a thick syenite intrusion. Many modern topographic, or Tertiary structural patterns may be recognised in deep structures.

Keywords: basement, gravity, magnetics, southeastern Tasmania, structure.

INTRODUCTION

Southeastern Tasmania is defined here as the area south of the latitude of New Norfolk and east of the longitude of the Picton River (fig. 1). The surface geology is dominated by exposures of Permo-Triassic Parmeener Supergroup rocks and Jurassic dolerite. Minor intrusions of Cretaceous igneous rocks occur near Cygnet, and Tertiary volcanics and sediments are also present, much of the latter lying beneath the waters of Storm Bay and the Derwent estuary.

Pre-Carboniferous rocks are rarely exposed and all known occurrences are shown in figure 1. Three Mines Department boreholes have penetrated basal Parmeener glacigene materials to reveal altered Cambrian (?) volcanics at Glenorchy (Everard 1976), Precambrian phyllite at Woodbridge (Farmer & Clarke 1985) and contact-metamorphosed Mathinna Beds at Eaglehawk Neck (Gulline & Clarke 1984). An extension of, or splay from the Tamar Lineament must lie between Glenorchy and Pirates Bay, in order to account for juxtaposition of basements of western and eastern Tasmania affinities. The difficulty of predicting the location of this junction was stressed by Williams (1976). The fragments of information available suggest, for most of the area, a complex terrane comparable to that exposed in northern and western Tasmania. Knowledge and understanding of it may well have ramifications for mineral or petroleum exploration.

A small petroleum explorer, Conga Oil, acquired airborne magnetic data across the region and infilled parts of the state gravity data base during 1987. The author was engaged to interpret this data in terms of pre-Carboniferous materials and structural controls and, in particular, to identify sites which might contain Ordovician Gordon Group. Carbonates of this group are believed to have sourced minor oil seepages in the region of Bruny Island.

This paper reports current understanding of pre-Carboniferous materials based on that interpretation as integrated with other fragmental data sources.

GEOLOGICAL DATA

Occurrences of pre-Carboniferous rocks are shown in figure 1. These include Late Precambrian rocks near Hastings and along the Weld River, Cambrian volcanics along the south coast, and Ordovician Gordon Group carbonates at New River, along the Picton River, at Ida Bay and at Hastings. Devonian granite, of eastern Tasmania affinity, occurs near Pirates Bay. Cambrian (?) mafic and ultramafic rocks have also been observed along the

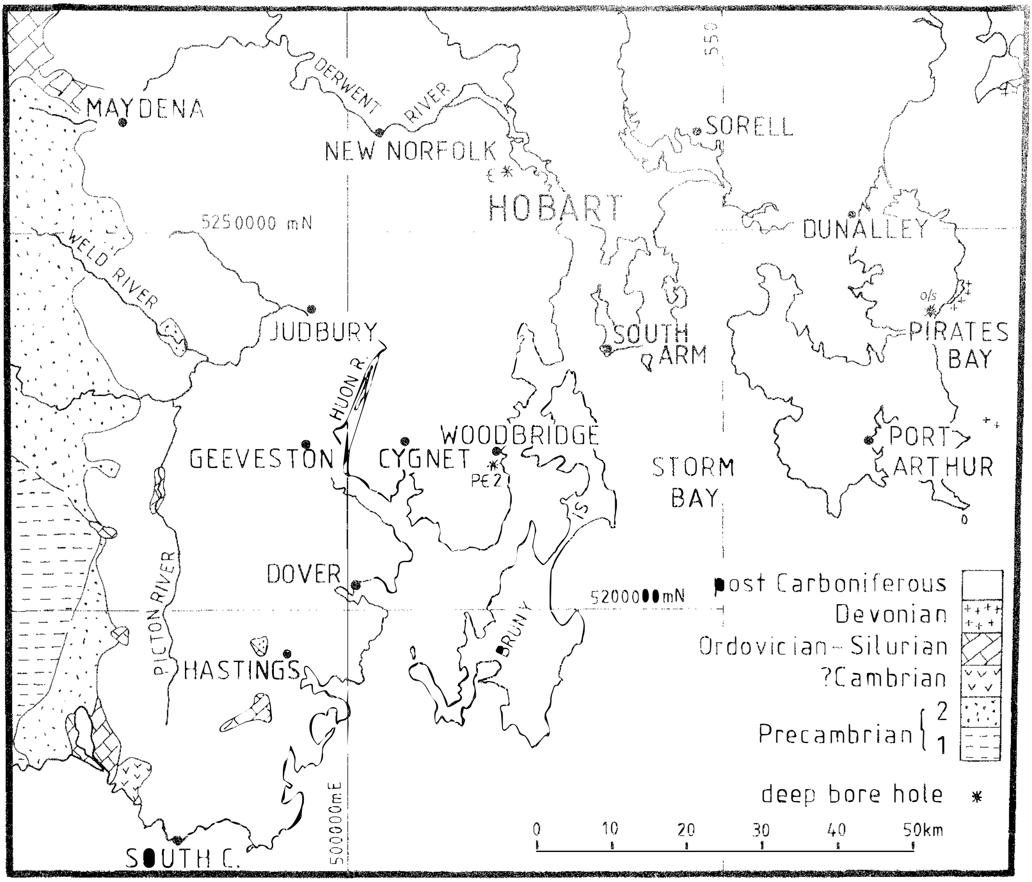


FIG. 1 — Locality map for southeastern Tasmania. All known exposures of pre-Carboniferous rocks are shown.

