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A CONTRIBUTION TO THE
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EARLY DEVELOPMENT OF THE OTWAY BASIN

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EXECUTIVE SUMMARY

During the period 1991-94, a co-operative study of the early development of the Otway Basin was undertaken as part of a National Geoscience Mapping Accord project. The partners in the project were the Australian Geological Survey Organisation (AGSO), the Geological Survey of Victoria (GSV), the Department of Mines and Energy, South Australia (MESA), and the Victorian Institute of Earth and Planetary Sciences (VIEPS) at Monash and La Trobe Universities. As part of the project, four subsurface horizons were mapped across the onshore parts of the basin using exploration industry and AGSO seismic data. MESA undertook mapping in the South Australian sector of the basin, GSV in the central (western Victorian) part of the basin, and AGSO and VIEPS in the eastern part of the basin. This is the first time such mapping has been published on a basin-wide scale in the Otway Basin.

This Record accompanies a folio of ten 1:500 000 scale maps compiled by AGSO from the data provided by NGMA partners from the western, central and eastern parts of the onshore basin. Four of these maps are presented as two-way times (in milliseconds) to four mega-sequence boundaries together with interpreted structural information. The four mega-sequence boundaries are: -

1) - base Wangerrip Group,
2) - top Eumeralla Formation,
3) - top Crayfish Group,
and 4) - top Palaeozoic basement.

Time thickness (isochron) maps (in milliseconds two-way time) for the Crayfish Group, the Eumeralla Formation and the Sherbrook Group, complete the horizon mapping. Also included are maps of seismic line information and tectonic elements, and geophysical maps of gravity and magnetic data. The maps are designed to improve the overall understanding of Otway Basin subsurface geometry and tectonic evolution as a guide to possible hydrocarbon resources.

INTRODUCTION

During 1991 the Australian Geological Survey Organisation (AGSO) entered into an agreement with the Department of Mines and Energy, South Australia (MESA), and the Geological Survey of Victoria (GSV) to conduct a co-operative study of the early history of the Otway Basin as a National Geoscience Mapping Accord (NGMA) project. Subsequently, the Victorian Institute of Earth and Planetary Sciences (VIEPS) at Monash and LaTrobe Universities joined the project because of mutual benefits to be gained from their expertise in the basin and access to data which would flow from the project.

The aims of the project were to provide new data on the early onshore structures of the Otway Basin and to improve knowledge of tectonic events that resulted in basin development and evolution. The strategies used to pursue these aims were to improve information on the deep basin sequences using deep seismic sounding techniques, to use exploration industry data to develop a better understanding of basin geometry and history, and to integrate interpretations from other geoscience disciplines to improve tectonic models for the basin.

Map products were regarded as an important output from the project. It was decided early in the project to conduct subsurface mapping across the onshore part of the basin at 1:250 000 and 1:500 000 scale; optional mapping was also to be conducted at 1:100 000 scale. Exploration industry and AGSO seismic data were to provide the database for the subsurface mapping. This was the first time that subsurface mapping had been completed on a basin-wide scale for public release. A previous conformable mapping program was undertaken in 1984 by Megallaa for Victoria and Cockshell (1986) for South Australia but combined maps were never published.

This Record accompanies a map folio at 1:500 000 scale for the onshore parts of the Otway Basin compiled by AGSO from grid, contour, structural and cultural data provided by all NGMA partners from the areas of their particular mapping responsibility (Fig. 1). MESA mapped the western Otway Basin, GSV the central Otway Basin and AGSO/VIEPS mapped the eastern Otway Basin. The mapped area is 36° 45'to 38° 55'S, 139° 30' to 144° 10'E (Fig. 1). The basis for interpretation of key

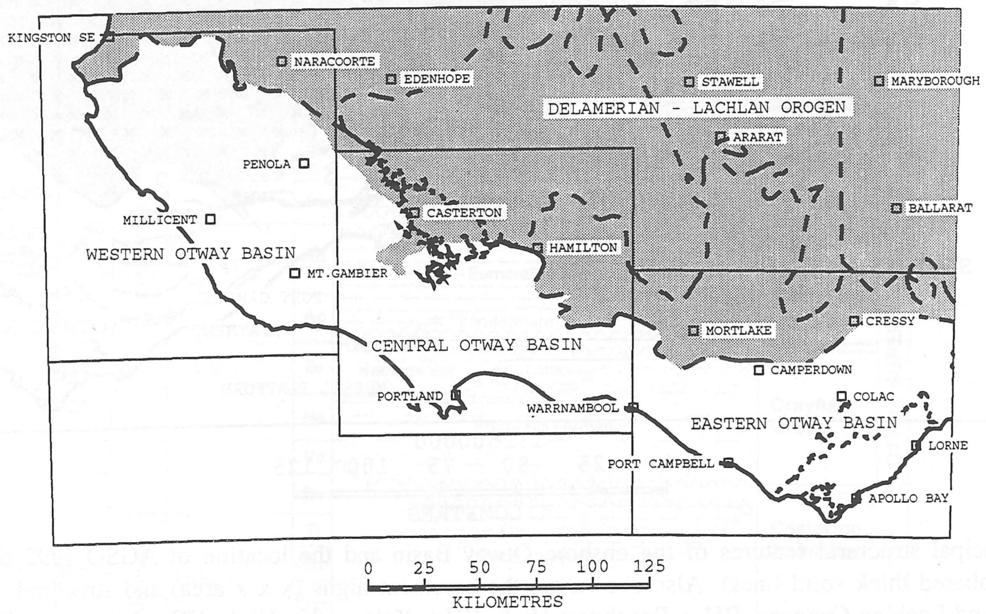

Fig. 1 - Onshore Otway Basin mapped area for the 1:500 000 scale map folio, together with the mapping areas for the western (MESA), central (GSV), and eastern (AGSO, VIEPS) parts of the basin.

horizons is discussed and the principles used in the compilation of the maps are set out. The maps aim to show the larger features of basin geometry and structure as a basis for resource exploration and management.

REGIONAL GEOLOGY

The regional geology of the Otway basin has been summarised in a number of papers (Megalla, 1986; Kopsen & Scholefield, 1990; Williamson et al., 1987, 1990; Sprigg, 1986; Laing et al., 1989; Hill & Durrand, 1993; Pettifer et al., 1991; Yu, 1988). The summary presented here has been adapted and simplified largely from the work of Richardson (1993), Morton et al. (1994), Perincek et al. (1994), Hill et al. (1994) and Finlayson et al. (1995 in press).

Structural Elements

A simplified map of the Early Cretaceous syn-rift faults and Late Cretaceous breakup faults for the onshore Otway Basin has been compiled from mapping by NGMA partners (e.g. Perincek et al, 1994; Hill et al., 1994; Finlayson et al., 1995 in press)(Fig. 2, Map 10). Three major trends are discerned: 1) E-W (e.g. Robe Trough, Morenda Trough, Elingamite Graben), 2) NW-SE (e.g. Penola Trough, Ardonachie Trough), and 3) NE-SW (e.g. Colac Trough, Yaloak Graben). As described below, many of the major faults are associated with rifting and the formation of Early Cretaceous half-graben. These faults are seen to play an important role in the development of structures