Weld River (T. Summons, K. Morrison, pers. comm.). Altered Cambrian volcanics occur at 600 m depth at Glenorchy (Leaman 1972, Everard 1976) and Precambrian phyllite underlies Truro Tillite at 998 m depth at Woodbridge (Farmer & Clarke 1985). The boreholes suggest minimum depths to pre-Carboniferous materials since the sites were specially selected. Another hole, at Cygnet, was abandoned after proving a tillite thickness in excess of 450 m (Farmer 1985). A hole at Eaglehawk Neck (Gulline & Clarke 1984) encountered a Mathinna Bedsadamellite contact at 398 m.

Basal Parmeener Supergroup formations are rarely exposed within the region and there are few opportunities to consider provenance of their contents. Although no rigorous study of the pebble compositions within the Truro Tillite has been completed at, or between, available exposures, Leaman & Naqvi (1968) and Banks (1981) have tabulated information on clast compositions. The tillites at Woodbridge and Cygnet are anomalous in a Tasmanian context; they are rich in igneous and Precambrian metamorphic material whereas clasts of many Palaeozoic sedimentary rock types, including limestone, are present but relatively rare. This anomalous enrichment implies passage of the ice sheet across a metamorphic terrane, winnowing, and/or a local predominance of such rock types, since it is known that the deposits are irregular and fill depressions in the Carboniferous topography. No tillite was found in the Glenorchy bore. In these conditions it might be expected that local rocks, within a radius of 10–50 km, might have fed much of the basal units. The implied provenance of the tills at Woodbridge and Cygnet is also wholly consistent with the known rock types at depth, or exposed west of the Picton River or Maydena. Even so, the lack of pebbles of Palaeozoic sedimentary rocks is abnormal, given the relative proportions recorded elsewhere, the general distribution of Precambrian and Palaeozoic rocks and a presumed ice movement from the west or northwest (Clarke 1988). These anomalies may indicate a very local, less than 20 km, derivation and lack of Palaeozoic sedimentary rock exposure to the ice sheet. This scale of source range was suggested by Banks (1981) for material at Maydena but cannot be verified in the region southeast of Maydena due to lack of exposure.

It may be argued that clast content of tills several hundred metres above their base is not a reliable indicator of provenance or local basement. The relief of the filled terrain is comparable, however, with the horizon levels sampled and this is probably not a critical objection.

Pyroclastic rocks offer an alternative sampling of basement rocks. Few mappers, however, have recorded ejecta compositions and, unfortunately, most Tertiary volcanic activity is restricted to the region east of the D'Entrecasteaux Channel and Mt Wellington. Contents of some volcanic centres have been described by Sutherland (1976), Leaman (1976) and Farmer (1985). Some other centres have been inspected by the writer. Fragments of Parmeener Supergroup rocks or dolerite are common, although proportions vary at each vent. Only two sites inspected to date, at Acton and Risdon east of Hobart, present distinctive amounts of any other material — a quartz-veined phyllite comparable to basement in the Woodbridge bore. These observations can be considered definitive and representative of basement east of Hobart.

Although sampling by volcanoes or drilling is limited, it does suggest that exposures at Weld River and Hastings may be typical of pre-Carboniferous basement in southeastern Tasmania — Precambrian rocks but not of the Tyennan region (Turner 1988). This accords with the more ambiguous implication based on tillite clast observations.

GEOPHYSICAL DATA

Seismic, magnetic and gravity data are available for large parts of southeastern Tasmania.

The seismic method, potentially very informative, is of limited value due to energy transmission and processing problems. Much research will be required before generally acceptable results are achievable. Most of the region south of Tasman Peninsula, including Storm Bay, was surveyed by Amoco (Amoco 1971). Water depth and character in Recent and Tertiary sediments and sedimentary rocks are clearly presented. Seismic basement, usually dolerite or Permian rocks, is encountered at reflection times much less than one second, and all seismic records are thereafter degraded. The base of the Parmeener Supergroup is never recognised, nor is the base of any dolerite sheet. In each case the large velocity–density (acoustic) contrast should generate a strong reflection. Similarly disappointing results appear to have been recorded during a recent survey by the Bureau of Mineral Resources during 1988 (P. Hill, pers. comm). Onshore surveys present poorer source–receiver transmission conditions but yield similar results (e.g. Leaman 1978, Leaman & Richardson 1981). Most energy appears to be reflected by the uppermost dolerite surface with production of a seismic shadow. However, Leaman (1978) was able to find rare sites in which good reflections were recoverable from the surface to Moho depths. A site near Clifton, on South Arm, suggested that either the problems were not intractable or that different conditions applied.

Conga Oil recorded a test line on North Bruny Island during 1987; the results were consistent with previous surveys. True reflection character was barely discernible at about 0.4 and 2 seconds respectively. The remainder of the record was typical of noise or homogeneous non-reflective material. At the velocities observed, the upper character change might represent the sub-Parmeener unconformity.

Results such as that noted at Clifton suggest that the method is either generally unworkable south of Hobart, for various reasons, or that deep reflectors are generally absent. The second explanation would imply that post-Cambrian sedimentary rocks (Gordon Group for example), which are heterogeneous and contrasting in properties and would present strong acoustic contrasts, are not common. Further research is necessary before this judgment can be refined or modified.

The potential field methods, gravity and magnetics, offer the best opportunity for regional appraisal. Four regional magnetic surveys have been completed in the area (Finney & Shelley 1967, Esso 1967, Leaman 1987, BMR 1988). Only that undertaken by Conga Oil (Leaman 1987) is fully defined and suitable for detailed analysis. It also covers onshore and offshore segments of the region.

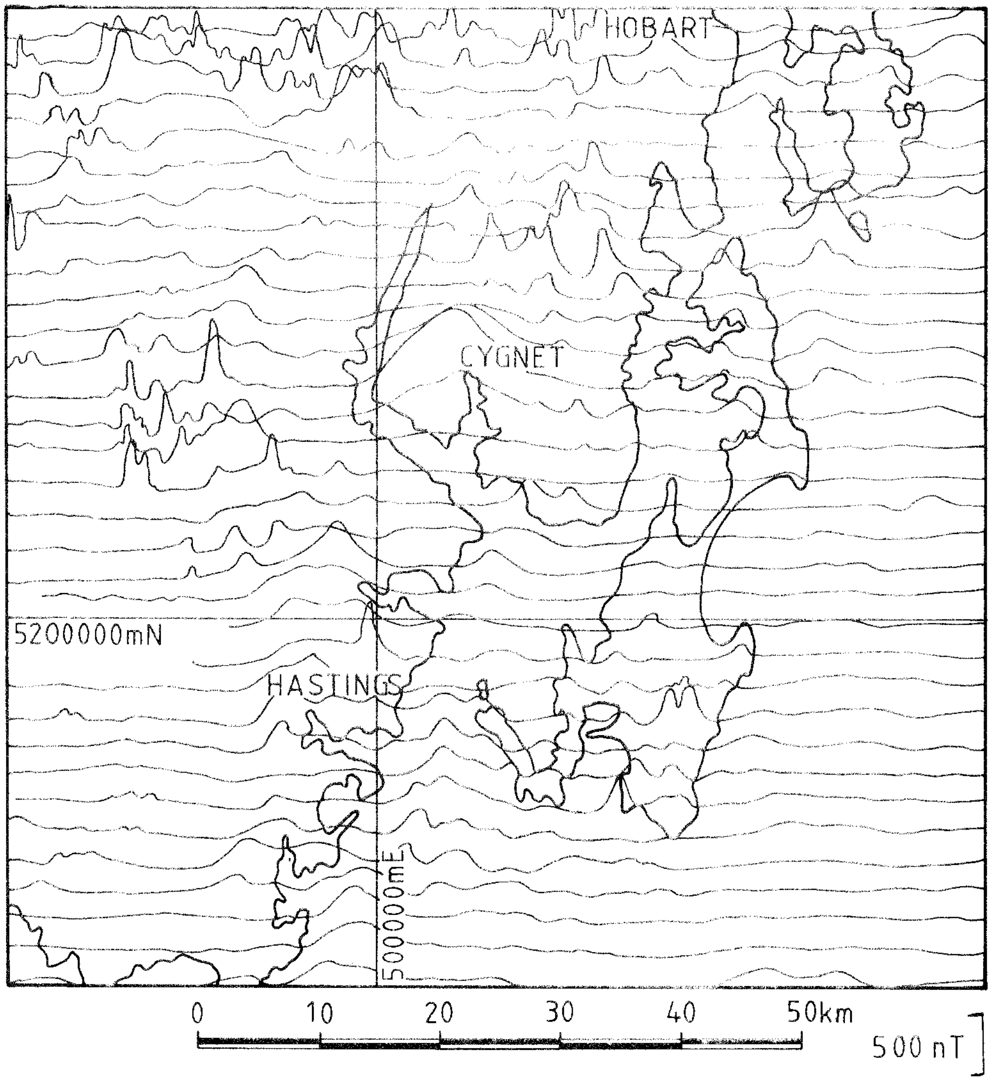


FIG. 2 — Magnetic profiles, 2.5 km apart, observed at 1000 m above sea level. The large Cygnet anomaly and tracts of magnetic basement are indicated by raised field intensity levels. Most high frequency character reflects dolerite-capped topography. Survey for Conga Oil.

Profiles of the magnetic field are shown in figure 2. The field was observed at an elevation of 1000 m a.s.l. and is generally free of any flight deviations. The figure stresses the characteristics of the magnetic field. Some areas contain large isolated anomalies, others extensive regional sources. Since the average terrain clearance was in excess of 700 m for most of the survey, only large, deep-seated or vertically extended sources are reflected in the data.

The gravity data base of Richardson & Leaman (1987) was infilled by Conga Oil to a variable but nominal station spacing of 2 km. The Bouguer map produced was compared to the state crustal model (MANTLE-88, Leaman 1988a, Leaman & Richardson 1989); the resulting residual anomalies are shown in figure 3. These reveal a broad belt of