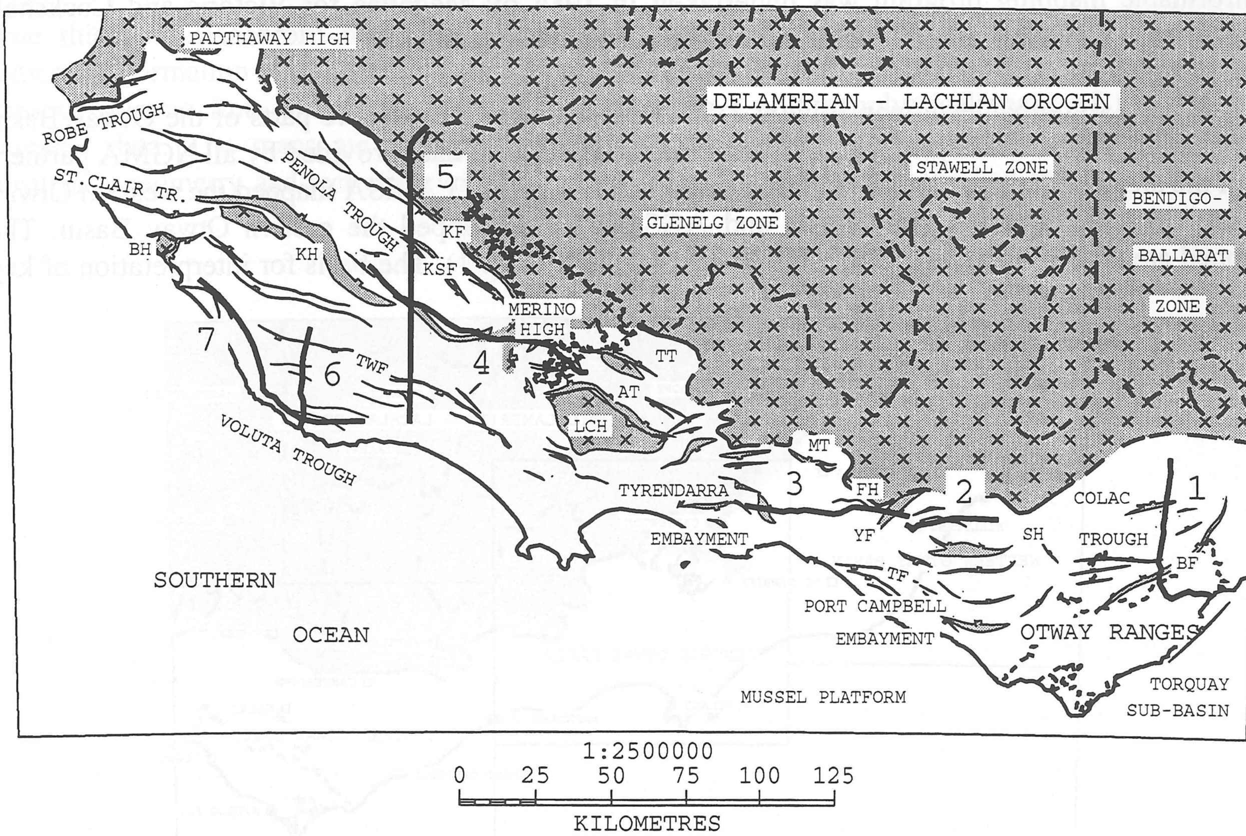

Fig. 2 - Principal structural features of the onshore Otway Basin and the location of AGSO 1992 deep seismic profiles (numbered thick solid lines). Also shown are the basement highs (x x x area) and structural zones of the Delamerian and Lachlan Orogens. BH = Beachport High, KH = Kalangadoo High, KF = Kanawinka Fault, KSF = Kanawinka South Fault, TWF = Tartwaup Fault Zone, LCH = Lake Condah High, AT = Ardonachie Trough, MT = Morenda Trough, TT = Tahara Trough, FH = Franlingham High, YF = Yaloak Fault, TF = Timboon Fault, SH = Stoneyford High, BF = Bambra Fault.

throughout the history of the basin. Seaward of the Early Cretaceous rifts are the Late Cretaceous Tartwaup and Timboon fault systems, interpreted as headwall faults for the extensional basin formed during the separation of Australia from Antarctica (Finlayson et al., 1995 in press). South of this headwall fault system, Early Cretaceous horizons are deep and difficult to map.

From various studies around the world, there is now a considerable body of information on the possible influence of pre-existing geology on the geometry of early rifting within a continental setting. In Africa, for instance, the Cainozoic rift system is influenced largely by older cratonic blocks separated by pre-existing zones of crustal weakness inherited from earlier pan-African orogeny (Binks and Fairhead, 1992; Guiraud & Maurin, 1992). In eastern Africa, Rosendahl et al. (1992) were "impressed with the role that Proterozoic dislocation zones seem to play in regard to the architectures of the Western Branch (East African) rifts". Detailed examination of continental rifting episodes in many parts of the world have shown that pre-existing structures have played a significant role in determining the pattern of rift segment formation during the early phase of basin formation (e.g. East African rift system - Daly et al., 1989; Rosendahl et al., 1992; North Sea rift system - Stewart et al., 1992; North Atlantic rift system - Dunbar & Sawyer, 1989; Ziegler, 1988).

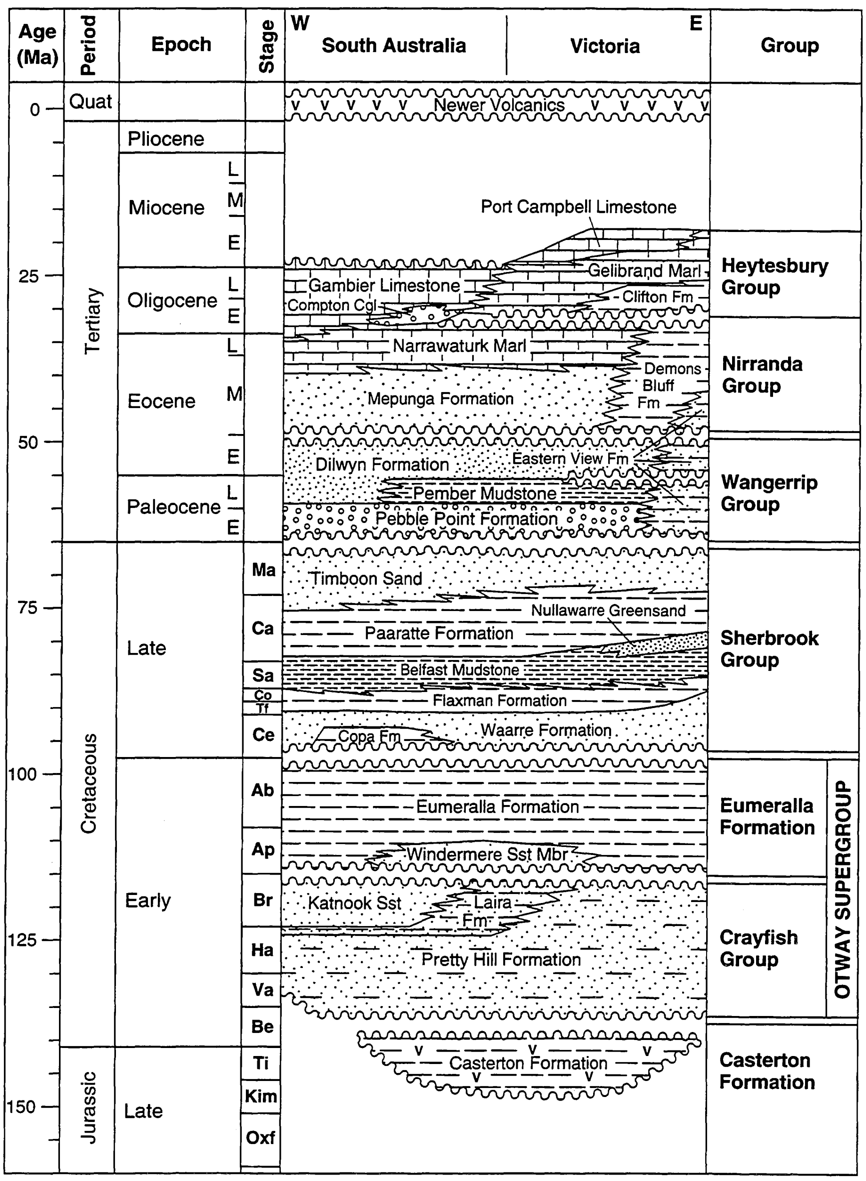

Fig. 3 - Otway Basin stratigraphy adapted from the unified nomenclature of Morton et al. (1994). Time scale adapted from the AGSO Phanerozoic Timescale, 1994.

Scott (1994), when studying some Australian passive margins, concludes that " rift zone scale geometry is influenced by pre-existing deep-seated, large-scale crustal structures and lateral heterogeneities in the lithosphere".

In southeastern Australia the structures within the Delamerian and Lachlan Orogens are likely to have influenced the early rift segments within the Otway Basin. Consequently, in this map folio, the principal structural zones within the Delamerian and Lachlan Orogens are indicated in the basement outcrop areas to the north of the Otway Basin. There is still considerable debate among earth scientists working in the area (see Fergusson & Glen, 1992), but the zones shown on the maps published here are those interpreted by Glen (1992), Wilson et al. (1992), and Grey (1988). The northern outcrop rocks of the Delamerian and Lachlan Orogens are overlain by Murray Basin sequences. To the south of the Delamerian/Lachlan outcrop, Tertiary sequences and Recent volcanics overly and obscure much of the pre-Cretaceous geology. The Delamerian/Lachlan boundaries shown on the folio maps are derived from the Geology of Victoria map at 1:1 000 000 scale (Geological Society of Australia, Victorian Division, 1988) and the draft Tectonic Map of Eastern Australia at 1:1 000 000 scale (Geological Society of Australia, in prep).

Basin Stratigraphy

As part of the NGMA Otway Basin Project, Morton et al. (1994) have described the stratigraphy of the whole Otway Basin in terms which seek to reconcile some of the diverse descriptions and views which have been expressed by a number of previous authors working in South Australian and Victorian parts of the basin. The stratigraphic nomenclature is shown in Figure 3. This nomenclature is favoured in this Record.

Wherever possible, four horizons were mapped throughout the basin as part of the NGMA project. The four horizons were the top Palaeozoic basement (Map 3), the top Crayfish Group (Map 4), the top Eumeralla Formation (Map 5), and the base Wangerrip Group (Map 6)(Fig.3). The base Wangerrip Group ("base Tertiary") has been nominated as the mapped horizon because in many parts of the basin Sherbrook Group sequences are sub-seismic or absent. The mapped horizons are all major sequence boundaries. It is therefore important to establish some common characteristics for identifying these sequences.

Seismic Sequence Definition

The interpretation of seismic data in the Colac Trough area has been described by Richardson (1993). The principles used by Richardson (op. cit.) are those described by Vail et al. (1987) for seismic sequence stratigraphic. These same principles have been used throughout the whole of the Otway mapsheet area.