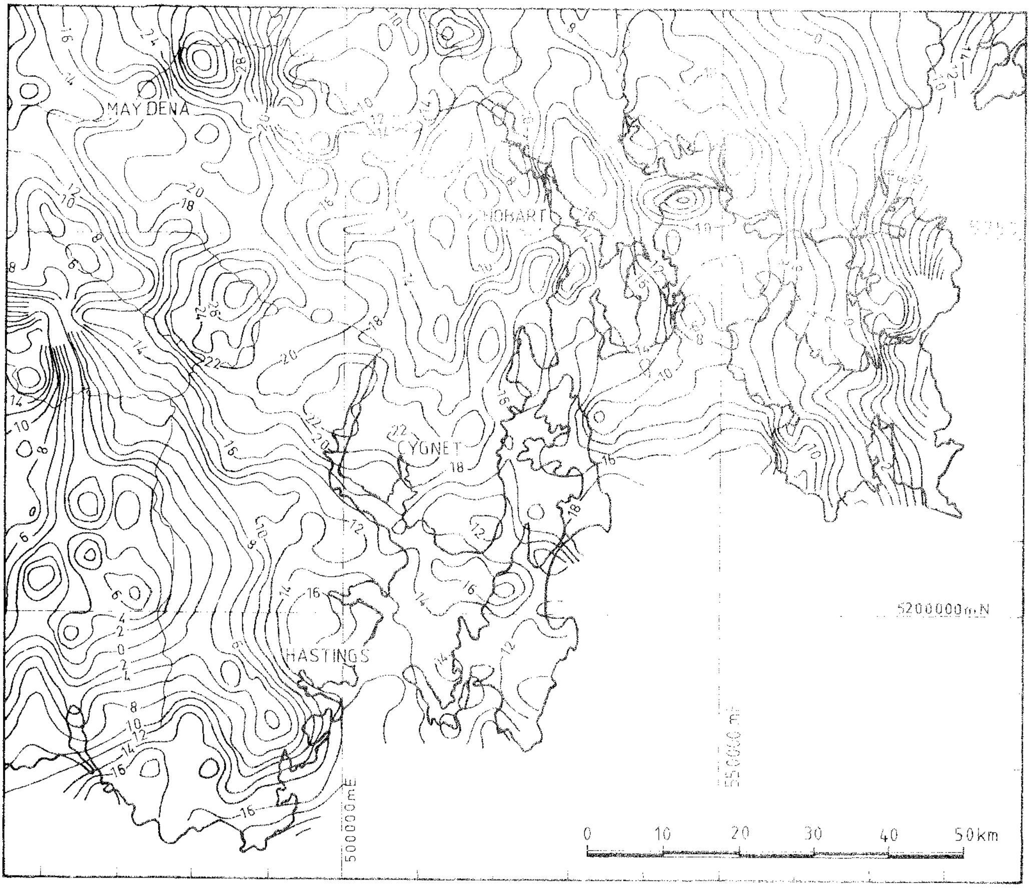


FIG. 3 — Residual Bouguer anomalies derived from observed Bouguer anomalies reduced at a density of 2.67 t/cu m after removal of crustal effects (see text). All data from Tasmanian Mines Department data base.

positive anomalies extending northwest from the Huon estuary.

Although trend information can be deduced from figures 2 and 3, or variations of them, each data set requires extended analysis before details of basement structure can be described reliably.

GRAVITY-MAGNETIC INTERPRETATION

Complete interpretive details and discussion are given by Leaman (1987) and only conclusions or critical aspects are presented here.

Quantitative modelling of both data sets was based on a N–S, E–W, NW–SE and SW–NE array of 17 interlocking profiles, and the solutions accepted were based on consistent profile matches and criteria for all data. Reliability of the interpretation is uniform south of 5255000 mN.

Figure 2 suggests that two distinct magnetic source types are present. Figure 4C illustrates the detailed character of the field and required sources and shows that the basic form of the profile is satisfied by a broad, deep, basin-like source of moderate contrast. Spiky elements reflect more local and shallower sources. The large spike doublet is part of the Cygnet anomaly (see fig. 2). The general response of the primary source is governed by its bulk contrast, depth range, marginal dips and depth to its upper surface. The depth range factor is least sensitive but must exceed 5–6 km. High frequency elements are related to dolerite or, exceptionally,