For the purpose of horizon mapping, five sequences are described briefly: - Palaeozoic basement, Casterton Formation and Crayfish Group, Eumeralla Formation, Sherbrook Group, and the combined Wangerrip, Nirranda and Heytesbury Groups (Fig. 3). As indicated above, a basin-wide description of Otway Basin sequences is given by Morton et al. (1994), but in the eastern Otway Basin, Tickell et al. (1991, 1992) have also compiled detailed information. Morton (1990) has previously discussed revisions to the Otway Basin stratigraphic nomenclature in the South Australian sector basin.

Palaeozoic Basement

Palaeozoic metasediments and igneous rocks underlie the Otway Basin sequences (Map 3). These are intersected in a number of wells on basement highs and along the northern margins of the eastern Otway Basin including Ballangeich-1, Ferguson Hill-1, Garvoc-1, Stoneyford-1, Tirrengowa-1, Carmut-1, Cressy-1, Mortlake-1, and Koort Koort Nong-1. In the western and central parts of the basin, basement is intersected in a number of wells including Hatherleigh-1, Kalangadoo-1, Lake Eliza-1, Robertson-1&2, Sawpit-1, Lucindale-1, Lake Hawdron-1 and Beachport East-1. The well completion data from these wells strongly suggest that the Palaeozoic metasediments and granites of the Lachlan Orogen cropping out to the north of the basin form basement to the Otway Basin sequences. Recent papers on the geology of the Lachlan Orogen have been compiled by Fergusson & Glen (1992).

The seismic character of basement rocks can vary considerably throughout the eastern Otway Basin. At two-way recording times (TWT) of less than 2 seconds the general chaotic nature of reflections and diffractions underlying a strong reflector sequence is often sufficient to identify the top basement unconformity. However, at larger two-way times (2-4 s TWT) the impedence contrast between Early Cretaceous sequences and basement metamorphic rocks is probably not great and the basement unconformity may not be readily identifiable.

Casterton Formation and Crayfish Group

The Late Jurassic (Kimmeridgian-Oxfordian to Tithonian) Casterton Formation has been described by Morton et al. (1994) as an essentially pre-rift or earliest synrift sequence comprising interbedded carbonaceous shale, minor feldspathic sandstone and siltstone and basaltic volcanics. Details of the formation geology are poorly known. An unconformity separates the formation from Crayfish Group sequences. Casterton Formation sequences are identified in Ballangeich No.1, Moyne Falls No.1, Hawkesdale No.1, Woolsthorpe No. 1, Pretty Hill No. 1, Bus Swamp No.1, Casterton No. 1, Sawpit No. 1, and others. Where it is present, the Casterton Formation appears to provide a good seismic marker (several high amplitude cycles) at the base of the Otway Basin sequences although correlation away from well intersections is somewhat contentious.

The overlying Early Cretaceous Crayfish Group (Berriasian to Barremian) consists of early syn-rift, non-marine, graben fill sequences that are separated from the overlying Eumeralla Formation by an unconformity e.g. Morton et al. (1994). A strong angular unconformity is evident in the western Otway Basin but is gradational in the east and not as easily recognised. The Crayfish Group comprises the Pretty Hill Formation (sand and shale), and, in the western basin, the overlying Laira Formation and Katnook Sandstone.

As might be expected in syn-rift sequences (e.g. Prosser, 1993), the Crayfish Group exhibit overall wedge-shaped geometries in a number of rift segments throughout the basin (Map 7). In the shallower parts of the eastern basin the Crayfish Group is intersected in wells such as Ballangeich-1, Garvoc-1, Ross Creek-1, Stoneyford-1, Tirrengowa-1, Purrumbete North-11, and Warracburunah-2. In the central and western parts of the basin the Crayfish Group is intersected in Moyne Falls No.1, Hawkesdale No.1, Pretty Hill No.1, Tullich No.1, Bus Swamp No.1, Penola No.1, Kalangadoo No.1, Crayfish No.A-1, Trumpet No.1, and others.

Interpreting the upper sequence boundary of the Crayfish Group on seismic sections is not always straightforward away from well ties. Sometimes a wedging of sequences can be identified and a seismic reflector picked at the unconformity. In the deeper parts of the basin the interpretation becomes more tenuous where structures offset sequence boundaries and line intersections are not ideal.

Eumeralla Formation

The Early Cretaceous Eumeralla sequence (Aptian to Albian) is a thick sequence, predominantly shaley in the west but sandier in the east. Unlike the Crayfish Group which mostly occurs in half graben separated by basement highs, the Eumeralla Formation is identified as a basin-wide blanketing sequence. It is identified in numerous wells below the top-Albian unconformity. The formation thickness can vary enormously across the basin (Map 8), ranging from 156 m in Warracburunah-2, 673 m in Ballangeich-1 and 696 m in Stoneford-1 to 2581 m in Ross Creek-1, 2743 m in Ferguson Hill-1, and more than 2302 m in Olangolah-1. Wells in the central and western part of the basin which intersected the Eumeralla Formation include Eumeralla No.1, North Eumeralla No.1, Tullich No.1, Penola No.1, Banyula No.1, Beachport No.1, Trumpet No.1, Crayfish No.A-1, Bus Swamp No.1,and Geltwood Beach No.1.

Felton (pers. comm.), using core and well-log data, has identified four lithofacies within the formation, with siltsone, mudstone, coals, and volcanolithic sandstones predominating. A marked change in depositional environment occurred during the early Albian with the central and eastern parts of the basin being blanketed by thick volcaniclastic sands deposited by large active rivers (Felton, pers. comm.). This may correspond to change from lower to upper Eumeralla sequences described by Richardson (1993).

In the Colac Trough area, Richardson (1993) describes the lower Eumeralla Formation as having wedge sequence geometry with thickening to the south-southeast (Map 8). The upper Eumeralla Formation reflectors are described as being mostly sub-parallel.

Sherbrook Group

The main emphasis in the NGMA Otway Basin project was on the early basin sequences, the Otway Super Group (Kopsen & Scholfield, 1990). However, the overlying Late Cretaceous and Tertiary sequences are of considerable importance as targets in the exploration for hydrocarbons (Map 9), particularly in the southern onshore and offshore areas. No attempt was made in this NGMA project to redefine the nomenclature for the Sherbrook Group and later sequences.

The Late Cretaceous Sherbrook Group (Cenomanian to Maastrichtian) comprises very large scale delta sequences, mostly conformable but locally unconformable (Morton et al., 1994) overlying the Eumeralla Formation. The large-scale flooding surfaces tend to contrast the Sherbrook Group sequences on seismic sections from the underlying Eumeralla Formation and this is used to map the top Eumeralla Formation horizon. The sequences of the Sherbrook Group have been described in detail by Mehin & Link (1994) but offshore mapping during recent phases of exploration will probably lead to future revision of Lower Sherbrook Group nomenclature.

In the eastern Otway Basin area the significant thicknesses of Sherbrook sequences are confined to the Port Campbell Embayment (Map 9). Many exploration wells intersect the Sherbrook Group sequences in the onshore part of this embayment. Thickness increases seaward from being absent in Elingamite-1 well and 309 m in Ross Creek-1 near the landward limits of the sequence, to 662 m in Bartons Corner-1, 694 m in Sherbrook-1, 1414 m in Curdie-1, 1155 m in Flaxmans-1 on the coast, and 1790 m in Port Campbell-2. Seismic data suggests that the sequence becomes deeper in the Sherbrook Trough in the southeast Port Campbell Embayment. In the western and central parts of the basin there are significant thicknesses of Sherbrook Group seaward of the Tartwaup Fault Zone (Map 9). Wells intersecting the Group include Kalangadoo No.1, Copa No.1, Caroline No.1, and Burrungule No.1.

Morton et al. (1994) describe the basal non-marine Waarre Sandstone, overlain by interbedded sand/shale of the Flaxman Formation, the Belfast Mudstone (pyritic marine prodelta shale), the Paaratte Formation (regressive paralic deltaic), and the non-marine Timboon Sandstone. Recent reviews of exploration targets in the eastern Otway Basin have identified a unit loosely equivalent to the Waarre Sandstone and informally termed the Shipwreck Group (O'Callaghan, 1993) which has mappable upper and lower sequence boundaries coincident with periods of tectonism and erosion on the eastern basin margin. The lower unconformity with the top Eumeralla Formation is one of the horizons mapped for the NGMA project across the onshore part of the basin.

Tertiary Sequences

In the Otway Basin the Tertiary sequences comprise the Wangerrip Group (Palaeocene to Mid-Eocene), the Nirranda Group (Mid-Eocene to Oligocene), and the Heytesbury Group (Late Oligocene to Mid-Miocene). These sequences blanket most of the basin, with noteable exceptions across the Otway Ranges and Merino High. The sequences have been described recently by Morton et al. (1994) and the detail is not repeated here; the groups are formed from a series of trangressive-regressive units that comprise the Tertiary sequence in the Otway Basin.

The base Wangerrip unconformity ("base Tertiary") is one of the horizons mapped for the NGMA project (Map 6). Where Sherbrook Group sequences is present, it can be taken as the top Sherbrook horizon. The sub-parallel internal reflector geometry of all the Tertiary sequences greatly assists the interpretation of the various units. Where Sherbrook Group sequences are absent, reflection terminations at the top Eumeralla Formation and top Crayfish Group, and basement diffractions commonly define the base Tertiary unconformity. Where Sherbrook Group sequences are present the Tertiary sequences are often conformable but the many exploration and water wells penetrating the Tertiary sequences can be used to confirm its base.

Representative thicknesses of Tertiary sequences in wells across the eastern Otway Basin mapping area are as follows: Ballangeich-1, 437 m; Bartons Corner-1, 1029 m; Curdie-1 1133 m; Ellingamite-1, 577 m; Ferguson Hill-1, 208 m; Flaxmans-1, 1068 m; Garvoc-1, 639 m; Port Campbell-1, 885 m; Ross Creek-1, 496 m; Stoneyford-1, 393 m; and Warracburunah-2, 659m.

Pre-drift Basin Development

Figure 4 shows a chronostratigraphic chart of the Otway Basin (from Richardson, 1993). In the Colac sheet area Pettifer et al. (1991), using gravity data, suggest that NE-SW to N-S trending lineaments were a feature of Palaeozoic rocks throughout the Otway Basin. Thus, by inference, these lineaments may exist in the Palaeozoic rocks beneath the basin. Numerous fault-independent basement highs and lows evident from seismic mapping indicate that uplift and erosion may have been a significant part of the post-Palaeozoic to latest Jurassic history of the region. Erosion, along with non-deposition, accounts for a general lack of Devonian to Late Jurassic rocks in the area.

In the basins of the Bass Strait and Otway region, the orientations of early rift segments have been described by Perincek et al. (1994), Hill et al. (1994), Willcox et al. (1992) and others. Perincek et al. (1994) have interpreted the fault timing across the onshore basin and it is evident that many of the major structures of the early rifting events are reactivated during subsequent extensional and compressional episodes throughout the basin's history.

Ziegler (1992), when discussing rift system development along the Atlantic margins, indicates that basin architecture clearly varies according to the relative importance at any one time of four factors:

1) frictional/viscous stresses exerted by a convecting mantle on the base of the lithosphere,
2) tensional stresses above mantle upwelling/diapirism and the thermal state of the lithosphere,
3) far-field stresses related to plate boundary processes,
and 4) the strong influence of pre-rift lithospheric architecture on the ultimate geometry of rift development.

In southern Australia we must expect similar variations in the relative dominance of these four factors. The application of a uniformitarian tectonic model for basin formation along the whole of Australia's southern margin such as has been proposed by Willcox et al. (1992) and Etheridge et al. (1987) is clearly inappropriate. The orientation of individual rift segments may vary significantly from the perceive direction of extension caused by mantle convection if upwelling/diapirism, the far-field stress regime, and pre-existing crustal architecture are more dominant constraints. Any model for the development of the basin system at a local scale must take all likely constraints into consideration.

As discussed earlier, Morton et al. (1994) describe the Late Jurassic (Kimmeridgian-Oxfordian to Tithonian) Casterton Formation as a pre-rift or earliest synrift sequence comprising interbedded carbonaceous shale, minor feldspathic sandstone and siltstone and basaltic volcanics. Major extension during the Early Cretaceous (Berriasian to Barremian) led to the deposition of the Crayfish Group sequences. In the Colac Trough there is strong divergence of the sequence internal reflectors towards a single E-W striking, north-dipping extensional fault (the Gellibrand Fault). Richardson (1993) indicates that growth of the Crayfish Group occurs only adjacent to NNE-SSW steeply dipping faults (probably transtensional). In the western Otway Basin, the rifting axis moved south from the major Robe-Penola Troughs to south of the Tartwaup hingeline after the Barremian. The Crayfish Group is bounded at the top by a major unconformity formed during the early Aptian which could have resulted from an increase in tectonic uplift over the region or thermal doming (Richardson, 1993).

Overlying the early Aptian unconformity is the widely distributed Eumeralla Formation indicating regional subsidence of the basin. In places there is a large amount of immature volcaniclastic sandstone. Constantine (1992) indicates the sediments were probably deposited in a wide flood plain over which flowed diverse river systems. Felton (pers. comm.) indicates that the broad extent of lithofacies implies a high degree of connection between depositional systems in the Otway Basin by the early Aptian, with the possibility of an rift-related volcanic source offshore from the present coast. Others (e.g. Hill et al., 1995) have favoured a sediment source in the arc-related volcanism on the eastern margin of Gondwana.

Otway Super-Group sedimentation was terminated by Mid-Cretaceous uplift and compression in the eastern Otway Basin. This resulted in the formation of the Otway Ranges and Cape Otway-King Island Highs. These structural highs partitioned the basin into two distinct sedimentary provinces (Williamson et al., 1987). The area, including and immediately east of the Cape Otway-King Island High, remained high during the Late Cretaceous with no evidence of deposition (note: farther east there is evidence of Late Cretaceous extension in the Durroon and Gippsland Basins). In contrast, the areas west of the high, including the Tyrendarra and Port Campbell Embayments, the Voluta Trough and the offshore Mussell Platform, subsided and the Sherbrook Group (Cenomanian to Maastrichtian) sequences were deposited. Onshore, the Stoneyford High separating the Colac Trough from the Port Campbell Embayment, is probably associated with the fundamental structures separating the eastern and western parts of the Otway Basin.

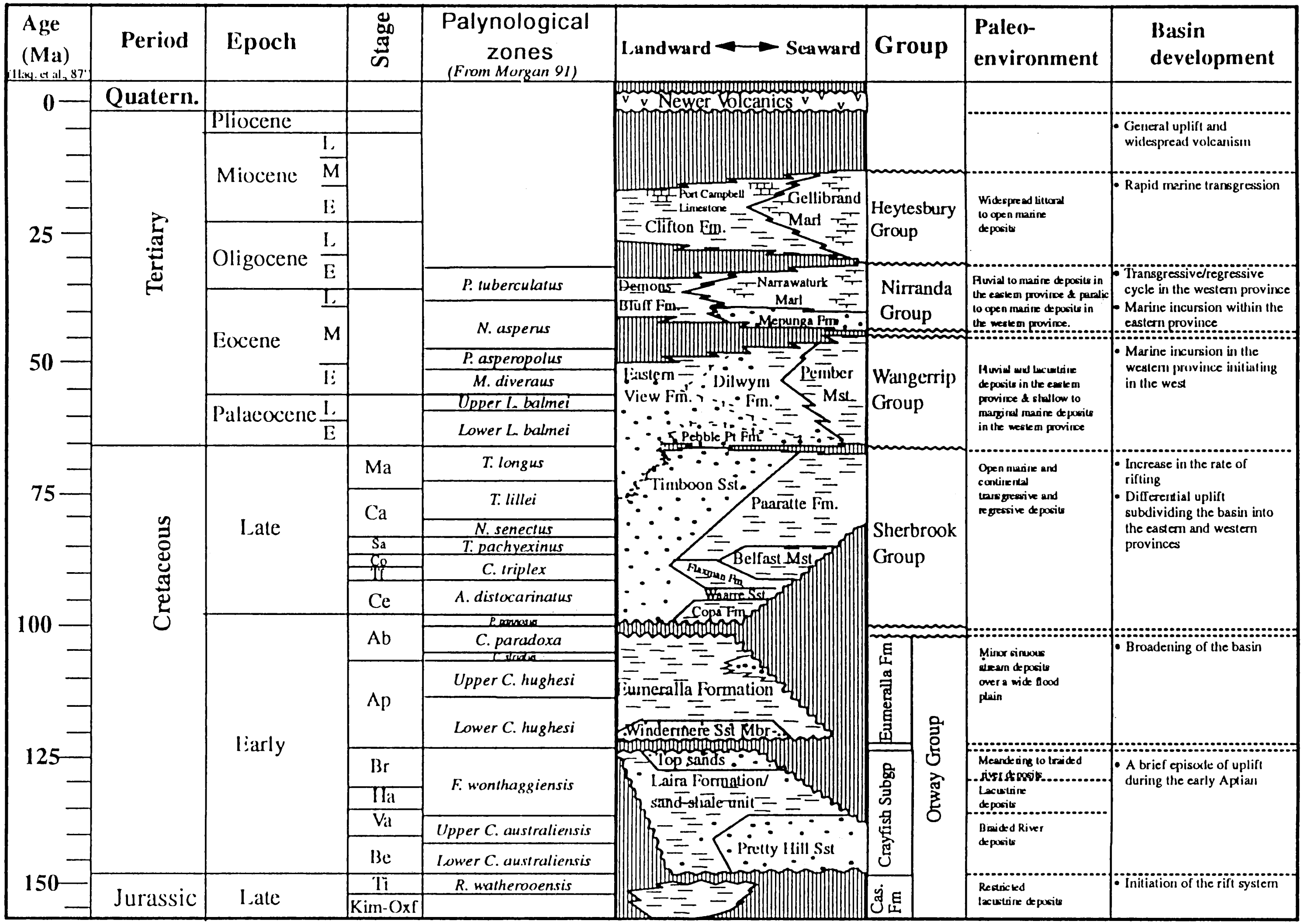

Fig.4 - Chronostratigraphic chart of the Otway Basin showing the age-time distribution of the sediments as well as the palaeoenvironments and significant stages of basin development interpreted from stratigraphy (from Richardson, 1993).