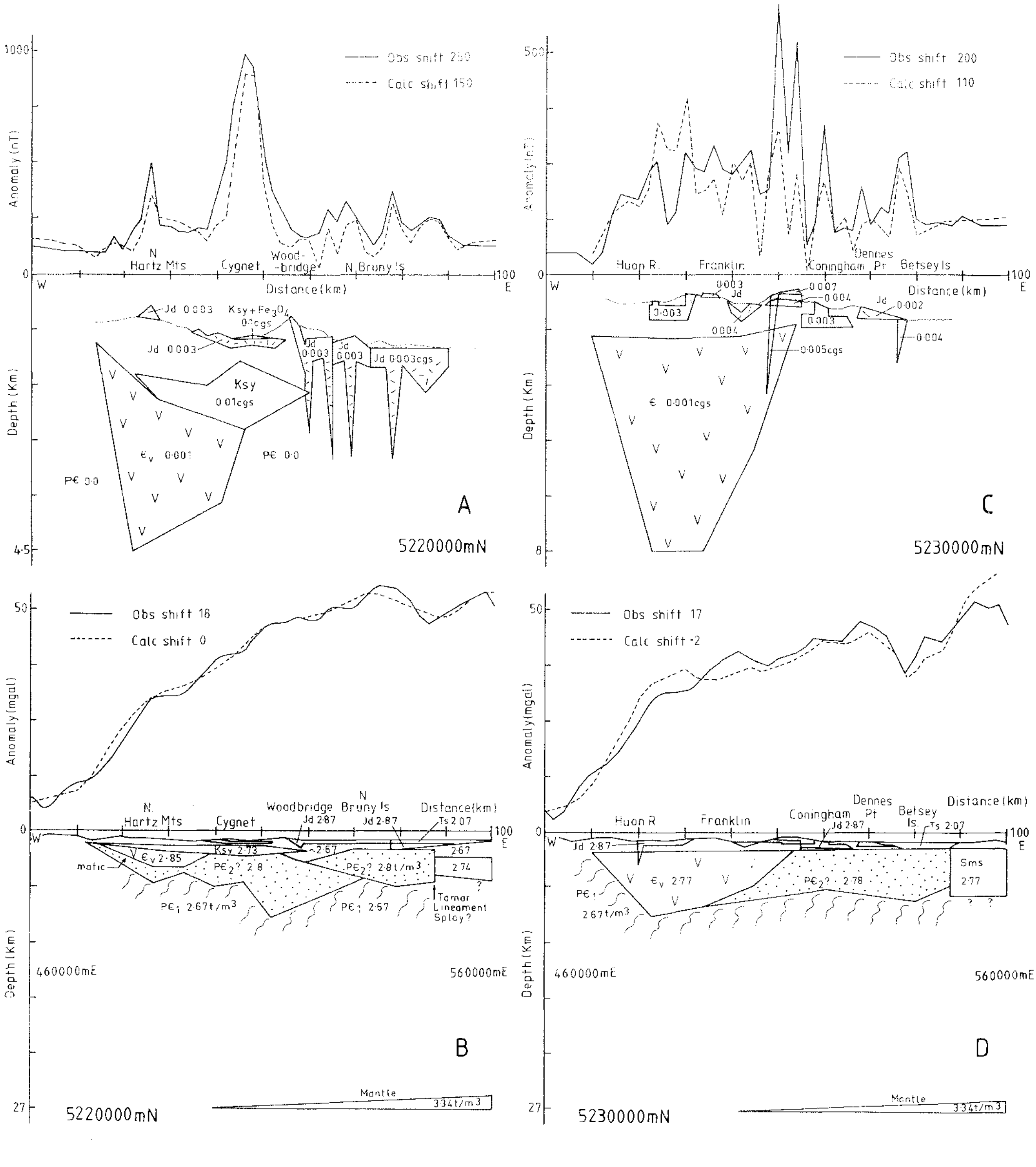


FIG. 4 — Typical magnetic and gravity interpretation models. (A, B) for E–W line at 5220000 mN, (C, D) at 5230000 mN. Symbols: Ts, Tertiary sediments; Ksy, Cretaceous syenite; Jd, Jurassic dolerite; Sms, Silurian Mathinna Beds; Dg, Devonian granite; Ev, Cambrian volcanic suites; pE_2, Jubilee region style Precambrian; pE_1, Tyennan region style Precambrian.

syenite (below). Only major changes in source geometry, especially those with sub-vertical aspects, can yield the field character observed after filtering by large terrain clearances. The precise character of each response is not easily reproduced by simple two-dimensional modelling but the style is definitive. Modelling of all profiles selected has shown that magnetic character is either of this binary type, large and deep sources with local shallow sources, or simply of the small source type.

Large, deep sources are restricted to distinct zones. Modelling also verifies that the marked, isolated anomalies, or spikes, evident in figures 2 and 4 are related to large dolerite dykes or feeder pipes with vertical ranges of at least 2 km. Only a small part of the observed responses can be associated with property or contrast change such as induced by the presence of granophyric or other extreme differentiates; the geometric factor is paramount.

Figure 4D presents the equivalent gravity solution. Some potentially ambiguous elements are minimised or resolved by the magnetic information. The gravity models of figure 4B and D are based on the observed, not residual, Bouguer anomalies and the crustal aspect of the model is therefore included.

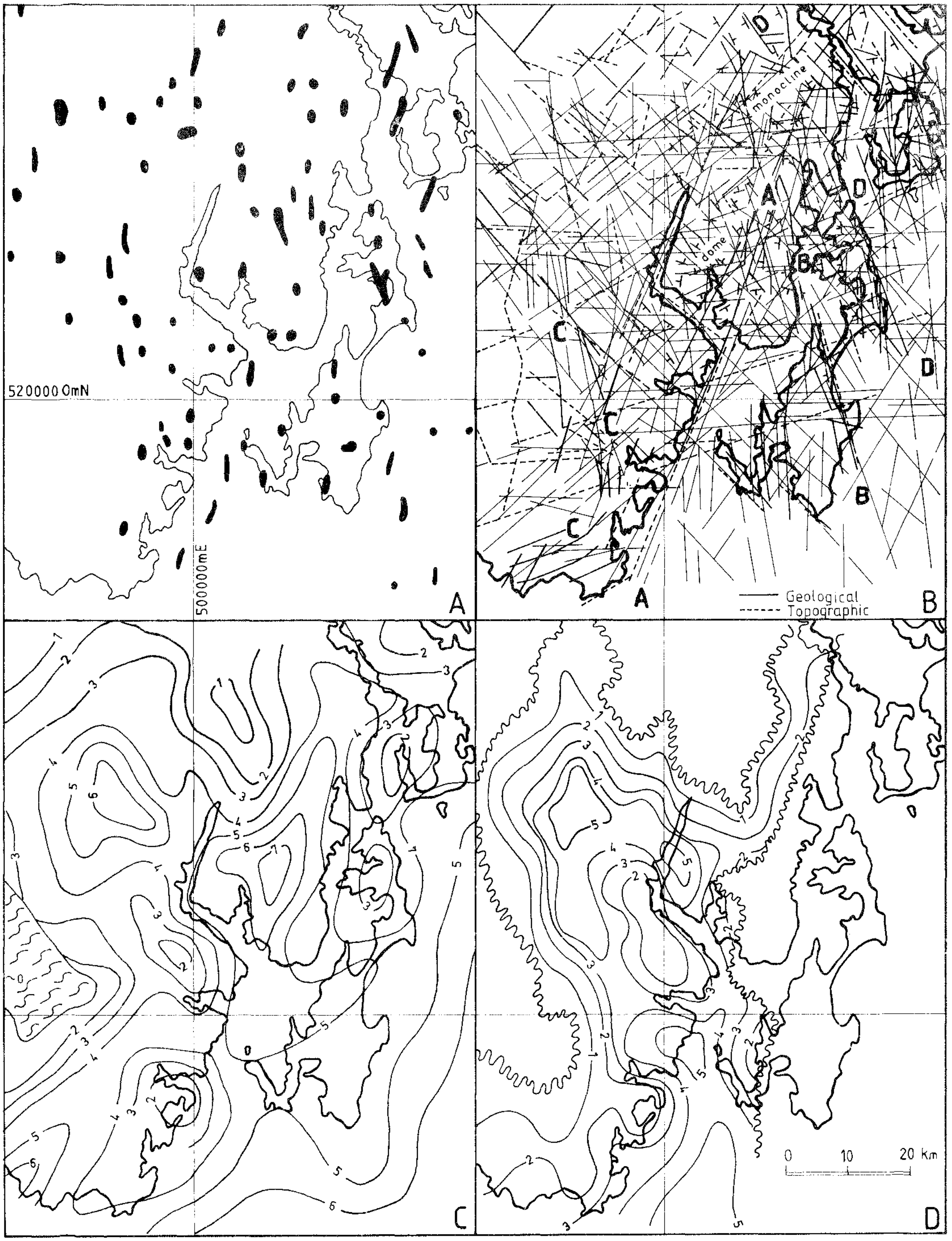
The large magnetic anomaly centred on Cygnet has long been known and always assumed to be associated with the Cretaceous syenite complex (e.g. Finney & Shelley 1967, Leaman & Naqvi 1968) although the precise origin has been debated. The anomaly correlates with a domal structure in the Cygnet region. Regional modelling of typical profiles shows that the Cygnet anomaly also has two source components; one near surface and of extreme contrast and another of large volume and moderate contrast at moderate depth. The near-surface source is volume limited and consistent with the alteration products, including free magnetite and pyrrhotite observed around Port Cygnet. The deeper source extends northeast toward Woodbridge, as does the syenite dyke swarm.