Post-Albian Basin Development

The post-Albian history in the western Otway Basin is essentially associated with continental breakup which ultimately separated Australia from Antarctica. Hill et al. (1994) have reviewed the information on pre-drift tectonics in the Otway Basin region and their preferred timing of ca 95 Ma for breakup follows the work of Cande & Mutter (1982) and subsequent work of Veevers (1986). Cooper et al. (1993) and Duddy (1994), using thermochronolgy, have emphasised the major nature of a regional rapid cooling event at 95±5 Ma which included the uplift and erosion of the Otway Ranges. This time is interpreted as the onset of slow drift between Australia and Antarctica by Veevers (1986, 1990) at a time when major events were also occurring in the Indian Ocean and the Tasman Sea (Veevers et al., 1991).

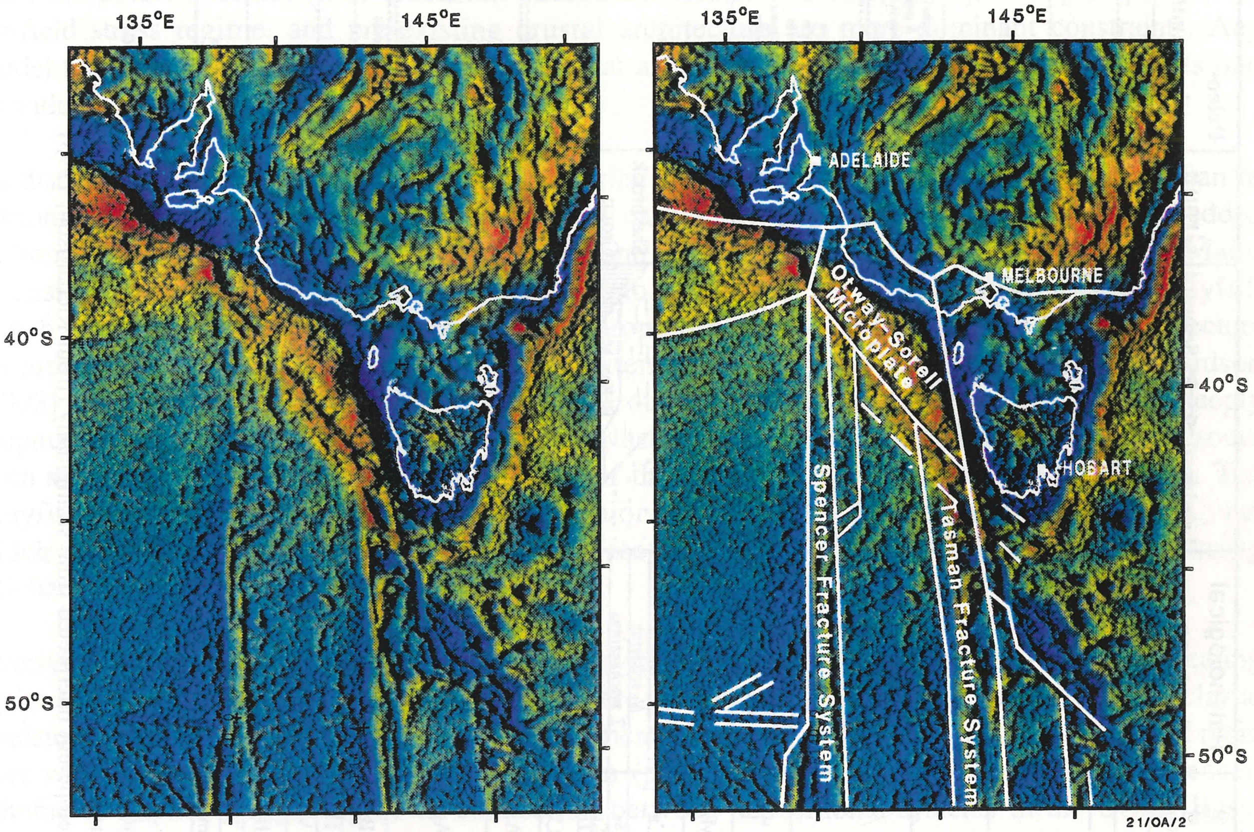

Fig. 5 - Combined offshore Geosat/Seasat and onshore Bouguer gravity image of the Otway Basin region showing the major oceanic fracture systems and the Otway-Sorell microplate (from Finlayson et al., 1993).

In the Southern Ocean, off southern Australia, the gravity information compiled from Geosat and Seasat data provide outstanding images of the pattern of post-Albian sea floor geology for the offshore Otway Basin and the adjacent oceanic crust (Finlayson et al., 1993a). A combined image of onshore Bouguer gravity and offshore satellite data (Fig. 5) shows the transitional location of the Otway Basin on Australia's southern margin. To the west, the separation between Australia and Antarctica occurred relatively close to continental Australia; to the east, rifting failed to develop through the Bass Strait, instead being offset to the south of Tasmania.

The triangular region of extended continental lithosphere to the northeast of the prominent Geosat gravity lineament between South Australia (Cape Jaffa) and southern Tasmania (South West Cape) has been termed the Otway-Sorell microplate by Finlayson et al. (1993) (Fig. 3). The eastern boundary of the microplate is taken to be the sinistral Tasman fracture system extending along western Tasmania and the South Tasman Rise (Exon et al., 1994), and the northern boundary is taken to be the failed rift system along the northern limits of the Otway Basin (Finlayson et al., 1993a). The essential crustal architecture of this microplate was formed in the period between the initiation of earliest Otway rifting (115-120 Ma; Williamson et al., 1990) and the formation of the oldest oceanic lithosphere adjacent to the microplate (95-96 Ma; Veevers et al., 1991). The microplate continued to be attenuated and modified by Late Cretaceous and Tertiary events. The Southern Ocean seaway probably did not develop fully until Antarctica cleared southern Tasmania in the Eocene (about 40 Ma) (Exon et al., 1994).

The transform system in the Southern Ocean between Australia and Antarctica has many similarities to the equatorial Atlantic transform system between Africa and South America (see Ziegler, 1988, 1992; Chang et al, 1992, for numerous references). Just as the Tasman and Spencer fracture systems significantly shift the locus of ocean spreading between southeast Australia and Antarctica, so the equatorial Atlantic transform system shifts the locus of spreading between South America and Africa. The region between the Spencer and Tasman Fracture Systems, the Otway-Sorell Microplate, is a transitional region between the margin to the west where rifting of the Precambrian craton occurred, and the margin to the east which has been influenced by Palaeozoic structures associated with the eastern Gondwana plate margin.

After the major uplift at about 95 Ma, there have been late compressional/inversion events affecting the Otway Basin sequences. K. C. Hill et al. (1995) have descibed Miocene to Recent inversion of earlier fault systems. They descibe Neogene inversion of Early Cretaceous extensional faults in the Colac Trough area and offshore in the Torquay Sub-Basin they descibe three southeast-verging monoclinal structures at the top Oligocene level. The offshore Nerita-1 well is drilled on an anticlinal structure interpreted to have formed by Pliocene to Recent inversion. The present structure of the Otway Ranges is interpreted to be due to Miocene-Pliocene inversion of Cretaceous and ?Palaeogene extensional faults at the time of the collision of the Australian craton with island-arc terrains to the north in the Indonesian - New Guinea region.

Perincek et al. (1994) descibe Miocene to Recent faulting (designated M on Map 10) as being characterised by a new generation of normal faulting and reactivation of major Cretaceous rift bounding faults. They interpret some structures consistent with right-lateral stike-slip movement roughly oriented NW-SE during post-Oligocene times.

SEISMIC LINE DATABASE

For the compilation of horizon maps for the Otway region, a library of open-file paper seismic sections was acquired from the Victorian Department of Energy and Minerals, the Department of Mines and Energy, South Australia (MESA), and exploration leaseholders in the region. The seismic data from the Otway Basin used in the horizon mapping has been acquired from 1968 onwards. Consequently, data quality varies and not all horizons are identifiable on all seismic sections. However, wherever possible, greater weight was given to the interpretation of 1980's and 1990's data which provided much-improved subsurface images than the earlier data.

Interpretation of seismic sections was assisted considerable by access to the well log information from a large number of hydrocarbon exploration and water wells available from GSV and MESA. As indicated in the introduction to this Record, mapping in the western part of the basin was conducted by MESA, in the central part of the basin (western Victoria) by GSV, and in the eastern

Otway Basin by AGSO and VIEPS (Finlayson et al., 1994) (Fig. 1).

The principal computing tool used in the compilation of maps in the NGMA Otway Basin project was the PETROSEIS™ software (Petrosys, 1993) which enables a comprehensive seismic line database to be built up from a variety of sources. However, GSV staff, working in the central part of the basin, initially digitised data into ENCOM and ECS mapping systems before transfer to PETROSEIS™ later in the mapping project. Seismic horizons can then be interpreted, digitized and mapped in a number of different formats. The PETROSEIS™ software is in common use in Australian exploration companies and hence NGMA databases and information can be readily transferred to industry. A seismic line location database was built up for the whole Otway Basin from data provided by the MESA, the Victorian Department of Energy and Minerals, and exploration companies. These data can be readily exported from PETROSEIS™.

The locations of seismic lines used in the compilation of the various maps in this Record are shown on Map 10. Although legislation applying to all companies with exploration and production leases requires that data be lodged with the respective South Australian and Victorian Departments, there is a confidentiality period on such data before it can be made public through the open file system. In South Australia the confidentiality period is two years from the date of acquisition, and in Victoria it is five years. However, through the good offices of leaseholders, NGMA staff had access to some recent data and the maps accompanying this Record are not incompatible with these data.

MAP COMPILATION

Interpreted seismic sections were digitised using the PETROSEIS™ system and the horizon two-way times and fault information built up into a database. The datum levels for some surveys were above the Australian Height Datum (AHD), e.g. 100 m or 150 m. Data from these surveys were reduced to the AHD using a near-surface velocity of 1750-1800 m/s.

The mis-tying of data at seismic line intersections can be checked using PETROSEIS™ routines. The results often meant the re-examination of interpretations and data changes. Different interpreters sometimes give a different emphasis in situations where the identification of horizons is difficult, some prefering to include data in order to achieve a regional picture whereas others might reject data on the basis of misties and thus leave blank map areas with no information.

For the data used in the compilation of horizon maps for the eastern Otway Basin the misties ranged up to 20 ms for the base Wangerrip Group and top Eumeralla Formation, with larger misties where interpretation uncertainties existed. For the deeper horizons, top Crayfish and top basement horizons, misties ranges up to 50 ms, with scattered instances of misties up to 100 ms in areas of interpretation uncertainty. In cases where misties were 50-100 ms, there was often genuine debate about interpretation of the seismic data at two-way times greater than 2.5 s. In the central and western parts of the Otway Basin, seismic line misties for the top Eumeralla and base Wangerrip horizons averaged 4-7 ms within a range up 20-25 ms; for the top Crayfish and top basement horizons the misties averaged 2-8 ms within a range up to 20-25 ms.

Fault maps were compiled that cut the four mapped horizons. Faulting is thought to have occurred during major orogenic events in the Early Cretaceous, Late Cretaceous, and Tertiary. It has been emphasised by others (e.g. Bally & Oldow, 1984) that orogenic events are probably continuous when examined in detail. Thus, for example, it is possible to identify intra-Early Cretaceous and intra-Late Cretaceous events (see earlier chapter on basin development). However, interpretation suggests that many faults active during, for example, the deposition of Crayfish Group sequences were probable active to varying degrees during the deposition of the Eumeralla Formation.

PETROSEIS™ enables a seismic database (seismic masterfile) to be interrogated and the two-way times to the various horizons from lines to be compiled into a grid of values over all or part of a mapsheet area. Grid cell size, extrapolation from data points, and smoothing could all be varied. These parameters must be chosen with the density of seismic lines in mind. In the compilation of grids, a cell size of 1000 m was chosen and data were extrapolated no more than 5000 m beyond any datum point. Usually grid smoothing was applied after compilation of the grid to eliminate any wild data swings in the surface not related to real geological features.

As mentioned earlier, MESA, GSV and AGSO/VIEPS compiled 1:250 000 scale horizon maps in the western, central and eastern parts of the Otway Basin respectively. For the compilation of the 1:500 000 scale maps, the seismic data, grids and contour files from these various individual map series were assembled and edited by MESA and AGSO and then integrated. Only minor changes to data were made along the boundaries of the data sets.

Various 1:500 000 scale map presentations were trialled. Eventually maps were displayed with a colour-filled grid of the various two-way times, together with contours of the two-way times to the horizons and general geological boundaries, well locations, and seismic line locations. Other display types, such as coloured contours and ERMapper colour images were prepared by MESA and GSV respectively for various parts of the basin during the course of the NGMA project. These are available upon request at a variety of scales.

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APPENDIX 1

EXPLANATORY NOTES FOR MAPS ACCOMPANYING AGSO RECORD 1994/51

These explanatory notes are designed to provide only a brief explanation of the main features of the maps and are not meant to represent a comprehensive interpretation. More detailed interpretations of data are contained in papers listed in the References section of this Record.

All maps contain background information such as coastlines, towns, wells, etc. Also shown are some of the boundaries associated with structural zones within the Delamerian and Lachlan Orogens north of the Otway Basin, the location of Early Cretaceous outcrop, and the interpreted northern limit of Early Cretaceous (Otway Super-Group) sequences. The structural zones shown on the maps are those interpreted by Glen (1992), Wilson et al. (1992), and Grey (1988). To the north, the outcrop rocks of the Delamerian and Lachlan Orogens are overlain by Murray Basin sequences. To the south, Delamerian/Lachlan outcrop is obscured by Tertiary sequences and Recent volcanics. The Delamerian/Lachlan boundaries shown on the folio maps are derived from the Geology of Victoria map at 1:1 000 000 scale (Geological Society of Australia, Victorian Division, 1988) and the draft Tectonic Map of Eastern Australia at 1:1 000 000 scale (Geological Society of Australia, in prep).

MAP 1

OTWAY BASIN: BOUGUER GRAVITY ANOMALIES

This gravity map of the whole onshore Otway Basin region provides an overall image of the main features of the basin. Within the onshore Otway Basin as a whole, the major early-rift depocentres are evident along the continental basin margin, including the Robe and Penola Troughs, the Tyrendarra and Port Campbell Embayments, the Colac Trough, the Torquay Sub-basin, and other smaller troughs. The map is included in this folio to highlight the gravity signature of basin features. Pettifer et al (1991) have described interpretations of the gravity trends within the Victorian part of the Otway Basin, and Reeves et al (1993) have interpreted some of the features in the western Otway Basin.

The major gravity lows north of the basin are associated within low density granite plutons with the Palaeozoic Lachlan and Delamerian Orogens (Wellman, in press 1994; Chappell et al, 1988; Parker, 1986; Murray et al., 1989). Finlayson et al. (1993) have discussed the onshore-offshore Geosat/Seasat and Bouguer gravity data and trends.

The grid-cell size for data included on this map is 5 km. Gravity data for this map was supplied by the AGSO Geophysical Mapping Group, the Geological Survey of Victoria (GSV), and the Department of Mines and Energy, South Australia (MESA).

Some of the significant features of the gravity map include the gravity highs within the onshore parts of the basin. There are major gravity highs associated with the Beachport area and the Otway Ranges. Reeves et al. (1993) interpret the Beachport anomaly as being due to a cylindrical body (radius 5500 m) with a top at a depth of about 2400 m (density contrast +0.25 t/cu.m.). A little to the north, Reeves et al. op. cit.) interpreted the Lucindale high as a circular plug with radius about 3500 m and minimum depth of 1000 m (density contrast +0.12 t/cu.m.). This plug is interpreted as a mafic intrusive body with little or no magnetite.

Some of the gravity highs within the onshore basin have general N-S to NNE-SSW trends, e.g. the ridges south of Casterton (the Merino High) and Woolsthorpe (the Warrnambool High), and east of Cobden (the Stoneyford High). Finlayson et al. (1995, in press), among others, have drawn attention to the association of these N-S features with offshore gravity features and possibly an expression of underlying Lachlan Orogen features.

MAP 2

OTWAY BASIN: TOTAL MAGNETIC INTENSITY RESIDUAL ANOMALIES

This map is compiled from data prepared by Chris Tarlowski (AGSO) for the 1992 Magnetic Map of Australia (Tarlowski et al., 1992) with the addition of AGSO data acquired during 1992 in the western Otway Basin (Reeves et al., 1993). The data for the Otway Basin are taken at 60" of arc intervals from the Magnetic Map of Australia grids. The data are presented in this map on a 2 km grid. This map is included in the map folio to illustrate the major Palaeozoic trends which are evident under the Otway Basin.

In particular, the major magnetic highs within the basin trending N-S through the towns of Hamilton and Casterton, and in the western Otway Basin near Reedy Creek-1 well. Other major magnetic highs are evident near Apollo Bay and north of Warrnambool. Pettifer et al. (1991) have interpreted some of the trends in the Victorian part of the Otway Basin, and Reeves et al. (1993), Finlayson et al. (1993) and O'Brien et al. (1994) have discussed interpretations of recent data in the western part of the basin.

Magnetic highs north of the basin are thought to be associated with Palaeozoic trends within the Lachlan and Delamerian Orogens (Wellman, in press 1994; Brown et al., 1988; Pettifer et al., 1991).

MAP 3

TWO-WAY TIME TO PALAEOZOIC BASEMENT

The data presented on this map represent the two-way times to Palaeozoic basement and consequently reflect features which may have resulted from tectonic episodes occuring at various times throughout the history of the basin. The faults represented on the map are those interpreted to intersect Palaeozoic basement (the K1 faults of Perincek et al., 1994, shown on Map 10). Many are thought to have been active during the Early Cretaceous rifting and extension episode within the basin when the Crayfish megasequence (KL_1 megasequence of Hill et al., 1995) was deposited, characterised by the development of half-graben trending WNW-ESE, NNE-SSW and E-W. Many of the structural features at this time were reactivated during later orogenic episodes up through the Tertiary and Recent times (Map 10).