Figure 4A suggests the magnitude of the source. A laccolithic syenite pod 750 m thick, with lateral extent suggested, emplaced at the base of the Truro Tillite, would be able to generate the doming observed around Cygnet. Such a pod also accounts for the anomalous regional metamorphism recorded by Leaman & Naqvi (1968) and Farmer (1985: 69). This new analysis shows that Leaman & Naqvi (1968) were correct in inferring a large laccolithic form but misplaced its location. Their use of the term hybrid for the alteration, especially of dolerite, south of Cygnet was misunderstood by Farmer (1985) who then failed to appreciate the significance of the metamorphism described. The roof of the laccolith may lie close to, or in the highly altered dolerite sheet exposed near Cygnet. The dyke swarm pattern appears to reflect anisotropic extension of the roof rocks.

The equivalent gravity profile (fig. 4B) indicates that the general increase in anomaly amplitude eastward is due partly to the presence of the magnetic rocks, but the effect is sustained by non-magnetic, dense materials further east. The crustal contribution is minimal on this line. The relationship between anomaly and exposed Tyennan region basement west of the Picton River suggests that this lithology is representative of ultimate basement at a general depth of about 5 km.

The combined analysis enables conversion of the magnetic field data (fig. 2) into a plan of dolerite feeder locations (fig. 5A), the reliability of which is limited only by survey specification. Most elements of dolerite intrusion form can be deduced from the two data sets, although inferences based on only one data set can sometimes be misleading. The strong anomaly near Betsey Island, first noted by Flinders and marked on marine charts ever since, is due to a large feeder system.

Modelling has also established that the dense, magnetic sequence is only present in parts of the region. Figure 4 shows this to have the form of a deformed onlapped or rift trough fill. The upper surface is generally at a depth consistent with the base of the Permo-Carboniferous sequence after allowance for normal formation thicknesses. Although tillite estimates are uncertain it seems likely that the tillite or basal formations either overlie the magnetic units directly or are separated by less than 500 m. Non-magnetic Gordon Group formations must be thin, if present. Although the magnetic sequence is not universally present, the response pattern can be traced to the south coast, where it is associated with exposures of mafic Cambrian units, or to Glenorchy, where altered (?) Cambrian volcanics were found to underlie Permian rocks. The principal belt of these presumed Cambrian rocks extends NW–SE from the Weld River to Hastings (fig. 2). The entire gravity-magnetic pattern is similar to that observed in western Tasmania, between the coast and the core of the Tyennan region east of the Birch Inlet–Elliott Bay axis, but as a mirror image (Leaman 1988b). The inferred rock properties are consistent with a predominantly mafic assemblage such as the Crimson Creek Formation and its correlates (Brown 1988). A secondary belt of such rocks extends from Cygnet toward Hobart but the greatest development lies south of Bruny Island. Review of the magnetic data from these volcanic sequences has shown that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some localities contain materials with bulk contrasts consistent with ultramafics. These are restricted to the western side of the Huon trough axis west of Geeveston and also near the Weld River.

The remainder of the basement is non-magnetic but quite dense, at least to depths of 3–5 km, in much of the region. The non-magnetic basement properties can be traced eastward from exposures west of Maydena and northwest of the Picton River. The properties and patterns are consistent with an ultimate, siliceous Tyennan-region-style Precambrian basement, generally overlain by a Jubilee-region-style Precambrian basement, such as exposed near Maydena (Turner 1988).

Figure 5C and D summarise the interpretation in terms of Cambrian and Precambrian units. The trend patterns (fig. 5B), compiled from the data sets and post-Carboniferous structures to indicate frequency of recognition and importance, can be compared with old trough structures. Any differential between the upper surface of siliceous basement and the base of the volcanic units is a measure of the thickness of presumed Jubilee region rock types (also fig. 6). The relationships are similar to those observed or inferred in northwestern Tasmania (Leaman 1988b).

DISCUSSION

Several strands of evidence and information have been utilised to obtain an indication of the constitution of the concealed pre-Carboniferous basement in southern Tasmania. There is much scope for refinement.

The Tertiary, Cretaceous and Jurassic igneous rocks, while not strictly part of the topic of this paper, occupy some of the volume below the Carboniferous unconformity. It could also be expected that their emplacement has been at least partly controlled by older structures. For example, several large dolerite feeders lie near the eastern edge of the Cambrian belt from Ferntree to Red Hill and Garden Island Creek; so does the Cygnet alkaline intrusion. Compare figure 5A, C and D. Figure 5C clarifies an issue raised by Leaman (1972). The gravity field in the region of Mt Wellington was considered locally negative and not explained by known materials or possible deficiencies in terrain corrections. The observations were thought to indicate a granite stock in basement, which also forced subsequent extensional fracturing to pass around this region. A local basement high composed of siliceous Precambrian materials, with a relief of several kilometres, surrounded or onlapped by a denser sequence would produce a similar effect. It is also possible to speculate on the origin of the only zone in the Hobart district with easterly dips. This lies between the city and Mt Wellington and includes several junctions involving large Tertiary and Jurassic movements, as well as overlying the pinched northern extension of the Cambrian trough. The dips may reflect a continuing process of rejuvenation of the old basement core beneath the Wellington tableland to the west (fig. 5C).