Many of the isolated troughs e.g. the Gellibrand, Elingamite, Morenda, Ardonachie, Penola, Robe, St Clair, and Yaloak troughs/graben are thought to represent early half-graben rift segments along the northern margins of the Otway Basin. Their expression is more clearly expressed in the isochron map of the Crayfish Group (Map 7).

MAP 4

TWO-WAY TIMES TO TOP CRAYFISH GROUP

The data presented on this map represent the two-way time to the top of the Crayfish (KL_1 of Hill et al., 1995) megasequence and consequently may have been affected by tectonic events occurring during Eumeralla (Aptian-Albian) and subsequent times.

The faults represented on this map intersect the top Crayfish horizon and many are thought to have been active during deposition of the Eumeralla Formation and associated with continued activity of earlier rift fault systems (the Ke faults of Perincek et al., 1994, see Map 10). Crayfish Group sequences are thought to have substantially filled the earliest Cretaceous half-graben and consequently the top Crayfish horizon is smoother than that represented in Map 4 for two-way time to basement.

MAP 5

TWO-WAY TIMES TO TOP EUMERALLA FORMATION

The two-way times to the top of the Eumeralla Formation reflect the substantial uplift which occurred in the Otway Ranges region at about 95 Ma, and the Late Cretaceous and subsequent subsidence within the Port Campbell Embayment. Consequently the Eumeralla Formation is at the surface or very shallow over much of the area east of the Stoneyford High and over the Merino High. Within the Port Campbell Embayment, many hydrocarbon plays are thought to be associated with structure at the top Eumeralla level. In the western part to the basin, the two-way time to the top Emeralla Formation is greatly increased seaward of the Tartwaup Fault Zone.

Faults depicted on the map intersect the top Eumeralla horizon and are interpreted to have been active during Late Cretaceous (Sherbrook Group deposition) times (the K2 faulting of Perincek et al., 1994, - see Map 10) associated with the Otway second phase of crustal extension which ultimately led to the separation of Australia from Antarctica. Some are thought to be reactivated earlier rift-stage faults. The main fault trends are predominantly NW-SE to E-W. The Timboon and Tartwaup fault systems are interpreted to be the landward limit of headwall faults associate with second stage extensional events.

MAP 6

TWO-WAY TIMES TO BASE WANGERRIP GROUP

This map shows the thickness of the Tertiary section into the Port Campbell Embayment which continues offshore with overall prograding systems that become increasingly carbonate dominated in the Oligocene-Miocene. It also illustrates local thick zones of Tertiary that correspond to preserved section off structure from Miocene to Recent compression. This later phase of compression appears to have both inverted older extensional faults and created new faults.

Faults displayed are interpreted to have been active during Teriary to Recent times (the T and M faults interpreted by Perincek et al., 1994, - see Map 10).

MAP 7

CRAYFISH GROUP ISOCHRONS

The Crayfish megasequence (the KL_1 megasequence of Hill et al., 1995) is a result of the Early Cretaceous first stage of crustal extension and rifting in the Otway Basin which is characterised by the development of half-graben trending mostly E-W, WNW-ESE, and NNE-SSW. The Casterton Beds, if they are present, are included in this interval. The fault timing is labelled K1 by Perincek et al., 1994 (Map 10); the precise timing relationships of the various faults is yet to be determined. The major basement highs (e.g. the Framlingham High, Elingamite Footwall Lake Condah High, Kalangadoo High, etc.) are prominent features where the KL_1 megasequence is thin or non-existent.

The largest rift segment from this time preserved onshore is the Penola Trough. Other troughs (e.g. the Elingamite, Yaloak, Ardonachie Troughs) were formed during this interval but were smaller in area and isolated from each other by basement highs which are interpreted to be early rift accommodation (or tranfer) zones, probably influenced in location by pre-existing Palaeozoic structures. A few of these small troughs are deep (isochrons greater than 2 s TWT) and must have undergone intense local rifting.

MAP 8

EUMERALLA FORMATION ISOCHRONS

This map illustrates the pronounced increase in the (two-way time) thickness of the Eumeralla Formation (the KL_2 megasequence of Hill et al., 1995) east of Port Campbell and highlights the importance of features associated with the Stoneyford High (Map 10) partitioning the depositional regimes during Eumeralla times. Over the onshore area west of the Stoneyford High, the thickness of Eumeralla Formation is relatively uniform (except in the Koroit region). Regional uplift of the order of 1-2 km over the Otway Ranges (K. L. Hill et al., 1994) has also removed a considerable thickness of Eumeralla section. Although well control is poor across the Otway Ranges, this region is interpreted to be a major depocentre during the Aptian-Albian (Cooper et al., 1993; in prep. 1994).

The faults depicted are those cutting the top Crayfish horizon, many thought to have been active during deposition of Eumeralla Formation sequences as reactivated older K1 faults (Perincek et al., 1994).

MAP 9

SHERBROOK GROUP ISOCHRONS

This map displays the two-way time thickness (isochrons) of Sherbrook Group sequences (the KU_1 and KU_2 megasequences of Hill et al., 1995) and faults thought to have been active during their deposition. Thin (sub-seismic) intersections of Sherbrook facies are also present in exploration, stratigraphic and water wells over a wider area to the northeast of the data shown on this map and also in the Colac Trough. Although these sequences were deposited at the same time as the major thicknesses of the Sherbrook Group, their deposition is probably only loosely associated with the Late Cretaceous subsidence phase in the Port Campbell Embayment and Voluta Trough .

Faults depicted on the map intersect the top Eumeralla horizon and some are interpreted to have been active during Late Cretaceous (Sherbrook Group deposition) times (the K2 faulting of Perincek et al., 1994, - see Map 10) associated with the Otway second phase of crustal extension which ultimately led to the separation of Australia from Antarctica. Some are thought to be reactivated earlier rift-stage faults. The main fault trends are predominantly NW-SE to E-W. The Timboon and Tartwaup fault systems are interpreted to be the landward limit of headwall faults associate with second stage extensional events.

MAP 10

STRUCTURAL ELEMENTS AND SEISMIC DATABSE

This map gives an indication of the main structural features of the onshore Otway Basin and shows the location of open file seismic lines used during the interpretation of the various mega-sequence horizons. Principal Early Cretaceous and Late Cretaceous faults are indicated together with fault timing interpreted by Perincek et al. (1994) and Finlayson et al. (1994). The names of many of the principal structural features are shown. Some of the names are recent and may not be formally recognised, e.g. we have used the names Yaloak Fault, Yaloak Trough, Framlingham High, Kanawinka South Fault, Tantanoola Trough, and Kalangadoo Fault because we think the features are significant. Where names have existed in the scientific literature or in industry references, we have used them.

The open-file seismic lines shown were interpreted and digitized by the NGMA partners in the various areas of responsibility. Through the good offices of exploration companies in Victoria, interpreters also had access to post-1990 seismic lines not yet available through the open-file system. These lines greatly assisted interpretation and the authors gratefully acknowledge this industry assistance.

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MINES AND ENERGY SOUTH AUSTRALIA

NGMA OTWAY BASIN PROJECT

VIEPS

MAP 1

BOUGUER GRAVITY ANOMALIES

o - gravity station

1: 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

Explanatory notes for this map are contained in AGSO Record 1994/51:
Otway Basin: horizon maps for the onshore areas at 1:500 000 scale.

Authors - D M Finlayson, K A Hill, C D Cockshell, B Finlayson, G R Pettifer, D Perincek, B Simons, M J Richardson, & C J Lavin

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- Geological Survey of Victoria (GSV)
- Victorian Institute of Earth and Planetary Sciences (VIEPS)

Map compiled by D. M. Finlayson (AGSO)

LEGEND

- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User: dfinlays File: px18415.dlt Date: December 14, 1994

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SOUTH AUSTRALIA

NGMA OTWAY BASIN PROJECT

VIEPS

MAP 2

TOTAL MAGNETIC INTENSITY RESIDUAL ANOMALIES

1: 500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

Explanatory notes for this map are contained in AGSO Record 1994/51:
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Map compiled by D. M. Finlayson (AGSO)

LEGEND
- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User : dfinlays File : px7425.djt Date : December 16, 1994

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NGMA OTWAY BASIN PROJECT

VIEPS

MAP 3

TWO-WAY TIME TO TOP PALAEOZOIC BASEMENT

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0 10 20 30 40 50
1:500000
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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Map compiled by D. M. Finlayson (AGSO)

LEGEND
- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User : dfinlays File : px9825.dlt Date : December 15, 1994

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NGMA OTWAY BASIN PROJECT

VIEPS

MAP 4

TWO-WAY TIME TO TOP CRAYFISH GROUP

1: 500000

KILOMETRES 0 10 20 30 40 50

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

Explanatory notes for this map are contained in AGSO Record 1994/51:
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Map compiled by D. M. Finlayson (AGSO)

LEGEND
- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User : dfinlays File : px27685.djt Date : December 29, 1994

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NGMA OTWAY BASIN PROJECT

VIEPS

MAP 5

TWO-WAY TIME TO TOP EUMERALLA FORMATION

1: 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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Map compiled by D. M. Finlayson (AGSO)