General inferences concerning the distribution and relationships of principal basement types are shown in figures 6 and 7. The basal Permian or Upper Carboniferous formations may generally overlie either Cambrian volcanics or Precambrian phyllites and units comparable to those of the Jubilee region. The gravity-magnetic interpretation is consistent with available pyroclastic and drilling data and the common seismic result. Nearly all seismic surveys have been undertaken where all the other methods imply a Precambrian basement beneath the unconformity. This would account for the general absence of deep reflections. It also explains the faint 2-second event observed on Bruny Island. This is equivalent to a depth of about 4 km, the level inferred for the interface between Precambrian units using gravity data.

Figures 6 and 7 also suggest sites where post-Cambrian veneers might be present but this aspect of the interpretation is most uncertain. No gap in excess of one kilometre has yet been inferred between the nominal base of Truro Tillite and Cambrian or older rocks, and much of the apparent gap could be subsumed by false assumptions concerning the amount of tillite in the particular area. It is possible to systematically trace a wedge of Gordon Group from the Picton River toward the Huon River but nowhere else.

The implied limited distribution of Gordon Group materials west of the Huon River, or as very thin

FIG. 5 — Summary of gravity-magnetic interpretation results: (A) Jurassic dolerite feeders, location and shapes as defined by available data; (B) compilation of all trend information (firm and broken lines represent post-Carboniferous or topographic features; fine lines represent features identified by gravity or magnetic data); (C) combined gravity-magnetic interpretation of depth to top of Tyennan-region-type Precambrian basement; (D) interpretation of depth of base of (?) Cambrian volcanic sequences (all contours in km below sea level).

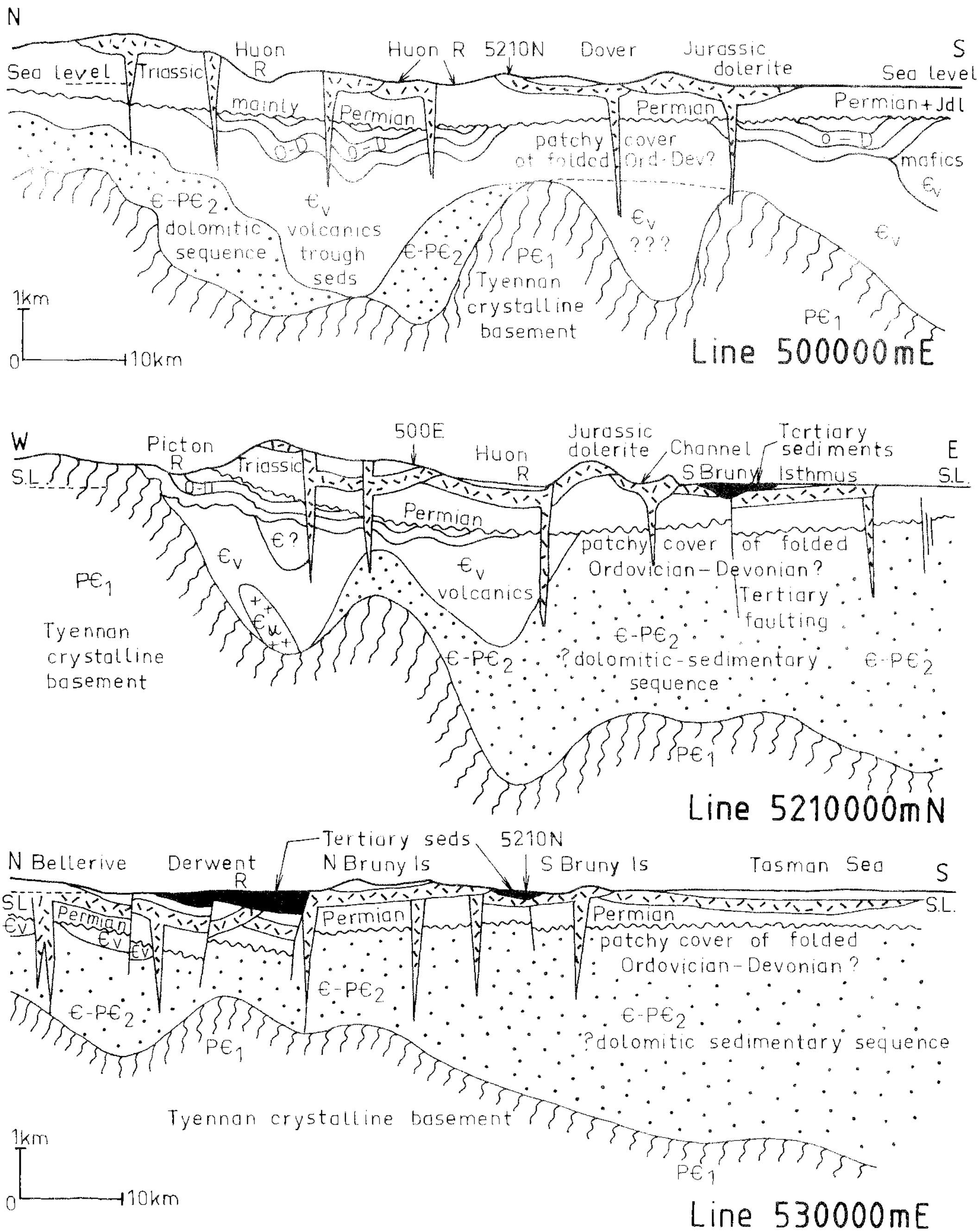

FIG. 6 — Representation of geophysical interpretation as conventional geological sections; symbols as figure 4. Phyllite drilled at Woodbridge is considered representative of E-pE$_2$ (Jubilee-region-style Precambrian).

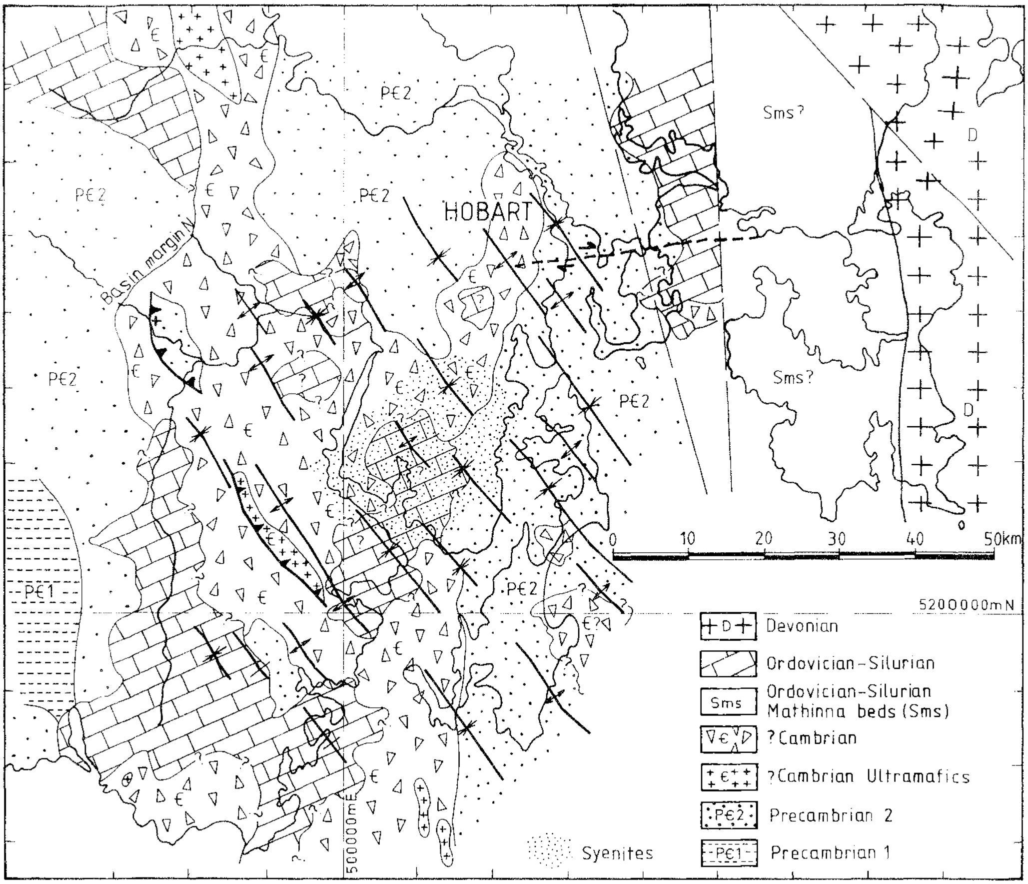

FIG. 7 — Distribution of inferred basement rock types at the base of the Parmeener Supergroup. The distribution of post-Cambrian Palaeozoic units is not well established and these may be present only as small patches. Possible regional fold trends and thrusts indicated in interpretation are shown.

veneers elsewhere, would account for the extraordinary bias toward metamorphic and igneous rocks in the Carboniferous tillites in southeastern Tasmania.

Several aspects of post-Carboniferous structuring and terrain development have long appeared enigmatic. These include the trend changes of the Huon and Derwent estuaries and the Derwent crosscut between New Norfolk and Bridgewater. No obvious post-Carboniferous controls or structures are present. Figure 5B shows that such features, and many coastal outlines, reflect basement features. Trends evident in regional gravity and magnetic data delimit major basement boundaries, and these have been impressed or rejuvenated periodically. Many direct correlations are apparent, while other relationships can be inferred. The dextral offset shown in figure 7 near Hobart is an example. This feature corresponds to many cross-trends (fig. 5B) and several Jurassic dislocations lie along it. Tertiary basin trends swing from NW–SE north of it to NE–SW south of it. Basement structural control is indicated.

Dolerite feeders can be associated with the form and changes in marginal gradients of the (?) Cambrian trough where present (fig. 5C, D) and with fracture-trend concentrations elsewhere (fig. 5B). Some major trends identified by all data sets and which imply a substantial ranging source depth, are labelled in figure 5B.

Williams (1976) suggested that the possible extension of the Tamar Lineament might occur east of South Arm. Gravity and magnetic data in the Storm Bay region do indicate a change in basement composition at the longitude of Sorell. Figure 3 shows that this is not due to the presence of granitoids. The western face of the adamellite complex lies at the longitude of Port Arthur and Dunalley and is marked by N–S coastal features. This relationship also suggests continual renewal of structural boundaries. The interpretation (fig. 7) suggests that northeast of Sorell the granitoid margin is offset to the northwest. The margin then continues N–S through the eastern midlands. The change in basement composition inferred on the eastern side of Storm Bay occurs where the margin in the midlands would occur if projected southward. Since the entire granitoid intrusion pattern indicates fracture control, the original fracture would appear to have been preserved south of Sorell. It is possible that the block between this projection of the granite margin and its actual margin at Port Arthur is composed of Ordovician-Devonian Mathinna Beds and possibly granodiorite, as occurs west of Scottsdale.

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