LEGEND

- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

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NGMA OTWAY BASIN PROJECT

VIEPS

MAP 6

TWO-WAY TIME TO BASE WANGERRIP GROUP

0 10 20 30 40 50 KILOMETRES 1: 500000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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LEGEND
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- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
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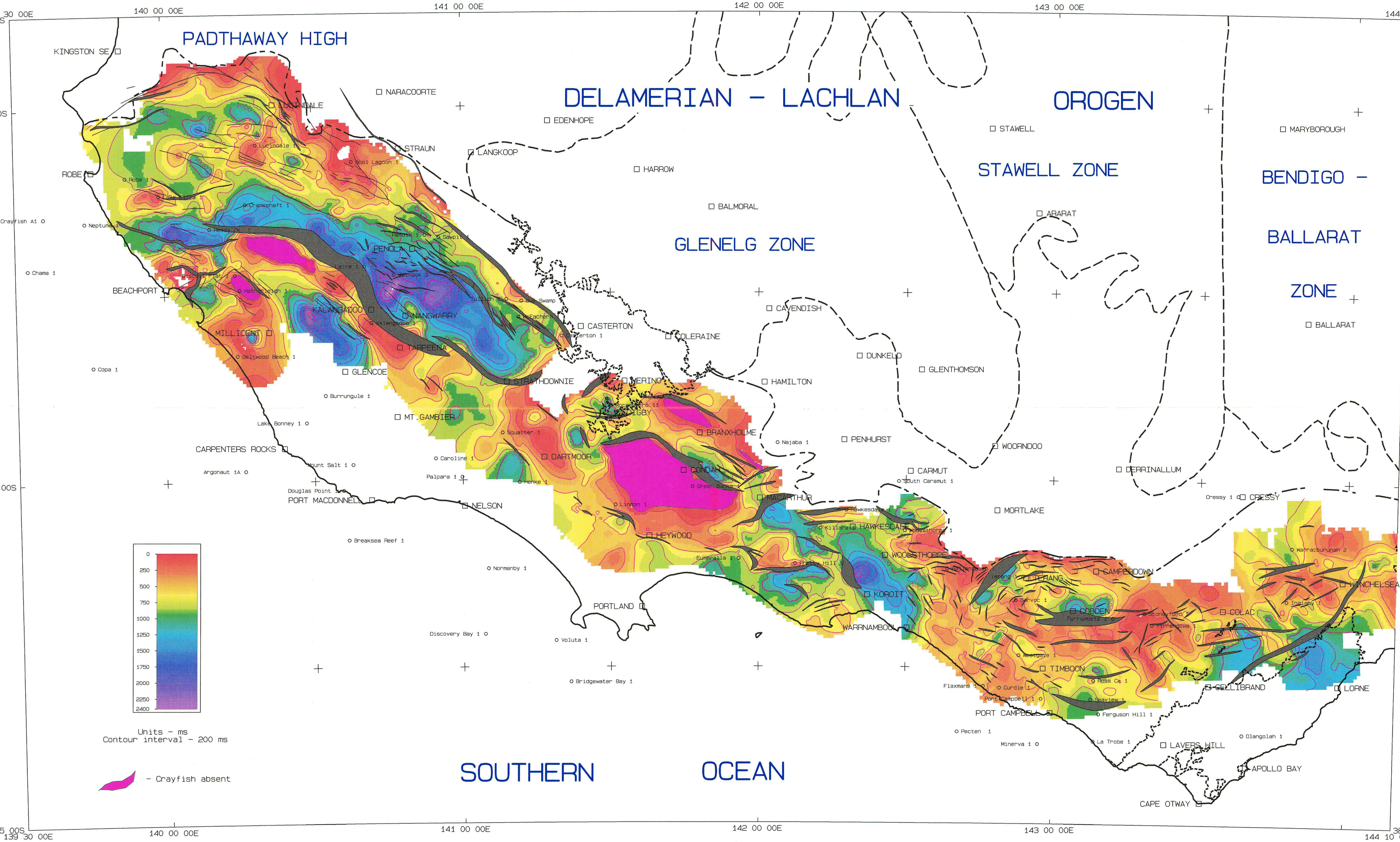
VIEPS

NGMA OTWAY BASIN PROJECT



MAP 7

CRAYFISH GROUP ISOCHRONS

1: 500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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LEGEND
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- Palaeozoic structural boundary.
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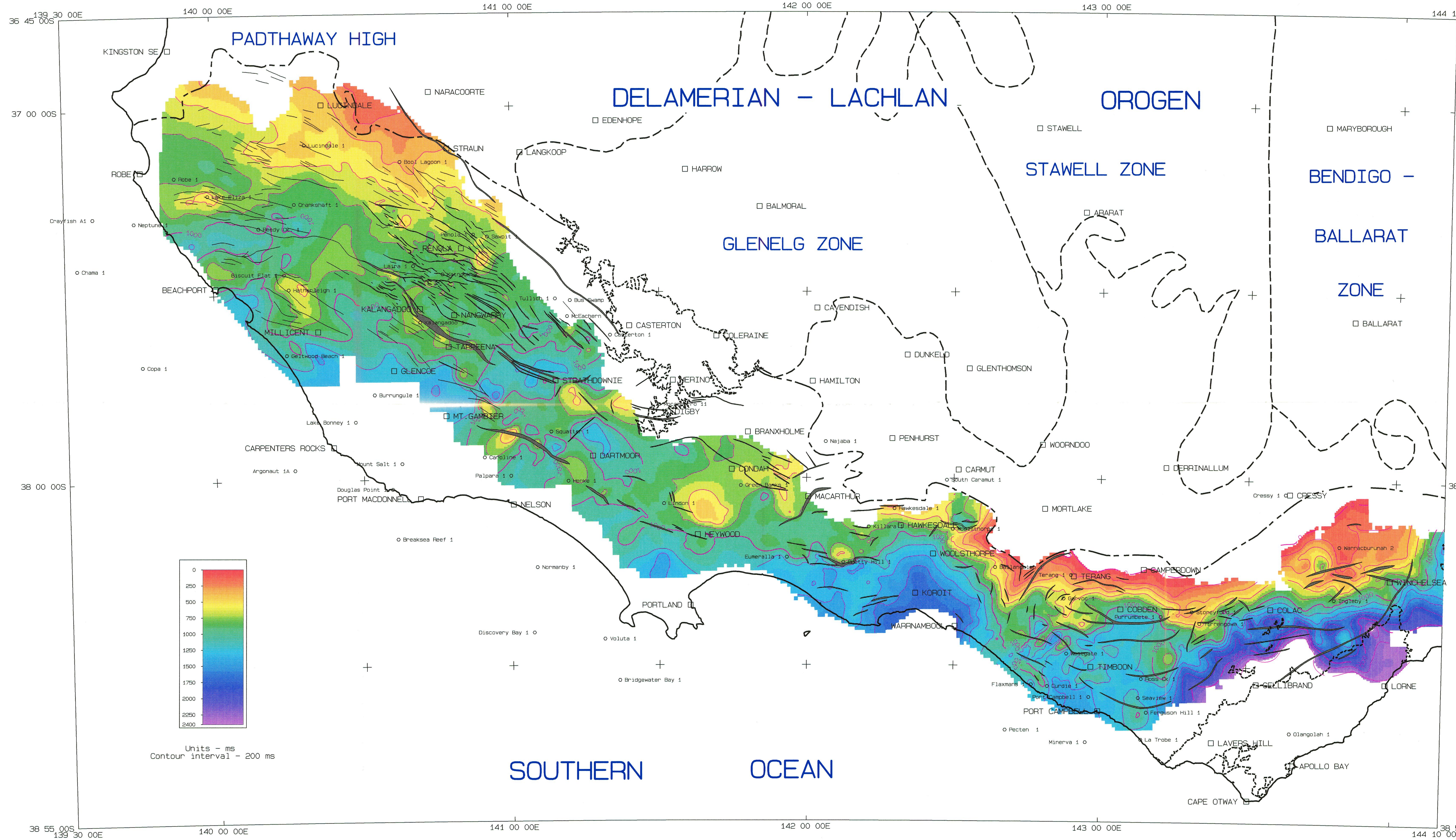
NGMA OTWAY BASIN PROJECT



MAP 8

EUMERALLA FORMATION ISOCHRONS

1: 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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Map compiled by D. M. Finlayson (AGSO)

LEGEND
- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User : dfinlays File : px25282.dit Date : December 28, 1994

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NGMA OTWAY BASIN PROJECT

VIEPS

MAP 9

SHERBROOK GROUP ISOCHRONS

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1: 500000

0 10 20 30 40 50

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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Map compiled by D. M. Finlayson (AGSO)

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- Northern limit, Early Cretaceous sequences.

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MINES AND ENERGY SOUTH AUSTRALIA

NGMA OTWAY BASIN PROJECT

VIEPS

MAP 10

STRUCTURAL ELEMENTS AND SEISMIC DATABASE

1: 500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 141 00 00E

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Map compiled by D. M. Finlayson (AGSO)

LEGEND
- Interpreted open file seismic lines.
- Palaeozoic structural boundary.
- Early Cretaceous outcrop boundary.
- Northern limit, Early Cretaceous sequences.

User: dfinlays File: px27523.dlt Date: December 29, 1994